

Andrew Fawcett

Foreword by:  
**Joshua Birk**  
Salesforce Developer Evangelist

# Force.com Enterprise Architecture

**Second Edition**

Architect and deliver packaged Force.com applications  
that cater to enterprise business needs



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BIRMINGHAM - MUMBAI

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## *Second Edition*

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First published: September 2014

Second edition: March 2017

Production reference: 1280317

Published by Packt Publishing Ltd.  
Livery Place  
35 Livery Street  
Birmingham B3 2PB, UK.

ISBN 978-1-78646-368-5

[www.packtpub.com](http://www.packtpub.com)

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# Foreword

As a Developer Evangelist for Salesforce.com, I've seen an ever-widening demand for the exact kind of material that Andrew brings to the table with this book. While I often get the joy of showing developers new features that are rolling out on Force.com, I am often also asked questions about daily challenges when it comes to leveraging those features and implementing solutions within the ecosystem required by enterprise developer teams. This book will go a long way in providing new reference material specifically for those concerns.

In 2007, I started developing at Salesforce.com, and the landscape looked quite different than it is today. There was no Visualforce. Apex had just launched and lacked many of the interfaces it enjoys now, such as batchable and schedulable. Most custom interfaces were accomplished through extensive amounts of JavaScript embedded in S-Controls, which is a portion of the platform that is no longer supported. Communicating back to the platform could be done via the SOAP API using the AJAX toolkit. If you wanted truly fine-tuned business logic on the server side, you exposed it via a custom SOAP endpoint in Apex.

In 2014, the capabilities of the platform completely eclipse those days. With Standard Controllers, Visualforce provides basic business logic out of the box, without additional code required. For custom processing, a developer is not limited to just a single option, but various routes ranging from extending Visualforce's components library to exposing Apex methods directly to JavaScript—providing the flexibility from the old AJAX toolkit without ever needing to access the scope of the platform APIs. Apex can be scheduled, it can churn through records in the background, and it can be used to create completely custom REST endpoints. Developers now have access to powerful new APIs such as Streaming and Analytics as well as industrial strength identity services.

The platform continues to evolve. At Dreamforce, each year, we announce new tools, features, and functionality to the platform. Last year was Salesforce1 with a new mobile application that would make deploying interfaces to smartphones a simple and integrated process. This coming October, we will deliver new industry-changing innovations.

This pace of technical evolution combined with an ever increasing adoption of Force.com for enterprise applications poses a specific challenge for developers: to continually think of the platform not as just a solution for various use cases, but as a complete ecosystem that uses the platform efficiently. It is no longer sufficient to consider that a given application simply works on the platform; developers need to consider whether their applications are being designed in a way that leverages the correct features and that will co-exist efficiently and well. It takes the ability to view how the platform is being limited from a high level and with a clear direction.

I knew Andrew was the kind of architect with such an ability when we started discussing a new set of articles he was writing based on Martin Fowler's Separation of Concerns and how such design patterns could be used to develop Apex for enterprise solutions. Seven years ago, thinking about Apex in such layers of abstraction was certainly possible – it just wasn't really necessary. With all the potential tools and features in the hands of a Force.com developer now, not considering such concepts is begging for maintenance debt down the road.

Andrew being in a position to write this book should be a surprise to nobody familiar with his company's work. FinancialForce.com has created some of the most robust applications I've seen on Force.com, and as Chief Technical Officer, Andrew has been at the forefront of making them successful.

Hence, I'm delighted to see Andrew writing this book, and that at its core, we can see an expanded version of his previous design pattern articles. Actually, simply a printed copy of those articles would not be a bad addition to an architect's library, but here, we also see a more complete vision of what a developer should know before building applications on the platform that levels off from higher order considerations like interfacing Apex classes together down to the concrete tasks of properly leveraging Source Control software for Force.com.

I'm excited to see this book on my shelf, and hopefully yours – it will help you map out not only this generation of Force.com applications, but to move forward with future ones as well.

**Joshua Birk**

Salesforce Developer Evangelist

# About the Author

**Andrew Fawcett** has over 25 years of experience, holding several software development-related roles with increasing focus and responsibility around enterprise-level product architectures with major international accounting and ERP software vendors over the years. He is experienced in performing and managing all aspects of the software development life cycle across various technology platforms, frameworks, industry design patterns, and methodologies, more recently Salesforce's Force.com and Heroku.

He is currently a CTO, Salesforce MVP, and Salesforce Certified Advanced Developer within a UNIT4 and Salesforce.com funded startup, FinancialForce.com. He is responsible for driving platform adoption, relationship, and technical strategy across the product suite. He is an avid blogger, open source contributor and project owner, and an experienced speaker at various Salesforce and FinancialForce.com events.

He loves watching movies and Formula1 motor racing and building cloud-controlled Lego robots! You can find him on Twitter at [@andyinthecloud](https://twitter.com/andyinthecloud), and his Lego robot Twitter handle and website is [@brickinthecloud](https://twitter.com/brickinthecloud).

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# Acknowledgements

Firstly, I would like to thank my wife, Sarah, for supporting me in writing this book, giving up our weekends, and encouraging me. Also, the endless supply of tea and biscuits when needed!

I'd like to acknowledge the Salesforce community for their excellent contributions, feedback, and encouragement in respect to the many open source frameworks used in this book. Thank you, one and all, and keep it up!

Lastly I'd like to acknowledge FinancialForce.com for its commitment to the Salesforce community by sharing code through its public GitHub repositories, many of which are featured and leveraged in this book. Open source is nothing without contributors; these repositories continue to benefit from contributions made both in the past and present by developers both internal and external to FinancialForce.com. So I also want to say a big thank you to those contributors!

# About the Reviewers

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Zarna and her team also have expertise in multiple appexchange products, including Conga Merge, Clicktools, Rollup Helper, and Drawloop.

Zarna herself holds multiple certifications: Salesforce.com Certified Administrator, Developer, Sales & Service Cloud Consultant. Previously, she worked for one of the leading Salesforce.com partners in USA. She has also reviewed Learning Force.com Application Development, Packt Publishing. To know more about Zarna and YES CRM Consultants, log on to [www.yescrm.org](http://www.yescrm.org) or visit her LinkedIn profile at <https://in.linkedin.com/in/zarnadesai>.

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I would like to thank my parents, in-laws, husband, sister, friends, and family for their continued support for my work.

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**John M. Daniel** has been working in the technology sector for over 20+ years. During that time, he has worked with a variety of technologies and project roles. Currently, he works at Morgan & Morgan Law Firm as their Lead Salesforce Platform Architect. He currently holds multiple certifications from Salesforce.com, including the Platform Developer I & II certifications and most of the Technical Architect Designer certifications. He is currently in the process of attaining the Certified Technical Architect certification. His loves to spend time with his family, swim at the beach, and work on various open source projects, such as ApexDocs and ApexUML. He co-leads his local area Salesforce Developers User Group and can be found on Twitter at @ImJohnMDaniel.

John has been a technical reviewer for:

- Force.com Enterprise Architecture (ISBN: 9781782172994), by Andrew Fawcett
- Learning Apex Programming (ISBN: 9781782173977), by Matt Kaufman and Michael Wicherksi
- Apex Design Patterns (ISBN: 9781782173656), by Jitendra Zaa and Anshul Verma

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I would like to thank my wife, Allison, for always giving me the freedom to pursue my interests.

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**Aaron Slettehaug** is senior director of Product Management for the Salesforce Platform. He has launched several products beloved by Salesforce developers, including custom metadata types and the Apex Metadata API.

Before joining Salesforce Aaron helped launch the global operations of an African NGO, led the product team at a leading IaaS innovator, and started a cloud computing company, leading it to acquisition by Citrix. He has an MBA from Stanford University and a bachelor in engineering.

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# Preface

Enterprise organizations have complex processes and integration requirements that typically span multiple locations around the world. They seek out the best in class applications that support not only their current needs but also those of the future. The ability to adapt an application to their practices, terminology, and integrations with other existing applications or processes is a key to them. They invest as much in your application as they do in you as the vendor capable of delivering an application strategy that will grow with them.

Throughout this book, you will be shown how to architect and support enduring applications for enterprise clients with Salesforce by exploring how to identify architecture needs and design solutions based on industry-standard patterns.

Large-scale applications require careful coding practices to keep the code base scalable. You'll learn advanced coding patterns based on industry-standard enterprise patterns and reconceive them for Force.com, allowing you to get the most out of the platform and build in best practices from the start of your project.

As your development team grows, managing the development cycle with more robust application life cycle tools and using approaches such as Continuous Integration become increasingly important. There are many ways to build solutions on Force.com; this book cuts a logical path through the steps and considerations for building packaged solutions from start to finish, covering all aspects from engineering to getting it into the hands of your customers and beyond, ensuring that they get the best value possible from your Force.com application.

## What this book covers

*Chapter 1, Building, Publishing, and Supporting Your Application*, gets your application out to your prospects and customers using packages, AppExchange, and subscriber's support.

*Chapter 2, Leveraging Platform Features*, ensures that your application is aligned with the platform features and uses them whenever possible, which is great for productivity when building your application, but—perhaps more importantly—it ensures whether your customers are also able to extend and integrate with your application further.

*Chapter 3, Application Storage*, teaches you how to model your application's data to make effective use of storage space, which can make a big difference to your customer's ongoing costs and initial decision-making when choosing your application.

*Chapter 4, Apex Execution and Separation of Concerns*, explains how the platform handles requests and at what point Apex code is invoked. This is important to understand how to design your code for maximum reuse and durability.

*Chapter 5, Application Service Layer*, focuses on understanding the real heart of your application: how to design it, make it durable, and future proofing around a rapidly evolving platform using Martin Fowler's Service pattern as a template.

*Chapter 6, Application Domain Layer*, aligns Apex code typically locked away in Apex Triggers into classes more aligned with the functional purpose and behavior of your objects, using object-orientated programming (OOP) to increase reuse and streamline code and leverage Martin Fowler's Domain pattern as a template.

*Chapter 7, Application Selector Layer*, leverages SOQL to make the most out of the query engine, which can make queries complex. Using Martin Fowler's Mapping pattern as a template, this chapter illustrates a means to encapsulate queries, making them more accessible and reusable and making their results more predictable and robust across your code base.

*Chapter 8, User Interface*, covers the concerns of an enterprise application user interface with respect to translation, localization, and customization, as well as the pros and cons of the various UI options available in the platform.

*Chapter 9, Lightning*, explains the architecture of this modern framework for delivering rich client-device agnostic user experiences, from a basic application through to using component methodology to extend Lightning Experience and Salesforce1 Mobile.

*Chapter 10, Providing Integration and Extensibility*, explains how enterprise-scale applications require you to carefully consider integration with existing applications and business needs while looking into the future by designing the application with extensibility in mind.

*Chapter 11, Asynchronous Processing and Big Data Volumes*, shows that designing an application that processes massive volumes of data either interactively or asynchronously requires consideration in understanding your customer's volume requirements and leverages the latest platform tools and features, such as understanding the query optimizer and when to create indexes.

*Chapter 12, Unit Testing*, explores the differences and benefits of unit testing versus system testing. This aims to help you understand how to apply dependency injection and mocking techniques to write unit tests that cover more code scenarios and run faster. You will also look at leveraging practical examples of using the Apex Stub API and the ApexMocks open source library.

*Chapter 13, Source Control and Continuous Integration*, shows that maintaining a consistent code base across applications of scale requires careful consideration of Source Control and a planned approach to integration as the application is developed and implemented.

## What you need for this book

In order to follow the practical examples in this book, you will need to install the Salesforce Force.com IDE, Apache Ant v1.9 or later, and Java v1.8 or later, and have access to Salesforce Developer Edition Orgs via [developer.salesforce.com](http://developer.salesforce.com).

The following is the list of software requirements for this book:

- Salesforce Developer Edition Orgs
- Java v1.8 (or later)
- Apache Ant v1.9 (or later)
- GitHub client (optional)
- Salesforce Force.com IDE
- Salesforce Developer Console (optional)

## Who this book is for

This book is aimed at Force.com developers who are looking to push past Force.com basics and learn how to truly discover its potential. You will find this handy if you are looking to expand your knowledge of developing packaged ISV software and complex, scalable applications for use in enterprise businesses with the Salesforce platform. This book will enable you to know your way around Force.com's non programmatic functionality as well as Apex and aid you in learning how to architect powerful solutions for enterprise-scale demands. If you have a background in developing inside other enterprise software ecosystems, you will find this book an invaluable resource for adopting Force.com.

## Conventions

In this book, you will find a number of text styles that distinguish between different kinds of information. Here are some examples of these styles and an explanation of their meaning.

Code words in text, database table names, folder names, filenames, file extensions, pathnames, dummy URLs, user input, and Twitter handles are shown as follows: "The Database.merge and merge DML statements support merging of accounts, leads, and contact records."

A block of code is set as follows:

```
public class ContestantService{  
  
    public class RaceRetirement{  
        public Id contestantId;  
        public String reason;  
    }  
}
```

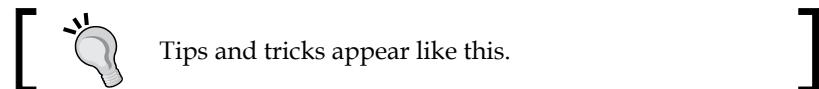
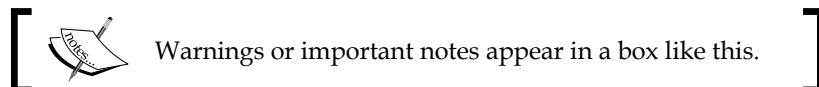
When we wish to draw your attention to a particular part of a code block, the relevant lines or items are set in bold:

```
public class ProvisionalResult{  
    public Integer racePosition {get; set;}  
    public Id contestantId {get; set;}  
    public String contestantName {get; private set;}  
}
```

Any command-line input or output is written as follows:

```
ant package.installdemo
```

**New terms** and **important words** are shown in bold. Words that you see on the screen, for example, in menus or dialog boxes, appear in the text like this: "You can see the current storage utilization from the **Custom Settings** page under **Setup**"



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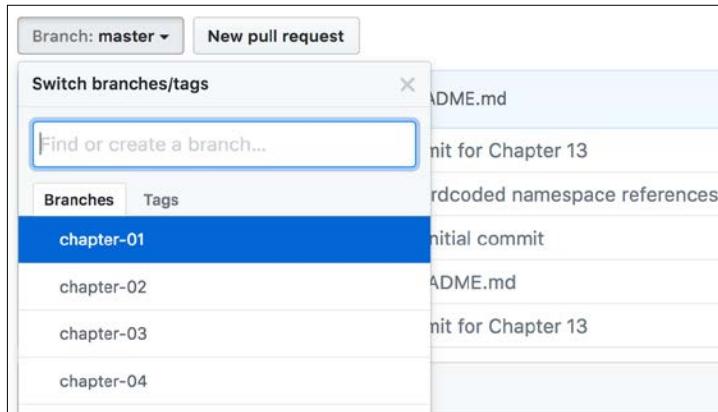
Once the file is downloaded, please make sure that you unzip or extract the folder using the latest version of:

- WinRAR / 7-Zip for Windows
- Zipeg / iZip / UnRarX for Mac
- 7-Zip / PeaZip for Linux

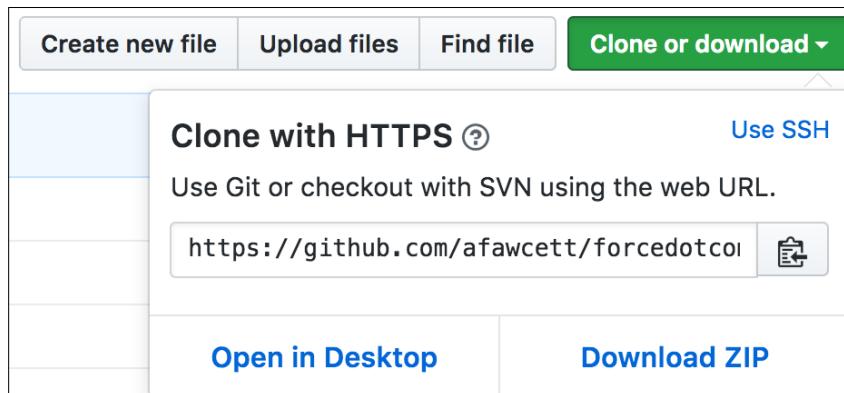
The collective source code for the application built throughout the book is available in the main branch. For each chapter, a branch has been provided containing the code added during that chapter building from the previous one, for example, branch chapter-02 will contain code from chapter-01.

The repository for this book can be found at <https://github.com/afawcett/forcedotcom-enterprise-architecture>.

An alternate way to download the source code is to navigate to [www.github.com](http://www.github.com) in your browser using the link given in the preceding section, locate the repository and branch you want to download, either the main branch or a specific chapter branch, and then click on the Download Zip button in the sidebar on the right.



Alternatively, you can download the GitHub desktop clients as listed above and click on the Clone in Desktop button.



Of course, if you are familiar with Git, you are free to use the tool of your choice.

## Deploying the source code

Once you have the source code downloaded for your chosen chapter, you should execute the Ant build script to deploy the code into your chosen Salesforce Developer Edition org (as described in *Chapter 1, Building, Publishing, and Supporting Your Application*).

Open a command line and navigate to the root folder where you downloaded the source code (this should be the folder with the build.xml file in it). To deploy the code, execute the following command, all on one line:

```
# ant deploy
-Dsf.username=myapp@packaging.andyinthecloud.com
-Dsf.password=mypasswordmytoken
```

Remember that the password and token are concatenated together.

Keep in mind that each chapter branch builds incrementally from the last and will overlay new files as well as changes into your chosen DE org. So, each branch may overwrite changes you make to existing files as you have been exploring that chapter. If you are concerned about this, it is best to use one of the desktop development tools listed earlier, and prior to running the previous command, download the code from the server for safe keeping.

## Downloading the color images of this book

We also provide you with a PDF file that has color images of the screenshots/diagrams used in this book. The color images will help you better understand the changes in the output. You can download this file from [https://www.packtpub.com/sites/default/files/downloads/ForcedotcomEnterpriseArchitectureSecondEdition\\_ColorImages.pdf](https://www.packtpub.com/sites/default/files/downloads/ForcedotcomEnterpriseArchitectureSecondEdition_ColorImages.pdf).

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# 1

# Building, Publishing, and Supporting Your Application

The key for turning an idea into reality lies in its execution. From having the inception of an idea to getting it implemented as an application and into the hands of users is an exciting journey, and one that constantly develops and evolves between you and your users. One of the great things about developing on **Force.com** is the support you get from the platform beyond the core engineering phase of the production process.

In this first chapter, we will use the declarative aspects of the platform to quickly build an initial version of an application that we will use throughout this book, which will give you an opportunity to get some hands-on experience with some of the packaging and installation features that are needed to *release applications* to subscribers. We will also take a look at the facilities available to *publish* your application through **Salesforce AppExchange** (equivalent to the Apple's App Store) and finally provide end user support.

We will then use this application as a basis for incrementally releasing new versions of the application throughout the chapters of this book, building on our understanding of enterprise application development. The following topics outline what we will achieve in this chapter:

- Required organizations
- Introducing the book's sample application
- Package types and benefits
- Creating your first managed package
- Package dependencies and uploading
- Introduction to AppExchange and creating listings

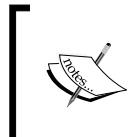
- Installing and testing your package
- Becoming a Salesforce partner and its benefits
- Licensing
- Supporting your application
- Customer metrics
- Trialforce and Test Drive

## Required organizations

Several Salesforce organizations are required to develop, package, and test your application. You can sign up for these organizations at <https://developer.salesforce.com/>. Though in due course, as your relationship with Salesforce becomes more formal, you will have the option of accessing their **Partner Portal** website to create organizations of different types and capabilities. We will discuss this in more detail later.

It's a good idea to have some kind of naming convention to keep track of the different organizations and logins. Use the following table as a guide and create the following organizations via <https://developer.salesforce.com/>. As stated earlier, these organizations will be used only for the purposes of learning and exploring throughout this book:

Username	Usage	Purpose
myapp@packaging.my.com	Packaging	Though we will perform initial work in this org, it will eventually be reserved solely for assembling and uploading a release.
myapp@testing.my.com	Testing	In this org, we will install the application and test upgrades. You may want to create several of these in practice, via the Partner Portal website described later in this chapter.
myapp@dev.my.com	Developing	In a later chapter, we will shift development of the application into this org, leaving the packaging org to focus only on packaging.



You will have to substitute myapp and my.com (perhaps by reusing your company domain name to avoid naming conflicts) with your own values. You should take the time to familiarize yourself with andyapp@packaging.andyinthecloud.com.

The following are other organization types that you will eventually need in order to manage the publication and licensing of your application. However, they are not needed to complete the chapters in this book:

Usage	Purpose
Production/CRM Org	Your organization may already be using this org for managing contacts, leads, opportunities, cases, and other CRM objects. Make sure that you have the complete authority to make changes, if any, to this org since this is where you run your business. If you do not have such an org, you can request one via the Partner Program website described later in this chapter by requesting (via a case) a CRM ISV org. Even if you choose to not fully adopt Salesforce for this part of your business, this type of org is still required when it comes to utilizing the licensing aspects of the platform.
AppExchange Publishing Org (APO)	This org is used to manage your use of AppExchange. We will discuss this a little later in this chapter. This org is actually the same Salesforce org you designate as your production org, and is where you conduct your sales and support activities from.
License Management Org (LMO)	Within this organization, you can track who installs your application (as leads), the licenses you grant them, and for how long. It is recommended that this is the same org as the APO described earlier.
Trialforce Management Org (TMO) and Trialforce Source Org (TSO)	Trialforce is a way to provide orgs with your preconfigured application data so that prospective customers can try out your application before buying. It will be discussed later in this chapter.

Typically, the LMO and APO can be the same as your primary Salesforce production org, which allows you to track all your leads and future opportunities in the same place. This leads to the rule of *APO = LMO = production org*. Though neither of them should be your actual developer or test orgs, you can work with Salesforce support and your Salesforce account manager to plan and assign these orgs.

## Introducing the book's sample application

For this book, we will use the world of **Formula 1** motor car racing as the basis for a packaged application that we will build together. Formula 1 is, for me, the motor sport that is equivalent to enterprise applications software, due to its scale and complexity. It is also a sport that I follow. My knowledge of both of these fields helped me when building the examples that we will use.

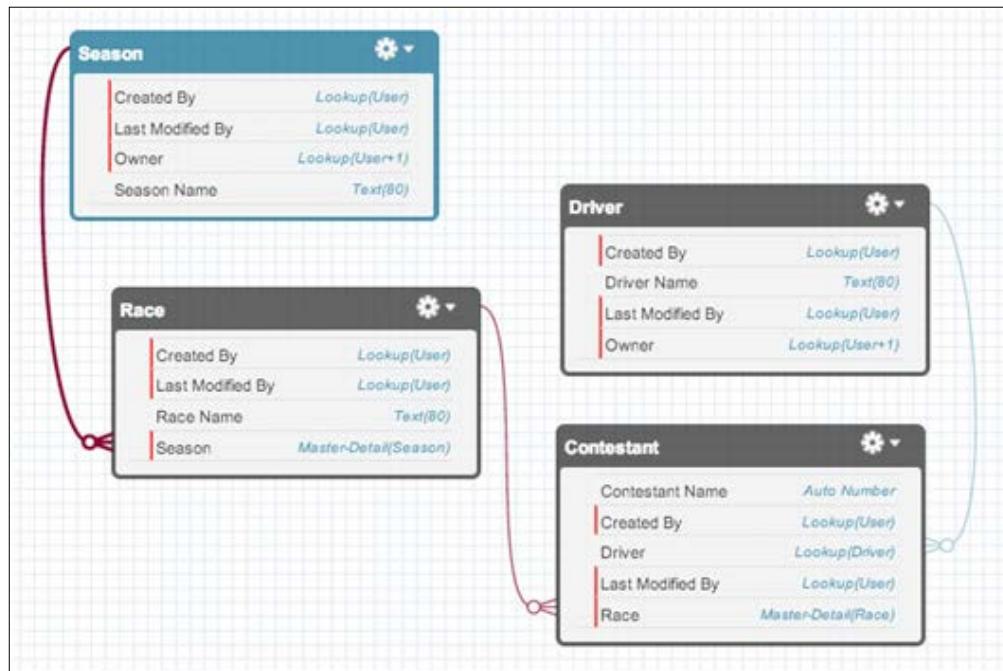
We will refer to our application as **FormulaForce** throughout this book, though please keep in mind Salesforce's branding policies when naming your own application, as they prevent the use of the word "Force" in the company or product titles.

This application will focus on the data collection aspects of the races, drivers, and their many statistics, utilizing platform features to structure, visualize, and process this data in both historic and current contexts.

For this chapter, we will create some initial **Custom Objects** and fields, as detailed in the following table. Do not worry about creating any custom tabs just yet. You can use your preferred approach to create these initial objects. Ensure that you are logged in to your **packaging org** (we will use the development org later in this book).

Object	Field name and type
Season__c	Name (text)
Race__c	Name (text) Season (Master Detail Lookup to Season)
Driver__c	Name (text)
Contestant__c	Name (Auto Number CONTEST-{00000000}) Race (Master Detail Lookup to Race) Driver (Lookup to Driver)

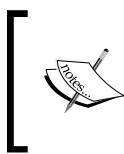
The following screenshot shows the preceding objects within the **Schema Builder** tool, available under the **Setup** menu:



## Package types and benefits

A **package** is a container that holds your application components, such as Custom Objects, Apex code, Apex triggers, Visualforce pages, Lightning Components, and so on. This makes up your application. While there are other ways to move components between Salesforce orgs, a package provides a container that you can use for your entire application or deliver optional features by leveraging the so-called **extension packages**.

There are two types of packages – **managed** and **unmanaged**. Unmanaged packages result in the transfer of components from one org to another; however, the result is as if those components had been originally created in the destination org, meaning that they can be readily modified or even deleted by the administrator of that org. Furthermore, they are not upgradable, and are not particularly ideal from a support perspective. Moreover, the Apex code that you write is also visible for all to see, so your intellectual property is at risk.



Unmanaged packages can be used for sharing template components that are intended to be changed by the subscriber. If you are not using GitHub and the GitHub Salesforce Deployment Tool (<https://github.com/afawcett/githubsfdeploy>), they can also provide a means to share open source libraries to developers.

## Features and benefits of managed packages

This book focuses solely on managed packages. Managed packages have the following features that are ideal for distributing your application. The org where your application package is installed is referred to as a **subscriber org**, since users of this org are subscribing to the services your application provides:

- **Intellectual Property (IP) protection:** Users in the subscriber org cannot see your Apex source code, although they can see your Visualforce pages code and static resources. While the Apex code is hidden, JavaScript code is not, so you may want to consider using a minify process to partially obscure such code.
- **The naming scope:** Your component names are unique to your package throughout the utilization of a namespace. This means that, even if you have object X in your application, and the subscriber has an object of the same name, they remain distinct. You will define a namespace later in this chapter.
- **The governor scope:** Code in your application executes within its own governor limit scope (such as DML and SOQL governors that are subject to passing Salesforce Security Review) and is not affected by other applications or code within the subscriber org. Note that some governors, such as the CPU time governor, are shared by the whole execution context (discussed in a later chapter), regardless of the namespace.
- **Upgrades and versioning:** Once the subscribers have started using your application, creating data, making configurations, and so on, you will want to provide upgrades and patches with new versions of your application.

There are other benefits to managed packages, but these are only accessible after becoming a Salesforce partner and completing the security review process; these benefits are described later in this chapter. Salesforce provides *ISVforce Guide* (otherwise known as the **Packaging Guide**) in which these topics are discussed in depth—bookmark it now! The *ISVforce Guide* can be found at [http://login.salesforce.com/help/pdfs/en/salesforce\\_packaging\\_guide.pdf](http://login.salesforce.com/help/pdfs/en/salesforce_packaging_guide.pdf).

## Creating your first managed package

Packages are created in your packaging org. There can be only one managed package being developed in your packaging org (though additional unmanaged packages are supported, it is not recommended to mix your packaging org with them). You can also install other dependent managed packages and reference their components from your application. The steps to be performed are discussed in the following sections:

- Setting your package namespace
- Creating the package and assigning it to the namespace
- Adding components to the package

## Setting your package namespace

An important decision when creating a managed package is the namespace; this is a prefix applied to all your components (Custom Objects, Visualforce pages, Lightning Components, and so on) and is used by developers in subscriber orgs to uniquely distinguish between your packaged components and others, even those from other packages. The namespace prefix is an important part of the branding of the application since it is implicitly attached to any Apex code or other components that you include in your package.

It can be up to 15 characters, though I personally recommend that you keep it to less than this, as it becomes hard to remember and leads to frustrating typos if you make it too complicated. I would also avoid underscore characters. It is a good idea to have a naming convention if you are likely to create more managed packages in the future (in different packaging orgs). The following is the format of an example naming convention:

[company acronym - 1 to 4 characters] [package prefix 1 to 4 characters]

For example, the *ACME Corporation's Road Runner* application might be named `acmerr`.

When the namespace has not been set, the **Packages** page (accessed under the **Setup** menu under the **Create** submenu) indicates that only unmanaged packages can be created. Click on the **Edit** button to begin a small wizard to enter your desired namespace. This can only be done once and must be globally unique (meaning it cannot be set in any other org), much like a website domain name.

### Assigning namespaces



For the purposes of following this book, please feel free to make up any namespace you desire, for example, `fforce{yourinitials}`. Do not use one that you may plan to use in the future, since once it has been assigned, it cannot be changed or reused.

The following screenshot shows the **Packages** page:

The screenshot shows the 'Packages' page with the following details:

Developer Settings		Edit
Your current developer settings are listed below. These settings determine the types of packages you can create and upload. To change these settings, click Edit.		
Package Types Allowed	Unmanaged Only	Your organization is configured to create unmanaged packages only. Unmanaged packages are not upgradeable.
Managed Package	None	Unable to select a package to be managed because your organization is configured to create unmanaged packages only. To create a managed package, change your developer settings.
Namespace Prefix	None	Unable to specify a namespace prefix for this organization because it is configured to create unmanaged packages only. To create a managed package, change your developer settings. <a href="#">What is this?</a>

Once you have set the namespace, the preceding page should look like the following screenshot, with the difference being that it is now showing the namespace prefix that you have used and that managed packages can now also be created. You are now ready to create a managed package and assign it to the namespace.

Packages

Developer Settings

Help for this Page

Your current developer settings are listed below. These settings determine the types of packages you can create and upload. To change these settings, click Edit.

Package Types Allowed	Managed and Unmanaged	Your organization is configured to contain one managed package and an unlimited number of unmanaged packages. Only managed packages can be upgraded.
Managed Package	None	You have not yet selected a package to be managed.
Namespace Prefix	fforce	Salesforce.com prepends this prefix (along with two underscores, "__") to components that need to be unique such as custom objects and fields.

## Creating the package and assigning it to the namespace

Click on the **New** button on the **Packages** page and give your package a name (it can be changed later). Be sure to tick the **Managed** checkbox as well. Click on **Save** and return to the **Packages** page, which should now look like the following:

Packages

Developer Settings

Help for this Page

Your current developer settings are listed below. These settings determine the types of packages you can create and upload.

Package Types Allowed	Managed and Unmanaged	Your organization is configured to contain one managed package and an unlimited number of unmanaged packages. Only managed packages can be upgraded.
Managed Package	FormulaForce	You have selected the following as the only managed package for this salesforce.com organization: FormulaForce
Namespace Prefix	fforce	Salesforce.com prepends this prefix (along with two underscores, "__") to components that need to be unique such as custom objects and fields.

Packages

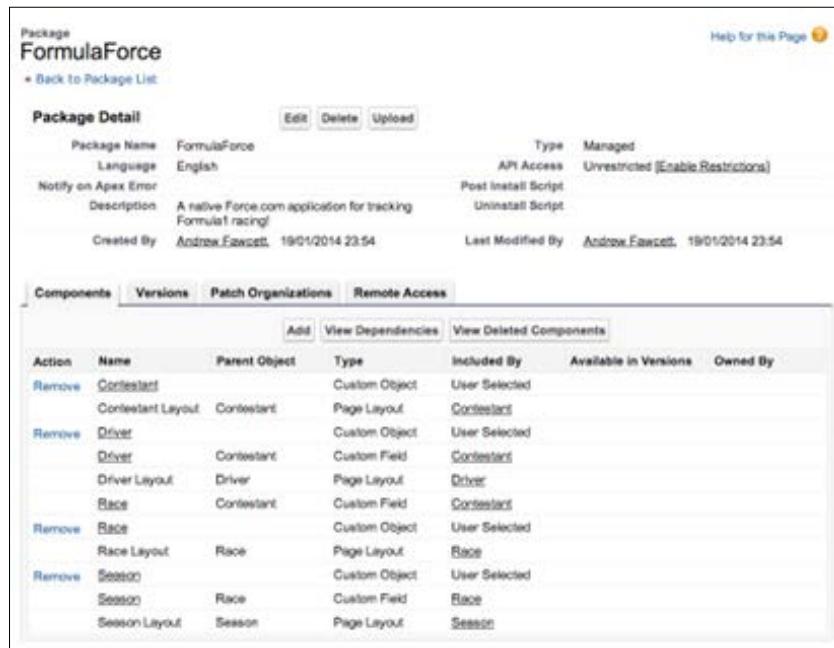
A package contains components such as apps, objects, reports, or email templates. These packages can be uploaded to share with others privately or posted on Force.com AppExchange to share publicly. The list below displays all packages created by your organization. To create a new package, click New.

Action	Package Name	Description
Edit	FormulaForce	A native Force.com application for tracking Formula1 racing!

## Adding components to the package

In the **Packages** page, click on the link to your package in order to view its details. From this page, you can manage the contents of your package and upload it. Click on the **Add** button to add the Custom Objects created earlier in this chapter. Note that you do not need to add any custom fields — these are added automatically.

The following screenshot shows broadly what your **Package Detail** page should look like at this stage:



The screenshot shows the 'Package Detail' page for a package named 'FormulaForce'. The page has a header with the package name and a 'Help for this Page' link. Below the header, there are buttons for 'Edit', 'Delete', and 'Upload'. The main content area displays package details: Package Name (FormulaForce), Language (English), Type (Managed), Notify on Apex Error (Post Install Script, Uninstall Script), Description (A native Force.com application for tracking Formula1 racing!), and Created By (Andrew.Fawcett, 19/01/2014 23:54). Last Modified By is also listed as Andrew.Fawcett, 19/01/2014 23:54. Below these details, there are tabs for 'Components', 'Versions', 'Patch Organizations', and 'Remote Access'. The 'Components' tab is selected, showing a table of components added to the package. The table has columns for Action, Name, Parent Object, Type, Included By, Available in Versions, and Owned By. The components listed are: Contestant (Custom Object, User Selected), Contestant Layout (Page Layout, Contestant), Driver (Custom Object, User Selected), Driver Layout (Page Layout, Driver), Race (Custom Object, Contestant), Race Layout (Page Layout, Race), Session (Custom Object, User Selected), Session Layout (Page Layout, Session).

When you review the components added to the package, you will see that some components can be removed while other components cannot be removed. This is because the platform implicitly adds some components for you, as they are dependencies. As we progress through this book, adding different component types, you will see this list automatically grow in some cases, and in others, we must explicitly add them.

## Extension packages

As the name suggests, **extension packages** extend or add to the functionality delivered by the existing packages they are based on, though they cannot change the base package contents. They can extend one or more base packages, and you can even have several layers of extension packages, though you may want to keep an eye on how extensively you use this feature, as managing inter-package dependency can get quite complex, especially during development.

Extension packages are created in pretty much the same way as the process you've just completed (including requiring their own packaging org), except that the packaging org must also have the dependent packages installed in it.

As code and Visualforce pages contained within extension packages make reference to other Custom Objects, fields, Apex code, and Visualforce pages present in base package, the platform tracks these dependencies and the version of the base package present at the time the reference was made.

When an extension package is installed, this dependency information ensures that the subscriber org has the correct version (minimum) of the base packages installed before permitting the installation to complete.

You can also manage the dependencies between extension packages and base packages yourself through the **Versions** tab or **XML metadata** for applicable components (we will revisit versioning in Apex in a later chapter when discussing API integration).

## Package dependencies and uploading

Packages can have dependencies on platform features and/or other packages. You can review and manage these dependencies through the usage of the **Package Detail** page and the use of dynamic coding conventions, as described here.

While some features of Salesforce are common, customers can purchase different editions and features according to their needs. Developer Edition organizations have access to most of these features for free. This means that as you develop your application, it is important to understand when and when not to use those features (this is done in order to avoid unwanted dependencies that might block or inhibit the adoption of your application).

By default, when referencing a certain Standard Object, field, or component type, you will generate a prerequisite dependency on your package, which your customers will need to have before they can complete the installation. Some Salesforce features, for example Multi-Currency or Chatter, have either a configuration or, in some cases, a cost impact to your users (different org editions). Carefully consider which features your package is dependent on.

Most of the feature dependencies, though not all, are visible via the **View Dependencies** button on the **Package Detail** page (this information is also available on the **Upload** page, allowing you to make a final check). It is good practice to add this check into your packaging procedures to ensure that no unwanted dependencies have crept in. Clicking on this button for the package that we have been building in this chapter so far confirms that there are no dependencies.

For dependencies that are not shown, it is a good idea to make sure that the features enabled for your testing orgs are clear, thus any other dependencies will show during installation or further testing.

Show Dependencies

## No Dependency Information for Package FormulaForce

« Back to Package: FormulaForce

There are no dependencies.

Later in this book, we will be discussing Lightning Components. If you're packaging these, you will be implicitly imposing the need for your customers to utilize the **Salesforce My Domain** feature. This is not enforced at installation time, so it is an optional dependency. However, users will not be able to use your packaged Lightning Components without first enabling and configuring My Domain.

## Uploading the release and beta packages

Once you have checked your dependencies, click on the **Upload** button. You will be prompted to give a name and version to your package. The version will be managed for you in subsequent releases. Packages are uploaded in one of two states, beta or release, as described shortly.

We will perform a release upload by selecting the **Managed - Release** option from the **Release Type** field, so make sure you are happy with the objects created in the earlier section of this chapter, as they cannot easily be changed after this point.

Upload Package Help for this Page

Please provide details about this package before upload. These settings determine what requirements must be met in order to install this package.

Package Details		Upload	Cancel
Version Name	1.0	Example: Spring 2014	
Version Number	1.0	Example: 1.2	
This version number will be used until the version is uploaded as Managed - Released			
Release Type	<input checked="" type="radio"/> Managed - Released: use when you are ready to publish to Force.com AppExchange. <b>Note:</b> you will not be able to edit some properties after release. <a href="#">Tell me more</a>		
	<input type="radio"/> Managed - Beta: use to test and validate this package internally and with selected customers before release. <b>Note:</b> this type of package can only be installed in Developer Edition, sandbox organizations, or testing organizations for registered partners.		

Once you are happy with the information on the screen, click on the **Upload** button once again to begin the packaging process. Once the upload process completes, you will see a confirmation page as follows:

Package Name	FormulaForce	Uploaded By	Book Packaging, 22/06/2014 08:48
Version Name	1.0	Post Install Script	
Version Number	1.0 (Released)	Uninstall Script	
Description		Password Protected	<input type="checkbox"/> [Change Password]
Installation URL	<a href="https://login.salesforce.com/packaging/installPackage.apexp?p0=04t200000000UJUx">https://login.salesforce.com/packaging/installPackage.apexp?p0=04t200000000UJUx</a>		

Packages can be uploaded in one of two states, as described here:

- **Release:** Release packages can be installed into subscriber production orgs and can also provide an upgrade path from previous releases. The downside is that you cannot delete the previously released components, or change certain things, such as a field's type. Changes to the components that are marked **global**, such as Apex code and Visualforce components, are also restricted. While Salesforce is gradually enhancing the platform to provide the ability to modify certain released aspects, you need to be certain that your application release is stable before selecting this option.
- **Beta:** Beta packages cannot be installed into subscriber production orgs; you can install only into Developer Edition (such as your testing org), **sandbox**, or Partner Portal created orgs. Also, Beta packages cannot be upgraded once installed; this is the reason why Salesforce does not permit their installation into production orgs. The key benefit is in the ability to continue to change new components of the release to address bugs and features relating to user feedback.



The ability to delete previously-published components (uploaded within a release package) is, at the time of writing this book, in pilot. It can be enabled by raising a support case with Salesforce Support. Once you have understood the full implications, they will enable it.

At this stage in the book, we have simply added some Custom Objects, so the upload should complete reasonably quickly. Note that what you're actually uploading to is AppExchange, which will be covered in the following sections.



If you want to protect your package, you can provide a password (this can be changed afterwards). The user performing the installation will be prompted for it during the installation process.



## Optional package dependencies

It is possible to make some Salesforce features and/or base package component references (Custom Objects and fields) an optional aspect of your application. There are two approaches to this, depending on the type of the feature.

### Dynamic bindings

For example, the Multi-Currency feature adds a `CurrencyIsoCode` field to the Standard and Custom Objects. If you explicitly reference this field, for example, in your Apex, Visualforce pages or Lightning pages or components, you will incur a hard dependency on your package. If you want to avoid this and make it a configuration option (for example) in your application, you can utilize dynamic Apex and Visualforce. Lightning value bindings are dynamic in nature, though `aura:attribute` element type references will form a compile time reference to the specified objects.

### Extension packages

If you wish to package component types that are only available in subscriber orgs of certain editions, you can choose to include these in extension packages. For example, you may wish to support the Professional Edition, which does not support record types. In this case, create an Enterprise Edition extension package for your application's functionality, which leverages the functionality from this edition.



Note that you will need multiple testing organizations for each combination of features that you utilize in this way to effectively test the configuration options or installation options that your application requires.



## Becoming a Salesforce partner and benefits

The Salesforce Partner Program has many advantages. The first place to visit is <https://partners.salesforce.com/>. You will want to focus on the areas of the site relating to being an **Independent Software Vendor (ISV)** partner. From here, you can click on **Join Now**. It is free to join, though you will want to read through the various agreements carefully, of course.

Once you wish to start listing a package and charging users for it, you will need to arrange billing details for Salesforce to take the various fees involved. While this book is not equipped to go into the details, do pay careful attention to the Standard Objects used in your package, as this will determine the license type required by your users and the overall cost to them, in addition to your charges.

Obviously, Salesforce would prefer your application to use as many features of the CRM application as possible, which may also be beneficial to you as a feature of your application, since it's an appealing immediate integration not found on other platforms, such as the ability to instantly integrate with accounts and contacts.

If you're planning on using Standard Objects, and are in doubt about the costs (as they do vary depending on the type), you can request a conversation with Salesforce to discuss this; this is something to keep in mind in the early stages.

Make sure, when you associate a Salesforce user with the **Partner Community**, you utilize a user that you use daily (known as your **Partner Business Org** user) and not one from a development or test org. Once you have completed the signup process, you will gain access to the Partner Community. The following screenshot shows what the current Partner Community home page looks like. From here, you can access many useful services:



This is your primary place to communicate with Salesforce and access additional materials and announcements relevant to ISVs, so do keep checking often. You can raise cases and provide additional logins to other users in your organization, such as other developers who may wish to report issues or ask questions.

## Security review and benefits

The following features require that a completed package release goes through a Salesforce-driven process known as the **security review**, which is initiated via your listing when logged into AppExchange. Unless you plan to give your package away for free, there is a charge involved in putting your package through this process.

However, the review is optional. There is nothing stopping you from distributing your package installation URL directly. However, you will not be able to benefit from the ability to list your new application on AppExchange for others to see and review. More importantly, you will also not have access to the following features to help you deploy, license, and support your application. The following is a list of the benefits you get once your package has passed the security review:

- **Bypass subscriber org setup limits:** Limits such as the number of tabs and Custom Objects are bypassed. This means that if the subscriber org has reached its maximum number of Custom Objects, your package will still install. This feature is sometimes referred to as **Aloha**. Without this, your package installation may fail. You can determine whether Aloha has been enabled via the **Subscriber Overview** page that comes with the LMA application, which is discussed in the next section.
- **Licensing:** You are able to utilize the Salesforce-provided **License Management Application (LMA)** in your LMO.
- **Subscriber support:** With this feature, the users in the subscriber org can enable, for a specific period, a means for you to log in to their org (without exchanging passwords), reproduce issues, and enable much more detailed debug information, such as Apex stack traces. In this mode, you can also see custom settings that you have declared as protected in your package, which is useful for enabling additional debug or advanced features.
- **Push upgrade:** Using this feature, you can automatically apply upgrades to your subscribers without their manual intervention, either directly by you or on a scheduled basis. You may use this for applying either smaller bug fixes that don't affect the Custom Objects or APIs, or for deploying full upgrades. The latter requires careful coordination and planning with your subscribers to ensure that changes and new features are adopted properly.



Salesforce asks you to perform an automated security scan of your software via a web page (<http://security.force.com/security/tools/forcecom/scanner>). This service can be quite slow depending on how many scans are in the queue. Another option is to obtain the Eclipse plugin from the actual vendor CheckMarx at <http://www.checkmarx.com>, which runs the same scan but allows you to control it locally. Finally, for the ultimate confidence as you develop your application, Salesforce can provide a license to integrate it into your **Continuous Integration (CI)** build system. CI is covered in the final chapter of this book.

This book focuses on building a fully native application, as such additional work involved with so-called "hybrid" applications (where parts of your application have been implemented on your own servers, for example) are not considered here. However, keep in mind that if you make any callouts to external services, Salesforce will also most likely ask you and/or the service provider to run a BURP scanner, to check for security flaws.

Make sure you plan a reasonable amount of time (at least two to three weeks, in my experience) to go through the security review process; it is essential that you initially list your package. Though if it becomes an issue, you have the option of issuing your package install URL directly to initial customers and early adopters.

## Getting the best out of the Partner Community

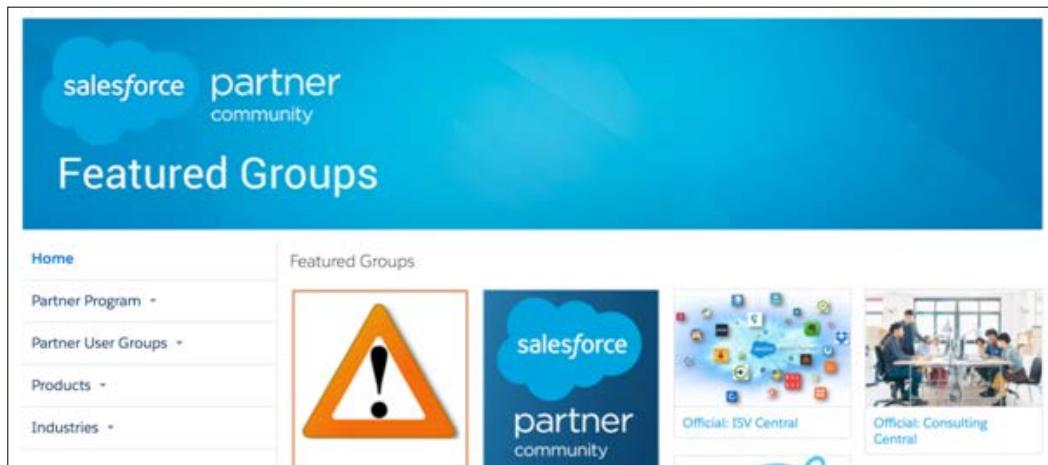
It's worth taking some time to review the content and facilities in the Partner Community. Some of the key areas to take a look at are listed as follows:

- **Education and Trailhead:** This allows you to monitor the progress of other users in your organization on Trailhead. Trailhead is Salesforce's way of learning while doing. Users read about new technologies or development approaches and are then asked to perform some challenges to validate their understanding. They are awarded badges, as part of a gamification system. Using this tab, you can see who has the most badges!
- **Featured Groups:** This page, under **More**, allows you quick access to a number of Salesforce-managed Chatter groups. A key group is the Partner Alerts group, I would strongly recommend you set up an E-mail digest for this group. Only Salesforce posts to this group, so a per-post digest level is tolerable and keeps you informed without having to log in to the community.
- **Support:** This is, of course, the place you go to raise cases with Salesforce. As you raise cases, the UI automatically attempts to search for known issues or support articles that might help answer your questions. You can also report and filter on open cases here.

- **Publishing:** This page allows you to list your creations on the Salesforce AppExchange site. Later sections in this chapter cover this in more detail.
- **Partner Alerts:** Partner Alerts are critical to keeping on top of changes to the service that could affect your development process and/or your customers. These might range from critical fixes, security improvements, or changes in behavior you need to be prepared for. Although rare, you may be asked to make changes to your solution by a certain deadline to ensure your users are not impacted.



There are many Chatter groups shown in the **Featured Groups** page in the Partner Community. Review them all and set up E-mail digests to help keep you informed without having to manually log in and check through this page each time.

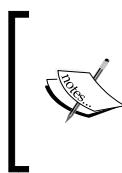


## Creating test and developer orgs via Environment Hub

Partners can use Environment Hub to create orgs for development and testing purposes. Orgs can be linked and logins managed here as well. Unlike the orgs you can get from the Salesforce Developer site, these orgs have additional user licenses. It is also possible to link your TSO and create orgs based on templates you define, allowing you to further optimize the base org configuration for your own development and testing process. For more information, review the Partner Community page detailing Environment Hub ([https://partners.salesforce.com/s/education/general/Environment\\_Hub](https://partners.salesforce.com/s/education/general/Environment_Hub)).

## Introduction to AppExchange and listings

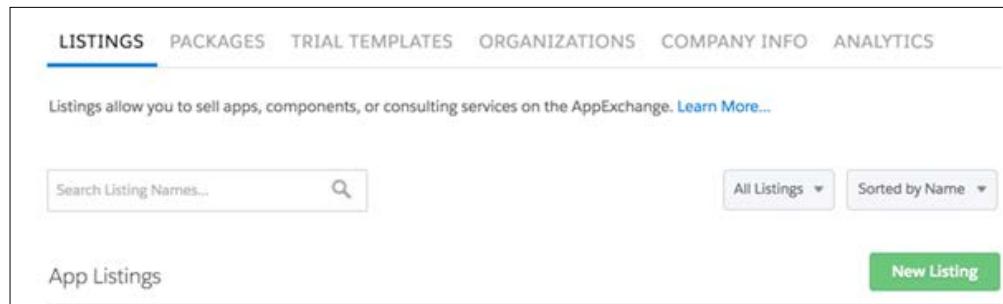
Salesforce provides a website referred to as **AppExchange**, which lets prospective customers find, try out, and install applications built using Force.com. Applications listed here can also receive ratings and feedback. You can also list your mobile applications on this site as well.



In this section, I will be using an AppExchange package that I already own. The package has already gone through the process to help illustrate the steps that are involved. For this reason, you do not need to perform these steps at this stage in the book; they can be revisited at a later phase in your development once you're happy to start promoting your application.

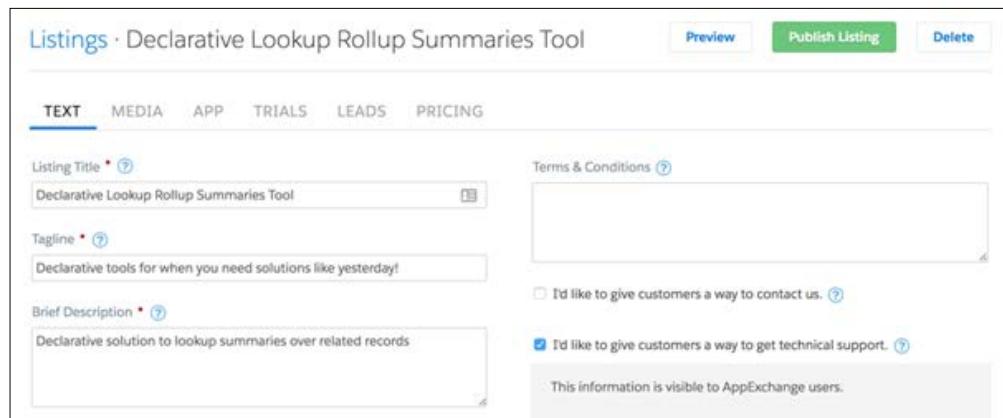
Once your package is known to AppExchange, each time you click on the **Upload** button on your released package (as described previously), you effectively create a private listing. Private listings are not visible to the public until you decide to make them so. It gives you the chance to prepare any relevant marketing details and pricing information while final testing is completed. Note that you can still distribute your package to other Salesforce users or even early beta or pilot customers without having to make your listing public.

In order to start building a listing, you need to log in to Partner Community and click the **Publishing** tab in the header. This will present you with your **Publishing Console**. Here, you can link and manage **Organizations** that contain your **Packages**, create **Listings** and review **Analytics** regarding how often your listings are visited.



Select the **Publishing Console** option from the menu, then click on the **Create New Listing** button and complete the steps shown in the wizard to associate the packaging org with AppExchange; once completed, you should see it listed.

It's really important that you consistently log in to AppExchange using your APO user credentials. Salesforce will let you log in with other users. To make it easy to confirm, consider changing the user's display name to something like MyCompany Packaging.



Although it is not a requirement to complete the listing steps, unless you want to try out the process yourself to see the type of information required. You can delete any private listings that you created after you complete this book.

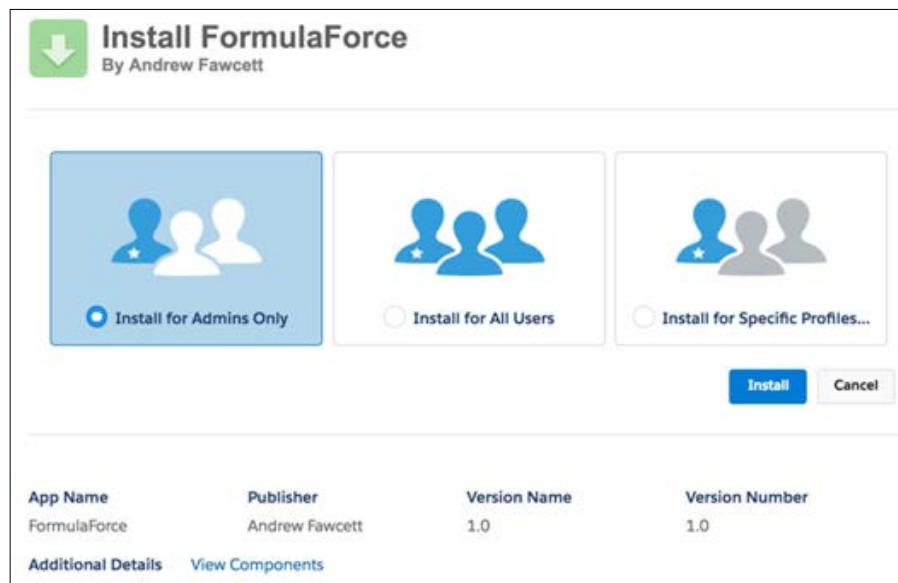
### Downloading the example code



You can download the example code files for all Packt books that you have purchased from your account at <http://www.packtpub.com>. If you purchased this book elsewhere, you can visit <http://www.packtpub.com/support> and register to have the files e-mailed directly to you.

## Installing and testing your package

When you uploaded your package earlier in this chapter, you will receive an e-mail with a link to install the package. If not, review the **Versions** tab on the **Package Detail** page in your packaging org. Ensure that you're logged out and click on the link. When prompted, log in to your testing org. The installation process will start. A reduced screenshot of the initial installation page is shown in the following screenshot; click on the **Continue** button and follow the default installation prompts to complete the installation:



Package installation covers the following aspects (once the user has entered the package password, if one was set):

- **Package overview:** The platform provides an overview of the components that will be added or updated (if this is an upgrade) to the user. Note that, due to the namespace assigned to your package, these will not overwrite existing components in the subscriber org created by the subscriber.
- **Connected App and Remote Access:** If the package contains components that represent connections to services outside of Salesforce services, the user is prompted to approve these.
- **Approve Package API Access:** If the package contains components that make use of the client API (such as JavaScript code), the user is prompted to confirm and/or configure these. Such components will generally not be called much; features such as **JavaScript Remoting** are preferred, and they leverage the Apex runtime security configured post-installation.
- **Security configuration:** In this step, you can determine the initial visibility of the components being installed (objects, pages, and so on), selecting admin only or the ability to select profiles to be updated. This option predates the introduction of **permission sets**, which permit post-installation configuration.



If you package profiles in your application, the user will need to remember to map these to the existing profiles in the subscriber org, as per step 2. This is a one-time option, as the profiles in the package are not actually installed, only merged. I recommend that you utilize permission sets to provide security configurations for your application. These are installed and are much more granular in nature.

When the installation is complete, navigate to the **Installed Packages** menu option under the **Setup** menu. Here, you can see the confirmation of some of your package details, such as namespace and version, as well as any licensing details, which will be discussed later in this chapter.



It is also possible to provide a **Configure** link for your package, which will be displayed next to the package when installed and listed on the **Installed Packages** page in the subscriber org. Here, you can provide a Visualforce page to access configuration options and processes, for example. If you have enabled **Seat based licensing**, there will also be a **Manage Licenses** link to determine which users in the subscriber org have access to your package components, such as tabs, objects, and Visualforce pages. Licensing, in general, is discussed in more detail later in this chapter.

## Automating package installation

It is possible to automate some processes using the **Salesforce Metadata API** and associated tools, such as the **Salesforce Migration Toolkit** (available from the **Tools** menu under **Setup**), which can be run from the popular Apache Ant scripting environment. This can be useful if you want to automate the deployment of your packages to customers or test orgs. In the final chapter of this book, we will study Ant scripts in more detail.

Options that require a user response, such as the security configuration, are not covered by automation. However, password-protected managed packages are supported. You can find more details on this by looking up the installed package component in the online help for the Salesforce Metadata API at [https://www.salesforce.com/us/developer/docs/api\\_meta/](https://www.salesforce.com/us/developer/docs/api_meta/).

As an aid to performing this from Ant, a custom Ant task can be found in the sample code related to this chapter (see `/lib/antsalesforce.xml`). The following is a `/build.xml` Ant script (also included in the chapter code) to uninstall and reinstall the package. Note that the installation will also upgrade a package if the package is already installed. The following is the Ant script:

```

<project name="FormulaForce"
  xmlns:sf="antlib:com.salesforce" basedir=".">
  <!-- Downloaded from Salesforce Tools page under Setup -->
  <typedef
    uri="antlib:com.salesforce"
    resource="com/salesforce/antlib.xml"
    classpath="${basedir}/lib/ant-salesforce.jar"/>
  <!-- Import macros to install/uninstall packages -->
  <import file="${basedir}/lib/ant-salesforce.xml"/>

```

```
<target name="package.installldemo">

    <uninstallPackage
        namespace="yournamespace"
        username="${sf.username}"
        password="${sf.password}"/>
    <installPackage
        namespace="yournamespace"
        version="1.0"
        username="${sf.username}"
        password="${sf.password}"/>
</target>
</project>
```

You can try the preceding example with your testing org by replacing the `namespace` attribute values with the namespace you entered earlier in this chapter. Enter the following commands, all on one line, from the folder that contains the `build.xml` file:

```
ant package.installldemo
-Dsf.username=testorgusername
-Dsf.password=testorgpasswordtestorgtoken
```



You can also use the Salesforce Metadata API to list packages installed in an org, for example, if you wanted to determine whether a dependent package needs to be installed or upgraded before sending an installation request. Finally, you can also uninstall packages if you wish.

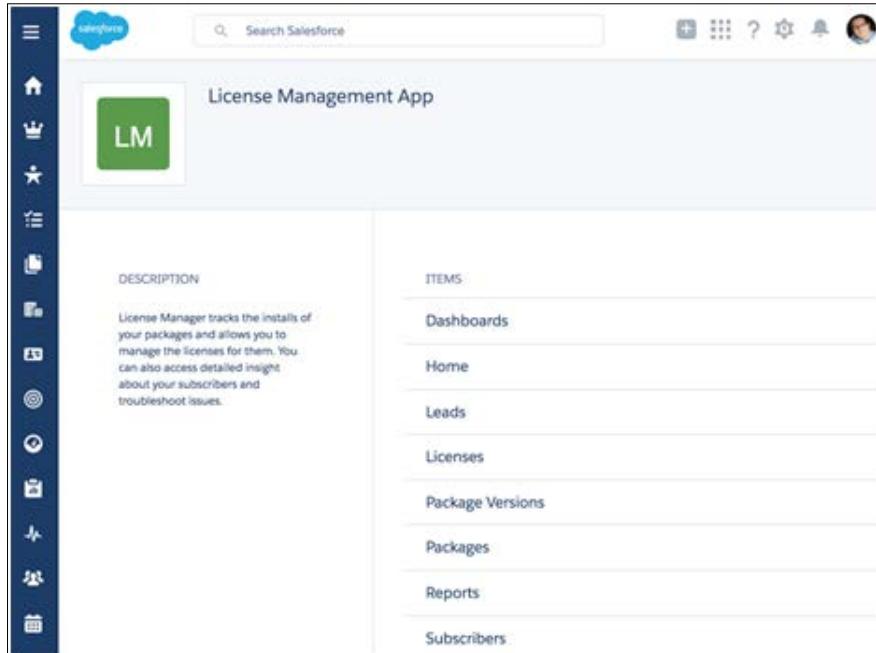
## Licensing

Once you have completed the security review, you are able to request by raising a support cases via the Partner Portal to have access to the LMA. Once this is provided by Salesforce, use the installation URL to install it like any other package into your LMO.



If you have requested a CRM for ISV's org (through a case raised within the Partner Portal), you may find the LMA already installed.

The following screenshot shows the main tabs of the **License Management Application** once installed:



In this section, I will use a package that I already own and have already taken through the process to help illustrate the steps that are involved. For this reason, you do not need to perform these steps.

After completing the installation, return to AppExchange and log in. Then, locate your listing in **Publisher Console** under **Uploaded Packages**. Next to your package, there will be a **Manage Licenses** link. After clicking on this link for the first time, you will be asked to connect your package to your LMO org. Once this is done, you will be able to define the license requirements for your package.

The following example shows the license for a free package with an immediately active license for all users in the subscriber org:

**Default License Settings**

**What organization do you use to manage your licenses (LMO)?**  
andyinthecloud.com (00D7000000JlxzEAG)

**What type of default license does your application have?**  
 Default license is a free trial  
 Default license is active

**What is the length of your default license?**  
 License does not expire  
 License length:

**How many seats are available with your default license?**  
 License is site-wide  
 Default number of seats:

In most cases regarding packages that you intend to charge for, you would offer a free trial rather than setting the license default to active immediately. For paid packages, select a license length, unless it's a one-off charge, and then select the license that does not expire. Finally, if you're providing a trial license, you need to consider carefully the default number of seats (users); users may need to be able to assign themselves different roles in your application to get the full experience.

 While licensing is currently expressed at a package level, it is very likely that more granular licensing around the modules or features in your package will be provided by Salesforce in the future. This will likely be driven by the permission sets feature. As such, keep in mind a functional orientation to your permission set design.

If you configure a number of seats against the license, then the **Manage Licenses** link will be shown on the **Installed Packages** page next to your package. The administrator in the subscriber org can use this page to assign applicable users to your package. The following screenshot shows how your installed package looks to the administrator when the package has licensing enabled:

Installed Packages						
Action	Package Name	Publisher	Version Number	Namespace Prefix	Status	Allowed Licenses
Uninstall   Manage Licenses	Declarative Lookup Rollup Summaries Tool	Home	1.4	dir	Active	3

Note that you do not need to keep reapplying the license requirements for each version you upload; the last details you defined will be carried forward to new versions of your package until you change them. Either way, these details can also be completely overridden on the **License** page of the LMA application.

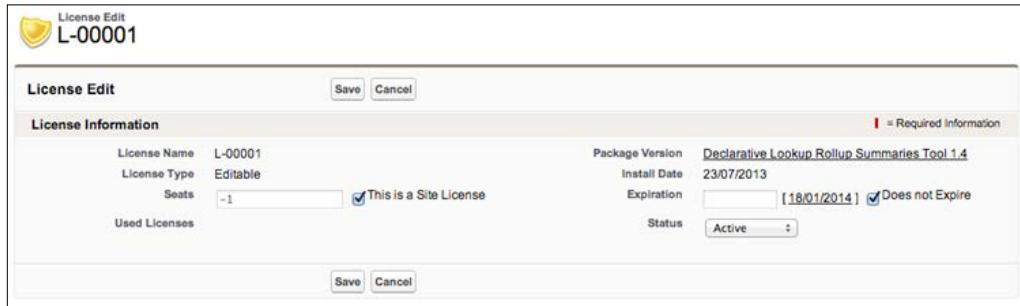
 You may want to apply a site-wide (org-wide) active license to extensions or add-on packages. This allows you to at least track who has installed such packages, even though you don't intend to manage any licenses around them, since you are addressing licensing on the main package.

## The Licenses tab and managing customer licenses

The **Licenses** tab provides a list of individual license records that are automatically generated when the users install your package into their orgs. Salesforce captures this action and creates the relevant details, including **Lead** information. This also contains the contact details of the organization and person who performed the install, as shown in the following screenshot:

Licenses						
All		50+ items • Sorted by License Name • Last updated 07/10/2016 at 23:36		<a href="#">New</a> <a href="#">Import</a>		
LICENSE NAME	LEAD	PACKAGE VERSION		LICENSED SEATS	INSTALL DATE	
L-00001	Fred Blogs	Declarative Lookup Rollup Summaries Too...		Site License	09/04/2014	

From each of these records, you can modify the current license details to extend the expiry period or disable the application completely. If you do this, the package will remain installed with all of its data. However, none of the users will be able to access the objects, Apex code, or pages, not even the administrator. You can also re-enable the license at any time. The following screenshot shows the **License Edit** section:



License Edit  
L-00001

License Edit Save Cancel

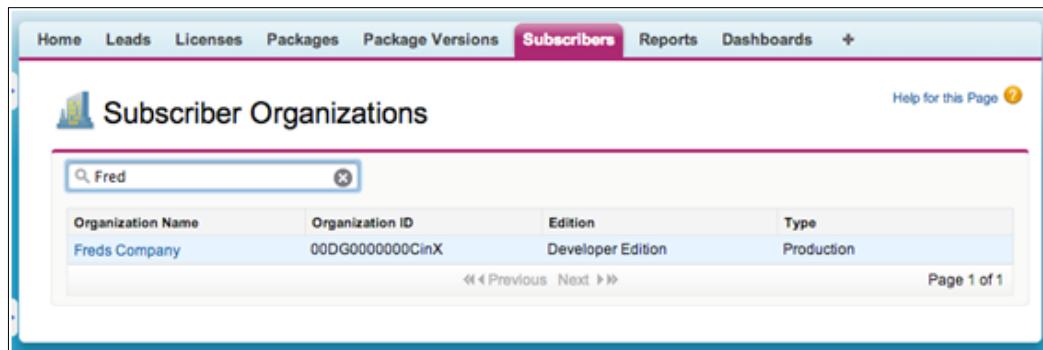
License Information ! = Required Information

License Name	L-00001	Package Version	Declarative Lookup Rollup Summaries Tool 1.4
License Type	Editable	Install Date	23/07/2013
Seats	-1	Expiration	<input type="text" value="18/01/2014"/> <input checked="" type="checkbox"/> Does not Expire
Used Licenses	Status: <input type="button" value="Active"/>		

Save Cancel

## The Subscribers tab

The **Subscribers** tab lists all your customers or subscribers (it shows their **Organization Name** from the company profile) that have your packages installed (only those linked via AppExchange). This includes their **Organization ID**, **Edition** (Developer, Enterprise, or others), and also the type of instance (sandbox or production).



Home Leads Licenses Packages Package Versions **Subscribers** Reports Dashboards +

Subscriber Organizations Help for this Page ?

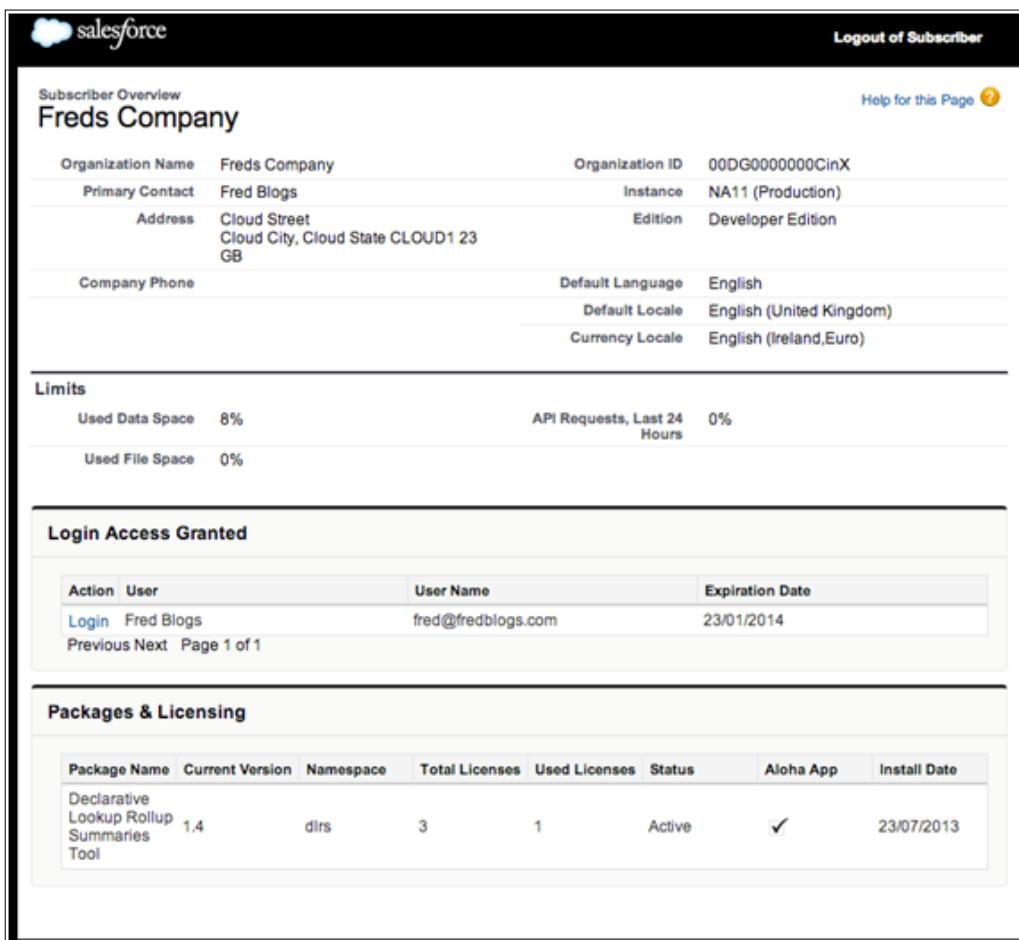
X

Organization Name	Organization ID	Edition	Type
Freds Company	00DG0000000CinX	Developer Edition	Production

« « Previous Next » » Page 1 of 1

## The Subscriber Overview page

When you click on **Organization Name** from the list in this tab, you are taken to the **Subscriber Overview** page. This page is sometimes known as the **Partner Black Tab**. This page is packed with useful information, such as the contact details (also seen via the **Leads** tab) and the login access that may have been granted (we will discuss this in more detail in the next section), as well as which of your packages they have installed, their current licensed status, and when they was installed. The following is a screenshot of the **Subscriber Overview** page:



The screenshot shows the Salesforce Subscriber Overview page for the organization 'Freds Company'. The page is divided into several sections:

- Organization Information:** Displays details like Organization Name (Freds Company), Organization ID (00DG0000000CinX), Primary Contact (Fred Blogs), Instance (NA11 (Production)), Address (Cloud Street, Cloud City, Cloud State CLOUD1 23 GB), Edition (Developer Edition), Company Phone, Default Language (English), Default Locale (English (United Kingdom)), and Currency Locale (English (Ireland,Euro)).
- Limits:** Shows Used Data Space (8%), API Requests, Last 24 Hours (0%), and Used File Space (0%).
- Login Access Granted:** A table showing login grants for users. One entry is visible: Action (Login), User (Fred Blogs), User Name (fred@fredblogs.com), and Expiration Date (23/01/2014). Navigation links for Previous, Next, and Page 1 of 1 are also present.
- Packages & Licensing:** A table showing installed packages. One entry is visible: Package Name (Declarative Lookup Rollup Summaries Tool), Current Version (1.4), Namespace (dlrs), Total Licenses (3), Used Licenses (1), Status (Active), Aloha App (checked), and Install Date (23/07/2013).

## How licensing is enforced in the subscriber org

Licensing is enforced in one of two ways, depending on the execution context in which your packaged Custom Objects, fields, and Apex code are being accessed from.

The first context is where a user is interacting directly with your objects, fields, tabs, and pages via the user interface or the Salesforce APIs (Partner and Enterprise). If the user or the organization is not licensed for your package, these will simply be hidden from view, and, in the case of the API, will return an error. Note that administrators can still see packaged components under the **Setup** menu.

The second context is the type of access made from Apex code, such as an Apex trigger or controller, written by the customers themselves or from within another package. This indirect way of accessing your package components is permitted if the license is site-wide (or org-wide) or there is at least one user in the organization that is allocated a seat.

This condition means that even if the current user has not been assigned a seat (via the **Manage Licenses** link), they are still accessing your application's objects and code, although indirectly, for example, via a customer-specific utility page or Apex trigger, which automates the creation of some records or the defaulting of fields in your package.



Your application's Apex triggers (for example, the ones you might add to Standard Objects) will always execute, even if the user does not have a seat license, as long as there is just one user seat license assigned in the subscriber org to your package. However, if that license expires, the Apex trigger will no longer be executed by the platform, until the license expiry is extended.

## Providing support

Once your package has completed the security review, additional functionality for supporting your customers is enabled. Specifically, this includes the ability to log in securely (without exchanging passwords) to their environments and debug your application. When logged in in this way, you can see everything the user sees, in addition to extended debug logs that contain the same level of detail as they would in a developer org.

First, your customer enables access via the **Grant Account Login** page. This time, however, your organization (note that this is the **Company Name** as defined in the packaging org under **Company Profile**) will be listed as one of those available in addition to Salesforce Support. The following screenshot shows the **Grant Account Login** page:

Grant Access To	Access Duration
Your Company's Administrator	--No Access--
Salesforce.com Support	5 day(s) left. Expires on 23/01/2014. Change
andyinthecloud.com Support	1 Week (exp. 25/01/2014)

Save Cancel

Next, you log in to your LMO and navigate to the **Subscribers** tab as described. Open **Subscriber Overview** for the customer, and you should now see the link to **Login** as that user. From this point on, you can follow the steps given to you by your customer and utilize the standard **Debug Logs** and **Developer Console** tools to capture the debug information you need. The following screenshot shows a user who has been granted login access via your package to their org:

Action	User	User Name	Expiration Date
Login	Fred Blogs	fred@fredblogs.com	23/01/2014

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 This mode of access also permits you to see protected custom settings, if you have included any of those in your package. If you have not encountered these before, it's well worth researching them as they provide an ideal way to enable and disable debug, diagnostic, or advanced configurations that you don't want your customers to normally see.

## Customer metrics

Salesforce has started to expose information relating to the usage of your package components in the subscriber orgs since the Spring '14 release of the platform. This enables you to report what Custom Objects and Visualforce pages your customers are using and, more importantly, those they are not. This information is provided by Salesforce and cannot be opted out of by the customer.

This facility needs to be enabled by Salesforce Support. Once enabled, the `MetricsDataFile` object is available in your production org and will receive a data file periodically that contains the metric's records. The **Usage Metrics Visualization** application can be found by searching on AppExchange, and can help with visualizing this information.

## Trialforce and Test Drive

Large enterprise applications often require some consultation with customers to tune and customize to their needs after the initial package installation. If you wish to provide trial versions of your application, Salesforce provides a means to take snapshots of the results of this installation and setup process, including sample data.

You can then allow prospective users who visit your AppExchange listing, or your website to sign up to receive a personalized instance of a Salesforce org based on the snapshot you made. The potential customers can then use this to fully explore the application for a limited time, until they sign up as a paying customer. Such orgs will eventually expire when the Salesforce trial period ends for the org created (typically 14 days). Thus, you should keep this in mind when setting the default expiry on your package licensing.

The standard approach is to offer a web form for the prospective user to complete in order to obtain the trial. Review the *Providing a Free Trial on your Website* and *Providing a Free Trial on AppExchange* sections of the *ISVforce Guide* for more on this.

You can also consider utilizing the Signup Request API, which gives you more control over how the process is started and the ability to monitor it, such that you can create the lead records yourself. You can find out more about this in the *Creating Signups using the API* section in the *ISVforce Guide*. As a more advanced option, if you are an ISV with an existing application and wish to utilize Salesforce.com as a backend service, you can use this API to completely create and manage orgs on their behalf. Review the *Creating Proxy Signups for OAuth* and the *API Access* section in the *ISVforce Guide* for more information on this.

Alternatively, if the prospective user wishes to try your package in their sandbox environment, for example, you can permit them to install the package directly, either from AppExchange or from your website. In this case, ensure that you have defined a default expiry on your package license, as described earlier. In this scenario, you or the prospective user will have to perform the setup steps after installation.

Finally, there is a third option called **Test Drive**, which does not create a new org for the prospective user on request, but does require you to set up an org with your application, preconfigure it, and then link it to your listing via AppExchange. Instead of the users completing a signup page, they click on the **Test Drive** button on your AppExchange listing. This logs them in to your test drive org as read-only users. Because this is a shared org, the user experience and features you can offer to users is limited to those that mainly read information. I recommend that you consider Trialforce over this option, unless there is a really compelling reason to use it.



When defining your listing in AppExchange, the **Leads** tab can be used to configure the creation of lead records for trials, test drives, and other activities on your listing. Enabling this will result in a form being presented to the user before accessing these features on your listing. If you provide access to trials through signup forms on your website, for example, lead information will not be captured.

## Distributing Salesforce Connected Apps

If you plan to build any kind of platform integration, including a dedicated mobile application, for example, using Salesforce APIs or any you build using Apex, you will need to create and package what's known as a Connected App. This allows you as the ISV to set up the OAuth configuration that allows users of these integrations to connect to Salesforce, and thus, your logic and objects running on the platform. You don't actually need to package this configuration, but you are encouraged to do so, since it will allow your customers to control and monitor how they utilize your solution.

## Summary

This chapter has given you a practical overview of the initial package creation process through installing it into another Salesforce organization. While some of the features discussed cannot be fully exercised until you're close to your first release phase, you can now head to development with a good understanding of how early decisions, such as references to Standard Objects, are critical to your licensing and cost decisions.

It is also important to keep in mind that, while tools such as Trialforce help automate the setup, this does not apply to installing and configuring your customer environments. Thus, when making choices regarding configurations and defaults in your design, keep in mind the costs to the customer during the implementation cycle.

Make sure you plan for the security review process in your release cycle (the free online version has a limited bandwidth) and ideally integrate it into your CI build system (a paid facility) as early as possible, since the tool not only monitors security flaws but also helps report breaches in best practices, such as lack of test asserts and SOQL or DML statements in loops.

In the following chapters, we will start exploring the engineering aspects of building an enterprise application as we build upgrades on the package created in this chapter, allowing us to better explore how the platform supports incremental growth of your application.



As you revisit the tools covered in this chapter, be sure to reference the excellent *ISVforce Guide* at <http://www.salesforce.com/us/developer/docs/packagingGuide/index.htm> for the latest detailed steps and instructions on how to access, configure, and use these features.

# 2

## Leveraging Platform Features

In this chapter, we will explore some key features of the Force.com platform that enables developers to build the application more rapidly, but also provides key features to end users of the application. Using these features in a balanced way is the key to ensuring that you and your users not only get the best out of the platform today, but continue to do so in the future as the platform evolves.

A key requirement for an enterprise application is the ability to customize and extend its functionality, as enterprise customers have varied and complex businesses. You should also keep in mind that, as your ecosystem grows, you should ensure that your partner relationships are empowered by the correct level of integration options and that they need to interface their solutions with yours; the platform also plays a key role here.

As we expand our FormulaForce package, we will explore the following to better understand some of the decision making around platform alignment:

- Packaging and upgradable components
- Custom field features
- Security features
- Platform APIs
- Localization and translation
- Building customizable user interfaces
- E-mail customization with e-mail templates
- Workflow and flow
- Social features and mobile

## Packaging and upgradable components

The time taken to install your application and get it prepared for live usage by your customers is a critical phase in your customer relationship. They are obviously keen to get their hands on your new and improved releases as quickly as possible. Careful planning and awareness of which of the components you are using are packable and upgradeable are important to monitor the effort involved at this stage.

When exploring the various platform features available to you, it is important to check whether the related component type can be packaged or not. For a full list of components that can be packaged, search for the *Available Components* section in *ISVforce Guide*, referenced in the previous chapter.

<https://developer.salesforce.com/docs/atlas.en-us.packagingGuide.meta/packagingGuide/>



If a component type relating to a feature you wish to use cannot be packaged, it does not necessarily mean it is of no use to you or your users, as it may well be something you can promote through your consulting team for your end user admins to take advantage of after installation. Though that keep in mind, how often you recommend this, especially if it starts to become a required post-installation task, will increase the time it takes for your users to go live on your application.

Another aspect to consider is whether the component type is upgradeable, that is, if you define and include one release of your package, then modify it in a subsequent release, it will be updated in the subscriber (customer) organization. The table in the *Available Components* section in *ISVforce Guide* will also give you the latest information on this. Some component types that are not upgradeable are as follows:

- Layouts
- E-mail templates
- Reports
- List view

These features are key to your application design and are covered in more detail later in this chapter. It is also important that end users can customize these; hence, Salesforce allows them to be edited. Unfortunately, this means they are not upgradable, that is, in the case of Layouts for example, any new fields you add to your Custom Objects do not appear by default after an upgrade is available for your users. However, new installations of your package will receive the latest versions of these components in your package.

This also applies to some attributes of components that are flagged as upgradeable in the table referenced previously, but have certain attributes that are then not upgradeable. Refer to the *Editing Components and Attributes After Installation* section in *ISVforce Guide* for the latest details on this. Some common attributes that are packable but not upgradable, and hence, end user modifiable are as follows:

- **Custom field:** Picklist values
- **Validation Rule:** Active
- **Custom Object:** Action overrides



The active status of the Validation Rule is quite a surprising one; while the user cannot modify your packaged Validation Rule, they can disable it. For most purposes, this means that this platform feature becomes a post-install optional activity left to the end user where they should wish to implement rules unique to them. For validations you wish to implement in **Apex**, you can utilize a protected Custom Setting to control activation if desired (such settings are only visible to your support teams via subscriber support).

## Custom field – picklist values

Probably the most surprising of the non-upgradeable attributes of the custom field is the list of picklist values. These are completely modifiable by end users; they can be added, modified, or deleted. This means that you need to be very careful about how you reference these in your Apex code, and consequently, you provide guidelines to your end users about editing and applying changes post upgrade.



The Salesforce **Translation Workbench** tool, under the **Setup** menu, can be used to effectively relabel a pick list value by editing the users' current language without having to rename its value on the field definition. This can be done after installation of the tool by the end user admin.

Also, remember that the platform treats picklist fields mostly as if they were text fields; as such, you can query and even update a picklist field with any value you like. Also, keep in mind that you can upgrade customer data (if you change or delete a picklist value) through an Apex post-install script.

## Global Picklists

An alternative to defining picklists at the field level is Global Picklists. Available under the **Setup** menu, they allow you to define and package picklists independent of fields and thus can be shared across multiple fields.

There are two significant differences to picklists defined this way.

- They cannot be modified in the subscriber org by the end user
- They are validated by the platform if the user or code attempts to update a field with an invalid picklist value

If you require picklists on your fields to be customized or don't have any issues with them being modified, then you can define picklists at the field level. Otherwise Global Picklists are the more natural and safest default to use in cases where your data model requires fields with fixed values, even if there is no reuse between fields. Keep in mind users can still modify the labels of global picklist entries through **Salesforce Translation Workbench** regardless of the route you choose.

## Automating upgrades with the Salesforce Metadata API

Salesforce as ever is great at providing APIs; the **Metadata API** is no exception, as it provides a pretty broad coverage of most things that can be done under the **Setup** menu. This means that it is feasible to consider the development of upgrade tools to assist in upgrading components, such as layouts or picklist values. Such tools will have to handle the logic of merging and confirming the changes with the user of, for example, providing a means to merge new fields into layouts, which the user selects from a UI prompt.

Currently, the Metadata API is not directly accessible from Apex (though I remain hopeful that it will be accessible in the future). However, it can be invoked via an Apex HTTP callout, as it is available as a SOAP API.

The Apex Metadata API library has provided an Apex wrapper at <https://github.com/financialforcedev/apex-mdapi> to make it easier to use. The following Apex code shows the library being used to programmatically update a layout to add a new custom button. This code can be used as part of a tool you provide with your application or separately by your consultants. For more information, you can refer to the **README** file in the GitHub repository.

```
// Read the layout
MetadataService.Layout layout =
    (MetadataService.Layout) service.readMetadata(
```

```
'Layout', new String''  
" 'Test__c-Test Layout' " ) .getRecords () '0';  
  
// Add a button to the layout  
layout.customButtons.add('anewbutton');  
  
// Update the layout  
List<MetadataService.SaveResult> result =  
service.updateMetadata(  
new MetadataService.Metadata' " layout " );
```



It is feasible to consider invoking this logic from a package post-install script. However, Salesforce currently requires that you define a remote site in order to authorize the callout, even to their own servers. As the end point differs for this API, based on the subscriber orgs Salesforce instance, it is hard to predefine and thus preinstall this configuration as part of your package. As such, unless you are confident that the remote site has been set up before an upgrade, it might be best to guide the user to a Visualforce page (perhaps through an e-mail from the post-install script), where you can prompt the user.

## Understanding the custom field features

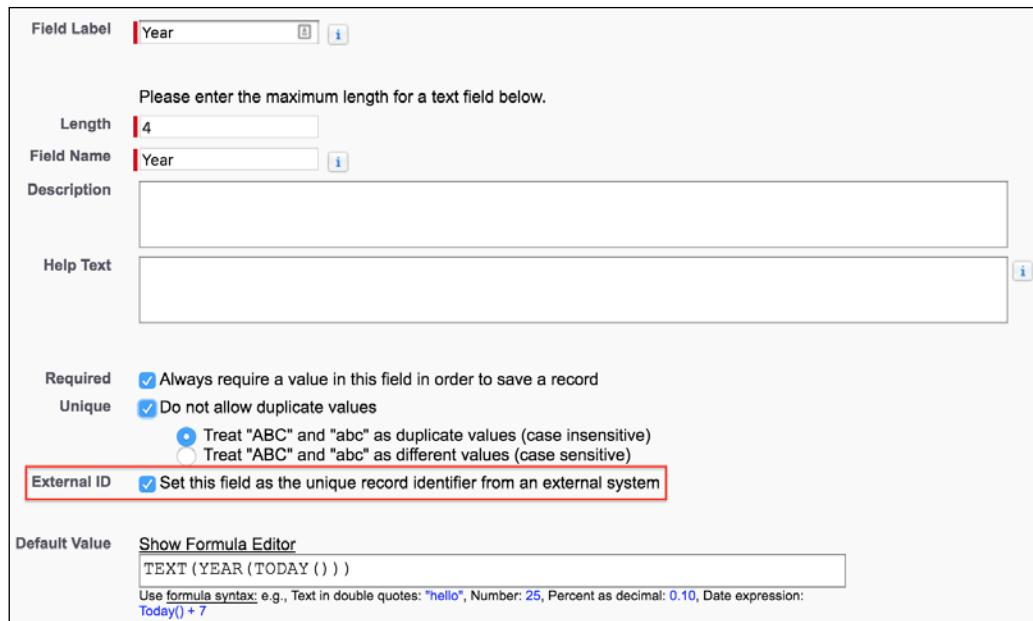
Custom fields carry many more features than you might think; they are much more than simple field definitions you find on other platforms. Having a good understanding of a custom field is the key to reducing the amount of code you have to write and improving the user experience and reporting of your application's data.

### Default field values

Adding default values to your fields improves the usability of your application and can reduce the number of fields needed on the screen, as users can remove fields with acceptable defaults from the layouts.

Default values defined on custom fields apply in the native user interfaces and Visualforce UIs (providing the `apex:inputField` component is used) and in some cases, through the APIs. You can define a default value based on a formula using either literal values and/or variables such as `$User`, `$Organization`, and `$Setup`.

Let's try this out. Create a **Year** text field on the **Season** object as per the following screenshot. Make sure that you select the **External ID** checkbox as this cannot be changed on the field once the package is uploaded at the end of this chapter. This will become important in the next chapter.



Field Label **Year**

Please enter the maximum length for a text field below.

Length **4**

Field Name **Year**

Description

Help Text

Required  Always require a value in this field in order to save a record

Unique  Do not allow duplicate values

Treat "ABC" and "abc" as duplicate values (case insensitive)  
 Treat "ABC" and "abc" as different values (case sensitive)

External ID  Set this field as the unique record identifier from an external system

Default Value [Show Formula Editor](#)  
TEXT (YEAR (TODAY ( ) ) )

Use formula syntax: e.g., Text in double quotes: "hello", Number: 25, Percent as decimal: 0.10, Date expression: Today() + 7

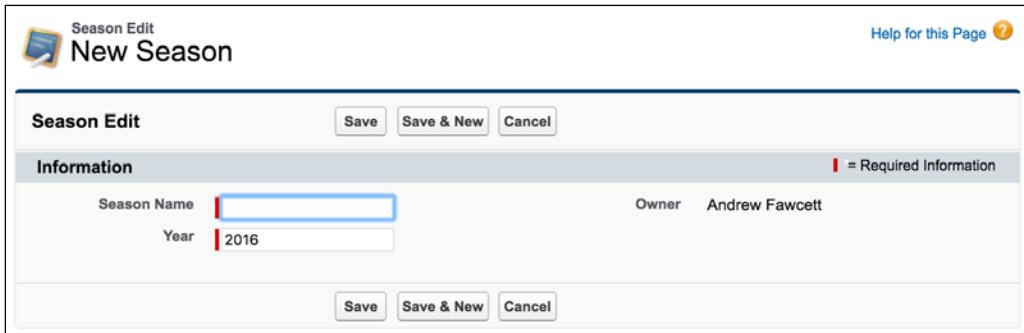


The default value you define cannot be overridden through a customization in the subscriber org, however, you can reference a Custom Setting (hierarchy type only) in a default value formula using a \$Setup reference. This allows for some customization through editing the Custom Setting at an organization, profile, or individual user level.

To create a record in the **Season** object, we need to first create a tab for it. Perform the following steps in the package org to try out this process:

1. Create a tab for the **Season** object.
2. Go to the **Season** tab and click on **New**.

3. This results in the current year being displayed in the **Year** field as shown in the following screenshot:



The screenshot shows a 'Season Edit' page for a 'New Season'. The 'Season Name' field is empty, and the 'Year' field contains the value '2016'. The 'Owner' is listed as Andrew Fawcett. At the top right, there is a 'Help for this Page' link. At the bottom, there are 'Save', 'Save & New', and 'Cancel' buttons.

[  The preceding screenshot shows the user interface shown by Salesforce when the user is using Salesforce Classic. Salesforce Classic is the predecessor to their latest user interface technology known as Lightning Experience. Both are options for users and will likely remain so for some time until users and applications are migrated over. This book also includes information on Lightning throughout its chapters, as well as a dedicated *Chapter 10, Lightning*. ]

Unfortunately, by default, the Apex code does not apply default values when you construct an SObject in the direct manner via `new Season()`; however, if you utilize the `SObjectType.newSObject` method, you can request for defaults to be applied as follows:

```
Season__c season = (Season__c)
    Season__c.SObjectType.newSObject(null, true);
    System.assertEquals('2016', season.Year__c);
```

## Encrypted fields

However unlikely you feel data theft might be, there are some markets and government regulations that require encrypted fields. Salesforce offers two ways to help ensure your application data is stored in their data centers in an encrypted form. There are two options to consider for encrypting field values at rest, that is records physically stored on permanent storage.

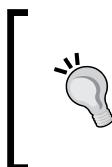
- **Classic Encryption:** Encrypted fields leverage 128-bit master keys and use the **Advanced Encryption Standard (AES)** algorithm to store values; they are displayed using a character mask (currently not developer definable). Such fields are packagable, though this only applies to Text fields.

- Platform Encryption: Customers that have purchased the Salesforce Shield add-on can enable 256-bit AES encryption for certain Standard fields and Custom fields of their choosing. It can be applied to E-mail, Phone, Text, Text Area, URL, Date and Date/Time fields. While the encryption level is higher this facility does come with some significant restrictions, these are covered in the next section.

Encrypted field values are visible to those who have the **View Encrypted Data** permission, which is a facility that may not be something your requirements tolerate. This also includes users whom you grant the login access to, such as through subscriber support. Apex, Visualforce Page, Lightning Components and Validation Rule logic you package can see the unencrypted values, so extra care is needed by developers if you want to mask field values. If your only concern is compliance with encryption at rest, this may not be such an issue for you.

## Special considerations for Platform Encryption

Salesforce recommend that you only consider this feature if government regulations for your market require it. When developing a packaged solution, your main consideration is what happens if a subscriber wishes to enable it on a Standard field you reference in your solution or on one of your packaged fields.



For those that do want to promote support for this feature through their AppExchange listing, there is an indicator that can be applied to your listing by Salesforce to show prospective customers that you support Platform Encryption.

When implementing the 256-bit encryption used by Platform Encryption, Salesforce opted for probabilistic encryption over deterministic encryption. Since the encryption is not deterministic (encrypted value is the same each time), it is not possible to index fields that have this level of encryption applied. This results in the most significant of restrictions to developers and platform functionality around querying the field.

Without an index, the platform cannot provide a performant way to allow code to filter, group or order by encrypted fields in queries. If code attempts to do so at runtime, an exception will occur. Your package installation may be blocked if it detects queries inside Apex code that would not be compatible with this restriction. Conversely once your package is installed and the user attempts to enable encryption, this action may fail. Salesforce provides a report in both cases to inform the user which fields are problematic.

It is possible to work around these restrictions conditionally, by using Dynamic SOQL to allow runtime formation and the execution of effected queries where encryption is not enabled. In cases where encryption is enabled you can perform filtering, grouping and ordering in Apex and/or via **Salesforce Object Search Language (SOSL)**. Though both these options should be considered carefully as they have their own restrictions and may not be the most performant. You may need to accept that you have to selectively hide functionality in your solution in some cases. The decision is something you have to make in conjunction with your users as to how acceptable a trade-off this would be.



Regardless of if you plan to support Platform Encryption or not, it may still be an important need for your enterprise customers where your application must co-exists with other Salesforce products and other Partner solutions. I would recommend that you prepare a statement to set expectations early on what level of support you provide, such as which standard fields and package fields are supported. Make sure your prospects can make informed decisions, otherwise they may dismiss your application from their shortlists unnecessarily.

I highly recommend that you leverage the **Education** section in the Partner Success Community. Under the **MORE RESOURCES** section you will find a dedicated page with videos and other resources dedicated to ISVs.

## Lookup options, filters, and layouts

The standard lookup UI from Salesforce can be configured to make it easier for users to recognize the correct record to select, filter out those that are not relevant, and if necessary, prevent them from deleting records that are in use elsewhere in your application, all without writing any code.

Perform the following steps in the package org to try out this process:

1. Create **Tabs** for the **Driver** and **Race** objects.
2. Add an **Active** checkbox field to the **Driver** Custom Object; ensure that the default is **checked**.
3. Create a driver record, for example, **Lewis Hamilton**.
4. From the **Season** record created in the previous section, create a **Race** record, for example, **Spa**.
5. Associate **Lewis Hamilton** with the **spa** race via the **Contestants** relationship.

First, let's ensure that drivers cannot be deleted if they are associated with a Contestant record (meaning they have or are taking part in a race). Edit the **Driver** field on the **Contestant** object and enable **Don't allow deletion of the lookup record that's part of a lookup relationship**. This is similar to expressing a **referential integrity** rule in other database platforms.

Lookup Options	
Related To	<b>Driver</b>
Child Relationship Name	<b>Contestants</b>
Related List Label	<b>Contestants</b>
Required	<input checked="" type="checkbox"/> Always require a value in this field in order to save a record <input type="radio"/> Clear the value of this field. You can't choose this option if you make this field required.
What to do if the lookup record is deleted?	<input type="radio"/> Don't allow deletion of the lookup record that's part of a lookup relationship.

Now if you try to delete **Lewis Hamilton**, you should receive a message as shown in the following screenshot. This also applies if you attempt to delete via Apex DML or the Salesforce API.

Deletion problems

 **Lewis Hamilton**

Help for this Page 

Back to Previous Page

Your attempt to delete Lewis Hamilton could not be completed because it is associated with the following contestants. If the following table is empty, it's because you don't have access to the records restricting the delete.

Contestant Name
CONTESTANT-00000001

You've just saved yourself some Apex Trigger code and used a platform feature.

Let's take a look at another lookup feature, known as **lookup filters**. Formula 1 drivers come and go all the time; let's ensure when selecting drivers to be in races via the **Driver** lookup on the **Contestant** record, that only the active drivers are shown and are permitted when entered directly.

Perform the following steps in the packaging org to try out the process:

1. Create a **Driver** record, for example, **Rubens Barrichello** and ensure that the **Active** field is unchecked.

2. Edit the **Driver** field on the **Contestant** object and complete the **Lookup Filter** section as shown in the following screenshot, entering the suggested messages in the **If it doesn't, display this error message on save** and **Add this informational message to the lookup window** fields, and click on **Save**:

**Lookup Filter**

Optionally, create a filter to limit the records available to users in the lookup field. [Tell me more!](#)

[Hide Filter Settings](#)

Filter Criteria	Insert Suggested Criteria				
Field	Driver: Active	Operator	equals	Value / Field	True
AND	Begin typing to search for a field...		--None--	Value	

[Add Filter Logic...](#)

Filter Type  **Required.** The user-entered value must match filter criteria.  
 If it doesn't, display this error message on save:  
 Only Active Drivers can be contestants in a race.  
[Reset to default message](#)

**Optional.** The user can remove the filter or enter values that don't match criteria.

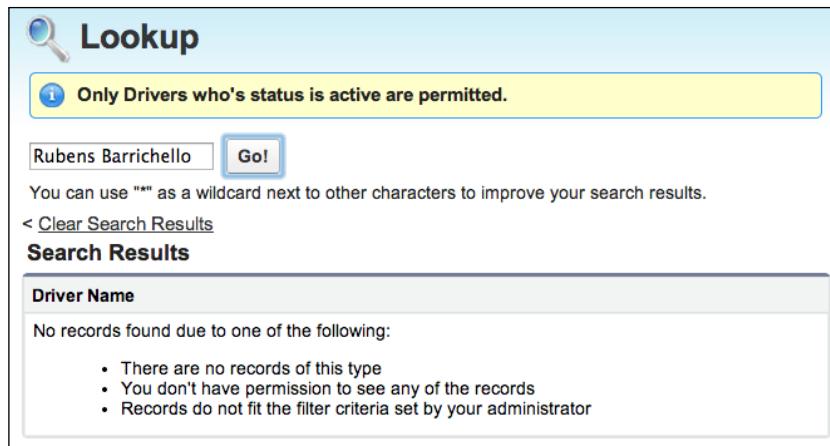
Lookup Window Text [Add this informational message to the lookup window.](#)  
 Only Drivers who's status is active are permitted.

Active  Enable this filter.

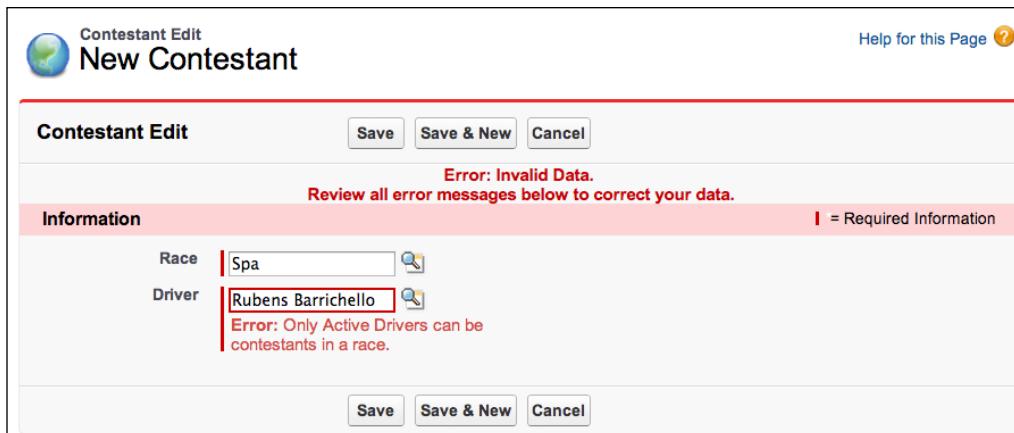
**Save** **Cancel**

You can have up to five active lookup filters per object. This is not a limit that is set by your package namespace. So, use them sparingly to give your end users room to create their own lookup filters. If you don't have a strong need for filtering, consider implementing it as an Apex Trigger validation.

Test the filter by attempting to create a Contestant child record for the Spa record. First, by using the lookup dialog, you will see the informational message entered previously and will be unable to select Rubens Barrichello, as shown in the following screenshot:



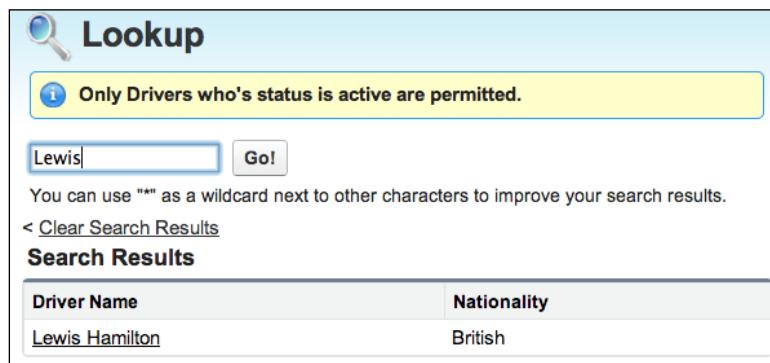
If you attempt to enter an inactive driver's name directly, this is also blocked as shown in the following screenshot:



This validation is also enforced through Apex DML and Salesforce APIs. Unlike Validation Rules, it cannot be disabled by the end user. However, changes related to records, such as making the Driver subsequently inactive, are permitted by the platform. In this case, the next time the Contestant record is edited, the error given in the preceding screenshot will occur.

Finally, you are also able to display additional columns on the lookup dialogs, which help the user identify the correct record based on other fields. The following steps describe how to do this:

1. Add a **Nationality** field to the **Driver** object of the **Picklist** type, and enter the following values: British, Spanish, Brazilian, Finnish, and Mexican.
2. Edit the existing **Driver** records and set an appropriate value in the **Nationality** field.
3. Locate the **Search Layouts** section of the **Driver** object, edit the **Lookup Dialogs** layout, add the **Nationality** field created in step 1, and save the layout. When selecting a driver, the lookup should now show this additional field, as follows:



Lookups are a hugely powerful declarative feature of the platform; they are not just used to express the application data model relationships, but they actually enforce the integrity of the data as well, thereby making the user's job of entering data much easier.

## Rollup summaries and limits

When it comes to performing calculations on your data, the platform provides a number of options: reports, Analytics API, dashboards, Apex Triggers, Visualforce, and Rollup summaries. The Rollup summary option provides a code-free solution with the ability to apply some condition filtering. Rollup summary fields can then also be referenced and combined with other features such as formula fields and Validation Rules.

The key requirement is that there is a Master-Detail relationship between the detail records being summarized on the field being added to the master records, such as that between **Race** and **Contestant**. The following example will total the number of competitors that did not finish a given race (or DNF in Formula 1 terms).

Perform the following steps in the package org to try out this process:

1. Create a **DNF** field on the **Contestant** object using the **Checkbox** field type.
2. Create a **Driver** record for Charles Pic and add him to the Spa race via the **Contestant** object, checking the **DNF** field.
3. Create a **Total DNFs** field on the **Race** object using a **Rollup Summary** field type. Select the **Contestants** object from the **Summarized Object** dropdown and **COUNT** as **Rollup-Up Type** and apply the **Filter Criteria** field as shown in the following screenshot, to select only **Contestant** records with the **DNF** field checked:

**Step 3. Define the summary calculation** Step 3 of 5

Previous Next Cancel

**Select Object to Summarize** |= Required Information

Master Object: Race  
Summarized Object:

**Select Roll-Up Type**

COUNT  SUM  MIN  MAX

Field to Aggregate:

**Filter Criteria**

All records should be included in the calculation  
 Only records meeting certain criteria should be included in the calculation

Field	Operator	Value		AND
<input style="width: 100px; height: 20px;" type="text" value="DNF"/>	<input style="width: 100px; height: 20px;" type="text" value="equals"/>	<input style="width: 100px; height: 20px;" type="text" value="True"/>		AND
<input style="width: 100px; height: 20px;" type="text" value="--None--"/>	<input style="width: 100px; height: 20px;" type="text" value="--None--"/>	<input style="width: 100px; height: 20px;" type="text" value="--None--"/>		AND
<input style="width: 100px; height: 20px;" type="text" value="--None--"/>	<input style="width: 100px; height: 20px;" type="text" value="--None--"/>	<input style="width: 100px; height: 20px;" type="text" value="--None--"/>		AND
<input style="width: 100px; height: 20px;" type="text" value="--None--"/>	<input style="width: 100px; height: 20px;" type="text" value="--None--"/>	<input style="width: 100px; height: 20px;" type="text" value="--None--"/>		AND
<input style="width: 100px; height: 20px;" type="text" value="--None--"/>	<input style="width: 100px; height: 20px;" type="text" value="--None--"/>	<input style="width: 100px; height: 20px;" type="text" value="--None--"/>		

For checkbox fields, enter a value of True for checked or False for not checked. For picklist fields, enter the master picklist field value in your corporate language.

Navigate to the **Spa** record and note that the **Total DNFs** shows the value **1**. Experiment by changing the status of the **DNF** field on the **Driver** records to see the value recalculate.

Rollup summaries provide a real-time calculation once configured. However, when creating or changing rollups, Salesforce states that it can take up to 30 minutes. You can read more about them by searching for *About Roll-Up Summary Fields* in the documentation and by reviewing the *Roll Up Summary Field Technology Overview* knowledge base article at <http://help.salesforce.com/apex/HTViewSolution?id=000004281>.



You can combine the use of Rollup summary fields in your Apex Trigger logic, for example, you can add the Apex logic to check the number of DNFs in the after phase of the trigger on the **Race** object. Your users can also apply Validation Rules on the **Race** object that references its Rollup summary fields. Any changes to **Contestant** detail records that cause this Validation Rule to be invalid will prevent updates to the related **Contestant** record.

As you can imagine, calculating Rollup summaries can be quite an intensive job for the Salesforce servers. As such, Salesforce limits the total number of Rollup summaries to 10 per object, though this can be increased to 25 by contacting Salesforce Support with a valid business case. Keep in mind that as a packaged application provider, this limit is not scoped by your namespace, unlike other limits. This means that if you use all 10, your end users will not be able to add their own post-installation. Similarly, if they have created their own post-installation and an upgrade causes the limit to be breached, the install will fail.



While this can be a powerful feature, carefully consider the other summarization options listed in the previous paragraph and if your users really need this information to be real-time or accessible from formulas and Validation Rules. If not, a good compromise is a Visualforce page that can be added inline into the **Page Layout** objects. The Visualforce page can utilize the `readonly=true` attribute in which the Apex Controller logic can utilize aggregate SOQL queries to aggregate up to 5 million records (subject to appropriate indexes and within standard timeout tolerance). This page can then display when the user reviews the record in the UI and is thus calculated on demand. Enhancing the Salesforce standard pages with Visualforce is discussed in more detail later in this chapter

## Understanding the available security features

The platform provides security controls to manage the accessibility of functionalities in your application and also the visibility of the individual records it creates. As an application provider, your code has a responsibility to enforce security rules as well as to provide integrations that help administrators configure security easily. This section is not aimed at taking a deep dive into the security features of the platform, but is more an aid in understanding the options, best practices, and packaging implications.

One of the key checks the security review process described in the previous chapter makes is to scan the code to ensure that it is using the appropriate Apex conventions to enforce the security rules administrators of your application configure, as not all security checks are enforced automatically for you.

This chapter discusses the following two categories of security as provided by the platform:

- **Functional security:** Security that applies to application objects and some code entry points (providing APIs) and also Visualforce pages that deliver the features of the application is referred to here as functional security
- **Data security:** In contrast to security applied to individual record data created and maintained by the application, this type of security is referred to as data security

## Functional security

Both **profiles** and **Permission Sets** can be created and packaged in your application to help administrators of your application control access to your objects, fields, tabs, and pages. Fundamentally, profiles have been historically used to prepackage the roles, such as *team principle*, you envisage users using in your application. In contrast, Permission Sets can be used to express the functionality in your application such as *the ability to assign a driver to a race*.

By now, most people are familiar with configuring profiles to control security. The issue is that they can eventually lead to a proliferation of profiles; as small differences in needs between users arise, profiles are then cloned and thus increases the administration overhead when performing common changes. To manage this, Salesforce created Permission Sets, which is a much more granular way of expressing security controls.

From an application perspective, you can package Permission Sets and even have them upgraded automatically as they change in accordance with the new or updated functionality in your application. You can also assign them after installation, in contrast to profiles, which can only be done during the installation. Also unlike profiles, administrators cannot edit them though they can clone them if there is a need (this is not possible in Professional and Group Editions of Salesforce). Because of these benefits, it is recommended that Permission Sets be used over profiles when packaging security information about your application.

It is important to plan your use of Permission Sets from the start so that your development team keeps them updated and their usage remains consistent throughout. Consider the following when designing your Permission Set strategy:

- **Think features not roles:** Do not be tempted to fall back to expressing the roles you envisage your application users being assigned. Enterprise organizations are large and complex; rarely does one size fit all. For example, a **team principle** can have many different responsibilities across your application from one installation to another. If you get this wrong, the administrator will be forced to clone the Permission Set, resulting in the start of the proliferation of unmanaged Permission Sets that do not track with the new or changed functionality as your package is upgraded.
- **Granularity:** As you design the functionality of your application, modules are defined (you can use **Application** under **Setup** to indicate these), and within these objects, tabs, or pages, each has distinct operations. For example, the **Contestant** object might describe the ability to indicate that a driver has crashed out of the race and update the appropriate **DNF** field, which is **Update DNF Status**. For example, this permission might be assigned to the race controller user. In contrast, you might have a less granular Permission Set called **Race Management**, which encompasses the **Update DNF Status** permission plus others. Considering this approach to design your Permission Sets means that administrators have less work to assign to users, while at the same time, they have the power to be more selective should they wish to.
- **Naming convention:** When the administrator is viewing your Permission Sets in the Salesforce UI ensure they are grouped according to the functional aspects of your application by considering a naming convention, for example, **FormulaForce - Race Management** and **FormulaForce - Race Management - Update DNF Status**.



One of the limitations of the **License Management Application (LMA)** described in the previous chapter is that it is not very granular; you can only effectively grant user licenses to the whole package and not modules or key features within it. With the introduction of Permission Set licenses, Salesforce looks to be heading down the path of providing a means to define your licensing requirements with respect to Permission Sets. At the time of writing this, there was no support for developers to create their own; this looks like the next obvious step. This is something to consider when designing your Permission Sets for use as license control, for example, one day you may be able to use this to enforce a pricing model for high-priced licenses associated with the **Race Management** permission.

Perform the following steps in the package org to try out this process:

1. Create a Race Management custom application (under **Setup | Create**) and add the **Driver**, **Season**, and **Race** tabs created earlier to it; make the **Race** tab the default.
2. Create a Race Analytics custom application and add the **Race** and **Reports** tabs to it; make the **Reports** tab the default.
3. Create the Permission Sets for the FormulaForce application as shown in the following table. Leave the **User License** field set to **None**.
4. Finally, add the following Permission Sets to the FormulaForce package.

Permission Set	Permissions
<b>FormulaForce - Race Management</b>	Race Management (Custom Application) Race Analytics (Custom Application) Season tab (Custom Tab) Race tab (Custom Tab) Driver tab (Custom Tab) Object (Custom Object, Full Access) Race object (Custom Object, Full Access) Driver object (Custom Object, Full Access) Contestant object (Custom Object, Full Access)
<b>FormulaForce - Race Management - Update DNF Status</b>	Contestant object (Custom Object, Read, Edit) DNF (Custom Field, Read, Edit)
<b>FormulaForce - Race Analytics</b>	Race Analytics (Custom Application) Race object (Custom Object, Read Only, Read DNF)

Here, Full Access means it gives access to read, create, edit, and delete all custom fields. Also, at the time of writing this, the Custom Application and Custom Tab components within Permission Sets are not packable. Until they become packable, it is recommended that you still maintain this information in the Permission Sets.

## Your code and security review considerations

Not all code you write will automatically be subjected to enforcement by the platform through the object- and field-level security defined by the Permission Sets or profiles assigned to users. While certain Visualforce components such as `apex:inputField` and `apex:outputField` enforce security, other ways in which you obtain or display information to users will not enforce security, such as `apex:inputText` and `apex:outputText`. The differences will be discussed in more detail in a later chapter.

When your code is performing calculations or transformations on fields in the controller, expose this data indirectly via Apex bindings or remote action methods on your controller; for this, you need to add additional checks yourself. This also applies to any customer facing the Apex code such as global methods or Apex REST APIs you build.

In these cases, you can use the **Apex Describe** facility to specifically check the user's profile or Permission Set assignment for access and prevent further execution by returning errors or throwing exceptions. The formal reference information for implementing this can be found in the following two Salesforce articles:

- **Enforcing CRUD and FLS:** [https://developer.salesforce.com/page/Enforcing CRUD\\_and\\_FLS](https://developer.salesforce.com/page/Enforcing CRUD_and_FLS)
- **Testing CRUD and FLS Enforcement:** [https://developer.salesforce.com/page/Testing CRUD\\_and\\_FLS\\_Enforcement](https://developer.salesforce.com/page/Testing CRUD_and_FLS_Enforcement)

The Salesforce security review scanner and team insist that you check Custom Object level security (CRUD security for short) and include checking for every field that is accessed (**field-level security (FLS)**).

Implementing code to check both needs careful consideration, planning, and monitoring. Implementing FLS is especially complex with multiple use cases and contexts applying different usage patterns within your code base. For some functionalities, you may wish the application to access certain objects and/or fields on the users' behalf without checking security; document these cases well as you might need to present them to Salesforce.

Implementing CRUD security is something we will revisit in later chapters on the Domain and Selector layers of your Apex code, where some automated support within the library used to support these patterns has been provided.



It's best to review and document your approach and use the CRUD and FLS checking as a part of defining your coding conventions, and if in doubt, discuss with your Salesforce **Technical Account Manager (TAM)** or by raising a support case in Partner Portal. This way, you will also have some reference decisions and conversations to use when providing input and background to the security review team. Meanwhile, the Salesforce community, including myself, is looking at ways of creating generic ways to enforce CRUD and FLS without having to see hardcoded checks throughout the code base.

Note that it is a common misconception that applying the `with sharing` keyword to your Apex classes will automatically enforce CRUD or FLS security, but it does not. This keyword solely controls the records returned when querying objects, so is in fact related only to data security.

## Data security

Regardless of which Custom Objects or fields are accessible to the end user through their profile or Permission Set assignments, there may still be a requirement to filter which records certain users can see, for example, certain race data during and after the race can only be visible to the owning teams.

Salesforce allows this level of security to be controlled through the **Owner** field on each record and optionally a facility known as sharing. This is defined via the **Sharing Settings** page (under **Security Controls | Setup**), in the packaging org for the FormulaForce application. This page is shown in the following screenshot:

**Sharing Settings**

Criteria-Based Sharing Rules Video Tutorial | Help for this Page 

This page displays your organization's sharing settings. These settings specify the level of access your users have to each others' data.

Manage sharing settings for: **All Objects** 

**Default Sharing Settings**

Organization-Wide Defaults		Edit	Organization-Wide Defaults Help 
Object	Default Access	Grant Access Using Hierarchies	
Lead	Public Read/Write/Transfer	✓	
Account, Contract and Asset	Public Read/Write	✓	
Contact	Controlled by Parent	✓	
Opportunity	Public Read/Write	✓	
Case	Public Read/Write/Transfer	✓	
Campaign	Public Full Access	✓	
Activity	Private	✓	
Calendar	Hide Details and Add Events	✓	
Price Book	Use	✓	
Contestant	Controlled by Parent		
Driver	Public Read/Write	✓	
Race	Controlled by Parent		
Season	Public Read/Write	✓	

You can see the Standard Objects and also the Custom Objects we have created so far listed here. When you click on **Edit**, **Default Access** shows that the access options vary based on whether the object is a standard or Custom Object, as Salesforce has some special access modes for certain Standard Objects such as **Price Book**.



Notice that where an object is in a child relationship with a parent record, in the case of **Race** and **Session**, there is no facility to control the security of this object. Thus, when you are designing your application object schema, make sure that you consider whether you or your users will need to utilize sharing on this object; if so, it might be better to consider a standard lookup relationship.

For the Custom Objects that exist as a part of the FormulaForce application, you can define **Public Read/Write**, **Public Read Only**, and **Private**. The default value is always **Public Read/Write**.

The default access defines the starting position for the platform to determine the visibility of a given record using the **Owner** field and the object's **sharing rules**. In other words, you cannot use these features to hide records from a given user if the object has **Public Read** or **Public Read/Write** default access.



Although this setting is packaged with Custom Objects, it is editable in the subscriber org and is thus not upgradable. If you decide to change this in a later release, this will need to be done manually as a post-install task.

If you set the **Private** default access and do nothing, the **Owner** field determines the visibility of the records. By default, the owner is the user that created the record. Thus, users can only see records they create or records created by other users below them in the **role hierarchy** (if enabled). A record owner can be a user or a group (known as **Queue** within the API), for example, members of a specific racing team. Users can choose to manually share a record they own with other users or groups also.

Sometimes, a more sophisticated and dynamic logic is required; in these cases, sharing rules can be added and they can be created either declaratively (from the **Sharing Settings** page) or programmatically. Regardless of the approach used, the platform creates a **Share** object (for example, for a **RaceData\_\_c** object, this would be **RaceData\_\_Share**) that contains records resulting from the evaluation of sharing rules; these records can be queried like any other object, useful for debugging.



For the ultimate in flexibility, you can write logic within an Apex Trigger or Scheduled Job to directly create, update, or delete the sharing records, for example, in the **RaceData\_\_Share** object. In this case, the criteria for sharing records can be practically anything you can express in code. You first define a sharing reason against the applicable Custom Object, which will be automatically included in your package. This is used as a kind of tag for the sharing records your application code creates versus sharing records created through sharing rules defined in the subscriber org. Also note that if the platform detects references to the **Share** object for a given object listed on the **Sharing Settings** page, it will prevent the subscriber org administrator from changing the default access from **Private** to **Public**.

## Your code and security review considerations

The platform will enforce record visibility in cases where the user attempts to navigate to the record directly in the Salesforce UI, including reports they run and access provided via Salesforce APIs when they use third-party applications.

However, keep in mind that your Apex code runs at system level by default; thus, it's important to pay attention to the use of the `with sharing` or `without sharing` keyword (for all key entry points to your code). This is also something the security review scanner will look for. You might as well ask when using the `without sharing` keyword makes sense; such a use case might be when you explicitly want a system-level logic to see all records on behalf of an operation or validation the user is performing.

## Platform APIs

Salesforce provides a number of APIs to access and manipulate records in its own objects that belong to applications such as CRM; these APIs are also extended to support Custom Objects created by admins or provided by packages installed in the subscriber org. Salesforce dedicates a huge amount of its own and community-driven documentation resources you can reference when educating partners and customer developers on the use of these APIs. Thus, it is important that your application works well with these APIs.

Platform APIs are enabled for Enterprise Edition orgs and above, though if you have a need to consume them in Professional or Group Edition orgs, Salesforce can provide a Partner API token (following security review completion) to enable their use; this is unique to your application and so does not provide access for code other than yours.

Typically, unless you are developing an off-platform utility or integration to accompany your application, you may not find your application consuming these APIs at all, though there are some you might want to consider, highlighted in the following bullets. Keep in mind, however, that if you do, in addition to the Partner API token, the subscriber org's daily API limit will also be consumed; hence, ensure that your usage is as network optimal as possible.

Enterprise-level customers often have complex integration requirements both on and off platform; typically, Salesforce utilizes the SOAP and REST technologies to make these APIs available to any number of platforms and languages such as Java and Microsoft .NET. In *Chapter 9, Providing Integration and Extensibility*, we will discuss how you can extend the features of the platform data-orientated APIs with your own more application process-orientated APIs.



Note that not all platform APIs have an Apex variant that can be called directly, though this does not necessarily mean that they cannot be used. Apex supports making outbound HTTP callouts either via a WSDL or by directly creating and parsing the required requests and responses. A good example of this is the Metadata API, which can be used to develop Visualforce wizards to automate common setup tasks via Apex, as shown in an Apex example Ok to delete later in this chapter.

The following list details some of the main APIs that may be of use to your Enterprise-level customers wishing to develop solutions around your application:

- **Enterprise API:** This SOAP API is dynamically generated based on the objects present at the time in the subscriber org, meaning that any tool (such as data-mapping tools) or developer consuming it will find the information it exposes more familiar and easier to access. One downside, however, is that this can end up being quite a large API to work with, as Enterprise customer orgs often have hundreds of objects and fields in them.
- **Partner API:** This is also a SOAP API; unlike the Enterprise API, it provides a more generic CRUD-based API to access the record in the subscriber org. Its name can be a bit misleading, as there is no restriction to non-partners using it, and as it is lighter than the Enterprise API, it's often a first choice.
- **REST API:** This provides another CRUD style API, similar to the Partner API, but in this case, it is based on the more popular REST technology standard. It's often preferred when building mobile applications and is also fast becoming popular as the default API for Java and .NET.
- **Metadata API and Tooling API:** These SOAP APIs provide a means to automate many of the tasks performed under the **Setup** menu and those performed by developers when editing code. While these might not be of direct interest to those integrating with your application, as many of these tasks are performed initially and then only rarely, it might be something to consider using in tools you want to provide to keep the implementation times for your application low.

- **Streaming API:** This API utilizes a HTTP long polling protocol known as the Bayeux protocol to allow callers to monitor in near real time and record activity in Salesforce. This API can be used on a page to monitor race data as it arrives and display it in near real time to the user.
- **Replication API:** Sometimes it is not possible or desirable to migrate all data into Salesforce through Custom Objects. In some cases, this migration is too complex or cost prohibitive. This REST and Apex API allows replication solutions to determine for a given period of time which records for a given object have been created, updated, or deleted.
- **Bulk API:** This REST-based API allows the import and export of large amounts of records in CSV or XML format up to 10 MB in size per batch job.

## Considerations for working well with OK platforms APIs

The following are some considerations to ensure that your application objects are well placed to work well with OK platform APIs:

- **Naming Custom Objects and fields:** When naming your Custom Objects and fields, pay attention to **API Name** (or **Developer Name**, as it is sometimes referenced). This is the name used when referencing the object or field in the APIs and Apex code mentioned in the previous section. Personally, I prefer to remove the underscore characters that the Salesforce Setup UIs automatically place in the default API names when you tap out of the **Label** field, as doing so makes the API name shorter and easier to type with fewer underscore characters. It then ends up reflecting the camel case used by most APIs, for example, `RaceData__c` instead of `Race_Data__c`.
- **Label and API name consistency:** While it is possible to rename the label of a custom field between releases of your application, you cannot rename the API name. Try to avoid doing so, as causing an inconsistency between the field label and API name makes it harder for business users and developers to work together and locate the correct fields.

- **Naming Relationships:** Whenever you define **Master-Detail** or **Lookup Relationship**, the platform uses the plural label value of the object to form a relationship API name. This API name is used when querying related records as part of a subquery, for example, `select Id, Name, (select Id, Name from Races) from Season__c`. When creating relationship fields, pay attention to the default value entered into the **Child Relationship Name** field, removing underscores if desired and checking whether the names make sense.

For example, if you create a lookup field to the `Driver__c` object called **Fastest Lap By** on the `Race__c` object, the default relationship API name will be **Races**. When using this in a subquery context, it will look like `select Id, Name, (select Id, Name from Races) from Race__c`. However, by naming the relationship **FastestLaps**, this results in a more self-describing query: `select Id, Name, (select Id, Name from FastestLaps) from Race__c`.

- **Apex Triggers bulkification and performance:** When testing Apex Triggers, ensure that you accommodate up to 200 records; this is the default chunk size that Salesforce recommends when utilizing its bulk APIs. This tests the standard guidelines around bulkification best practices; although smaller chunk sizes can be configured, it will typically reduce the execution time of the overall process. Also related to execution time is the time spent within Apex Trigger code, when users solely update fields that have been added in the subscriber org. In these cases, executing the Apex Trigger logic is mostly redundant, as none of the fields this logic is interested in will have changed. Therefore, encourage the optimization of the Apex Trigger logic to execute expensive operations (such as the execution of SOQL) only if fields that have been packaged have changed.

## Localization and translation

It is important to take localization and translation into consideration from the beginning as it can become difficult and costly to apply it later. Fortunately, the platform can do a lot of work for you.

## Localization

When using the native user interface, it automatically formats the values of the numeric and date fields according to the **Locale** field on the user profile. **Visualforce** pages using the `apex:outputField` and `apex:inputField` components will automatically format values, and outputting local sensitive values in any other way will need to be handled manually in your Apex Controller code or in your JavaScript code.



It's not always possible to use the Visualforce `apex:inputField` and `apex:outputField` tags as described earlier in this chapter. For example, if the information you are displaying is not contained within a Custom Object field, but in some calculated view state in your Apex Controller. The format methods on various type classes such as `Date`, `DateTime`, and `Decimal`, can be used to generate a formatted string value that you can bind to on your pages. You can also determine the users' ISO locale code via `UserInfo.getLocale()`.

## Translation

Literal text entered when defining components such as Custom Objects, fields, and layouts are automatically available to the Salesforce **Translation Workbench** tool. However, literal text used in the Apex code and Visualforce pages need special attention from the developer through the use of Custom Labels.

It is important to avoid the concatenation of Custom Label values when forming messages to the end user, as it makes it harder for translators to understand the context of the messages and if needed, resequence the context of the message for other languages. For example, take the message The driver XYZ was disqualified. The bad practice is:

```
String message =
    Label.TheDriver + driverName + Label.WasDisqualified;
```

The good practice is as follows:

```
String message = String.format(
    Label.DriverDisqualified, new String[] { driverName});
```

The DriverDisqualified Custom Label will be defined as follows:

**New Custom Label**

**Custom Label Edit**

<b>Short Description</b>	DriverDisqualified 	<b>Name</b>	DriverDisqualified 
<b>Namespace Prefix</b>	fforce	<b>Protected Component</b>	<input checked="" type="checkbox"/>
<b>Language</b>	English 		
<b>Categories</b>			
<b>Value</b>	The driver {0} was disqualified.		
<b>Save</b> <b>Save &amp; New</b> <b>Cancel</b>			

[  When creating Custom Labels, be sure to pay attention to the **Protected** checkbox. If you uncheck it, end users can reference your labels, which you might want to consider if you wish them to reuse your messages, for example in custom **Email Templates** or **Visualforce** pages. However, the downside is that such labels cannot ever (currently) be deleted from your package as your functionality changes. ]

Finally, remember that in Visualforce you can utilize `apex:outputField` within `apex:apex:pageBlockSection` and the field labels will automatically be rendered next to the fields on the page.

## Building customizable user interfaces

The most customizable aspect of the user interface your application delivers is the one provided by Salesforce through its highly customizable layout editor that provides the ability to customize the standard user interface pages (including those now delivered via the mobile client Salesforce1) used to list, create, edit, and delete records.

Lightning Experience is the latest user interface experience available for your desktop users. Salesforce Classic or Aloha is the name given to the existing user interface. Its radically different both in appearance and technology. Fortunately, your existing investments in layouts and Visualforce are still compatible. Lightning however does bring with it a more component driven aspect and with it new tools to that allow even greater customization of the overall user experience.

Keep in mind any user experience you deliver that is not leveraging the standard user interface takes added effort on behalf of the developer typically utilizing Custom Settings and Fieldsets to provide customization facilities. Visualforce pages or Lightning components can be used to customize parts of or completely replace the standard user interface. This will be covered in more detail in *Chapter 8, User Interface*.



It is worth noting that subscriber org administrators can modify the page overrides defined and packaged on your Custom Objects to re-enable the Salesforce standard user interface instead of using your packaged Visualforce page. As such, it's worth keeping in mind giving some aesthetic attention to all your Custom Object layouts. Also, note that action overrides and layout components do not get upgraded.

## Layouts

The following is a brief summary of the customization features available beyond the standard sections and field ordering. These allow you to add graphs and custom UIs that help combine the layout customization with the flexibility and power of Visualforce:

- **Visualforce:** Layout sections allow you to embed a Visualforce page using the Standard Controllers. While this is only supported on the standard view pages, you are able to do whatever you wish on the Visualforce page itself.
- **Report charts:** Recently, the ability to embed a report chart into a layout has been added to the platform. This is a powerful feature to enhance the information provided to the user using a parameterized report.
- **Actions:** This allows you to describe, either declaratively or programmatically, additional actions beyond the standard platform actions. They are only applicable if you have enabled Chatter for the object.
- **Custom Buttons:** Much like actions, this allows additional buttons on the detail and list view pages to invoke application specific functionality. Creating Custom Buttons and hooking them up to your Apex code is covered in *Chapter 8, User Interface*.

## Visualforce

When you are considering building dedicated or even embedded (within layouts) Visualforce pages, always give consideration to end users who want to extend the layout and/or tables on the page with their own custom fields. Fieldsets offer the best means to achieve this; a later chapter will go into this in more detail.

## Lightning App Builder and Components

Lightning App Builder (available under the **Setup** menu) can be used by users in the subscriber org to customize the user experience of Salesforce Mobile and Lightning Experience. This tool allows users to build brand new pages using a drag and drop tool as well as to customize existing Lightning Experience pages provided by Salesforce such as the Home page and Record Detail pages.



The Record Detail component leverages the existing layouts defined via the existing layout editor to determine the layout of fields when displaying records.



Lightning Components are the fundamental building blocks that determine what information and functionality is available in Salesforce Mobile and Lightning Experience user experiences. Some standard components are provided by Salesforce and can also be built by other developers, as well as included in your package to expose your functionality. In a later chapter will be taking a deeper look at the architecture of Lightning and how that effects how you deliver functionality in your application.

## E-mail customization with e-mail templates

Using Apex, you can write code to send e-mails using the Messaging API. This allows you to dynamically generate all attributes of the e-mails you wish to send, the from and to address, subject title, and body. However, keep in mind that end users will more than likely want to add their own logo and messaging to these e-mails, even if such e-mails are simply notifications aimed at their internal users.

Instead of hardcoding the structure of e-mails in your code, consider using email templates (under the **Setup** menu). This feature allows administrators in the subscriber org to create their own e-mails using replacement parameters to inject dynamic values from records your objects define. Using a Custom Setting, for example, you can ask them to configure DeveloperName of the e-mail template to reference in your code. You can package e-mail templates as starting points for further customization, though keep in mind that they are not upgradable.



If data being included in the e-mail is not stored as a field on a Custom Object record or formula field, consider providing some Visualforce custom components in your package that can be used in Visualforce e-mail templates. These components can be used to invoke the Apex code from the e-mail template to query information and/or perform calculations or a reformat of information.

## Process Builder, Workflow and Flow

Salesforce provides several declarative tools to implement business processes and custom user experience flows. End user operations such as creating, updating, or starting an approval process for a record, can be customized through two tools known as **Workflow** and **Process Builder**. When you need to implement a UI flow that provides a wizard or interview style user experience, you can use the **Visual Flow** tool. This tool can be used to define more complex conditional business processes that need to read and update records. Automation Flows or sometimes "headless flows" are Visual Flows that do not interact with the user and can be referenced within Apex code as well as Process Builder.

Process Builder is the successor to Workflow. It provides the same functionality as it plus additional features for updating child records for example and extensibility for developers. It is also easier for end users to build and visualize more complex processes with its more modern graphical layout. Though you can use both interchangeably its best to focus on one or the other, making it easier to locate and maintain customizations.

As an application developer, these can be created and packaged as part of your application. Such components are upgradable (provided that they are marked as **Protected**). Typically, however, package developers tend to leave the utilization of these features to consultants and subscriber org admins in preference to Apex and/or Visualforce, where more complex logic and user experiences can be created.



Just as these tools can be used by administrators to customize their orgs. You may want to consider exposing your Apex driven application business processes through Invocable Methods, to effectively extend the functionality available to admins through these tools. Put another way this allows users of the Process Builder and Visualflow Flow tools to invoke your application functionality through clicks not code. We will be revisiting this in *Chapter 10, Providing Integration and Extensibility*.

## Social features and mobile

Chatter is a key social feature of the platform; it can enable users of your application to collaborate and communicate contextually around the records in your application as well as optionally invite their customers to do so, using the Chatter Communities feature. It is a powerful aspect of the platform but covering its details is outside the scope of this book.

You can enable Chatter under the **Chatter Settings** page under **Setup**, after which you can enable **Feed Tracking** (also under **Setup**) for your Custom Objects. This setting can be packaged, though it is not upgradable and can be disabled by the subscriber org administrator. Be careful when packaging references to Chatter such as this, as well as including references to the various Chatter-related objects, since this will place a packaging install dependency on your package, requiring all your customers to also have this feature enabled.

By creating actions on your Custom Objects, you can provide a quick way for users to perform common activities on records, for example, updating a contestant's status to DNF. These actions are also visible through the Salesforce1 Mobile application, so they enhance the productivity of the mobile user further compared to standard record editing.

Perform the following steps in the packaging org to try out the process:

1. Enable **Feed Tracking** for the **Race**, **Driver**, and **Contest** Custom Objects as described earlier; the fields being tracked are not important for the following steps, but you may want to select them all to get a better feel for the type of notifications Chatter generates. Also enable **Publisher Actions** from the **Chatter Settings** page.

2. Navigate to the **Contestant** object definition and locate the **Buttons, Links and Actions** section. Create a new action and complete the screen as follows:

Contestant Actions  
New Action

Enter Action Information

Object Name	Contestant
Namespace Prefix	fforce
Action Type	Update a Record
Label	Out of Race
Standard Label Type	--None--
Name	OutOfRace
Description	Update the records DNF field to True
Icon	⚡ Change Icon

Save Cancel

3. When prompted to design the layout of the action, accept the default layout shown and click on **Save**. On the **Contestant Action** page shown, click on **New** to add a new **Predefined Field Value** option to assign TRUE to the DNF field as part of the action to update the record:

Contestant Action  
Out of Race

Help for this Page ?

Predefined Field Values [1]

Action Detail

Label	Out of Race	Object Name	Contestant
Standard Label Type		Action Type	Update a Record
Name	OutOfRace	Icon	🌐
Namespace Prefix	fforce		
Description	Update the records DNF field to True		
Created By	Andrew Fawcett, 03/02/2014 21:08	Modified By	Andrew Fawcett, 03/02/2014 21:08

Edit Delete Edit Layout

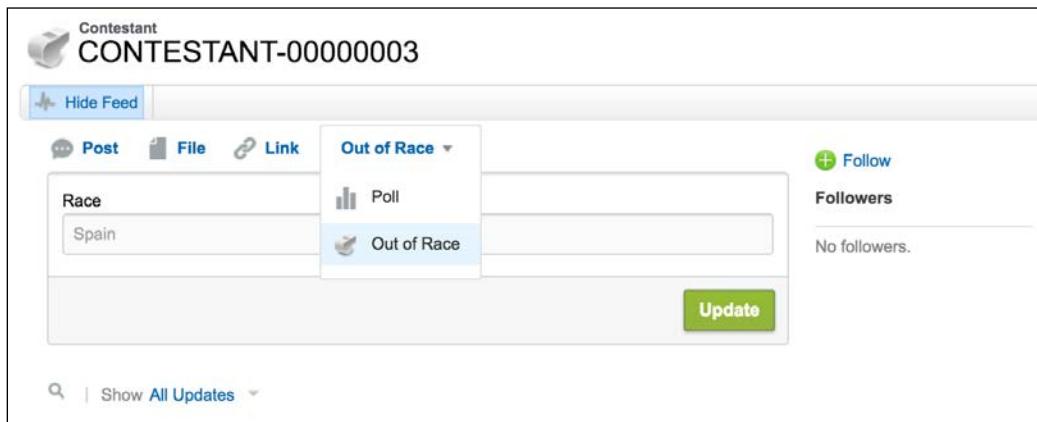
Predefined Field Values

Action	Field Name	API Name	Field Type	Value
Edit   Del	DNF	fforce_DNF_c	Checkbox	TRUE

^ Back To Top Always show me ▼ more records per related list

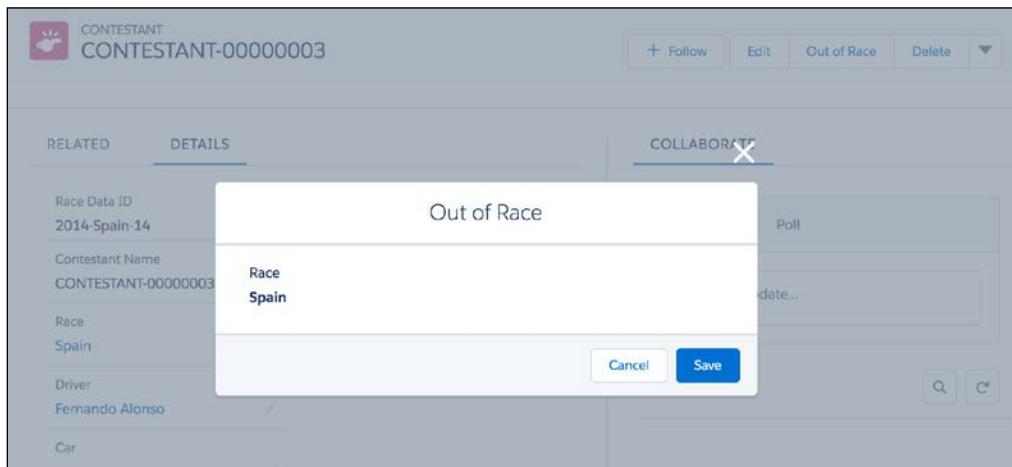
## Leveraging Platform Features

4. Finally, edit the **Contestant** layout and drag the **Out of Race** action onto the layout (you may need to click on the **override the global publisher layout** link in the layout editor before you can do this).
5. After performing these steps, you will see the **Out of Race** action being displayed in the UI as shown in the following screenshots. If you are viewing a Contestant record in the Salesforce Classic UI, the action is accessed from a drop down menu from the Chatter UI region of the page and will look like this.



The screenshot shows a Contestant record in the Salesforce Classic UI. The top navigation bar has 'Contestant' and the record ID 'CONTESTANT-00000003'. Below the navigation is a 'Hide Feed' button. The main content area shows a 'Race' field with 'Spain' selected. To the right, there is a 'Chatter' feed with a 'Post' button, a 'File' button, a 'Link' button, and a 'Follow' button. A dropdown menu is open, showing 'Out of Race' as the selected action. Other options in the dropdown are 'Poll' and 'Out of Race'. Below the dropdown is a 'Followers' section stating 'No followers.' and a green 'Update' button. At the bottom of the page are search and 'Show All Updates' links.

If you are viewing the Contestant record in the Lightning Experience UI it will look like this:

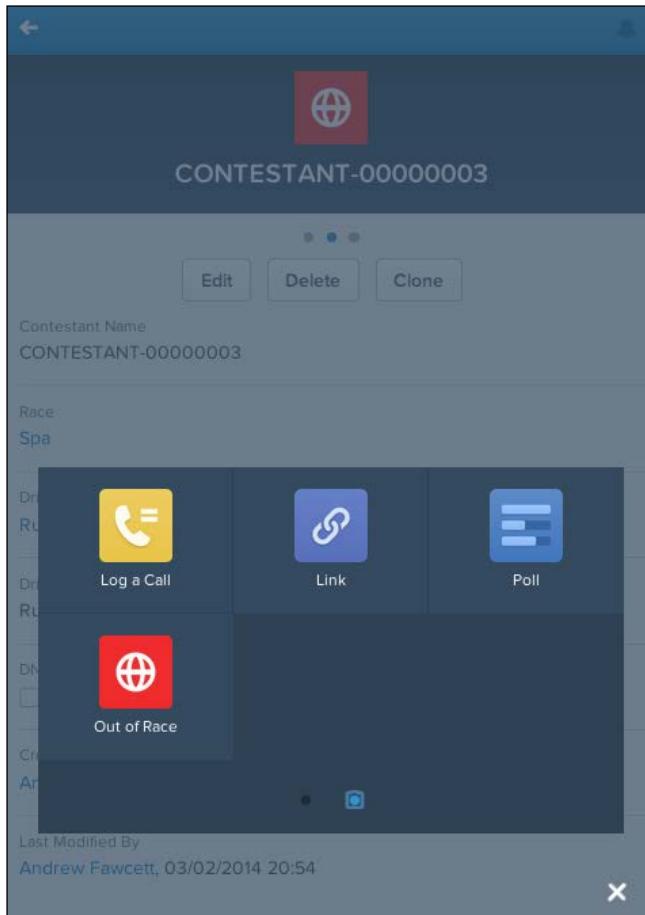


The screenshot shows a Contestant record in the Salesforce Lightning Experience UI. The top navigation bar has 'Contestant' and the record ID 'CONTESTANT-00000003'. Below the navigation are buttons for '+ Follow', 'Edit', 'Out of Race', and 'Delete'. The main content area has tabs for 'RELATED' and 'DETAILS'. In the 'DETAILS' tab, there is a table with columns for 'Race Data ID' (2014-Spain-14), 'Contestant Name' (CONTESTANT-00000003), 'Race' (Spain), 'Driver' (Fernando Alonso), and 'Car'. A modal dialog is open over the table, titled 'Out of Race'. It contains a 'Race' field with 'Spain' selected. At the bottom of the dialog are 'Cancel' and 'Save' buttons. The background of the page shows the rest of the record details.

 Notice how Lightning Experience relocates the Action "Out of Race" button from the Chatter UI in Salesforce Classic to include it alongside other buttons (top right) that are relevant to the record. A modal popup style is also used. This is one of many examples where Salesforce has adopted a different UX design for existing functionality you define.

 You can enable the Lightning Experience UI for your user under the Setup menu and follow the onscreen instructions to enable it. Once enabled you can toggle between the two UI types.

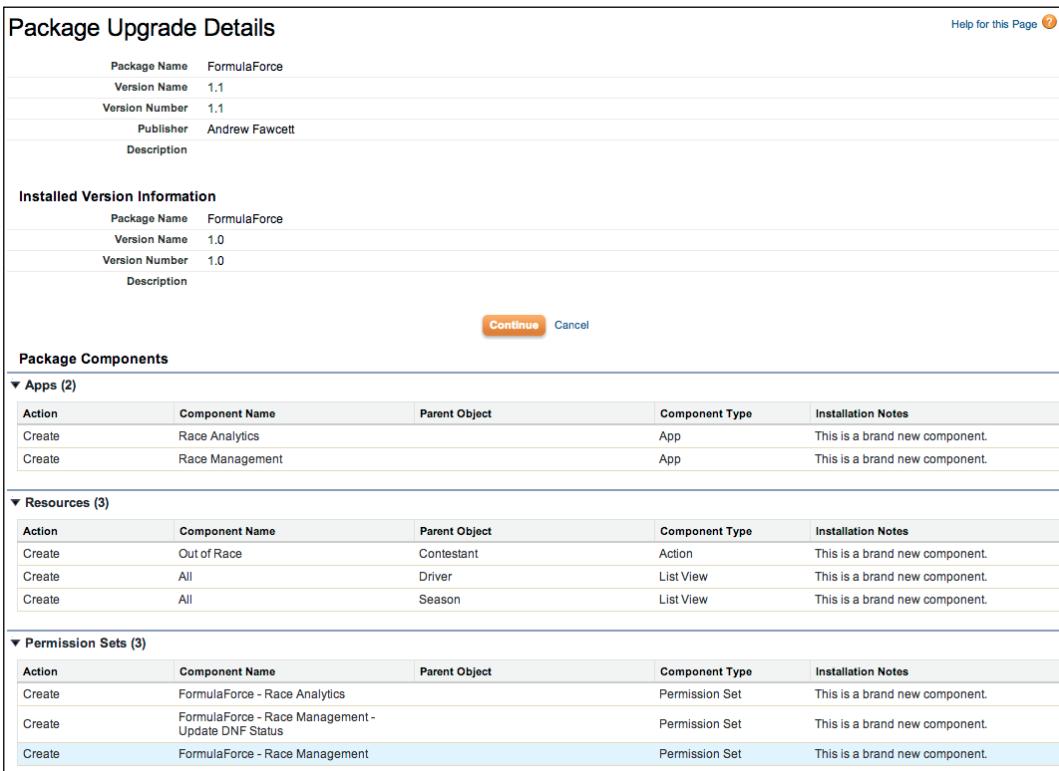
If you are viewing the record via the Salesforce1 Mobile application, it looks like this:



## Leveraging Platform Features

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Take time to review your package contents after completing the steps in this chapter and then perform another upload and test an upgrade of the package in your testing org. When installing the upgrade, you should see a confirmation page like the one shown in the following screenshot, showing new or changed components being installed:



The screenshot shows the 'Package Upgrade Details' page. At the top, it displays package metadata: Name: FormulaForce, Version: 1.1, Publisher: Andrew Fawcett. Below this is the 'Installed Version Information' section, which shows the same details but for version 1.0. The main content area is titled 'Package Components' and contains three expandable sections: 'Apps (2)', 'Resources (3)', and 'Permission Sets (3)'. Each section contains a table with columns: Action, Component Name, Parent Object, Component Type, and Installation Notes. The 'Apps' section shows two entries: 'Create' for 'Race Analytics' (App, Installation Notes: 'This is a brand new component.') and 'Create' for 'Race Management' (App, Installation Notes: 'This is a brand new component.'). The 'Resources' section shows three entries: 'Create' for 'Out of Race' (Action, Installation Notes: 'This is a brand new component.'), 'Create' for 'All' (Driver, List View, Installation Notes: 'This is a brand new component.'), and 'Create' for 'All' (Season, List View, Installation Notes: 'This is a brand new component.'). The 'Permission Sets' section shows three entries: 'Create' for 'FormulaForce - Race Analytics' (Permission Set, Installation Notes: 'This is a brand new component.'), 'Create' for 'FormulaForce - Race Management - Update DNF Status' (Permission Set, Installation Notes: 'This is a brand new component.'), and 'Create' for 'FormulaForce - Race Management' (Permission Set, Installation Notes: 'This is a brand new component.'). At the bottom of the page are 'Continue' and 'Cancel' buttons.

Action	Component Name	Parent Object	Component Type	Installation Notes
Create	Race Analytics		App	This is a brand new component.
Create	Race Management		App	This is a brand new component.

Action	Component Name	Parent Object	Component Type	Installation Notes
Create	Out of Race	Contestant	Action	This is a brand new component.
Create	All	Driver	List View	This is a brand new component.
Create	All	Season	List View	This is a brand new component.

Action	Component Name	Parent Object	Component Type	Installation Notes
Create	FormulaForce - Race Analytics		Permission Set	This is a brand new component.
Create	FormulaForce - Race Management - Update DNF Status		Permission Set	This is a brand new component.
Create	FormulaForce - Race Management		Permission Set	This is a brand new component.

Only a part of the screenshot is shown, though you can see that it shows the custom application, action, and Permission Set components added in this chapter. Further down, the upgraded confirmation page shows the updated Custom Object and new custom fields as shown in the following screenshot:

▼ Objects (2)				
Action	Component Name	Parent Object	Component Type	Installation Notes
Update	Contestant		Custom Object	This is an upgraded component. It will be updated to the new version.
Update	Driver		Custom Object	This is an upgraded component. It will be updated to the new version.
▼ Fields (8)				
Action	Component Name	Parent Object	Component Type	Installation Notes
Create	Active	Driver	Custom Field	This is a brand new component.
Create	DNF	Contestant	Custom Field	This is a brand new component.
Create	Nationality	Driver	Custom Field	This is a brand new component.
Update	Driver	Contestant	Custom Field	This is an upgraded component. It will be updated to the new version.
Create	Total DNFs	Race	Custom Field	This is a brand new component.
Create	Fastest Lap By	Race	Custom Field	This is a brand new component.
Create	Driver and Race	Contestant	Custom Field	This is a brand new component.
Create	Year	Season	Custom Field	This is a brand new component.



Notice that once you have upgraded the package in your testing org, the layouts for **Season**, **Driver**, and **Race** do not feature the new fields added in this release of the package. This is due to the fact that layouts are not upgraded.

## Summary

In this chapter, you have seen a number of platform features that directly help you build key structural and functional aspects of your application without writing a line of code, and in turn, further enabling your customers to extend and customize their application. The chapter also focused on optimizing the tasks performed by consultants and administrators to install and configure the application. Finally, you were made aware of limits imposed within the subscriber org, the ways to avoid them, and to have an awareness of them when packaging.

Continue to review and evolve your application by first looking for opportunities to embrace these and other platform features, and you will ensure that you and your customers' strong alignment with the current and future platform features continue to grow. In the next chapter, we will dive deeper into options and features surrounding the storage of data on the platform.



Be sure to reference the *Salesforce Limits Quick Reference Guide* PDF describing the latest limits of the features discussed in this chapter and others at [http://login.salesforce.com/help/pdfs/en/salesforce\\_app\\_limits\\_cheatsheet.pdf](http://login.salesforce.com/help/pdfs/en/salesforce_app_limits_cheatsheet.pdf).



# 3

# Application Storage

It is important to consider your customers' storage needs and use cases around their data creation and consumption patterns early in the application design phase. This ensures that your object schema is the most optimum one with respect to large data volumes, data migration processes (inbound and outbound), and storage cost. In this chapter, we will extend the Custom Objects in the **FormulaForce** application as we explore how the platform stores and manages data. We will also explore the difference between your applications operational data and configuration data and the benefits of using **Custom Metadata Types** for configuration management and deployment.

You will obtain a good understanding of the types of storage provided, and how the costs associated with each are calculated. It is also important to understand the options that are available when it comes to reusing or attempting to mirror the Standard Objects such as **Account**, **Opportunity**, or **Product**, which extend the discussion further into license cost considerations. You will also become aware of the options for standard and custom indexes over your application data, which will lead to the topic of handling large data volumes, covered in an entire chapter later in this book. Finally, we will gain some insight into new platform features for *consuming external data storage* from within the platform.

In this chapter, we will cover the following topics:

- Mapping out end user storage requirements
- Understanding the different storage types
- Record identification, uniqueness, and auto numbering
- Record relationships
- Reusing existing Standard Objects
- Applying external IDs and unique fields

- Importing and exporting application data
- Options for replicating and archiving data
- External data sources

## Mapping out end user storage requirements

During the initial requirements and design phase of your application, the best practice is to create user categorizations known as personas. Personas consider the users' typical skills, needs, and objectives. From this information, you should also start to extrapolate their data requirements, such as the data they are responsible for creating (either directly or indirectly, by running processes), and what data they need to consume (reporting). Once you have done this, try to provide an estimate of the number of records that they will create and/or consume per month.



Share these personas and their data requirements with your executive sponsors, your market researchers, early adopters, and finally the whole development team, so that they can keep them in mind and test against them as the application is developed.

For example, in our FormulaForce application, it is likely that **managers** will create and consume data, whereas **race strategists** will mostly consume a lot of data.

**Administrators** will also want to manage your application's configuration data.

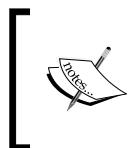
Finally, there will likely be a background process in the application, generating a lot of data, such as the process that records race data from the cars and drivers during the qualification stages and the race itself, such as sector (a designated portion of the track) times.



You may want to capture your conclusions regarding personas and data requirements in a spreadsheet along with some formulas that help predict data storage requirements (discussed later in this chapter). This will help in the future as you discuss your application with Salesforce during the AppExchange listing process, and will be a useful tool during the Sales cycle as prospective customers wish to know how to budget their storage costs with your application installed.

## Understanding the different storage types

The storage used by your application records contributes to the most important part of the overall data storage allocation on the platform. There is also another type of storage used by the files uploaded or created on the platform. From the **Storage Usage** page under the **Setup** menu, you can see a summary of the records used, including those that reside in the Salesforce Standard Objects.



Later in this chapter, we will be creating a Custom Metadata Type object to store configuration data. Storage consumed by this type of object is not reflected on the **Storage Usage** page and is managed and limited in a different way.

**Storage Usage** Help for this Page 

Your organization's storage usage is listed below.

Storage Type	Limit	Used	Percent Used
Data Storage	256.0 MB	284 KB	0%
File Storage	902.0 MB	13 KB	0%

**Current Data Storage Usage**

Record Type	Record Count	Storage	Percent
Opportunities	31	62 KB	22%
Cases	26	52 KB	18%
Leads	22	44 KB	15%
Contacts	20	40 KB	14%
Campaigns	4	32 KB	11%
Accounts	12	24 KB	8%
Solutions	10	20 KB	7%
Drivers	2	4 KB	1%
Races	1	2 KB	1%
Seasons	1	2 KB	1%
Contestants	1	2 KB	1%
Tasks	0	0 B	0%
Photos	2	0 B	0%



The preceding page also shows which users are using the most amount of storage. In addition to the individual's **User Details** page, you can also locate the **Used Data Space** and **Used File Space** fields; next to these are the links to view the users' data and file storage usage.

The limit shown for each is based on a calculation between the minimum allocated data storage depending on the type of organization or the number of users multiplied by a certain amount of MB, which also depends on the organization type; whichever is greater becomes the limit. For full details of this, click on the **Help for this Page** link shown on the page.

## Data storage

Unlike other database platforms, Salesforce typically uses a fixed 2 KB per record size as part of its storage usage calculations, regardless of the actual number of fields or the size of the data within them on each record. There are some exceptions to this rule, such as **Campaigns** which take up 8 KB, and stored **Email Messages** use up the size of the contained e-mail, though all Custom Object records take up 2 KB. Note that this record size also applies even if the Custom Object uses large text area fields.



Salesforce **Big Objects** offer a different kind of storage solution, these objects are designed for the storage of billions of records, receiving device input, in **Internet of Things (IoT)** scenario for examples. Information is written on mass using bulk loading and later read frequently, or stated another way, written less and read often. Although not disclosed by Salesforce, the expectation is that the storage cost for these objects will be cheaper than equivalent records stored in Custom Objects. The Race Data object introduced later in this chapter could be considered a good candidate for this type of object for the FormulaForce application, since this information is uploaded after the race in bulk and used to analyze the race.

## Columns versus rows

Given the calculation in the preceding section, you may want to consider whether your data model has multiple occurrences of data that have a known maximum value. In these cases, consider the option of creating multiple columns (or multiple sets of columns) instead of a new object that will use up additional storage. Enterprise Edition orgs currently support up to 500 fields per object. For example, in Formula 1 racing, it is well established that there are only three rounds of qualification before the race in order to determine the starting positions, where each driver competes for the fastest lap.

This could be modeled as a **Qualification Lap** child object to the **Contestant** object; however, in this case, it will only ever have a maximum of three records per contestant in it. A more optimal data storage design is a set of new fields in the **Contestant** object.

Perform the following steps in the packaging org to try out this process:

1. Create three fields of type Number (6, 3), for example, **Qualification 1 Lap Time** (Qualification1LapTime\_\_c), on the **Contestant** object. Ensure that the **Required** checkbox is unchecked when creating these fields, since not all drivers make it through to the final qualification rounds. Note that here we have used numerals instead of words, for example QualificationOneLapTime\_\_c, as this can help in situations where dynamic Apex is iterating over the fields.
2. Create a roll-up summary field on the **Race** object, **Pos1 Position Lap Time**, utilize the **MIN** option when selecting **Roll-Up Type**, and select the **Qualification 1 Lap Time** field in **Field to Aggregate**, as shown in the following screenshot:

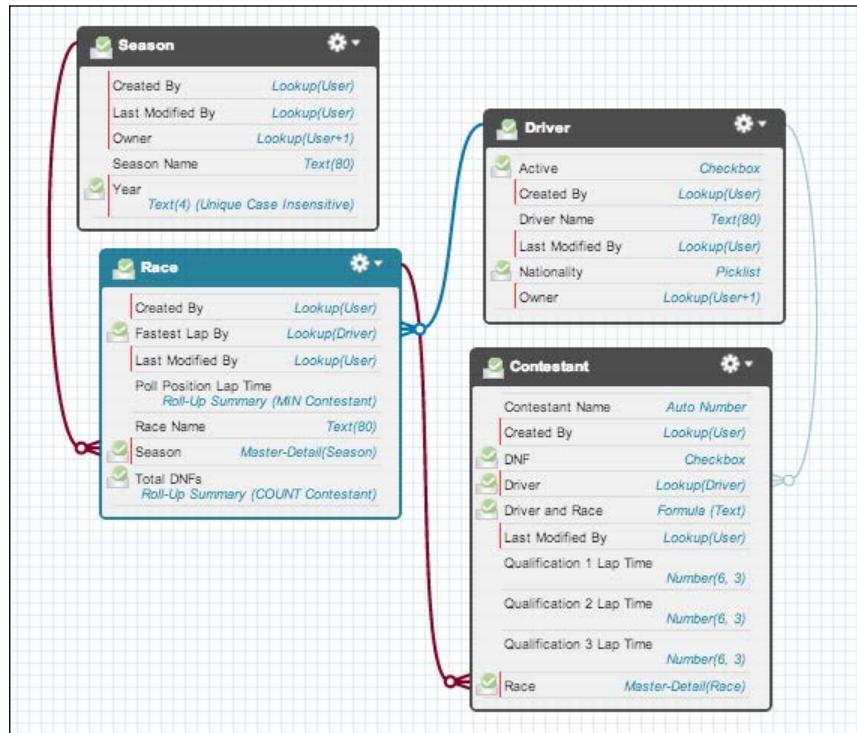


3. Finally, update the permission sets to grant read and write access to the new fields that you have just added in the **Race Management** permission set and read access within the **Race Analytics** permission set.

Keep in mind that you can also use **Formula fields** to add or apply further logic to data stored in columns, emulating what would have been filtered or aggregating queries over equivalent rows. There is also a benefit to reducing the number of SOQL and DML operations that your code needs to perform when taking this approach.

## Visualizing your object model

It is an essential idea to build an **Entity Relationship Diagram (ERD)** of your object model; not only is this a good resource for you and your team, but it can also help your customers understand where the data that they are creating resides, and help them build reports and integration solutions. Salesforce provides an interactive tool known as **Schema Builder** (accessed via the button from the **Objects** page under **Setup**) that can help with this; it can also be used to create new objects and fields. At this stage in the book, the FormulaForce application data model should look something like this:





If you are creating **logging** solutions in your application, keep in mind the storage usage for this type of data. For example, how does the user perform bulk deletion of the records? Should this be scheduled? Also, how do you communicate this information to them? A log object can be configured with workflow rules by the subscriber to perhaps e-mail users as critical log entries are inserted.

If your users are using Chatter, you may want to consider providing the facility (perhaps as an option through dynamic Apex, to avoid a package dependency) of using a Chatter post to notify the user. Chatter posts, comments, and track changes are not counted by Salesforce under storage usage. However, any files and photos you upload are counted against file storage.

## Considerations for configuration data

Most applications need to provide some way to configure their functionality to allow administrators and users to tailor it to their needs. As we have seen in *Chapter 2, Leveraging Platform Features*, Salesforce provides a great deal of facilities for this for you and your users. However, what if the part of your application you want to provide configuration for is unique to your application domain, for example in a list of official fastest lap times for each track.

In our case, imagine we want to provide to our customers as part of the package the current approved list of fastest lap times for each track, so that they don't have to look this up themselves and enter them manually. However, you still want to allow users to manage fastest laps for tracks not known to your application.

Custom Settings and Custom Metadata Types are two platform features to consider for storing and managing configuration for your application before considering Custom Objects. Custom Metadata in many ways is a successor to both alternatives, though at this time there are still some features that may cause you to consider using other options.

## *Application Storage*

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The following table helps you decide which object type to use based on your configuration requirements:

<b>Configuration Object Requirement</b>	<b>Custom Object</b>	<b>Custom Setting Object</b>	<b>Custom Metadata Type Object</b>
Objects can be hidden from org administrators	No	Yes	Yes
Records can be included in your package	No	No	Yes
Packaged records can be protected from user edits and upgraded	N/A	N/A	Yes
Ability to edit fields on packaged records can be controlled	N/A	N/A	Yes
Layout of the standard Salesforce UI can be defined and packaged	Yes	No	Yes
Object relationships are supported for more complex configuration	Yes	No	Yes
Apex access	CRUD	CRUD	Read **
Records can be defined at an org, user or profile level	No	Yes	No
Records can have custom validation applied via Validation Rules and/or Apex Triggers	Yes	No	No
Reduction in configuration management overhead	Rekey or use Data Loaders	Rekey or use Data Loaders	Install by default also use native Change Sets and Packages to manage customer specific configuration
Ability for partners and other developers to build extension packages that package specific forms of your configuration	No	No	Records can also be included in extension packages

When reading Custom Metadata Type records, SOQL can be used and it does not count towards the SOQL query governor, though the 50k row limit still applies. Custom Metadata Type records can be manipulated using the Salesforce SOAP Metadata API CRUD operations.

 Though the Metadata SOAP API can be called via Apex, restrictions around HTTP callouts still apply. Restrictions around the frequency and when HTTP callouts can be made make this approach less desirable when scaling above 200 records. Also, maintaining referential integrity between calls is not supported, as there is no database transaction scope around the API calls. At the time of writing Salesforce have announced that native support for Metadata API is under development, although there is no commitment to deliver with their statement.

In our case, the desire to package track lap time configuration records and thus allow it to be upgraded fits well with Custom Metadata Types. There is also no need to update this configuration information programmatically from Apex, only read it.

The current inability to update Custom Metadata Type records is something that might be an issue for you if you wish to build a custom UI for your configuration, in our case the Standard Salesforce UI is sufficient.

## Custom Metadata Type storage

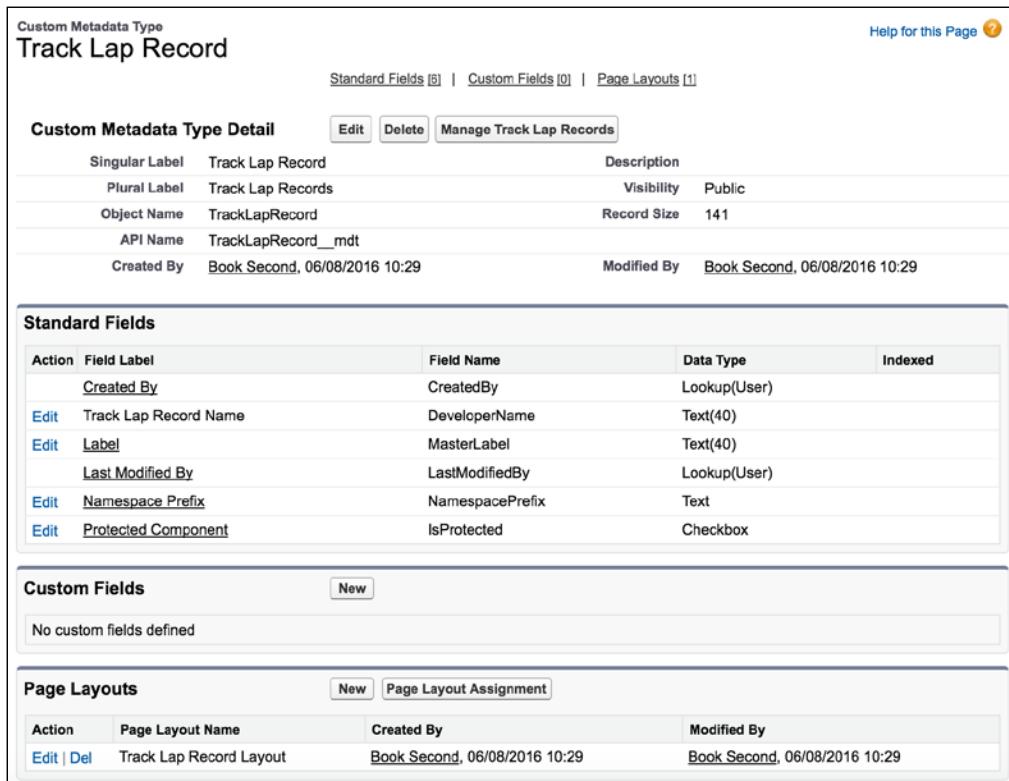
From the **Custom Metadata Types** page under **Setup** you can both create Custom Metadata Type objects and manage the records they contain. Any records you create can be included in your package and are thus available to your Apex logic immediately after the installation of your package.

Perform the following steps to create the **Track Lap Records** MDT object.

1. Create a **Track Lap Records** custom metadata type by clicking on **New**, and enter **TrackLapRecords** as the API name.
2. From the **Visibility** field select **All Apex code and APIs can use the type, and it is visible in Setup**. This is done since we want to allow the administrator to record their own fastest lap times in addition to those we include. You would choose the option **Only Apex code in the same managed package can see the type**, if all records in this object are to be used only by your application logic, for example for internal configuration.

## Application Storage

3. The page for describing your new Custom Metadata Type object looks very similar to that used by Custom Object. As noted in the preceding table, you cannot define some features like Validation Rules and Custom Buttons, though in comparison to Custom Settings you can define your own layout. There are also more field types available.



The screenshot shows the 'Custom Metadata Type Detail' page for 'Track Lap Record'. The page has a header with 'Custom Metadata Type' and 'Track Lap Record', and a 'Help for this Page' link. Below the header are buttons for 'Edit', 'Delete', and 'Manage Track Lap Records'. The main content area is divided into sections: 'Custom Metadata Type Detail', 'Standard Fields', 'Custom Fields', and 'Page Layouts'.

**Custom Metadata Type Detail**

Singular Label	Track Lap Record	Description
Plural Label	Track Lap Records	Visibility Public
Object Name	TrackLapRecord	Record Size 141
API Name	TrackLapRecord__mdt	
Created By	Book Second, 06/08/2016 10:29	Modified By Book Second, 06/08/2016 10:29

**Standard Fields**

Action	Field Label	Field Name	Data Type	Indexed
	Created By	CreatedBy	Lookup(User)	
Edit	Track Lap Record Name	DeveloperName	Text(40)	
Edit	Label	MasterLabel	Text(40)	
Edit	Last Modified By	LastModifiedBy	Lookup(User)	
Edit	Namespace Prefix	NamespacePrefix	Text	
Edit	Protected Component	IsProtected	Checkbox	

**Custom Fields**

New

No custom fields defined

**Page Layouts**

Action	Page Layout Name	Created By	Modified By
Edit   Del	Track Lap Record Layout	Book Second, 06/08/2016 10:29	Book Second, 06/08/2016 10:29

Note that the API name for Custom Metadata Type objects ends with `_mdt` and has different standard fields. We will use the `DeveloperName` field as a unique name for the race track on which the lap record was achieved. Later we will include records from this object in the package. The `isProtected` field is used to determine whether the recorded data can be edited by the administrator of the package.

Follow these steps to create some fields on the object.

1. Create the following fields as described in the following table. Accept the default shown for the **Field Manageability** field.
2. Add the **Track Lap Records** Custom Metadata Type object to the package.

Object	Field name and type
TrackLapRecords__mdt	DriverName__c Text (60)
	Time__c Number (5, 3)
	Year__c Text (4)

You may have noticed the following option when creating the preceding fields:

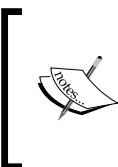
Field Manageability	Who can change field values after records are installed via managed package?
<input checked="" type="radio"/> Only the package developer (via package upgrade) <input type="radio"/> Any user with the Customize Application permission (package upgrades won't overwrite the value) <input type="radio"/> No one	

This option only applies with respect to records included in the package. It determines which fields the package administrator can change for those records. For example, you might want to add a Notes text field to the object that the administrator can edit, but protect all other fields. For the fields that we added here, the default is important since we want package updates to update changes in new lap records on tracks known to the application.

Custom Fields							
Action	Field Label	API Name	Data Type	Field Manageability	Indexed	Controlling Field	Modified By
Edit   Del	Driver Name	DriverName__c	Text(60)	Upgradable			App Developer, 06/08/2016 13:26
Edit   Del	Time	Time__c	Number(5, 3)	Upgradable			App Developer, 06/08/2016 13:27
Edit   Del	Year	Year__c	Text(4)	Upgradable			App Developer, 06/08/2016 13:28

Enter the following sample data. From the object definition page click on the **Manage Track Lap Records** to begin entering configuration data. Deselect the **Protected** checkbox when adding records.

## Application Storage



**Protection:** This determines if the record is visible in the customer org. Protected records are hidden from the user, but your own packaged Apex code can still query them. Use protected records for internal configuration.

**Track Lap Records**

Help for this Page 

View: All  

Action	Label	Track Lap Record Name	Namespace Prefix	Protected Component	Time	Driver Name	Year
Edit	 Circuit Spa-Francorchamps	Circuit_Spa_Francorchamps	ff2	<input type="checkbox"/>	105.108	Kimi Räikkönen	2004
Edit	 Nürburgring	Nurburgring	ff2	<input type="checkbox"/>	84.468	Michael Schumacher	2004
Edit	 Silverstone Circuit	Silverstone_Circuit	ff2	<input type="checkbox"/>	90.874	Fernando Alonso	2010



You can also define a **List View** to make it easier for you to manage Custom Metadata Type records in the packaging org. You cannot initially edit the default **All** view, though you can create one with the same name; click on **Create New View**. This List View is not packaged.

Storage used by Custom Metadata Type records is not shown on the **Storage Usage** page. The calculation used is based on the maximum record size based on the field size and not the standard 2 KB used on Custom Objects. Records created by users can total up to 10 MB. Your packaged records also get their own 10 MB limit. You can calculate the storage used by reviewing the record size shown on the **Custom Metadata Types** page.

**All Custom Metadata Types**

Help for this Page 

Custom metadata types enable you to create your own setup objects whose records are metadata rather than data. These are typically used to define application configurations that need to be migrated from one environment to another, or packaged and installed.

Rather than building apps from data records in custom objects or custom settings, you can create custom metadata types and add metadata records, with all the manageability that comes with metadata: package, deploy, and upgrade. Querying custom metadata records doesn't count against SOQL limits.

New Custom Metadata Type						
Action	Label	Namespace Prefix	Visibility	Api Name	Record Size	Description
<a href="#">Del</a>   <a href="#">Manage Records</a>	Track Lap Record		Public	TrackLapRecord__mdt	213	

To add the records to the package, follow these steps:

1. From the **Package Detail** page click **Add Components**.
2. Select **Track Lap Record** from the dropdown and select all records.

When completing *Step 2*, the **Add to Package** page will look like the following:

Add to Package

Help for this Page ?

**FormulaForce**

A package contains components such as apps, objects, reports, or email templates. These packages can be uploaded to share with others privately or posted on Force.com AppExchange to share publicly. The list below displays all packages created by your organization. To create a new package, click New.

Component Type: Track Lap Record

Add to Package Cancel

Name
Circuit_Spa_Francorchamps
Nurburgring
Silverstone_Circuit

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z All

Add to Package Cancel

**Trivia:** In its pilot phase the Custom Metadata Type feature was known as Platform on Platform. The branding later changed, but at the time Salesforce felt that this described one of the potentials of this technology to start to build your own platform packages that added to new metadata types to the platform. As stated in the considerations table earlier, the ability for others to package your custom metadata type records is a realization of this vision.

## Custom Settings storage

Custom settings are slightly different from Custom Objects with respect to data storage limits, in that they do not exist in the same storage area. Custom settings are ideal for data that is read often but written to infrequently. Salesforce caches data in these objects in something it calls the **Application Cache** and provides a means to query it quickly without query governor limits being applied. However, unlike Custom Objects, they do not support Apex Triggers or Validation Rules.

There are limits on the storage they can consume, per organization, per namespace. This means that if you create a custom setting and add it to your managed package, it gets its own storage limit. The storage limit for custom settings starts with 1 MB for a full licensed user and can go up to a maximum of 10 MB. You can see the current storage utilization from the **Custom Settings** page under **Setup**.

## File storage

Salesforce has a growing number of ways to store file-based data, ranging from the historic **Document** tab, to the more sophisticated **Content** tab, to using the **Files tab**, not to mention Attachments, which can be applied to your Custom Object records if enabled. Each has its own pros and cons for end users and file size limits that are well defined in the Salesforce documentation. Going forward only Files will be supported by Salesforce and so use of this is recommended over other file storage options. For example, only the Files tab is supported in Lightning Experience.

From the perspective of application development, as with data storage, be aware of how much your application is generating on behalf of the user and give them a means of controlling and deleting that information. In some cases, consider whether the end user would be happy to have the option of recreating the file on demand (perhaps as a PDF) rather than always having the application to store it.

## Record identification, uniqueness, and auto numbering

Every record in Salesforce has an **Id** field, and with a few exceptions, also a **Name** field or **DeveloperName** for Custom Metadata Type objects. The **Id** field is unique, but is not human readable, meaning it cannot be entered or, for most of us on this planet, easily remembered!

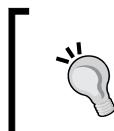
The Standard and Custom Objects default value for the **Name** field is to provide a means for the user to enter their own textual description for the record, such as the race name or the driver name. The **Name** field is not enforced as being unique. Being the primary means by which the user identifies records, this can be a problem and is something that the end user needs to avoid. This aspect of the platform can be particularly problematic with accounts and contacts hence AppExchange has a number of so-called "Deduplication" applications you can try.



The `Database.merge` and `merge` DML statements support the merging of accounts, leads, and contact records.

## Unique and external ID fields

When adding fields, you can indicate that the values stored within them are **unique** and/or **external identifiers**. For unique fields, the platform will automatically enforce this rule regardless of how records are created or updated, rejecting records with no unique values. By utilizing fields designated as external ID fields, you can simplify the data-loading process for users; this will be discussed later in this chapter in more detail. Both of these field modifiers result in a custom index being created, which can help optimize query performance.



You can help users avoid creating duplicate records with the same name by ensuring that other identifying fields such as these are also added to the **lookup layout** as described in the previous chapter.

Let's add a **Unique** and **External Id** field to record the driver's Twitter handle. Perform the following steps in the packaging org to try this out:

1. Create a new **Text** field, **Twitter Handle** (`TwitterHandle__c`), with a length of **15** on the **Driver** object, and check the **Unique** and **External Id** checkboxes.
2. Utilize the **Driver** records entered in the previous chapters to update the fields and confirm that the system prevents duplicate Twitter handles. Lewis Hamilton's Twitter handle is `LewisHamilton` and Ruben's is `rubarrichello`.
3. Update the permission sets that have read and write permissions for the new field to **Race Management**, and the read-only permission to **Race Analytics**.

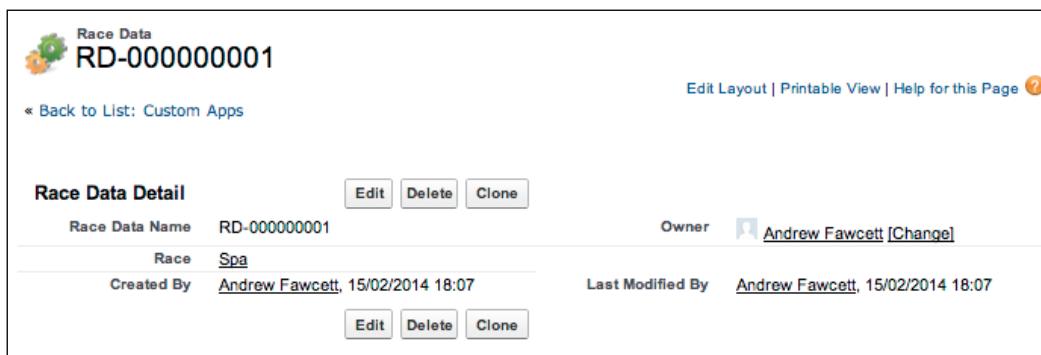
## Auto Number fields

The platform supports an auto sequence field type, which can be applied to the **Name** field during and after object creation (as long as the object has not been previously included as part of a prior package release upload). It can also be applied to a brand new field. The platform handles incrementing the sequence and ensures that there are no duplicates.

Apply **Auto Number** within the FormulaForce application to give a unique auto incrementing identifier to the **Race Data** records as they are inserted. Perform the following steps in the packaging org to try this out:

1. Create a new **Race Data** (`RaceData__c`) object; for **Record Name**, enter `Race Data` `Id`, and select **Auto Number** from the **Data Type** field.
2. In the **Display Format** field, enter `RDID-{000000000}` and **1** in the **Starting Number**. Finally, check the **Allow Reports** field.

3. Add a **Lookup** field called `Race (Race__c)` to relate records in this object to the existing `Race` object. Select the **Don't allow deletion of the lookup record that's part of a lookup relationship** option to prevent the deletion of race records if race data exists. We will add further fields to this object in a later chapter.
4. Create a tab for the **Race Data** object that we just created and add the tab to the **Race Management** and **Race Analytics** applications. By doing this, the tab and object will automatically be added to the package ready for the next upload.
5. Create a test record to observe the **Race Data Name** field value.



Race Data

RD-000000001

« Back to List: Custom Apps

Edit Layout | Printable View | Help for this Page ?

Race Data Detail

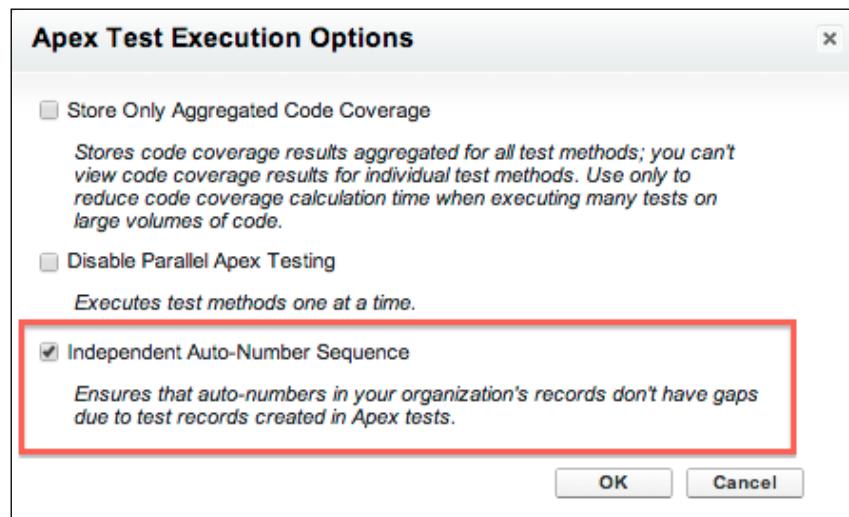
Race Data Name	RD-000000001	Owner	Andrew Fawcett [Change]
Race	Spa	Created By	Andrew Fawcett, 15/02/2014 18:07
Created By	Andrew Fawcett, 15/02/2014 18:07	Last Modified By	Andrew Fawcett, 15/02/2014 18:07

Edit Delete Clone

6. Update the permission sets with the new object and fields, giving a read and write permission to **Race Management** and a read-only permission to **Race Analytics**.

While it is possible to add new custom fields to objects that have already been packaged and released to your customers, you cannot currently add new **Auto Number** fields to an object that has already been packaged, for example, the **Driver** object.

Apex tests creating test records that utilize **Auto Number** fields can be configured by an org setting to not increment the sequence number outside of the test, which would create gaps in the sequence from the end user's perspective. Access this setting in the subscriber org via the **Options...** button on the **Apex Test Execution** page under **Setup** as follows:



The **Display Format** determines the formatting but not the maximum sequence number. For example, if a format of `SEQ{0000}` is used, and the next sequence number created is 10,000, the platform will display it as `SEQ10000`, ignoring the format digits. The maximum of an Auto Number field is stated in the Salesforce documentation as being a maximum length of 30 characters, of which 10 are reserved for the prefix characters. It also states that the maximum starting number must be less than 1,000,000,000.

The platform does not guarantee that there will be no gaps in an auto number sequence field. Errors in creating records can create gaps as the number assigned during the insert process is not reused. Thus, set expectations accordingly with your users when using this feature.



One workaround to creating an unbroken sequence would be to create a Custom Object with the **Name** field that utilizes the **Auto Number** field type, for example, Job References. Then, create a relationship between this object and the object records to which you require the sequence applied, for example Jobs. Then, write an **Apex Scheduled** job that inserts records on a daily basis into the Job References object for each Jobs record that is currently without a Job Reference relationship. Then, run reports over the Job References object. To ensure that no Job records are deleted, thus creating gaps, you can also enable the lookup referential integrity feature described in the following sections.

## Subscribers customizing the Auto Number Display Format

Be aware that **Display Format** cannot be customized once it is packaged and installed in the subscriber org. However, it is possible to create a custom formula field in the subscriber org to remove the prefix from the **Name** field value and reapply whatever prefix is needed. For example, the following formula will isolate the numeric portion of the **Name** field value and apply a new prefix specified in the formula (this could also be driven by a custom setting or conditional logic in the formula):

```
'MYID-' + MID(Name, 4, LEN(Name) - 4)
```

When this formula field is applied for a record whose Auto Number is RD-000000001, the formula would display as follows:

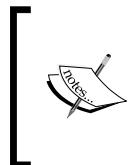
The screenshot shows the 'Race Data Detail' page for a record named 'RD-000000001'. The page includes a navigation bar with a gear icon and the text 'Race Data', a back-link to 'Custom Object Definitions', and three buttons: 'Edit', 'Delete', and 'Clone'. The main detail section shows the following fields:

Race Data Name	RD-000000001
Alternative Race ID	MYID-000000001
Race	Spa
Created By	Andrew Fawcett, 15/02/2014 18:07

Below the detail section are three more buttons: 'Edit', 'Delete', and 'Clone'. The 'Alternative Race ID' field is highlighted with a red box.

## Record relationships

A relationship is formed by a **Lookup** field being created from one object to another, often referred to as a parent and child relationship. There are two types of relationships in Salesforce: **Master-Detail** and **Lookup**.



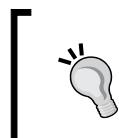
Custom Metadata Type objects only support Lookup relationships to other Custom Metadata Type objects or to other Custom Object or custom field metadata. Some features described in this section only apply to Custom Objects, such as lookup filters and referential integrity. Custom Setting objects do not support any form of record relationships.

In some aspects, they share similarities in how they are referenced when using SOQL and Apex and how they are input through the user interface (such as **lookup filters** described in the previous chapter). However, there are differences regarding **limits** and **referential integrity** features, and they are as follows:

- Utilizing the Master-Detail form of relationship provides a powerful way to model containment, where one parent object record acts as a container for other child records; in our example, a race contains **Contestants**.
  - The platform will automatically cascade deletion of child records when the parent is deleted, and it will also enforce the need for a parent reference when the child records are created.
  - By default, the platform prevents users from moving the child records to another parent by editing the relationship field. However, you can disable this validation and permit this by selecting the **Child records can be reparented to other parent records after they are created** option.
  - With the use of **Rollup Summary** fields, it also becomes possible to build calculated fields based on values of the child record fields.
  - Salesforce, however, does recommend that this kind of parent-and-child relationship does not exceed 10,000 child records; otherwise, the platform will not support the cascade delete of child records.
  - You can define up to three levels of Master-Detail relationships.

- Utilizing the **Lookup** type of relationship allows you to model connections between related records that are optional and may also have other relationships not necessarily in an ownership or containing aspects of their parents. Keep in mind the following points when using Lookup fields to define relationships:
  - Deletion of parent records will not result in a cascade delete of related child records; this can be enabled via **Salesforce Support**, though this setting will not be packaged.
  - Unlike with Master-Detail, you can elect for the platform to enforce referential integrity during the creation of the field by utilizing the **Don't allow deletion of the lookup record that's part of a lookup relationship** option.
  - Currently, the **Rollup Summary** fields are not supported when using a Lookup relationship.

Lookup fields of either kind are automatically indexed by the platform, making queries, in some cases, faster. We will focus more on indexes in a later chapter. The maximum number of relationship fields per object is 40.



While it is possible to add new custom fields to objects that have already been packaged and released to your customers, you cannot add a new Master-Detail relationship to an object that has already been packaged.

## Reusing the existing Standard Objects

When designing your object model, a good knowledge of the existing **Standard Objects** and their features is the key to knowing when and when not to reference them. Keep in mind the following points when considering the use of Standard Objects:

- **From a data storage perspective:** Ignoring Standard Objects creates a potential data duplication and integration effort for your end users if they are already using similar Standard Objects as pre-existing Salesforce customers. Remember that adding additional custom fields to the Standard Objects via your package will not increase the data storage consumption for those objects.

- **From a license cost perspective:** Conversely, referencing some Standard Objects might cause additional license costs for your users, since not all are available to the users without additional licenses from Salesforce. Make sure that you understand the differences between **Salesforce (CRM)** and **Salesforce Platform** licenses with respect to the Standard Objects available. Currently, the Salesforce Platform license provides **Accounts** and **Contacts**; however, to use **Opportunity** or **Product** objects, a Salesforce (CRM) license is needed by the user. Refer to the Salesforce documentation for the latest details on these.

Use your user personas to define what Standard Objects your users use and reference them via lookups, Apex code, and Visualforce accordingly. You may wish to use **extension packages** and/or **dynamic Apex** and SOQL to make these kind of references optional. Since **Developer Edition** orgs have all these licenses and objects available (although in a limited quantity), make sure you review your package dependencies before clicking on the **Upload** button each time to check for unintentional references.

## Importing and exporting data

Salesforce provides a number of its own tools for **importing** and **exporting** data, as well as a number of third-party options based on the Salesforce APIs; these are listed on AppExchange. When importing records with other record relationships, it is not possible to predict and include the IDs of related records, such as the **Season** record ID when importing **Race** records; this section will present a solution to this.

Salesforce provides **Data Import Wizard**, which is available under the **Setup** menu:

**Data Import Wizard**

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**Before you import your data . . .**

**Clean up your data import file**  
You'll have fewer errors to resolve if your data file is clean and free of duplicates. [Watch video](#)

**Make sure your field names match Salesforce field names**  
You'll be required to map your data fields to Salesforce data fields. Data in unmapped fields is not imported. [View a list of Salesforce data fields](#).

**Make sure you're not importing too many records**  
Using the Data Import Wizard, you can import up to 50,000 records at a time.

It is straightforward to import a CSV file with a list of race **Seasons** since this is a top-level object and has no other object dependencies. However, to import **Race** information (which is a related child object to **Season**), the **Season** and **Fastest Lap By** record IDs are required, which will typically not be present in a **Race** import CSV file by default. Note that IDs are unique across the platform and cannot be shared between orgs.



If you need a reminder of the structure of these objects, refer to the Schema Builder screenshot shown in *Chapter 2, Leveraging Platform Features*.

External ID fields help address this problem by allowing Salesforce to use the existing values of such fields as a secondary means to associate records being imported that need to reference parent or related records. All that is required is that the related record **Name** or, ideally, a unique external ID be included in the import data file.

The **Races.csv** file is included in the sample code for this chapter in the `/data` folder. This CSV file includes three columns: **Year**, **Name**, and **Fastest Lap By** (of the driver who performed the fastest lap of that race, indicated by their Twitter handle). You may remember that a **Driver** record can also be identified by this since the field has been defined as an **External ID** field:

	A	B	C
1	Year	Name	Fastest Lap By
2	2014	Melbourne	LewisHamilton
3	2014	Shanghai	LewisHamilton
4	2014	Monte Carlo	LewisHamilton
5	2014	Budapest	LewisHamilton

Both the 2014 **Season** record and the Lewis Hamilton **Driver** record should already be present in your packaging org. If not, refer to the previous chapter to create these. Now, run the **Data Import Wizard** and complete the settings as shown in the following screenshot:

Next, complete the field mappings as shown in the following screenshot:

Edit Field Mapping: Races					
Your file has been auto-mapped to existing Salesforce fields, but you can edit the mappings if you wish. Unmapped fields will not be imported.					
Edit	Mapped Salesforce Object	CSV Header	Example	Example	Example
Change	Fastest Lap By	Fasted Lap By	LewisHamilt	LewisHamilt	LewisHamilton
Change	Race Name	Name	Spa	Melbourne	Shanghai
Change	Season	Year	2014	2014	2014

Click on **Start Import** and then on **OK** to review the results once the data import has completed. You should find that four new **Race** records have been created under 2014 **Season**, with the **Fasted Lap By** field correctly associated with the Lewis Hamilton **Driver** record.



Note that these tools will also stress your **Apex Trigger** code for volumes, as they typically have the bulk mode enabled and insert records in chunks of 200 records. Thus, it is recommended that you test your triggers to at least this level of record volumes. Later chapters will present coding patterns to help ensure that code supports the bulk mode.

## Options for replicating and archiving data

Enterprise customers often have legacy and/or external systems that are still being used or that they wish to phase out in the future. As such, they may have requirements to replicate aspects of the data stored in the Salesforce platform to another. Likewise, in order to move unwanted data off the platform and manage their data storage costs, there is a need to archive data.

The following lists some platform and API facilities that can help you and/or your customers build solutions to replicate or archive data. There are, of course, a number of **AppExchange** solutions listed that provide applications that use these APIs already:

- **Replication API:** This API exists in both the web service SOAP and Apex form. It allows you to develop a scheduled process to query the platform for any new, updated, or deleted records within a given time period for a specific object. The `getUpdated` and `getDeleted` API methods return only the IDs of the records, requiring you to use the conventional Salesforce APIs to query the remaining data for the replication. The frequency in which this API is called is important to avoid gaps. Refer to the Salesforce documentation for more details.
- **Outbound Messaging:** This feature offers a more real-time alternative to the replication API. An outbound message event can be configured using the standard workflow feature of the platform. This event, once configured against a given object, provides a **Web Service Definition Language (WSDL)** file that describes a web service endpoint to be called when records are created and updated. It is the responsibility of a web service developer to create the end point based on this definition. Note that there is no provision for deletion with this option.

- **Bulk API:** This API provides a means to move up to 5000 chunks of Salesforce data (up to 10 MB or 10,000 records per chunk) per rolling 24-hour period. Salesforce and third-party data loader tools, including the Salesforce Data Loader tool, offer this as an option. It can also be used to delete records without them going into the recycle bin. This API is ideal for building solutions to archive data.



Heroku Connect is seamless data synchronization solution between Salesforce and Heroku Postgres. For further information see <https://www.heroku.com/connect>.



## External data sources

One of the downsides of moving data off the platform in an archive use case, or with not being able to replicate data onto the platform, is that the end users have to move between applications and logins to view data; this causes an overhead as the process and data is not connected.

The Salesforce Connect (previously known as Lightning Connect), a chargeable add-on feature of the platform, is the ability to surface external data within the Salesforce user interface via the so-called **External Objects** and **External Data Sources** configurations under **Setup**. They offer a similar functionality to Custom Objects, such as List View, Layouts and Custom Buttons. Currently **Reports**, and **Dashboards** are not supported, though it is possible to build custom report solutions via Apex, Visualforce or Lightning Components.

External Data Sources can be connected to existing OData based end points and secured through OAuth or Basic Authentication. Alternatively, Apex provides a Connector API whereby developers can implement adapters to connect to other HTTP based APIs. Depending on the capabilities of the associated External Data Source users accessing External Objects using the data source can read and even update records through the standard Salesforce UIs such as Salesforce Mobile and desktop interfaces.

## Summary

This chapter has further explored the declarative aspects of developing an application on the platform that applies to how an application is stored and how relational data integrity is enforced through the use of the Lookup field deletion constraints and applying unique fields. The Master-Detail relationships allow you to model containment concepts in your data model. We also considered the data storage implications of extending your schema across columns instead of rows and the benefits on the cost of storage for your end users.

Upload the latest version of the `FormulaForce` package and install it into your test org. The summary page during the installation of new and upgraded components should look something like the following screenshot. Note that the permission sets are upgraded during the install.

The screenshot shows the Salesforce package installation summary page with the following data:

Tabs (1)				
Action	Component Name	Parent Object	Component Type	Installation Notes
Create	Race Data		Tab	This is a brand new component.

Resources (3)				
Action	Component Name	Parent Object	Component Type	Installation Notes
Create	All	RaceData__c	List View	This is a brand new component.
Create	Race Data Layout	RaceData__c	Page Layout	This is a brand new component.
Create	Track Lap Record Layout	TrackLapRecord__mdt	Page Layout	This is a brand new component.

Objects (2)				
Action	Component Name	Parent Object	Component Type	Installation Notes
Create	Race Data		Custom Object	This is a brand new component.
Create	Track Lap Record		Custom Metadata Type	This is a brand new component.

Permission Sets (3)				
Create	Twitter Handle	Driver	Custom Field	This is a brand new component.
Create	Race	RaceData__c	Custom Field	This is a brand new component.
Create	Qualification 3 Lap Time	Contestant	Custom Field	This is a brand new component.
Create	Driver Name	TrackLapRecord__mdt	Custom Field	This is a brand new component.
Create	Qualification 1 Lap Time	Contestant	Custom Field	This is a brand new component.
Create	Year	TrackLapRecord__mdt	Custom Field	This is a brand new component.
Create	Time	TrackLapRecord__mdt	Custom Field	This is a brand new component.
Create	Qualification 2 Lap Time	Contestant	Custom Field	This is a brand new component.
Create	Poll Position Lap Time	Race	Custom Field	This is a brand new component.

Fields (9)				
Action	Component Name	Parent Object	Component Type	Installation Notes
Create	Twitter Handle	Driver	Custom Field	This is a brand new component.
Create	Race	RaceData__c	Custom Field	This is a brand new component.
Create	Qualification 3 Lap Time	Contestant	Custom Field	This is a brand new component.
Create	Driver Name	TrackLapRecord__mdt	Custom Field	This is a brand new component.
Create	Qualification 1 Lap Time	Contestant	Custom Field	This is a brand new component.
Create	Year	TrackLapRecord__mdt	Custom Field	This is a brand new component.
Create	Time	TrackLapRecord__mdt	Custom Field	This is a brand new component.
Create	Qualification 2 Lap Time	Contestant	Custom Field	This is a brand new component.
Create	Poll Position Lap Time	Race	Custom Field	This is a brand new component.

Custom Metadata Record (3)				
Action	Component Name	Parent Object	Component Type	Installation Notes
Create	Circuit Spa-Francorchamps		Track Lap Record [ff2]	This is a brand new component.
Create	Silverstone Circuit		Track Lap Record [ff2]	This is a brand new component.
Create	Nürburgring		Track Lap Record [ff2]	This is a brand new component.

Once you have installed the package in your testing org, visit the **Custom Metadata Types** page under **Setup** and click **Manage Records** next to the object. You will see that the records are shown as managed and cannot be deleted. Click on one of the records to see that the field values themselves cannot be edited either. This is the effect of the **Field Manageability** checkbox when defining the fields.

The **Namespace Prefix** value shown will differ from yours.

Try changing or adding **Track Lap Time** records in your packaging org, for example update a track time on an existing record. Upload the package again then upgrade your test org. You will see the records are automatically updated. Conversely, any records you created in your test org will be retained between upgrades.

In this chapter, we have now covered some major aspects of the platform with respect to packaging, platform alignment, and how your application data is stored, as well as the key aspects of your application's architecture. Custom Metadata has been used in this chapter to illustrate a use case for configuration data. This book will explain further use cases for this flexible platform feature throughout upcoming chapters.

In the next few chapters of this book, we will start to look at **Enterprise coding patterns** and effectively engineering your application code to work in harmony with the platform features, and grow with your needs and the platform.



# 4

## Apex Execution and Separation of Concerns

When starting to write Apex, it is tempting to start with an Apex Trigger or Apex Controller class and start placing the required logic in these classes to implement the desired functionality. This chapter will explore a different starting point, one that gives the developer focus on writing application business logic (the core logic of your application) in a way that is independent of the calling context. It will also explain the benefits that it brings in terms of reuse, code maintainability, and flexibility, especially when applying code to different areas of the platform.

We will explore the ways in which Apex code can be invoked, the requirements and benefits of these contexts, their commonalities, their differences, and the best practices that are shared. We will distill these into a layered way of writing code that teaches and embeds **Separation of Concerns (SOC)** in the code base from the very beginning. We will also introduce a naming convention to help with code navigation and enforce SOC further.

At the end of the chapter, we will have written some initial code, setting out the framework to support SOC and the foundation for the next three chapters to explore some well-known **Enterprise Application Architecture** patterns in more detail. Finally, we will package this code and install it in the test org.

This chapter will cover the following topics:

- Apex execution contexts
- Apex governors and namespaces
- Where is Apex used?
- Separation of Concerns
- Patterns of Enterprise Application Architecture

- Unit testing versus system testing
- Packaging the code

## Execution contexts

An execution context on the platform has a beginning and an end; it starts with a user or system action or event, such as a button click or part of a scheduled background job, and is typically short lived; with seconds or minutes instead of hours before it ends. It is especially important in multitenant architecture because each context receives its own set of limits around queries, database operations, logs, and duration of the execution.

In the case of background jobs (**Batch Apex**), instead of having one execution context for the whole job, the platform splits the information being processed and hands it back through several execution contexts in a serial fashion. For example, if a job was asked by the user to process 1000 records and the batch size (or scope size in Batch Apex terms) was 200 (which is the default), this would result in five distinct execution contexts, one after another. This is done so that the platform can throttle the execution of jobs up or down or if needed pause them between scopes based on the load on the service at the time.

You might think that an execution context starts and ends with your Apex code, but you would be wrong. Using some Apex code is introduced later in this chapter; we will use the debug logs to learn how the platform invokes the Apex code.

## Exploring execution contexts

For the next two examples, imagine that an Apex Trigger has been created for the **Contestant** object and an Apex class has been written to implement some logic to update the contestants' championship points dependent on their position when the race ends.

In the first example, the **Contestant** record is updated directly from the UI and the **Apex Debug** log shown in the next screenshot is captured.

Notice the **EXECUTION\_STARTED** and **EXECUTION\_FINISHED** lines; these show the actual start and end of the request on the Salesforce server. The **CODE\_UNIT\_STARTED** lines show where the platform invokes Apex code. Also, note that the line number shows **EXTERNAL**, indicating the platform's internal code called the Apex code. For the sake of brevity, the rest of the execution of the code is collapsed in the screenshot.

Log		
Text	Category	Line
EXECUTION_STARTED	EXECUTION_STARTED	
TRIGGERS		
fforce.ContestantsTrigger on Contestant trigger event BeforeUpdate for [a03b0000006WVph]	CODE_UNIT_STARTED	[EXTERNAL]
fforce.ContestantsTrigger on Contestant trigger event AfterUpdate for [a03b0000006WVph]	CODE_UNIT_STARTED	[EXTERNAL]
EXECUTION_FINISHED	CODE_UNIT_STARTED	[EXTERNAL]
	EXECUTION_FINISHED	

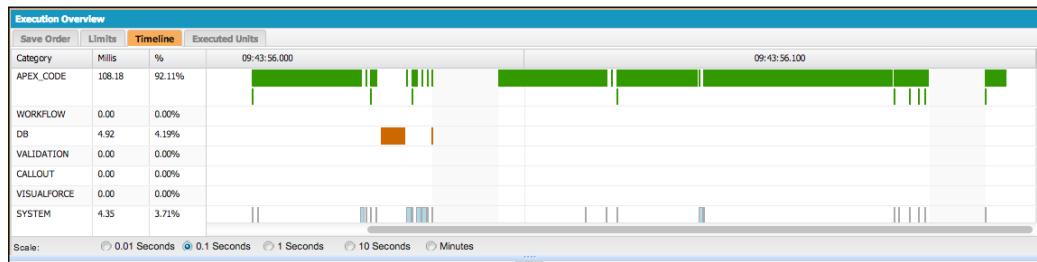
In this second example, imagine that some Apex code was executed to calculate the contestants' championship points once the race ends. In this case, the code was executed from an **Execute Anonymous** prompt (though in the application, this would be a button); again, the Apex Debug log was captured and is shown in the next screenshot.

Again, you can see the **EXECUTION\_STARTED** and **EXECUTION\_FINISHED** entries, along with the three **CODE\_UNIT\_STARTED** entries: one for the `RaceService.awardChampionshipPoints` Apex method called from the **Execute Anonymous** prompt and two others for the Apex Trigger code.

Log		
Text	Category	Line
EXECUTION_STARTED	EXECUTION_STARTED	
execute_anonymous_apex	CODE_UNIT_STARTED	[EXTERNAL]
<init>(Integer)	SYSTEM_CONSTRUCTOR_ENTRY	[1]
RaceService.RaceService()	METHOD_ENTRY	[1]
fforce.RaceService.awardChampionshipPoints(SET<Id>)	METHOD_ENTRY	[1]
fflib_SObjectUnitOfWork.fflib_SObjectUnitOfWork()	METHOD_ENTRY	[54]
<init>()	SYSTEM_CONSTRUCTOR_ENTRY	[9]
<init>((LIST<Schema.SObjectType>)	CONSTRUCTOR_ENTRY	[9]
Aggregations:1 select id, (select Id, fforce__ChampionshipPoints__c from Contestants__r) from Race__c	SOQL_EXECUTE_BEGIN	[14]
QueryLocatorIterator.QueryLocatorIterator()	SYSTEM_METHOD_ENTRY	[7]
fforce.fflib_SObjectUnitOfWork.registerDirty(SObject)	METHOD_ENTRY	[23]
fforce.fflib_SObjectUnitOfWork.registerDirty(SObject)	METHOD_ENTRY	[23]
fforce.fflib_SObjectUnitOfWork.commitWork()	METHOD_ENTRY	[28]
SavepointValue0	SAVEPOINT_SET	[166]
fforce.fflib_SObjectUnitOfWork.Relationships.resolve()	METHOD_ENTRY	[172]
Op:Updated(Type:SObject Rows:2	DML_BEGIN	[177]
fforce.ContestantsTrigger on Contestant trigger event BeforeUpdate for [a03b0000006WVph, a03b00000072xx9]	CODE_UNIT_STARTED	[EXTERNAL]
fforce.ContestantsTrigger on Contestant trigger event AfterUpdate for [a03b0000006WVph, a03b00000072xx9]	CODE_UNIT_STARTED	[EXTERNAL]
CUMULATIVE_LIMIT_USAGE	CUMULATIVE_LIMIT_USAGE	
(default)	LIMIT_USAGE_FOR_NS	
fforce	LIMIT_USAGE_FOR_NS	
CUMULATIVE_LIMIT_USAGE_END	CUMULATIVE_LIMIT_USAGE_END	
EXECUTION_FINISHED	EXECUTION_FINISHED	

What is different from the first example is, as you can see by looking at the **Line** column, that the execution transitions show lines of the Apex code being executed and **EXTERNAL**. When DML statements are executed in Apex to update the **Contestants** records, the Apex code execution pauses while the platform code takes over to update the records. During this process, the platform eventually then invokes Apex Triggers and once again, the execution flows back into Apex code.

Essentially, the execution context is used to wrap a request to the Salesforce server; it can be a mix of execution of the Apex code, Validation Rules, workflow rules, trigger code, and other logic executions. The platform handles the overall orchestration of this for you. The Salesforce **Developer Console** tool offers some excellent additional insight into the time spent in each of these areas.



If the subscriber org has added Apex Triggers to your objects, these are executed in the same execution context. If any of these Apex code units throw unhandled exceptions, the entire execution context is stopped and all database updates performed are rolled back, which is discussed in more detail later in this chapter.

## Execution context and state

The server memory storage used by the Apex variables created in an execution context can be considered the state of the execution context; in Apex, this is known as the **heap**. On the whole, the server memory resources used to maintain an execution context's state are returned at the end; thus, in a system with short lived execution contexts, resources can be better managed. By using the CPU and heap governors, the platform enforces the maximum duration of an execution context and Apex heap size to ensure the smooth running of the service; these are described in more detail later in this chapter.

**State management** is the programming practice of managing the information that the user or job needs between separate execution contexts (requests to the server) invoked as the user or job goes about performing the work, such as a wizard-based UI or job aggregating information. Users, of course, do not really understand execution contexts and state; they see tasks via the user interface or jobs they start based on field inputs and criteria they provide. It is not always necessary to consider state management, as some user tasks can be completed in one execution context; this is often preferable from an architecture perspective as there are overheads in the managing state. Although the platform provides some features to help with state management, using them requires careful consideration and planning, especially from a data volumes perspective.

In other programming platforms such as Java or Microsoft .NET, static variables are used to maintain the state across execution contexts, often caching information to reduce the processing of subsequent execution contexts or to store common application configurations. The implementation of the `static` keyword in Apex is different; its scope applies only to the current execution context and no further. Thus, an Apex static variable value will not be retained between execution contexts, though they are preserved between multiple Apex code units (as illustrated in the previous section). Thus, in recursive Apex Trigger scenarios, allow the sharing of the static variable to control recursion.



Custom Settings may offer a potential parallel in Apex where other programming languages use static variables to store or cache certain application information. Such information can be configured to be org, user, or profile scope and are low cost to read from Apex. However, if you need to cache information that may have a certain life span or expiry, such as the user session or across a number of users, you might want to consider Platform Cache. Platform Cache also provides greater flexibility for your customers in terms of purchasing additional storage (Custom Settings are limited to 10 MB per package).

## Platform Cache

Caching information is not a new concept and is available on many other platforms, for example **MemCache** is a popular open source framework for providing a cache facility. The main motivation for considering caching is performance.

As stated earlier, state is not retained between requests. You may find that common information needs to be constantly queried or calculated. If the chances of such information changing is low, caches can be considered to gain a performance benefit. The cost, in terms of Apex execution (CPU Governor) and/or database queries (SOQL and Row Governors) has to be less than retrieving it from the cache.



Salesforce recommend the use of the `System.currentTimeMillis` method to output debug statements around code and/or queries to determine the potential benefit. Do not depend on the debug log timestamps.

Platform Cache allows you to retain state beyond the scope of the request, up to 48 hours for the org level cache and 8 hours for the session level cache. Session level cache only applies to the interactive context, it is not available in async Apex. Your code can clear cached information ahead of these expiry times if users change information that the cached information is dependent on. Apex provides APIs under the `Cache` namespace for storing (putting), retrieving (getting), and clearing information from either of these caches. There is also a `$Cache` variable to retrieve information from the Session cache within a Visualforce page. Unfortunately, there is currently no `$Cache` access for Lightning Component markup at time of writing, as such Apex Controllers must be used.



You can enable **Cache Diagnostics** on the **User Detail** page. Once enabled you can click the **Diagnostics** link next to a cache partition (more on this later in this section). This provides useful information on the size of entries in the cache and how often they are being used. This can be useful during testing. Salesforce advises to use this page sparingly, as generating the information is expensive.

Think carefully about the lifespan of what you put in the cache, once it goes in, the whole point is that it stays in the cache as long as possible and thus the performance benefit is obtained more often than not. If you are constantly changing it or clearing the cache out, the benefit will be reduced. Equally information can become stale and out of date if you do not correctly consider places in your application where you need to invalidate (clear) the cache. This consideration can become quite complex depending on what you are storing in the cache, for example if the information is a result of a calculation involving a number of records and objects.



Stale cached information can impact on your validations and user experience and thus potentially cause data integrity issues if not considered carefully. If you are storing information in the org level cache for multiple users, ensure that you are not indirectly exposing information other users would not have access to via their Sharing Rules, Object, or Field Level security.

The amount of cache available depends on the customer's org type, Enterprise Edition orgs currently get 10 MB by default, whereas Unlimited and Performance Edition orgs get 30 MB. You cannot package storage, though more can be purchased by customers. To test the benefits of Platform Cache in a Developer Edition org, you can request a trail allocation from Salesforce from the **Platform Cache** page under **Setup**. Salesforce uses a **Least Recently Used (LRU)** algorithm to manage cache items.

The amount of cache available can be partitioned (split), much like storage partitions on a hard disk. This allows the administrator to guarantee a portion of the allocation is used for a specific application only, and if needed, adjust it depending on performance needs. As the package developer, you can reference local partitions (created by the administrator) by name dynamically. You can also package a partition name for use exclusively by your application and reference it in your code. This ensures any allocation assigned after the installation of your package by the administrator to your partition is guaranteed to be used by your application. If your code was to share a partition you may not want other applications constantly pushing out your cached entries for example.



Packaged partitions cannot be accessed by other code in the customer's org or other packages, only by code in that corresponding package namespace. You may want to provide the option (via Custom Settings) for administrators to configure your application to reference local partitions, perhaps allowing administrators to pool usage between applications. Consider using the `Cache.Visibility.NAMESPACE` enumeration when adding entries to the cache to avoid code outside your package accessing entries. This could be an important security consideration depending on what your caching.



Salesforce themselves use MemCache internally to manage the platform. Platform Cache is likely a wrapper exposing part of these internals to Apex Developers. Refer to the blogpost "*Salesforce Architecture - How They Handle 1.3 Billion Transactions A Day*" at <http://highscalability.com/blog/2013/9/23/salesforce-architecture-how-they-handle-13-billion-transacti.html>

The *Salesforce Apex Developers Guide* contains a Platform Cache sub-section which goes in to further detail on the topics I have covered in this section, including further best practices and usage guidelines. You can refer to this guide at [https://developer.salesforce.com/docs/atlas.en-us.apexcode.meta/apexcode/apex\\_cache\\_namespace\\_overview.htm](https://developer.salesforce.com/docs/atlas.en-us.apexcode.meta/apexcode/apex_cache_namespace_overview.htm).

## Execution context and security

As discussed in the last chapter, the platform provides security features to allow subscribers or administrators to manage CRUD operations on your objects as well as individual **Field-Level security (FLS)** ideally through the assignment of some carefully considered permission sets that you have included in your package, in addition to providing the ability to define sharing rules to control record visibility and editing.

Within an Apex execution context, it is important to understand whose responsibility it is (the platform's or developer's) to provide enforcement of these security features. With respect to sharing rules, there is a default security context, which is either set by the platform or can be specified using specific keywords used within Apex code. These two types of security are described in further detail in the following bullets:

- **Sharing security:** Through the use of the `with sharing` keyword when applied to an Apex class declaration, the Apex runtime provides support to filter out records returned by SOQL queries automatically that do not meet the sharing rules for the current user context. If it is not specified, then this is inherited from the outermost Apex class that controls the execution. Conversely, the `without sharing` keyword can be used to explicitly enable the return of all records meeting the query regardless of sharing rules. This is useful when implementing referential integrity, for example, where the code needs to see all the available records regardless of the current users sharing rules.
- **CRUD and FLS security:** As discussed in the previous chapter, it is the Apex developers' responsibility to use appropriate programming approaches to enforce this type of security. On a Visualforce page, CRUD and FLS are only enforced through the use of the appropriate Visualforce components such as `apex:inputField` and `apex:outputField`. The Apex code within an execution context runs within the system mode with respect to CRUD and FLS accessibility, which means that, unless your code checks for permitted access, the platform will always permit access. Note that this is regardless of the use of the `with sharing` keyword, which only affects the records that are visible to your code.

In summary, both are controlled and implemented separately as follows:

- Row-level security applies only to the `with sharing` usage
- CRUD security and FLS needs separate coding considerations

In the later chapters of this book, we will see some places to position this logic to make it easier to manage and less intrusive for the rest of the code.

## **Execution context transaction management**

Handling database transactions in Apex is simpler than other platforms. By default, the scope of the transaction wraps the entire execution context. This means that if the execution context completes successfully, any record data is committed. If an unhandled exception or error occurs, the execution context is aborted and all record data is rolled back.

Unhandled Apex exceptions, governor exceptions, or Validation Rules can cause an execution context to abort. In some cases, however, it can be desirable to perform only a partial rollback. For these cases, the platform provides **Savepoints** that can be used to place markers in the execution context to record what data is written at the point the Savepoint was created. Later, a Savepoint can be used in the execution as the rollback position to resume further processing in response to error handling or a condition that causes the alternative code path resulting in different updates to the database.

 It is important to realize that catching exceptions using the Apex `try` and `catch` keywords, for example, in Visualforce controller methods, results in the platform committing any data written up until the exception occurs. This can lead to partially updated data across the objects being updated in the execution context giving rise to data integrity issues in your application. Savepoints can be used to avoid this by using a rollback in the `catch` code block. This does, however, present quite a boilerplate overhead for the developer each time. Later in this book, we will review this practice in more detail and introduce a pattern known as **Unit Of Work** to help automate this.

## Apex governors and namespaces

Platform governors prevent any one execution context from consuming excessive resources on the service, which could be detrimental to its users. Overall, an execution context cannot exceed 10 minutes, though within an execution context in practice, other limits would likely be reached before this.

For example, Apex code units executing within an execution context can only collectively execute for a maximum of 10 or 60 seconds depending on the context. Over the years, Salesforce has worked hard to consolidate what was once a confusing array of governors, which also varied based on a number of Apex code contexts. Thankfully, these days governors are much easier to follow and vary only based on the context being interactive or batch (asynchronous).

## Namespaces and governor scope

An important consideration for a packaged solution is the scope of a governor. In other words, does it apply only to the packaged code or for all code executing in the execution context? Remember that an execution context can contain code from other developers within the subscriber org or other packaged solutions installed.

Your package namespace acts as a container for some governors, which protects your code from limits being consumed by other packaged code (triggers for example) running in the execution context. The platform supports an unlimited number of namespace scopes within one execution context. For code that has not been deployed as part of a managed package, such as code developed directly in the subscriber org, there is a default namespace.

Code running in a namespace cannot exceed governors that are scoped by the namespace (as highlighted later in this chapter). Although an execution context can run code from unlimited namespaces, a cross-namespace cumulative limit is enforced. This is 11 times the specific per namespace limit. For example, a maximum of 1650 DML statements (150 per namespace) would be allowed across any number of namespaces. For more examples refer to the *Execution Governors and Limits* page in the *Apex Developer Guide*, in the sub-section entitled *Per-Transaction Certified Managed Package Limits*.

 In reality 150 in my view is quite a lot of DML for a single namespace to be performing. If you are observing bulkification this would require you to be updating 150 distinct objects in one request! If that is the case and you are following DML bulkification, you may want to review your object model design to see if you can denormalize it a bit further. Though not documented, I suspect the 11 cumulative multiplier is likely based on the historic 10 namespace limit plus the default namespace.

You can see evidence of namespaces in play when you observe the debug logs within your packaging org. Just before each Apex code unit completes, notice how the `LIMIT_USAGE_FOR_NS` section of the debug log is repeated for the `default` and `fforce` namespaces (your namespace will be different) as follows, allowing you to review the incremental usage of governors throughout the execution context:

```
13:47:43.712 (412396000) | CUMULATIVE_LIMIT_USAGE
13:47:43.712 | LIMIT_USAGE_FOR_NS | (default) |
  Number of SOQL queries: 0 out of 100
  Number of query rows: 0 out of 50000
  Number of SOSL queries: 0 out of 20
  Number of DML statements: 0 out of 150
  Number of DML rows: 0 out of 10000
  Number of code statements: 0 out of 200000
  Maximum CPU time: 0 out of 10000
  Maximum heap size: 0 out of 6000000
  Number of callouts: 0 out of 10
```

```
Number of Email Invocations: 0 out of 10
Number of fields describes: 0 out of 100
Number of record type describes: 0 out of 100
Number of child relationships describes: 0 out of 100
Number of picklist describes: 0 out of 100
Number of future calls: 0 out of 10

13:47:43.712 | LIMIT_USAGE_FOR_NS | fforce |
Number of SOQL queries: 1 out of 100
Number of query rows: 1 out of 50000
Number of SOSL queries: 0 out of 20
Number of DML statements: 2 out of 150
Number of DML rows: 3 out of 10000
Number of code statements: 85 out of 200000
Maximum CPU time: 0 out of 10000
Maximum heap size: 0 out of 6000000
Number of callouts: 0 out of 10
Number of Email Invocations: 0 out of 10
Number of fields describes: 0 out of 100
Number of record type describes: 0 out of 100
Number of child relationships describes: 0 out of 100
Number of picklist describes: 0 out of 100
Number of future calls: 0 out of 10

13:47:43.712 | CUMULATIVE_LIMIT_USAGE_END
13:47:43.412 | CODE_UNIT_FINISHED | execute_anonymous_apex
```

Note that all governors are shown in the summary regardless of their scope; for example, the CPU time governor is an execution scope governor. This allows you to follow the consumption of the Apex CPU time across Apex code units from all namespaces. The **Developer Console** option provides some excellent tools to profile the consumption of governors.

## **Deterministic and non-deterministic governors**

When considering governors from a testing and support perspective, you should be aware of which governors are deterministic and which are not. For example, when profiling your application, this is being able to obtain the exact same results (such as the preceding results) from the debug logs from the repeated running of the exact same test. The following outlines examples of both types of governors:

- Examples of deterministic governors are the SOQL and DML governors. If you repeat the same test scenario (within your development or packaging orgs), you will always get the same utilization of queries and updates to the database; thus, you can determine reliably if any changes in these need to be investigated.
- An example of a non-deterministic governor is the CPU time governor. The amount of time used between executions will vary based on the load at any given time on the Salesforce servers. Thus, it is hard to determine accurately whether changes in your application are truly affecting this or not. That being said, it can be a useful indicator depending on the variance you're seeing between builds of your software. However, keep in mind that the base line information you capture will become increasingly less accurate as time goes by, for example, between platform releases.

In the CPU governor, the platform limits the length of time the execution context is allowed to spend executing the Apex code to 10 seconds for interactive context and 60 seconds for asynchronous context (for example, Batch Apex), though in practice the platform appears to exercise some tolerance. In contrast, the number of SOQL queries or DML statements is always constant when applied to a consistent test scenario.

As the CPU governor is non-deterministic, it should only be used as a guideline when testing. My recommendation is not to use the `Limits.getCPULimit()` method as a branching mechanism between interactive and batch processing in your application. If you require this type of branching, focus on using aspects of your application such as selection criteria, number of rows selected, or some other configurable setting in the subscriber org perhaps via a Custom Setting.



You may want to consider testing certain governors within an Apex test context to monitor for changes in how many queries or DML are being consumed. Such tests can give you an early warning sign that inefficiency has crept into your code. Use the `Limits` class methods to capture the before and after state of the SOQL and/or DML governors. Then, apply either a strict comparison of the expected usage (for example, 10 queries expected after the execution of the test) or a plus or minus tolerance to allow for code evolution.

## Key governors for Apex package developers

The following table is a summary of key governors, their scope, and whether they are deterministic. Note that Salesforce is constantly monitoring the use of its service and adapting its governors. Always check for the latest information on governors in the *Apex Developer Guide*.

Governor	Scope	Deterministic
Execution context timeout	Execution context	No
Apex CPU governor	Execution context	No
SOQL queries	Namespace	Yes
DML statements	Namespace	Yes
Query rows	Namespace	Yes

## Where is Apex used?

The following table lists the types of execution contexts the Apex code can run from and considerations with respect to security and state management. While a description of how to implement each of these is outside the scope of this book, some aspects such as Batch Apex are discussed in more detail in a later chapter when considering data volumes.

Execution context	Security	State management
Anonymous Apex	<p>Sharing is enforced by default, unless disabled by applying the <code>without sharing</code> keyword to the enclosing class.</p> <p>CRUD and FLS are enforced by default, but only against the code entered directly into the <b>Execute Anonymous</b> window. The code will fail to compile if the user does not have access to the objects or fields referenced.</p> <p>Note that the checking is only performed by the platform at compilation time; if the code calls a pre-existing Apex class, there is no enforcement within this class and any other class it calls.</p>	See Note 2.
Apex Controller Action Method  <b>Note:</b> Used only by Visualforce pages	<p>Sharing is not enforced by default; the developer needs to apply the <code>with sharing</code> keyword to the enclosing class.</p> <p>CRUD and FLS are not enforced by default; the developer needs to enforce this in code.</p>	<p>Any member variable declared on the Apex Controller that is not static or marked with the <code>transient</code> keyword will be included in <b>View State</b>.</p> <p>Visualforce automatically maintains this between interactions on the page. Use it carefully, as large View State sizes can cause performance degradation for the page.</p> <p><b>Developer Console</b> has an excellent View State browser tool.</p>

Execution context	Security	State management
Apex Controller Remote and Aura Actions  <b>Note:</b> Remote Actions methods are used by Visualforce and Aura Actions methods are used by Lightning Components	Sharing is not enforced by default; the developer needs to apply the <code>with sharing</code> keyword to the enclosing class. It is required for Salesforce security review. CRUD and FLS are not enforced by default; the developer needs to check this in code.	Remote Action and Aura Action Apex methods are already static, as stated previously; any static data is not retained in Apex. Thus, there is no state retained between remote action calls made by the client JavaScript. Typically, in these cases, the state of the task the user is performing is maintained on the page itself via the client-side state. As a result of not having to manage the state for the developer, these type of methods are much faster than Action Methods described in the preceding section.
Apex Trigger	Sharing is not enforced by default; the developer needs to apply the <code>with sharing</code> keyword in the outermost Apex class (if present, for example, Apex Controller). Triggers invoked through the Salesforce UIs or APIs run without sharing implicitly; if you need to apply <code>with sharing</code> , move your trigger code into an Apex class and call that from the trigger code. CRUD and FLS are not enforced by default; the developer needs to enforce this in the code.	Static variables are shared between Apex Trigger invocations within an execution context. This allows some caching of commonly used information and/or recursive trigger protection to be implemented if needed.

Execution context	Security	State management
Batch Apex	Sharing is not enforced by default; the developer needs to apply the <code>with sharing</code> keyword to the enclosing class.  CRUD and FLS are not enforced by default; the developer needs to enforce this in the code.	Batch Apex splits work into distinct execution contexts, driven by splitting up the data into scopes (typically, 200).  If the <code>Database.Stateful</code> interface is implemented, class member variable values of the implementing Apex class are retained between each invocation. The <code>transient</code> keyword also applies here.  The <code>final</code> keyword can be used to retain the initial member variable values throughout the job execution.
Queueable	See Note 1.	See Note 2.
Apex Scheduler	See Note 1.	See Note 2.
Inbound messaging	See Note 1.	See Note 2.
Invocable Method	See Note 1.	See Note 2.
Apex REST API	See Note 1.	See Note 2.
Apex Web Service	See Note 1.	See Note 2.

- **Note 1:** Unless otherwise stated in the preceding table, the default position is as follows regarding security:
  - Sharing is not enforced by default; the developer needs to apply the `with sharing` keyword to the enclosing class
  - CRUD and FLS are not enforced by default; the developer needs to check this in the code
- **Note 2:** For state management, unless stated otherwise in the previous table, the default position is as follows:
  - No static or member variable values are retained between invocations of the Apex class methods between execution contexts

## Separation of Concerns

As you can see there are a number of places Apex code is invoked by various platform features. Such places represent areas for valuable code to potentially hide. It is hidden because it is typically not easy or appropriate to reuse such logic as each of the areas mentioned in the previous table has its own subtle concerns with respect to security, state management, transactions, and other aspects such as error handling (for example, catching and communicating errors) as well as varying needs for bulkification.

Throughout the rest of this chapter, we will review these requirements and distill them into a Separation of Concerns that allows a demarcation of responsibilities between the Apex code used to integrate with these platform features versus the code implementing your application business logic, such that the code can be shared between platform features today and in the future more readily. Wikipedia describes the benefits of Separation of Concerns as the following:

*"The value of Separation of Concerns is simplifying development and maintenance of computer programs. When concerns are well separated, individual sections can be developed and updated independently. Of especial value is the ability to later improve or modify one section of code without having to know the details of other sections, and without having to make corresponding changes to those sections."*

## Apex code evolution

Apex Triggers can lead to a more traditional pattern of `if/then/else` style coding resulting in a very procedural logic that is hard to maintain and follow. This is partly due to them not being classes and as such they don't naturally encourage breaking up the code into methods and separate classes. As we saw in the previous table, Apex Triggers are now not the only execution context for Apex; others do support Apex classes and the **object-orientated programming (OOP)** style, often leveraging system-defined Apex interfaces to allow the developer to integrate with the platform such as Batch Apex.

Apex has come a long way since its early introduction as a means of writing more complex Validation Rules in Apex Triggers. These days, the general consensus in the community is to write as little code as possible directly in Apex Trigger, instead of delegating the logic to separate Apex classes. For a packaged application, there is no real compelling reason to have more than one Apex Trigger per object. Indeed, the Salesforce security review has been known to flag this even if the code is conditioned to run independently.

A key motivation to move the Apex Trigger code into an Apex class is to gain access to the more powerful language semantics of the Apex language, such as OOP, allowing the developer to structure the code more closely to the functions of the application and gain better code reuse and visibility.

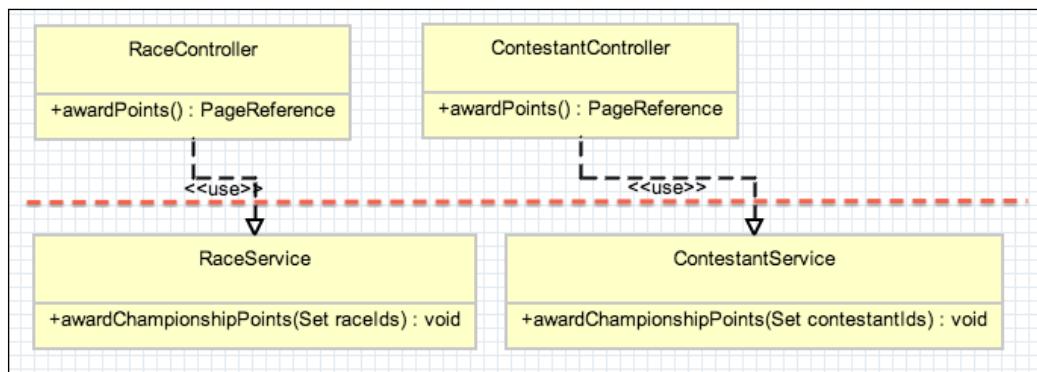
## Separating concerns in Apex

Each execution context has its own requirements for your code, such as implementing system interfaces, annotations, or controller bindings. Within this code are further coding requirements relating to how you engineer your application code, which lead to a set of common architecture layers of concern, such as loading records, applying validations, and executing business logic.

Understanding these layers allows us to discover a different way to write the application code than simply writing all our code in a single Apex class, which becomes tightly coupled to the execution context and thus less flexible in the future.

To manage these layers of concern in the code, create separate classes – those that are bound to the specific execution context (such as Batch Apex, Scheduler, Apex REST, and Inbound Messaging) and those that contain the application business logic that implements the actual task for the user.

The following UML diagram shows the Apex classes that implement the requirements (or concerns) of the execution context and Apex classes to execute the application business logic. The dotted line indicates a Separation of Concerns between UI controller (these could be Visualforce or Lightning Component Controllers) classes and classes implementing the application business logic.



## Separation of concerns in Lightning Component JavaScript

Like Visualforce's use of the **Model View Controller (MVC)**, Lightning Components also think in terms of SOC by splitting up the implementation of the component into several distinct files that each have their own concerns. As Lightning Components are mostly implemented on the client side these files represent a way to implement separation of concerns within the JavaScript code you write.

When creating a Lightning Component in the Salesforce **Developer Console**, you are presented with the following side panel which outlines the different files that make up your component:

DriverStats		
Ctrl + Shift + 1	COMPONENT	
Ctrl + Shift + 2	CONTROLLER	Create
Ctrl + Shift + 3	HELPER	Create
Ctrl + Shift + 4	STYLE	Create
Ctrl + Shift + 5	DOCUMENTATION	Create
Ctrl + Shift + 6	RENDERER	Create
Ctrl + Shift + 7	DESIGN	Create
Ctrl + Shift + 8	SVG	Create

We will go into more detail on these in *Chapter 9, Lightning*, for now let's consider the **CONTROLLER**, **HELPER** and **RENDER** files.

1. **CONTROLLER:** Code in this file is responsible for implementing bindings to the visual aspects of the component. Defined via the markup defined in the **COMPONENT** file. Unlike a Visualforce controller, it only contains logic providing bindings to the UI. The client side state of your component is accessed via the controller.
2. **HELPER:** Code in this file is responsible for the logic behind your components behavior, button presses and other interactions, which lead to accessing the backend Apex controller, combining inputs and outputs to interface with the user and the backend. Methods on the helper take an instance of the controller to manipulate the state and UI.

3. **RENDER:** Code in this file is only needed in more advanced scenarios where you want to override or modify the HTML DOM created by the Lightning Framework itself using markup expressed in your COMPONENT file. It is focused on the presentation of your component in the browser.

Lightning Components client-side controllers can communicate with an Apex Controller class via the `@AuraMethod` annotation and thus access classes implementing your share application business logic as shown in the preceding diagram.



Later in this book we will be building a Lightning Component to package within our FormulaForce application.



## Execution context logic versus application logic concerns

In this section, we will review the needs/concerns of the execution context and how each can lead to a common requirement of the application business logic. This helps define the guidelines around writing the application business logic, thus making it logical and more reusable throughout the platform and application:

- **Error handling:** When it comes to communicating errors, traditionally, a developer has two options: Let the error be caught by the execution context or catch the exception to display it in some form. In the Visualforce Apex controller context, it's typical to catch exceptions and route these through the `ApexPage.addMessage` method to display messages to the user via the `apex:pageMessages` tag. In contrast to Batch Apex, letting the platform know that the job has failed involves allowing the platform to catch and handle the exception instead of your code. In this case, Apex REST classes, for example, will automatically output exceptions in the REST response.
  - **Application business code implication:** The point here is that there are different concerns with regard to error handling within each execution context. Thus, it is important for application business logic to not dictate how errors should be handled by calling the code.

- **Transaction management:** As we saw earlier in this chapter, the platform manages a single default transaction around the execution context. This is important to consider with the error handling concern, particularly if errors are caught, as the platform will commit any records written to the database prior to the exception occurring, which may not be desirable and may be hard to track down.
  - **Application business code implication:** Understanding the scope of the transaction is important, especially when it comes to writing application business logic that throws exceptions. Callers, especially those catching exceptions, should not have to worry about creating `Database.Savepoint` to rollback the state of the database if an exception is thrown.
- **Number of records:** Some contexts deal with a single database record, such as a Visualforce Standard Controller, and others deal with multiple records, such as Visualforce Standard Set Controllers or Batch Apex. Regardless of the type of execution context, the platform itself imposes governors around the database operations that are linked with the number of records being processed. Every execution context expects code to be bulkified (minimal queries and DML statements).
  - **Application business code implication:** Though some execution contexts appear to only deal with a single record at a time in reality because database-related governors apply to all execution context types, it is good practice to assume that the application code should consider bulkification regardless. This also helps make the application code more reusable in future from different contexts.
- **State management:** Execution contexts on Force.com are generally stateless; although as described earlier in this chapter, there are some platform facilities to store state across execution contexts.
  - **Application business code implications:** As the state management solutions are not always available and are also implemented in different ways, the application code should not attempt to deal directly with this concern and should make itself stateless in nature. If needed, provide custom Apex types that can be used to exchange the state with the calling execution context code, for example, a controller class.

- **Security:** It could be said that the execution context should be the one concerned with enforcing this, as it is the closest to the end user. This is certainly the case with a controller execution context where Salesforce recommends the `with sharing` keyword is placed. However, when it comes to CRUD and FLS security, the practicality of placing enforcement at the execution context entry point will become harder from a maintenance perspective, as the code checking the users' permissions will have to be continually maintained (and potentially repeated) along with the needs of the underlying application business code.
  - **Application business code implication:** The implication here is that it is the concern of both the execution context and the application business logic to enforce the users permissions. However, in the case of sharing, it is mainly the initial Apex caller that should be respected. As we dive deeper into the engineering application business logic in later chapters, we will revisit security several times.

A traditional approach for logging errors for later review by administrators or support teams is to use a **log table**. While in Force.com this can be implemented to some degree, keep in mind that some execution contexts work more effectively with the platform features if you don't catch exceptions and let the platform handle it. For example, the **Apex Jobs** page will correctly report failed batches along with a summary of the last exception. If you implement a logging solution and catch these exceptions, visibility of failed batch jobs will be hidden from administrators. Make sure that you determine which approach suites your users best. If you decide to implement your own logging, keep in mind that this requires some special handling of Apex database transactions and the provision of application functionality to allow users to clean up old logs.

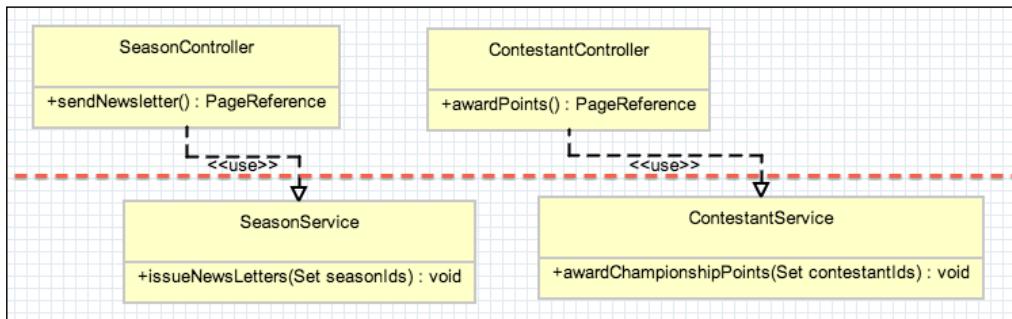
## Improving incremental code reuse

There is Separation of Concerns between code invoked directly through an execution context and the application business logic code within an application. This knowledge is important to ensure whether you can effectively reuse application logic easily, incrementally, and with minimal effort. It is the developer's responsibility to maintain this Separation of Concerns by following patterns and guidelines set out in the chapters of this book and those you devise yourself as part of your own coding guidelines.

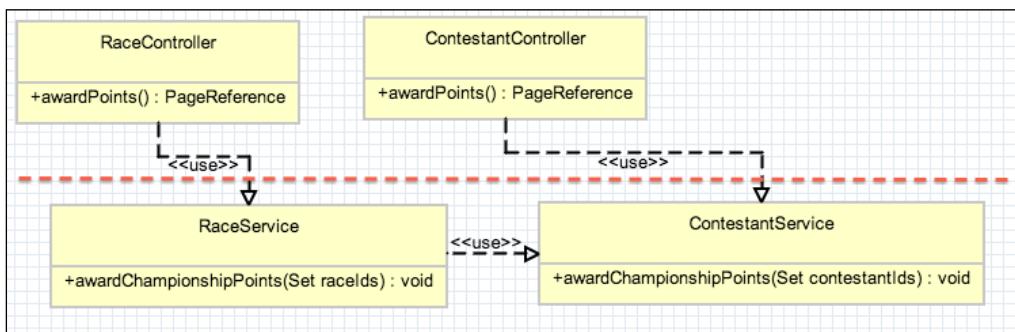
Reuse needs may not always be initially obvious. However, by following Separation of Concerns and the design patterns in this book, when they do arise as your application evolves and/or new platform features are added, the process is more organic without refactoring, or worse, copying and pasting the code!

To illustrate a reuse scenario, imagine that in the first iteration of the FormulaForce application, awarding points to a race contestant was accomplished by the user through an **Award Points** button on the **Contestant** detail page for each contestant. Also, the newsletter functionality was accessed by manually clicking a **Send News Letter** button on the **Season** detail page each month.

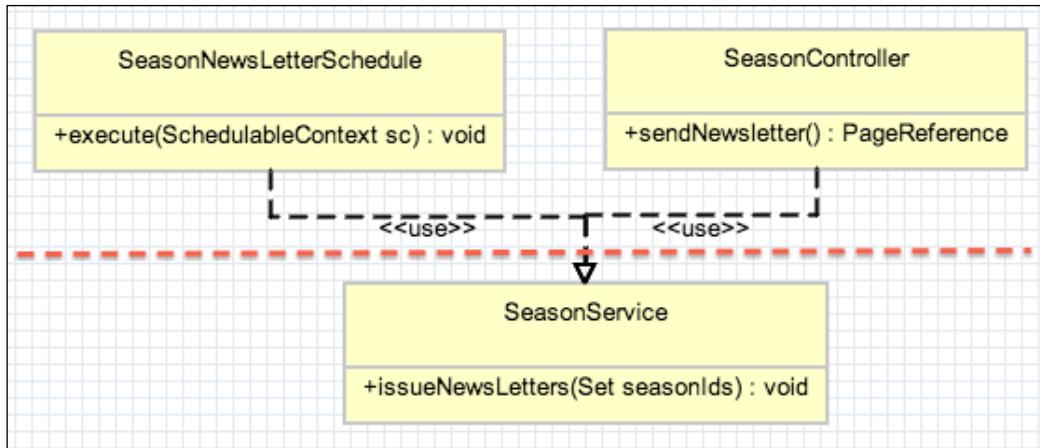
The class diagram for the first iteration is shown in the next diagram. Note that you can already see the beginning of a separation of concern between the Apex controller logic and application business logic, which is contained in the classes ending in **Service**. The Service layer is discussed in more detail later in this chapter.



Now, imagine that in the second iteration of the application, user feedback requested that the awarding of points should also be available at the race level and applied in one operation for all contestants through a button on the **Race** detail page. In the following class diagram, you can see that the **ContestantService** class is now reused by the **RaceService** class in order to implement the **RaceController.awardPoints** service method:



An additional enhancement was also requested to permit the newsletter functionality to use the platform scheduler to automatically issue the newsletter. The following diagram shows that the `SeasonService` class is now reused by both the `SeasonNewsLetterSchedule` class as well as the `SeasonController` class:



The preceding examples have shown that code from the first iteration can be reused either from the new application business logic or from a new execution context in the case of the scheduler. In the next chapter, we will take a further look at the Service layer, including its design guidelines that make this kind of reuse possible.

## Patterns of Enterprise Application Architecture

So far, we have only discussed Separation of Concerns between the Apex code invoked from an execution context (Apex Controller, Scheduler, Batch Apex, and so on) and reusable application business logic code placed in the Service classes. However, there are further levels of granularity and patterns that help focus and encapsulate application logic further, known as Enterprise Application Architecture patterns.

The general definitions of the patterns used in the next three chapters of this book are not inherently new, but are a new implementation for this platform. They have been and continue to be incredibly popular on other platforms. The original author of these patterns is Martin Fowler, who describes the other patterns in his book, *Patterns of Enterprise Application Architecture* (<http://www.martinfowler.com/books/eaa.html>)

This book takes some of the patterns in Martin Fowler's book and applies them to the platform while also taking the opportunity to bake in a few best practices on the Force.com platform. The next section is a short summary of those we will be taking a closer look at.

## The Service layer

The following is Martin Fowler's definition of the Service layer (<http://martinfowler.com/eaaCatalog/serviceLayer.html>):

*"Defines an application's boundary with a layer of services that establishes a set of available operations and coordinates the application's response in each operation."*

You had a little preview of this pattern in action within this chapter. You can see that for the business application logic, it forms an initial entry point, encapsulating operations and tasks the end users perform.

Its methods and behavior are designed such that it is agnostic of the caller, making it adaptable to multiple execution contexts easily, as shown in the earlier examples. It also has a role to play in your applications API strategy.

## The Domain Model layer

The following is Martin Fowler's definition of the Domain layer (<http://martinfowler.com/eaaCatalog/domainModel.html>):

*"An object model of the domain that incorporates both behavior and data. At its worst, business logic can be very complex. Rules and logic describe many different cases and slants of behavior, and it's this complexity that objects were designed to work with."*

If you think of the Service layer as the band conductor, the Apex classes that make up the Domain layer are the instruments it conducts, each with its own role and responsibility in making the music!

The Domain layer in a Force.com context helps group and encapsulate logic specific to each physical Custom Object in the application. Also, while utilizing object-oriented concepts such as interfaces and inheritance to apply common behavioral aspects between your Custom Objects in your application, such as security, it is responsible for applying validations and processing historically done in the Apex Triggers code directly. Note that the Service layer can leverage these classes to form high-level business application logic that spans multiple objects and thus can access and reuse domain object-specific logic.

## The Data Mapper (Selector) layer

The following is Martin Fowler's definition of the Data Mapper layer (<http://martinfowler.com/eaaCatalog/dataMapper.html>):

*"A layer of Mappers (473) that moves data between objects and a database while keeping them independent of each other and the mapper itself."*

Making effective use of database queries to fetch data is as important on Force.com as any other platform. For complex object models, having SOQL do some of the heavy lifting can lead to some fairly sophisticated queries. Encapsulating how data from the database is mapped into memory is the role of the Data Mapper layer.

In Martin Fowler's world, this usually involves mapping database result set records returned into Java classes (known as **Plain Old Java Objects (POJO)** or **Data Transformation Objects (DTO)**). However, Apex provides us with these data structures for each of our custom objects in the form of SObject. Thus, the role of this pattern is slightly different, as the SOQL query itself explicitly selects SObject representing the data. Hence, this pattern has been renamed to reflect its key responsibility more accurately.

## Introducing the FinancialForce.com Apex Commons library

There exists an Apex class library used to support these patterns, which is also used in this book. The Apex Commons library is from an open source project started by FinancialForce.com and launched to the community at the Dreamforce 2012 event.

Since then, the patterns have been adopted by other developers on the platform and have been extended with additional features such as Fieldsets and Security. We will be using this library in the next three chapters as we explore the enterprise patterns they support in more detail. The GitHub repository can be found at <https://github.com/financialforcedev/fflib-apex-common>.

## Unit testing versus system testing

When it comes to testing the Apex code, we know the drill: Write good tests to cover your code, assert its behavior, and obtain at least 75 percent coverage. Force.com will not allow you to upload packaged code unless you obtain this amount or higher. You also have to cover your Apex Trigger code, even if it's only a single line, as you will soon see is the case with the implementation of the Apex Triggers in this book.

However, when it comes to unit testing, what Force.com currently lacks, however, is a mocking framework to permit more focused and isolated testing of the layers mentioned in the previous sections without having to set up all the records needed to execute the code you want to test. This starts to make your Apex tests feel more like system-level tests having to execute the full functional stack each time.

While conventions such as **test-driven development (TDD)** are possible, they certainly help you think about developing true unit tests on the platform. Doing so can also be quite time consuming to develop and then wait for these tests to run due to growing data setup complexity. Such tests end up feeling more like system- or integration-level tests because they end up testing the whole stack of code in your application.

The good news is that the layering described in this book does give you opportunities to isolate smaller tests to specific aspects, such as validation or insert logic. As we progress through each layer in the upcoming chapters, we finish with an entire chapter focusing on implementing a true unit testing approach using an open source mocking framework known as Apex Mocks. It has been shared with the community by FinancialForce.com and is heavily based on the Java Mockito framework. <https://github.com/financialforcedev/fflib-apex-mocks>.

## Packaging the code

The source code provided with this chapter contains skeleton Apex classes shown in the UML diagrams used earlier in this chapter. In the upcoming chapters, we will flesh out the methods and logic within them. For now, deploy them into your packaging org and add them into your package. Note that once you add Apex classes, any Apex classes they subsequently go on to reference will be automatically pulled into the package. The following is a list of the Apex classes added in this chapter and the application architecture layer they apply to:

Apex class	Layer
SeasonController.cls	Visualforce Controller
SeasonControllerTest.cls	Apex test
ContestantController.cls	Visualforce Controller
ContestantControllerTest.cls	Apex test
RaceController.cls	Visualforce Controller
RaceControllerTest.cls	Apex test
SeasonNewsletterScheduler.cls	Apex Scheduler
SeasonNewsletterSchedulerTest.cls	Apex test
RaceService.cls	Race Service
RaceServiceTest.cls	Apex test
SeasonService.cls	Season Service
SeasonServiceTest.cls	Apex test
ContestantService.cls	Contestant Service
ContestantServiceTest.cls	Apex test

 Note that there is one class, `SeasonNewsletterSchedule`, that requires the use of the global access modifier. This ensures that this class cannot be deleted or renamed in future releases. This might feel restrictive, but is the key to supporting the Apex Scheduler feature in this case. As it is important when users upgrade to new versions of your package, the schedules they have defined continue to reference the code in your package.

Upload a new version of the package and install it into your test org. You should see a confirmation install summary page that looks something like the following:

▼ Code (14)				
Action	Component Name	Parent Object	Component Type	Installation Notes
Create	SeasonNewsletterScheduler		Apex Class	This is a brand new component.
Create	SeasonController		Apex Class	This is a brand new component.
Create	SeasonService		Apex Class	This is a brand new component.
Create	RaceService		Apex Class	This is a brand new component.
Create	RaceServiceTest		Apex Class	This is a brand new component.
Create	SeasonNewsletterSchedulerTest		Apex Class	This is a brand new component.
Create	RaceController		Apex Class	This is a brand new component.
Create	ContestantServiceTest		Apex Class	This is a brand new component.
Create	SeasonControllerTest		Apex Class	This is a brand new component.
Create	ContestantControllerTest		Apex Class	This is a brand new component.
Create	ContestantController		Apex Class	This is a brand new component.
Create	RaceControllerTest		Apex Class	This is a brand new component.
Create	SeasonServiceTest		Apex Class	This is a brand new component.
Create	ContestantService		Apex Class	This is a brand new component.

## Summary

In this chapter, we have taken an in-depth look at how the platform executes the Apex code and the different contexts from which it does so. We have also taken time to understand how key concepts like state and security are managed, in addition to highlighting some Apex governors and their respective scopes.

This has allowed us to observe some common needs from which we have distilled into a Separation of Concerns that we can start to apply as guidelines into layers in our business application code, making the Apex logic more reusable and accessible from different contexts as your application functionality and indeed the platform itself evolves.

As we progress further into practicing Separation of Concerns, the Domain, Service, and Selector layers' patterns will become a further layer of separation within our application business logic. We will continue to define the naming and coding guidelines as we progress through the next three chapters so that it becomes easier to maintain a good Separation of Concerns for the existing developers and those just starting to work on the code base.



If you have an existing code base and are wondering where to start with refactoring its code up into the layers described in this chapter, my advice is to concentrate initially on forming your Service layer contract and refactoring as much true business logic code into it as possible. Make your execution context classes, such as controllers and Batch Apex classes (but not triggers initially), as thin as possible, leaving them to focus solely on their responsibilities such as error handling. This will get some of your true business application logic at least contained below the Service layer, even if it might not be factored precisely how you would want it had you have written it from scratch. After this, you can focus on expanding this out to refactoring the Trigger logic into Domain, then the Query logic into separate Selector classes, perhaps incrementally, as you revise the areas of the application for enhancements.

# 5

## Application Service Layer

If your application were considered a living organism, the Service layer would be its beating heart. Regardless of how the environment and the things that interact with it change over time, it must remain strong and able to adapt. In this chapter, we begin our journey with the three coding patterns: Service, Domain, and Selector, which were introduced in *Chapter 4, Apex Execution and Separation of Concerns*.

In this chapter, we will review the pattern as set out by Martin Fowler and then review how it has been applied on the Force.com platform in Apex, describing design guidelines born from the *Separation of Concerns* we defined in the previous chapter.

One concern of this layer is interacting with the database; a later chapter will cover querying this in more detail. This chapter will focus on updating the database and introducing a new pattern, **Unit Of Work**, which helps make your code more streamlined and bulkified.

At the end of this chapter, we will extend the FormulaForce application to provide a means to calculate driver championship points and issue a newsletter. The code developed in the Service layer will be invoked from Custom buttons and the Apex Scheduler. Later chapters will also cover further uses of the Service layer.

The following aspects of the Service layer will be covered in this chapter:

- Introducing the Service layer pattern
- Implementation design guidelines
- Handling DML with the Unit Of Work
- Services calling services
- Contract Driven Development
- Testing the services
- Calling the services

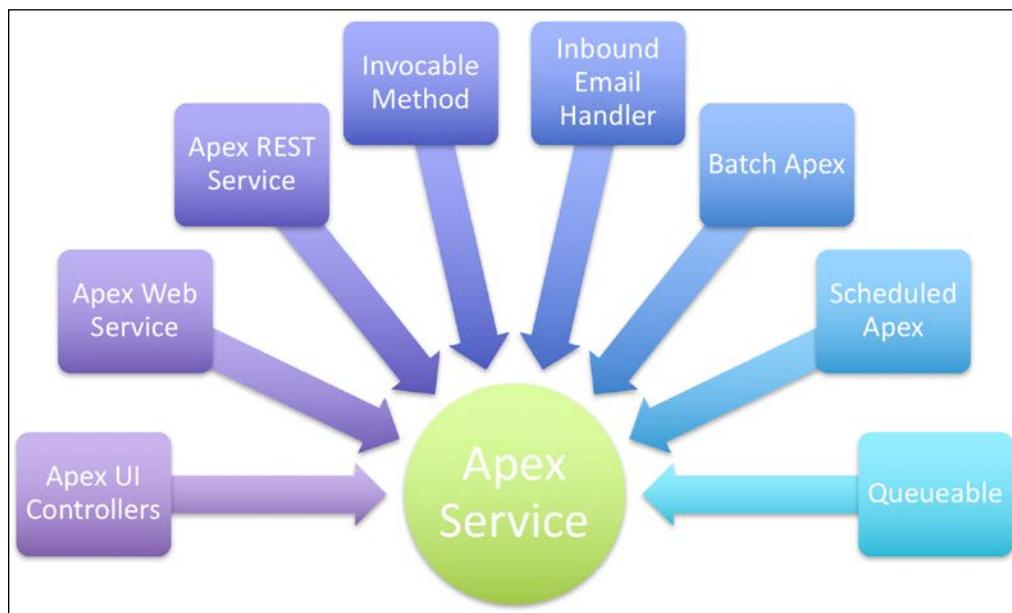
## Introducing the Service layer pattern

The following is Martin Fowler's definition of the Service layer (<http://martinfowler.com/eaaCatalog/serviceLayer.html>):

*"Defines an application's boundary with a layer of services that establishes a set of available operations and coordinates the application's response in each operation."*

The use of the word *boundary* in Martin's definition is interesting, as this literally represents the point of separation or boundary between the concerns of the application's business logic in the Service layer and execution context or caller, be that a Visualforce or Lightning Component Controller class or a Batch Apex class, as illustrated in the UML diagrams shown in the previous chapter.

The following illustration shows just some of the types of callers that an Apex Service layer is designed to support. By following the design guidelines given in the next diagram, you can ensure that your Service layer code can be called from any one of these features and others in the future:



This book will illustrate the use of the Service layer in a number of these areas.

The reference to boundaries in Martin's definition is also an important point with respect to the encapsulation of the application's true business logic. You must be diligent about this encapsulation since the Service layer cannot coordinate the behavior of the application without it. The patterns in this book help to promote better thinking about encapsulation. However, there are no ways to express dependencies between Apex code in the way other languages such as Java might use the package and protected keywords, for example. As such, it is down to us to make sure that there is a solid awareness and desire to honor them.



Code reviews are an integral part of any development process. One easy indicator that your application business logic may be leaking outside of your service layer is the increasing amount of code in the calling classes, such as Visualforce or Lightning Component Controllers or Batch Apex classes. Remember that these classes have their own concerns as well, such as handling and reporting errors and presenting information that the Service layer or your custom objects need. Though generally, if the code looks to be doing more than this, it could be a sign that there is some code that should have been factored into a Service method. The hard part is often failing a code review based on this observation, particularly if the author claims there is no current reuse case. While that may be true, ignoring it in the beginning and letting it remain increases technical debt, limits reuse (will the next developer have time to refactor?), and increases the risk of inconsistent behavior across your application.

Finally, keep in mind that the information exchanged with the Service layer is not necessarily targeted to a specific use case or caller requirement. It is the responsibility of the calling code, such as a Visualforce or Lightning Component Controller or even code written by a subscriber org developer, to translate between the chosen client user interface and the Service layer interface.

In *Chapter 10, Providing Integration and Extensibility*, we will also explore exposing your Service layer as an API for external consumption. For these reasons, the Service layer has to be agnostic or unbiased towards any particular caller.

## Implementation of design guidelines

Having studied the *Separation of Concerns* in the previous chapter and reflected on the previous illustration, the following design guidelines help ensure that the Service layer is agnostic towards the caller, easy to locate, and encourages some Force.com best practices, such as bulkification. Note that bulkification is not just a concept for Apex Triggers; all the logic in your application must make efficient use of governed resources.

### Naming conventions

A colleague of mine used to reference the following when talking about naming:

*"There are only two hard things in Computer Science: cache invalidation and naming things."*

- Phil Karlton

In my career so far, I have come to realize that there is some truth in this statement. Naming conventions have never been so important on Force.com as it is currently without a means to group or structure code files, using a directory structure for example. Instead, all classes are effectively in one root folder called /classes.

Thus, it comes down to the use of naming conventions to help clarify purpose (for developers, both new and old, working on the codebase) and to which layer in your architecture a class belongs. Naming does not, however, stop at the class name level; the enums, methods, and even parameter names all matter.



It is a good idea to work with those designing and documenting your application in order to establish and agree on an **application vocabulary of terms**. This is not only a useful reference for your end users to get to know your application, but also helps in maintaining consistency throughout your user interface and can also be used in the implementation of it, right down to the method and class names used. This comes in handy, especially if you are planning on exposing your Service layer as a public API (I'm a big fan of clear self-documenting APIs).

The following points break down some specific guidelines for the Service layer, though some are also applicable throughout your application code:

- **Avoid acronyms:** In general, try to avoid using acronyms (as far as possible). While these might be meaningful to those experienced in working on the application, newcomers will find it harder to navigate the code as they learn the application functionality and codebase. This applies more so if you're using your Service layer as an API. Though it can be tempting from a typing perspective, a good editor with autocompletion should resolve this concern pretty well. Widely used and understood acronyms like ID are reasonable.
- **Class names:** Ending your class name with the `Service` suffix allows developers to filter easily in order to find these critical classes in your application codebase. The actual name of the service can be pretty much anything you like, typically a major module or a significant object in your application. Make sure, however, that it is something from your application's vocabulary. If you've structured your application design well, your service class names should roughly fall into the groupings of your application's modules; that is, the naming of your Service layer should be a by-product of your application's architecture, and not a thing you think up when creating the class.
  - Some bad examples are `UtilService`, `RaceHelper`, `BatchApexService`, and `CalcRacePointsService`. These examples either use acronyms that are platform feature bias or potentially too contextualized. Classes with the name `Helper` in them are often an indication that there is a lack of true understanding of where the code should be located; watch out for such classes.
  - Some good examples are `CommonService`, `RaceService`, and `SeasonService`. These examples clearly outline some major aspects of the application and are general enough to permit future encapsulation of related operations as the application grows.

- **Method names:** The `public` or `global` method names are essentially the business operations exposed by the service. These should also ideally relate or use terms expressed in your application's end user vocabulary, giving the same thought to these as you would to a label or button for the end user, for example. Avoid naming them in a way that ties them to their caller; remember that the Service layer doesn't know or care about the caller type.
  - Some bad examples are `RaceService.recalcPointsOnSave`, `SeasonService.handleScheduler`, and `SeasonService.issueWarnings`. These examples are biased either towards the initial caller use case or towards the calling context. Nor does the `handleScheduler` method name really express enough about what the method is actually going to perform.
  - Some good examples are `RaceService.awardChampionshipPoints`, `SeasonService.issueNewsLetter`, and `DriverService.issueWarnings`. These examples are named according to what they do, correctly located, and unbiased to the caller.
- **Parameter names and types:** As with method and class names, keep them focused on the data they represent, and ideally use consistent terms. Keep in mind that the type of your parameter can also form a part of the meaning of the parameter, and may help in some cases with the implementation of the service method. For example, if the parameter is intended to receive a list of IDs, consider using `Set` instead of `List`, as typically, duplicate IDs in the list are unwanted. For the `Map` parameters, I always try to use the `somethingABySomethingB` convention in my naming so that it's at least clear what the map is keyed by. In general, I actually try to apply these conventions to all variables, regardless of them being method parameters.
  - Some bad examples are `List<String>driverList` and `Map<String, DriverPerformance>mapOfPerformance`. These examples are either don't use the correct data type and/or are using unclear data types as to the list or map contents; there is also some naming redundancy.
  - Some good examples are `Set<Id>driverIds` and `Map<String, DrivePerformance>drivePerformanceByName`. These examples use the correct types and help in documenting how to use the `Map` parameter correctly; the reader now knows that the `String` key is a name. Another naming approach would be `thingsToName`, for example. Also, the `Map` parameter name no longer refers to the fact that it is a map because the type of parameter communicates this well enough.

- **Inner class names:** While there is no formal structure to Apex classes in the form of a typical directory facility (or package structure, in Java terms), Apex does support the concept of inner classes to one level. These can sometimes be used to define classes that represent parameter data that is only relevant to the service methods. Because inner classes are always qualified by the name of the parent class, you do not need to repeat it.
  - Some bad examples are `SeasonService.SeasonSummary` and `DriverService.DriverRaceData`. These examples repeat the parent class name.
  - Some good examples are `SeasonService.Summary` and `DriverService.RaceDetails`. These examples are shorter as they are qualified by the outer class.

These guidelines should not only help you to ensure that your Service layer remains more neutral to its callers and thus more consumable now and in the future, but also to follow some best practices around the platform. Finally, as we will discuss in *Chapter 9, Providing Integration and Extensibility*, following these guidelines leaves things in good shape to expose as an actual API, if desired.

If you're having trouble agreeing on the naming, you can try a couple of things. Firstly, try presenting the name and/or method signatures to someone not as close to the application or functionality to see what they interpret from it. This approach could be considered as parallel to a popular user experience acceptance testing approach, **fly-by reviews**. Obviously, they may not tell you precisely what the actual intent is, but how close or not they get can be quite useful when deciding on the naming.



Secondly, try writing out pseudo code for how calling code might look; this can be useful to spot redundancy in your naming. For example, `SeasonService.issueSeasonNewsLetter(Set<Id>seasonIds)` could be reduced to `SeasonService.issueNewsLetter(Set<Id>seasonIds)`, since the scope of the method within the `SeasonService` method need not include `Season` again, and the parameter name can also be shortened since its type infers a list.

## Bulkification

It's well known that the best practice of Apex is to implement bulkification within Apex Triggers, mainly because they can receive and process many records of the same type. This is also true for the use of `StandardSetController` classes or Batch Apex, for example.

As we identified in the previous chapter, handling bulk sets of records is a common requirement. In fact, it's one that exists throughout your code paths, since DML or SOQL in a loop at any level in your code will risk hitting governor limits.

For this reason, when designing methods on the Service layer, it is appropriate that you consider list parameters by default. This encourages development of bulkified code within the method and avoids the caller having to call the Service method in a loop.

The following is an example of non-bulkified code:

```
RaceService.awardChampionShipPoints(Id raceId)
```

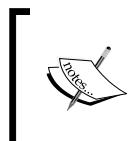
The following is another example of non-bulkified code:

```
RaceService.awardChampionShipPoints(Set<Id>raceIds)
```

A non-bulkified method with several parameters might look like this, for example:

```
RaceService.retireFromRace(Id raceId, String reason)
```

A bulkified version of the preceding method signature can utilize an Apex inner class as described earlier and shown in the following example in the *Defining and passing data* sub-section.



Sometimes, implementing bulkified versions of service methods are more costly and complex than what the callers will realistically require, so this should not be seen as a fixed guideline, but should at least always be considered.

## Sharing rules enforcement

As discussed in the previous chapter, by default Apex code runs in system mode, meaning no sharing rules are enforced. However, business logic behavior should, in general, honor sharing rules. To avoid sharing information to which the user does not have access, sharing rule enforcement must be a concern of the Service layer.

Salesforce security review requires Apex controller class entry points to honor this, although your Service layer will be called by these classes and thus could inherit this context. Keep in mind that your Service layer is effectively an entry point for other points of access and integrations (as we will explore in a later chapter and throughout the book).

Thus the default concern of the Service layer should be to enforce sharing rules. Code implemented within the Service layer or called by it should inherit this. Code should only be elevated to running in a context where sharing rules are ignored when required, otherwise known as the `without sharing` context. This would be in cases where the service is working on records on behalf of the user. For example, a service might calculate or summarize some race data but some of the raw race data records (from other races) may not be visible to the user.

To enforce sharing rules by default within a Service layer the `with sharing` keyword is used on the class definition as follows:

```
public with sharing class RaceService
```

Other Apex classes you create, including those we will go on to discuss around the Selector and Domain patterns, should leave it unspecified such that they inherit the context. This allows them to be reused in either context more easily.

If a `without sharing` context is needed, a private inner class approach, as shown in the following example, can be used to temporarily elevate the execution context to process queries or DML operations in this mode:

```
// Class used by the Service layer
public class SomeOtherClass {

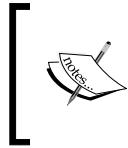
    // Work in this method inherits with sharing context from
    // Service
    public static void someMethod {
        // Do some work in inherited context
        // ...

        // Need to do some queries or updates in elevated context
        new ElevatedContext().restOfTheWork(workToDo);
    }

    private void restOfTheWork(List<SomeWork>workToDo) {
        // Additional work performed by this class
        // ...
    }

    private without sharingclass ElevatedContext {
        public void restOfTheWork(List<SomeWork>workToDo) {
            // Do some work in a elevated (without sharing) context
            SomeOtherClass.restOfWork(workToDo);
        }
    }
}
```

Note you can consider making the ability to run logic, a parameter of your Service layer if you feel certain callers will want to disable this enforcement. The preceding code sample could be adapted to conditionally execute the `restOfWork` method directly or via the `ElevatedContext` inner class in this case.



Object and field level security are also an important consideration when deciding when to enforce and when not. Later chapters that focus more on the Domain and Selector patterns will discuss this topic further.



## Defining and passing data

While defining data to be exchanged between the Service layer and its callers, keep in mind that the responsibility of the Service layer is to be caller-agnostic. Unless you're explicitly developing functionalities for such data formats, avoid returning information through JSON or XML strings; allow the caller (for example, a JavaScript remoting controller) to deal with these kinds of data-marshalling requirements.

As per the guidelines, using inner classes is a good way to express and scope data structures used by the service methods. The following code also illustrates a bulkified version of the multi-parameter non-bulkified method shown in the previous section.



Thinking about using inner classes this way can also be a good way to address the symptom of primitive obsession (<http://c2.com/cgi/wiki?PrimitiveObsession>).



Have a look at the following code:

```
public class ContestantService{  
  
    public class RaceRetirement{  
        public Id contestantId;  
        public String reason;  
    }  
  
    public static void retireFromRace(List<RaceRetirement> retirements)  
    {  
        // Process race retirements...  
    }  
}
```



Try to avoid too much service coupling by reusing inner classes between services. If this is starting to happen, it may be an indication that you perhaps need a new shared or common service.

Always keep in mind that the service method really only needs the minimum information to do its job, and express this through the method signature and related types so that callers can clearly see that only that information is required or returned. This avoids doubt and confusion in the calling code, which can result in it passing too little or redundant information.

The preceding example utilizes read and write member variables in the `RaceRetirement` class, indicating both are required. The inner class of the `RaceRetirement` class is only used as an input parameter to this method. Give some consideration before using an inner class such as both input and output type, since it is not always clear which member variables in such classes should be populated for the input use case or which will be populated in the output case.

However, if you find such a need for the same Apex type to be used as both an output and input parameter, and some information is not required on the input, you can consider indicating this via the **Apex property** syntax by making the property read-only. This prevents the caller from populating the value of a member field unnecessarily. For example, consider the following service methods in the `RaceService` method:

```
public static Map<Id, List<ProvisionalResult>> calculateProvisionalResults(Set<Id> raceIds)
{
    // Implementation
}

public static void applyRaceResults (Map<Id, List<ProvisionalResult>> provisionalResultsByRaceId)
{
    // Implementation
}

public class ProvisionalResult{
    public Integer racePosition {get; set;}
    public Id contestantId {get; set;}
    public String contestantName {get; private set;}
}
```

While calling the `calculateProvisionalResults` method, the `contestantName` field is returned as a convenience, but is marked as read-only since it is not needed when applied in the context of the `applyRaceResults` method.

## Considerations when using SObject in the Service layer interface

In the following example, the Service method appears to add the `Race` records as the input, requiring the caller to query the object and also to decide which fields have to be queried. This is a loose contract definition between the Service method and the caller:

```
RaceService.awardChampionShipPoints(List<Race__c> races)
```

A better contract to the caller is to just ask for what is needed, in the case of the following example, the IDs:

```
RaceService.awardChampionShipPoints(Set<Id>raceIds)
```

Even though IDs that relate to records from different object types could be passed (one might consider performing some parameter validation to reject such lists), this is a more expressive contract, focusing on what the service really needs. The caller now knows that only the ID is going to be used.

In the first example, when using the `Race__c` SObject type as a parameter type, it is not clear which fields callers need to populate, which can make the code fragile, as it is not something that can be expressed in the interface definition. Also, the fields required within the service code could change and require caller logic to be refactored. This could also be an example of failing in the encapsulation concern of the business logic within the Service layer.

It can be said that this design approach incurs an additional overhead, especially if the caller has already queried the `Race` record for presentation purposes and the service must then re-query the information. However, in such cases, maintaining the encapsulation and reuse concerns can be more compelling reasons. Careful monitoring of this consideration makes the service interface clearer, better encapsulated, and ultimately more robust.

## Transaction management

A simple expectation of the caller when calling the Service layer methods is that if there is a failure via an exception, any work done within the Service layer up until that point is rolled back. This is important as it allows the caller to handle the exception without fear of any partial data being written to the database. If there is no exception, then the data modified by the Service method can still be rolled back, but only if the entire execution context itself fails, otherwise the data is committed.

This can be implemented using a `try/catch` block in combination with `Database.Savepoint` and the `rollback` method, as follows:

```
public static void awardChampionshipPoints(Set<Id> raceIds) {
    // Mark the state of the database
    System.SavepointserviceSavePoint = Database.setSavePoint();
    Try{
        // Do some work
    } catch (Exception e){
        // Rollback any data written before the exception
        Database.rollback(serviceSavePoint);
        // Pass the exception on for the caller to handle
        throw e;
    }
}
```

Later in this chapter, we will look at the Unit Of Work pattern, which helps manage the Service layer transaction management in a more elegant way than having to repeat the preceding boilerplate code in each Service method.

## Compound services

As your Service layer evolves, your callers may find themselves needing to call multiple Service methods at a time, which should be avoided.

To explain this, consider that a new application requirement has arose for a single custom button to update the *Drivers* standings (their position in the overall season) in the championship with a feature to issue a new season newsletter.

The code behind the Apex controller action method might look like the following code:

```
try {
    Set<Id> seasons = new Set<Id> { seasonId };
    SeasonService.updateStandings(seasons);
    SeasonService.issueNewsLetters(seasons);
}
```

```
    catch (Exception e) {
        ApexPages.addMessage(e);
    }
```

The problem with the preceding code is that it erodes the encapsulation and thus reuses the application Service layer by putting functionality in the controller, and also breaks the transactional encapsulation.

For example, if an error occurs while issuing the newsletter, the standings are still updated (since the controller handles exceptions), and thus, if the user presses the button again, the driver standings in the championship will be updated twice!

The best way to address this type of scenario, when it occurs, is to create a new compound service, which combines the functionality into one new service method call. The following example also uses an inner class to pass the season ID and provide the issue newsletter option:

```
try {

    SeasonService.UpdateStandings updateStandings = new SeasonService.
    UpdateStandings();
    updateStandings.seasonId = seasonId;
    updateStandings.issueNewsletter = true;

    SeasonService.updateStandings(new List <SeasonService.
    UpdateStandings> { updateStandings })
}

catch (Exception e) {
    ApexPages.addMessage(e);
}
```

It may be desirable to retain the original Service methods used in the first example in cases where this combined behavior is not always required.

Later in this chapter, we will see how the implementation of the preceding new Service method will reuse the original methods and thus introduce the ability for existing Service methods to be linked to each other.

## A quick guideline checklist

Here is a useful table that summarizes the earlier guidelines:

When thinking about...	The guidelines are...
Naming conventions	<ul style="list-style-type: none"> <li>• Suffix class names with service</li> <li>• Stick to application vocabulary</li> <li>• Avoid acronyms</li> <li>• Class, method, and parameter names matter</li> <li>• Avoid redundancy in names</li> <li>• Utilize inner classes to scope by service</li> </ul>
Sharing Rules	<ul style="list-style-type: none"> <li>• Use the <code>with sharing</code> keyword on Service classes</li> <li>• Elevate to without sharing only when needed and only for as short a time as possible</li> </ul>
Bulkification	<ul style="list-style-type: none"> <li>• On Service methods, utilize list parameters over single parameters to encourage optimized service code for bulk callers</li> <li>• Single instance parameters can be used where it's overly expensive to engineer bulkified implementations and there is little functional benefit</li> </ul>
Defining and passing data	<ul style="list-style-type: none"> <li>• Keep data neutral to the caller</li> <li>• Leverage inner classes to scope data</li> <li>• Pass only what is needed</li> </ul>
Transaction management	<ul style="list-style-type: none"> <li>• Callers can assume that work is rolled back if exceptions are raised by the service methods, so they can safely handle exceptions themselves</li> <li>• Wrap service method code in <code>SavePoint</code></li> </ul>
Compound services	<ul style="list-style-type: none"> <li>• Maintain the Service layer's functional encapsulation by monitoring for multiple service method calls in one execution context</li> <li>• Create new service methods to wrap existing ones or merge existing methods as needed</li> </ul>

## Handling DML with the Unit Of Work pattern

The database maintains relationships between records using record IDs. Record IDs are only available after the record is inserted. This means that the related records, such as child object records, need to be inserted in a specific dependency order. Parent records should be inserted before child records, and the parent record IDs are used to populate the relationship (lookup) fields on the child record objects before they can be inserted.

The common pattern for this is to use the `List` or `Map` keyword to manage records inserted at a parent level, in order to provide a means to look up parent IDs, as child records are built prior to being inserted. The other reasoning for this is bulkification; minimizing the number of DML statements being used across a complex code path is vital to avoid hitting governor limits on the number of DML statements required as such lists are favored over executing individual DML statements per record.

The focus on these two aspects of inserting data into objects can often detract from the actual business logic required, making code hard to maintain and difficult to read. The following section introduces another of Martin Fowler's patterns, the Unit Of Work, which helps address this, as well as providing an alternative to the boilerplate transaction management using `SavePoint`, as illustrated earlier in this chapter.

The following is Martin Fowler's definition of Unit Of Work (<http://martinfowler.com/eaaCatalog/unitOfWork.html>) :

*"Maintains a list of objects affected by a business transaction and coordinates the writing out of changes and the resolution of concurrency problems."*

In an extract from the given webpage, he also goes on to make these further points:

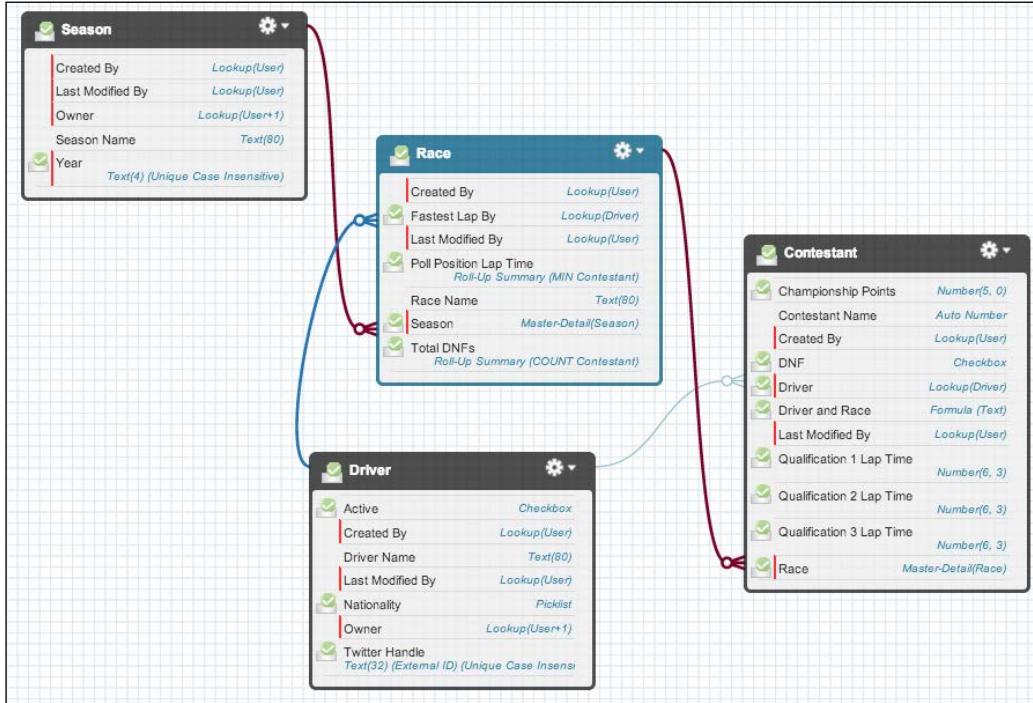
*"You can change the database with each change to your object model, but this can lead to lots of very small database calls, which ends up being very slow."*

*A Unit of Work keeps track of everything you do during a business transaction that can affect the database. When you're done, it figures out everything that needs to be done to alter the database as a result of your work."*

Although these statements don't appear to relate to Force.com, there are parallels with respect to the cost of making multiple DML statements, both in terms of governors and general performance. There is also a statement about transaction

management at a business (or service) level, which applies to the responsibility of the Service layer.

In order to best illustrate these benefits, let's review the implementation of a service to load some historic data into the `Season`, `Race`, `Driver`, and `Contestant` objects. Each of these objects has several relationships, as illustrated in the following screenshot:



Consider the following sample JSON format to import data into the application:

```
{
  "drivers": [
    {
      "name": "Lewis Hamilton",
      "nationality": "British",
      "driverId": "44",
      "twitterHandle": "lewistwitter"
    },
    "seasons": [
      {
        "year": "2013",
        "races": [
          {
            "round": 1,

```

```
        "name": "Spain",
        "contestants": [
            {
                "driverId": "44",
                "championshipPoints": 44,
                "dnf": false,
                "qualification1LapTime": 123,
                "qualification2LapTime": 124,
                "qualification3LapTime": 125
            }
        ]
    ]
}
}
```

## Without a Unit Of Work

This first example shows a traditional approach using `Map` and `List` to import the data, obeying bulkification and inserting a dependency order. The important logic highlighted in the following code copies data from the imported data structures into the objects; everything else is purely managing transaction scope and inserting dependencies:

```
public static void importSeasons(String jsonData) {

    System.SavepointserviceSavePoint = Database.setSavePoint();
    try{
        // Parse JSON data
        SeasonsData seasonsData =
            (SeasonsData) JSON.deserializeStrict(jsonData,
        SeasonService.SeasonsData.class);

        // Insert Drivers
        Map<String, Driver__c> driversById =
            new Map<String, Driver__c>();
        for(DriverData driverData : seasonsData.drivers)
            driversById.put(driverData.driverId, new Driver__c(
                Name = driverData.name,
                DriverId__c = driverData.driverId,
                Nationality__c = driverData.nationality,
                TwitterHandle__c = driverData.twitterHandle));
            insert driversById.values();

        // Insert Seasons
        Map<String, Season__c> seasonsByYear =

```

```

    new Map<String, Season__c>();
    for(SeasonData seasonData : seasonsData.seasons)
        seasonsByYear.put(seasonData.year,
            new Season__c(
                Name = seasonData.year, Year__c = seasonData.year));
        insert seasonsByYear.values();

    // Insert Races
    Map<String, Race__c> racesByYearAndRound =
        new Map<String, Race__c>();
    for(SeasonData seasonData : seasonsData.seasons)
        for(RaceData raceData : seasonData.races)
            racesByYearAndRound.put(seasonData.Year + raceData.round,
                new Race__c(
                    Season__c = seasonsByYear.get(seasonData.year).Id,
                    Name = raceData.name));
            insert racesByYearAndRound.values();

    // Insert Contestants
    List<Contestant__c> contestants =
        new List<Contestant__c>();
    for(SeasonData seasonData : seasonsData.seasons)
        for(RaceData raceData : seasonData.races)
            for(ContestantData contestantData
                : raceData.contestants)
                contestants.add(
                    new Contestant__c(
                        Race__c = racesByYearAndRound.get(
                            seasonData.Year + raceData.round).Id,
                        Driver__c = driversById.get(
                            contestantData.driverId).Id,
                        ChampionshipPoints__c =
                            contestantData.championshipPoints,
                        DNF__c = contestantData.dnf,
                        Qualification1LapTime__c =
                            contestantData.qualification1LapTime,
                        Qualification2LapTime__c =
                            contestantData.qualification2LapTime,
                        Qualification3LapTime__c =
                            contestantData.qualification3LapTime
                    )));
                insert contestants;
} catch (Exception e) {
    // Rollback any data written before the exception
}

```

```
        Database.rollback(serviceSavePoint) ;
        // Pass the exception on
        throw e;
    }
}
```

 This data import requirement could have been implemented by using the **Salesforce Data Loaders** and external field references, as described in the earlier chapter. One reason you may decide to take this approach is to offer an easier option from your own UIs that can be made available to general users without administrator access.

## With Unit Of Work

Before we take a closer look at how the **FinancialForce Apex Enterprise Pattern** library has helped us implement this pattern, lets first take a look at the following revised example of the code shown earlier. This code utilizes a new Apex class called `Application`. This class exposes a static property and method to create an instance of a Unit Of Work.

 The source code for this chapter includes the FinancialForce Apex Enterprise Pattern library, as well as the FinancialForce Apex Mocks library it depends on. The Apex Mocks library will become the focus in a later chapter where we will focus on writing unit tests for each of the patterns introduced in this book.

The `fflib_ISObjectUnitOfWork` Apex Interface is used to expose the features of the Unit Of Work pattern to capture the database work as records are created, thus the remaining logic is more focused and avoids `Map` and `List` and repeated iterations over the imported data shown in the previous example. It also internally bulkifies the work (DML) for the caller. Finally, the `commitWork` method call performs the actual DML work in the correct dependency order while applying transaction management.

Consider the following code:

```
// Construct a Unit Of Work to capture the following working
fflib_ISObjectUnitOfWorkuow = Application.UnitOfWork.newInstance();

// Create Driver__c records
Map<String, Driver__c>driversById =
new Map<String, Driver__c>();
```

```

for(DriverDatadriverData : seasonsData.drivers) {
    Driver_c driver = new Driver_c(
        Name = driverData.name,
        DriverId_c = driverData.driverId,
        Nationality_c = driverData.nationality,
        TwitterHandle_c = driverData.twitterHandle);
    uow.registerNew(driver);
    driversById.put(driver.DriverId_c, driver);
}

for(SeasonDataseasonData : seasonsData.seasons) {
    // Create Season_c record
    Season_c season = new Season_c(
        Name = seasonData.year,
        Year_c = seasonData.year);
    uow.registerNew(season);
    for(RaceDataraceData : seasonData.races) {
        // Create Race_c record
        Race_c race = new Race_c(Name = raceData.name);
        uow.registerNew(race, Race_c.Season_c, season);
        for(ContestantDatacontestantData : raceData.contestants) {
            // Create Contestant_c record
            Contestant_c contestant = new Contestant_c(
                ChampionshipPoints_c = contestantData.championshipPoints,
                DNF_c = contestantData.dnf,
                Qualification1LapTime_c =
                    contestantData.qualification1LapTime,
                Qualification2LapTime_c =
                    contestantData.qualification2LapTime,
                Qualification3LapTime_c =
                    contestantData.qualification3LapTime);
            uow.registerNew (contestant, Contestant_c.Race_c, race);
            uow.registerRelationship(contestant,
                Contestant_c.Driver_c,
                driversById.get(contestantData.driverId));
        }
    }
}
// Insert records registered with uow above
uow.commitWork();

```

The following is the implementation of the `Application` class and the `UnitOfWork` static property. It leverages a simple factory class that dynamically creates instances of the `fflib_SObjectUnitOfWork` class through the `newInstance` method:

```
public class Application
{
    // Configure and create the UnitOfWorkFactory for
    // this Application
    public static final fflib_Application.UnitOfWorkFactory
        UnitOfWork = new fflib_Application.UnitOfWorkFactory(
            new List<SObjectType> {
                Driver__c.SObjectType,
                Season__c.SObjectType,
                Race__c.SObjectType,
                Contests__c.SObjectType
            });
}
```

The class `fflib_Application.UnitOfWorkFactory` exposes the `newInstance` method that internally creates a new `fflib_SObjectUnitOfWork` instance. This is not directly exposed to the caller; instead the `fflib_ISObjectUnitOfWork` interface is returned (this design aids the mocking support we will discuss in a later chapter). The purpose of this interface is to provide the methods used in the preceding code to register records for insert, update, or delete, and implement the `commitWork` method.

I recommend that you create a single application Apex class like the one shown previously, where you can maintain the full list of objects used in the application and their dependency order; as your application's objects grow, it will be easier to maintain.

The `fflib_ISObjectUnitOfWork` interface has the following methods in it. The preceding example uses the `registerNew` and `registerRelationship` methods to insert records and ensure that the appropriate relationship fields are populated. Review the documentation of these methods in the code for more details. The following screenshot shows a summary of the methods:

```

▼ 1 fflib_ISObjectUnitOfWork
  ● A registerNew(SObject) : void
  ● A registerNew(List<SObject>) : void
  ● A registerNew(SObject, SObjectField, SObject) : void
  ● A registerRelationship(SObject, SObjectField, SObject) : void
  ● A registerDirty(SObject) : void
  ● A registerDirty(List<SObject>) : void
  ● A registerDeleted(SObject) : void
  ● A registerDeleted(List<SObject>) : void
  ● A commitWork() : void
  ● A registerWork(IDoWork) : void
  ● A registerEmail(Email) : void

```

Call the `registerDirty` method with a `SObject` record you want to update and the `registerDeleted` method to delete a given `SObject` record. You can also call a combination of the `registerNew`, `registerDirty`, and `registerDeleted` methods.

## The Unit Of Work scope

To make the most effective use of the Unit Of Work's ability to coordinate database updates and transaction management, maintain a single instance of the Unit Of Work within the scope of the Service method, as illustrated in the previous section.

If you need to call other classes that also perform database work, be sure to pass the same Unit Of Work instance to them, rather than allowing them to create their own instance. We will explore this a little later in this chapter.


 It may be tempting to maintain a static instance of Unit Of Work so that you can refer to it easily without having to pass it around. The downside of this approach is that the scope becomes broader than the service layer execution scope as Apex can be invoked within an execution context multiple times. Code registering records with a static execution scope Unit Of Work depending on an outer Apex code unit committing the work. It also gives a false impression that the Unit Of Work is useable after a commit has been performed.

## Unit Of Work special considerations

Depending on your requirements and use cases, the standard methods of Unit Of Work may not be appropriate. The following is a list of some use cases that are not handled by default and may require a custom work callback to be registered:

- **Self and recursive referencing:** Records within the same object that have lookups to each other are not currently supported, for example, account hierarchies.
- **More granular DML operations:** The `Database` class methods allow the ability to permit some records to be processed when others fail. The DML statements executed in the Unit Of Work are defaulted to all or nothing.
- **Sending e-mails:** Sending e-mails is considered a part of the current transaction; if you want to register this kind of work with the Unit Of Work, you can do so via the `registerEmail` method. Multiple registrations will be automatically bulkified.

The following is a template for registering a customer work callback handler with Unit Of Work. This will be called during the `commitWork` method within the transaction scope it creates. This means that if work fails in this work callback, it will also call other work registered in the standard way with Unit Of Work to rollback.

Take a look at the code:

```
public class CustomAccountWork implements
    fflib_SObjectUnitOfWork.IDoWork {

    private List<Account> accounts;

    public CustomAccountWork (List<Account> accounts) {
        this.accounts = accounts;
    }

    public void doWork() {
        // Do some custom account work e.g. hierarchies
    }
}
```

Then, register the custom work as per the following example:

```
uow.registerNew...
uow.registerDirty...
uow.registerDeleted...
uow.registerWork(new CustomAccountWork(accounts));
uow.commitWork();
```

## Services calling services

In the previous chapter, I described a reuse use case around a FormulaForce application feature that awards championship points to contestants. We imagined the first release of the application providing a Custom Button only on the **Contestant** detail page and then the second release also providing the same button but on the **Race** detail page.

In this part of the chapter, we are going to implement the respective service methods, emulating this development cycle and, in turn, demonstrating an approach to call between Service layer methods, passing the Unit Of Work correctly.

First, let's look at the initial requirement for a button on the **Contestant** detail page; the method in the **ContestantService** class looks like the following:

```
public static void awardChampionshipPoints(Set<Id> contestantIds) {
    fflib_SObjectUnitOfWork uow =
        Application.UnitOfWork.newInstance();

    // Apply championship points to given contestants
    Map<Integer, ChampionshipPoint__mdt> pointsByTrackPosition =
        new ChampionshipPointsSelector().selectAllByTrackPosition();
    for (Contestant__c contestant :
        new ContestantsSelector().selectById(contestantIds)) {
        // Determine points to award for the given position
        ChampionshipPoint__mdt pointsForPosition =
            pointsByTrackPosition.get(
                Integer.valueOf(contestant.RacePosition__c));
        if (pointsForPosition != null) {
            // Apply points and register for update with uow
            contestant.ChampionshipPoints__c =
                pointsForPosition.PointsAwarded__c;
            uow.registerDirty(contestant);
        }
    }
}
```

This method utilizes the **Selector** pattern to query the database; this will be described in its own chapter later in this book. The method also uses a protected Custom Metadata Type object **Championship Points**, to look up the official championship points awarded for each position the contestants finished in the race. This Custom Metadata Type object and its records are provided with the source code for this chapter:



Championship Points			
View: All <a href="#">Edit</a>   <a href="#">Create New View</a>			
Action	Label	Championship Point Name	Points Awarded
<a href="#">Edit</a>   <a href="#">Del</a>	<u>1st</u>	TrackPosition1	25
<a href="#">Edit</a>   <a href="#">Del</a>	<u>2nd</u>	TrackPosition2	18
<a href="#">Edit</a>   <a href="#">Del</a>	<u>3rd</u>	TrackPosition3	15
<a href="#">Edit</a>   <a href="#">Del</a>	<u>4th</u>	TrackPosition4	12
<a href="#">Edit</a>   <a href="#">Del</a>	<u>5th</u>	TrackPosition5	10
<a href="#">Edit</a>   <a href="#">Del</a>	<u>6th</u>	TrackPosition6	8
<a href="#">Edit</a>   <a href="#">Del</a>	<u>7th</u>	TrackPosition7	6
<a href="#">Edit</a>   <a href="#">Del</a>	<u>8th</u>	TrackPosition8	4
<a href="#">Edit</a>   <a href="#">Del</a>	<u>9th</u>	TrackPosition9	2
<a href="#">Edit</a>   <a href="#">Del</a>	<u>10th</u>	TrackPosition10	1

Custom Metadata records can be packaged and installed with the FormulaForce application without any further configuration by the customer. Since they belong to a protected Custom Metadata Type object, they will not be visible or editable to the user. Indeed, this information is tightly controlled by the **Federation Internationale de l'Automobile (FIA)** and is updated a minimum of once a year. In this form they can easily be edited using the **Manage Records** link under the **Custom Metadata Type** page under **Setup**, then upgraded when the customers install the latest version of the package or you Push the package to them. While this information could have been hard coded in Apex code, it is easier to manage and update in this form and demonstrates how internal configuration can be encoded using Custom Metadata Types and records.

The service is called from the `ContestantController` action method, which is bound to the button on the **Contestant** detail page (via a Visualforce page), as follows:

```
public PageReferenceawardPoints() {
    try {
        ContestantService.awardChampionshipPoints(
            new Set<Id> { standardController.getId() });
    }catch (Exception e) {
```

```

        ApexPages.addMessages(e);
    }
    return null;
}

```

In the next release, the same behavior is required from the `RaceController` method to apply the logic to all contestants on the *Race* page. The controller method looks like the following:

```

public PageReference awardPoints() {
    try {
        RaceService.awardChampionshipPoints(
            new Set<Id> { standardController.getId() });
    }

    catch (Exception e) {
        ApexPages.addMessages(e);
    }
    return null;
}

```

In order to provide backward compatibility, the original custom button on the *Contestant* detail page and thus the service method used by the controller are to be retained. Because the original method was written with bulkification in mind to begin with, reusing the `ContestantService` logic from the new `RaceService` method is made possible.

The following code is what the `RaceService.awardChampionshipPoints` method looks like. Again, a `Selector` class is used to query the *Race* records and the *Contestant* child records in a single query such that the child records are also available:

```

public static void awardChampionshipPoints(Set<Id> raceIds) {
    fflib_SObjectUnitOfWork uow =
        Application.UnitOfWork.newInstance();

    // Query Races and contestants, bulkify contestants
    List<Contestant__c> contestants = new List<Contestant__c>();
    For(Race__c race :
        new RacesSelector().selectByIdWithContestants(raceIds)) {
        contestants.addAll(race.Contestants__r);
    }

    // Delegate to contestant service
    ContestantService.awardChampionshipPoints(uow, contestants);
    // Commit work
    uow.commitWork();
}

```

By using method overloading, a new version of the existing `ContestantService.awardChampionshipPoints` method was added to implement the preceding code without impacting other callers. The overloaded method takes as its first parameter the Unit Of Work (created in `RaceService`) and then the `Contestant` list.

 The problem with this additional method is that it inadvertently exposes an implementation detail of the service to potential non-service calling code. It would be ideal if Apex supported the concept of the `protected` keyword found in other languages, which would hide this method from code outside of the Service layer. The solution is to simply ensure that developers understand that such method overrides are only for use by other Service layer callers.

The following resultant code shows that the `ContestantService` methods now support both the new `RaceService` caller and the original `ContestantController` caller. Also, there is only one instance of Unit Of Work in either code path, and the `commitWork` method is called once all the work is done:

```
public static void awardChampionshipPoints(Set<Id> contestantIds)
{
    fflib_ISObjectUnitOfWorkuow =
        Application.UnitOfWork.newInstance();

    // Apply championship points to selected contestants
    awardChampionshipPoints(uow,
        new ContestantsSelector().selectById(contestantIds));

    uow.commitWork();
}

public static void awardChampionshipPoints(
    fflib_ISObjectUnitOfWorkuow, List<Contestant__c> contestants)
{
    // Apply championship points to given contestants
    Map<Integer, ChampionshipPoint__mdt>pointsByTrackPosition =
        new ChampionshipPointsSelector().selectAllByTrackPosition();
    for(Contestant__c contestant : contestants) {
        // Determine points to award for the given position
        ChampionshipPoint__mdtpointsForPosition =
            pointsByTrackPosition.get(
                Integer.valueOf(contestant.RacePosition__c));
        if(pointsForPosition!=null) {
```

```

    // Apply points and register for update with uow
    contestant.ChampionshipPoints__c =
        pointsForPosition.PointsAwarded__c;
    uow.registerDirty(contestant);
}
}
}
}

```

## Contract Driven Development

If you have a large piece of functionality to develop, with a complex Service layer and user interface client logic, it can be an advantage to decouple these two streams of development activity so that developers can continue in parallel, meeting up sometime in the future to combine efforts.

An approach to this is sometimes referred to as **Contract Driven Development**. This is where there is an agreement on a contract (or service definition) between the two development streams before they start their respective developments. Naturally, the contract can be adjusted over time, but having a solid starting point will lead to a smoother parallel development activity.

This type of development can be applied by implementing a small factory pattern within the Service layer class. The main methods on the service class are defined as normal, but their internal implementation can be routed to respective inner classes to provide an initial **dummy implementation** of the service, which is active for the client developers, for example, and another **production implementation**, which can be worked on independently by the service developers.



Because the static Service methods actually exposed to callers don't expose this factory implementation, it can easily be removed later in the development cycle.

Take for example a requirement in the FormulaForce application to provide a Visualforce page to preview the final finishing positions of the drivers once the race is complete (known as the provisional positions). Development needs to start on the user interface for this feature as soon as possible, but the Service layer code has not been written yet. The client and Service layer developers sit down and agree what is needed, and define the skeleton methods in the Service layer together.

The first thing they do within the service class is to create an Apex interface that describes the service methods, which is the contract. The methods on this interface follow the same design guidelines as described earlier in this chapter.

The following code shows the definition of the `IRaceService` Apex interface:

```
public interface IRaceService {
    Map<Id, List<RaceService.ProvisionalResult>>
        calculateProvisionResults(Set<Id>raceIds);
    void applyRaceResults(Map<Id,
        List<RaceService.ProvisionalResult>>
            provisionalResultsByRaceId);
    void awardChampionshipPoints(Set<Id>raceIds);
}
```

Next, an implementation of this interface for the dummy (or sometimes known as a **Stub**) client implementation of this service is created `RaceServiceImplStub`, along with another class for the service developers to continue to develop independently as the client developer goes about their work `RaceServiceImpl`.

Consider the following code:

```
public class RaceServiceImplStub implements IRaceService {

    public Map<Id, List<RaceService.ProvisionalResult>>
        calculateProvisionResults(Set<Id>raceIds) {

        // Dummy behavior to allow callers of theservice be developed
        // independent of the main service implementation
        Id raceId = new List<Id>(raceIds)[0];
        RaceService.ProvisionalResulthamilton =
            new RaceService.ProvisionalResult();
        hamilton.racePosition = 1;
        hamilton.contestantName = 'Lewis Hamilton';
        hamilton.contestantId = 'a03b0000006WVph';
        RaceService.ProvisionalResultrubens =
            new RaceService.ProvisionalResult();
        rubens.racePosition = 2;
        rubens.contestantName = 'Rubens Barrichello';
        rubens.contestantId = 'a03b00000072xx9';
        return new Map<Id, List<RaceService.ProvisionalResult>> {
            new List<Id>(raceIds)[0] =>
            new List<RaceService.ProvisionalResult>
            { hamilton, rubens } };
    }

    public void applyRaceResults(Map<Id,
        List<RaceService.ProvisionalResult>>
            provisionalResultsByRaceId) {
        throw new RaceService.RaceServiceException('Not implemented');
    }
}
```

```
public void awardChampionshipPoints(Set<Id>raceIds) {
    throw new RaceService.RaceServiceException('Not implemented');
}

public class RaceServiceImpl implements IRaceService {
    public Map<Id, List<RaceService.ProvisionalResult>>
        calculateProvisionResults(Set<Id>raceIds) {
        throw new RaceService.RaceServiceException('Not implemented');
    }

    public void applyRaceResults(Map<Id, List<RaceService.ProvisionalR
esult>>provisionalResultsByRaceId) {
        throw new RaceService.RaceServiceException('Not implemented');
    }

    public void awardChampionshipPoints(Set<Id>raceIds) {

        fflib_ISObjectUnitOfWorkuow =
            Application.UnitOfWork.newInstance();

        // Query Races and contestants and bulkify list of all
        contestants
        List<Contestant__c> contestants = new List<Contestant__c>();
        for(Race__c race :
            new RacesSelector().selectByIdWithContestants(raceIds)) {
            contestants.addAll(race.Contestants__r);
        }

        // Delegate to contestant service
        ContestantService.awardChampionshipPoints(uow, contestants);

        // Commit work
        uow.commitWork();
    }
}
```

Finally, the standard service methods are added, but are implemented via the `service` method, which is used to resolve the correct implementation of the service methods to use. The following service methods leverage the appropriate implementation of the preceding interface:

```
public with sharing class RaceService {

    public static Map<Id, List<ProvisionalResult>>
        calculateProvisionResults(Set<Id>raceIds) {
        return service().calculateProvisionResults(raceIds);
    }

    public static void applyRaceResults(
        Map<Id, List<ProvisionalResult>>
            provisionalResultsByRaceId) {
        service().applyRaceResults(provisionalResultsByRaceId);
    }

    public static void awardChampionshipPoints(Set<Id>raceIds) {
        service().awardChampionshipPoints(raceIds);
    }

    private static IRaceService service() {
        return (IRaceService)
            Application.Service.newInstance(IRaceService.class);
    }

    public class RaceServiceException extends Exception {}

    public class ProvisionalResult {
        public Integer racePosition {get; set;}
        public Id contestantId {get; set;}
        public String contestantName {get; set;}
    }
}
```

The service method utilizes the Application class once more; this time a Service factory has been used to allow the actual implementation of the IRaceService interface to vary at runtime. This allows developers to control which of the two preceding implementations shown they want the application to use based on their needs. The default is to use the RaceServiceImpl class, however by inserting a record in the **Services** Custom Metadata Type object this can be overridden. More on this to follow.

The factory exposed via the Service field in the Application class extends the fflib\_Application.ServiceFactory class, which instantiates the configured class provided in the Map passed to the factory. This factory also supports mocking the service implementation; something that will be discussed in more detail in a later chapter.

The factory has been extended to look for configured alternative service implementation classes via a protected (and thus hidden to end users) custom metadata object called **Services**, which is included in the source code for this chapter.

You can see this being queried as following:

```
public class Application {
    //Configure and create the ServiceFactory for this Application
    public static final fflib_Application.ServiceFactory Service =
        new Application.ServiceFactory (
            new Map<Type, Type> {
                IRaceService.class => RaceServiceImpl.class });
    // Customised Service factory overrides via Custom Metadata
    private class ServiceFactory extends
        fflib_Application.ServiceFactory {
        private Map<String, String> servicesByClassName =
            new Map<String, String>();
        public ServiceFactory(Map<Type, Type>
            serviceInterfaceTypeByServiceImplType) {
            super(serviceInterfaceTypeByServiceImplType);
            // Map of overridden services defined by the developer
            for(Service__mdtServiceOverride : [select DeveloperName,
                NamespacePrefix, ApexClass__c from Service__mdt]) {
                servicesByClassName.put(
                    serviceOverride.NamespacePrefix + '.'
                    serviceOverride.DeveloperName,
                    serviceOverride.ApexClass__c);
            }
        }
    }
}
```

## Application Service Layer

```
        }
    }

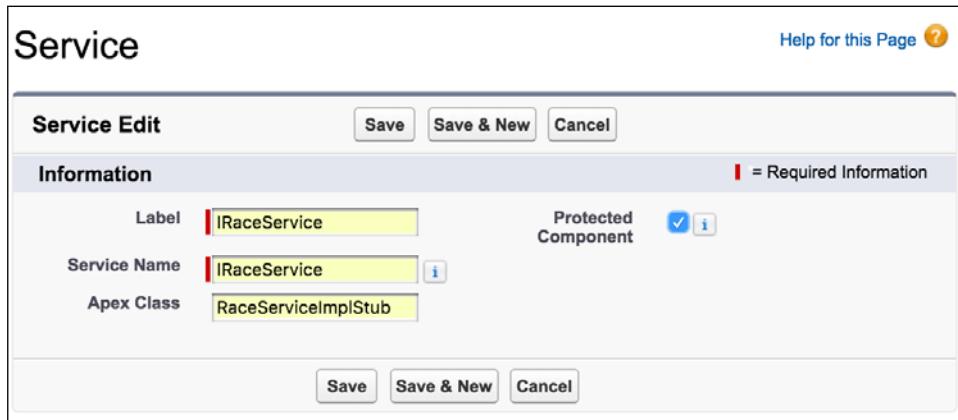
    public override Object newInstance(
        Type serviceInterfaceType) {

        // Has the developer overridden the Service impl?
        if(!Test.isRunningTest() && servicesByClassName.containsKey(
            serviceInterfaceType.getName())) {
            String overriddenServiceImpl = servicesByClassName.get(
                serviceInterfaceType.getName());
            return Type.forName(overriddenServiceImpl).newInstance();
        }

        //Base factory returns mocked or registered impl
        return super.newInstance(serviceInterfaceType);
    }
}
```

 Querying Custom Metadata records does not count against the SOQL governor; however, the records returned do count against the maximum 50k record limit.

By creating the following Custom Metadata record the client developers can configure the application to use the stub implementation without making any code changes.



The screenshot shows the 'Service Edit' page in the Salesforce interface. The page title is 'Service'. At the top right, there is a 'Help for this Page' link. Below the title, there are three buttons: 'Save', 'Save & New', and 'Cancel'. The main area is titled 'Information' and contains the following fields:

Label	<input type="text" value="IRaceService"/>	Protected Component	<input checked="" type="checkbox"/> <small>1</small>
Service Name	<input type="text" value="IRaceService"/>	<small>i</small>	
Apex Class	<input type="text" value="RaceServiceImplStub"/>		

At the bottom of the page, there are three buttons: 'Save', 'Save & New', and 'Cancel'.



This approach could be used to provide a custom extensibility feature in your application by making the Custom Metadata Type object **Public** and allowing customers or partners to override packaged implementations of your services. Use this approach with care, however, and only when it adds value to your customers or partners.

## Testing the Service layer

It is tempting to allow the testing of the Service layer to be done via tests around the calling code, such as Visualforce controller tests. However, depending solely on this type of testing leaves the Service layer logic open to other use cases that may not strictly be covered by the controller logic. For example, a custom controller using `StandardController` will only pass in a single record and not multiple ones. Make sure to develop specific Apex tests against the Service layer as the functionality is developed.

## Mocking the Service layer

Sometimes, the data setup requirements of the Service layer are such that it makes writing Apex tests for controllers or other callers, such as Batch Apex, quite complex and thus expensive, not only in terms of server time for the test to run (due to data setup for each test method) but also in terms of developer time, while preparing a full set of test data.

While you still need to test the full stack of your code, there is an approach called **mocking**, which can be used in conjunction with the previously mentioned factory pattern, which will allow the test context for the given service caller to implement its own test implementation of the service that mimics (with hardcoded test responses) different behaviors that the controller is expecting from the service method. This allows the controller tests to be more varied and focused when devising tests. Again, this mocking approach has to be used in combination with full stack tests that truly execute all the code required. *Chapter 12, Apex Mocks*, will cover mocking the Service layer in more detail.

## Calling the Service layer

The preceding examples have shown the use of the service class methods from Visualforce Controller methods. Let's take a closer look at what is happening here, the assumptions being made, and also at an Apex Scheduler example. Other examples of service methods in action, such as from a Lightning Component, will feature throughout later chapters.

The following code represents code from a controller class utilizing `StandardController` that provides support for the Visualforce page associated with a Custom Button on the `Race` object. Notice how it wraps the record ID in `set`, honoring the bulkified method signature:

```
public PageReferenceawardPoints() {
    try{
        RaceService.awardChampionshipPoints(
            new Set<Id> {standardController.getId() } );
    }

    catch (Exception e){
        ApexPages.addMessages(e);
    }
    return null;
}
```

The constructor of these controllers is not shown, but it essentially stores `StandardController` or `StandardSetController` in a member variable for later reference by the controller methods.

The following code outlines a similar version that can be used when `StandardSetController` is being used, in cases where a Custom Button is required on the objects' list view:

```
public PageReferenceawardPointsToRaces() {
    try {
        RaceService.awardChampionshipPoints(
            new Map<Id, SObject>(
                standardSetController.getRecords() ).keySet() );
    }

    catch (Exception e){
        ApexPages.addMessages(e);
    }
    return null;
}
```

The `Map` constructor in Apex will take a list of `SObjects` and automatically build a map based on the IDs of the `SObjects` passed in. Combining this with the `keySet` method allows for a quick way to convert the list of records contained in `StandardSetController` into a list of IDs required by the service method.

In both cases, any exceptions are routed to the `apex:pageMessages` component on the page (which should be one of the first things you should consider adding to a page) by calling the `ApexPages.addMessages` method that is passing in the exception.

Note that there is no need for the controller code to roll back changes made within the service that may have been made to object records up to the exception being thrown, since the controller is safe in the assumption that the service method has already ensured this is the case. This arrangement between the two is essentially a *Separation of Concerns* at work!

Finally, let's look at an example from the `SeasonNewsletterScheduler` class. As with the controller example, it handles the exceptions itself, in this case, e-mails the user with any failures. Consider the following code:

```
global void execute(SchedulableContextsc) {
    try{
        SeasonService.issueNewsLetterCurrentSeason();
    }catch (Exception e){
        Messaging.SingleEmailMessage mail =
            new Messaging.SingleEmailMessage();
        mail.setTargetObjectId(UserInfo.getUserId());
        mail.setSenderDisplayName(UserInfo.getUserName());
        mail.setSubject('Failed to send Season Newsletter');
        mail.setHtmlBody(e.getMessage());
        mail.setSaveAsActivity(false);
        Messaging.sendEmail(new Messaging.SingleEmailMessage[] { mail });
    }
}
```

## Updating the FormulaForce package

Finally, deploy the code included in this chapter and ensure any new Apex classes (especially test classes) are added to the package and perform a release upload. You may want to take some time to further review the code provided with this chapter, as not all of the code has been featured in the chapter. Some new fields have been also added to the `Contestant` and `Season` objects also, which will automatically be added to the package. Two new metadata objects `Championship Points` and `Services` have been added. `Championship Point` records must also be added to the package. Do not package any `Service` records.

## Summary

In this chapter, we have taken the first step in developing a robust coding convention to manage and structure the coding complexities of an enterprise application. This first layer encapsulates your application's business process logic in an agnostic way, in a way that allows it to be consumed easily across multiple Apex entry points; both those required today by your application and those that will arise in the future as the platform evolves.

We have also seen how the Unit Of Work pattern can be used to help bulkify DML statements, manage record relationships and implement a database transaction, and allow your Service layer logic to focus more on the key responsibility of implementing business logic. In the upcoming chapters, we will see how it quickly becomes the backbone of your application. Careful adherence to the guidelines around your Service layer will ensure it remains strong and easy to extend.

In the next chapter, we will look at the Domain layer, a pattern that blends the data from a Custom Object alongside applicable logic related to a Custom Object's behavior relating to that data. This includes logic traditionally placed in Apex Triggers but it is also optional to further distribute and layer code executed in the Service layer.

# 6

# Application Domain Layer

The objects used by your application represent its domain. Unlike other database platforms where record data is, by default, hidden from end users, the Force.com platform displays record data through the standard Salesforce UI, reports, dashboards, and Salesforce1 mobile application. Surfacing the labels and relationships, you give your objects and fields directly to the end user. From the moment you create your first object, you start to define your application's domain, just as Salesforce Standard Objects represent the CRM application domain.

Martin Fowler's *Patterns of Enterprise Application Architecture* also recognizes this concept as a means of code encapsulation to combine the data expressed by each object with behaviors written in code that affect or interact with that data. This could be Apex Trigger code, providing defaulting and validation, or code awarding championship points to contestant records or checking rules compliance.

This chapter will extend the functionality of the FormulaForce application using the Domain layer pattern, as well as highlighting specific concerns, guidelines, and best practices, and how it integrates with both Apex Triggers and the application's Service layer code.

The following aspects will be covered in this chapter:

- Introducing the Domain layer pattern
- Implementing design guidelines
- The Domain class template
- Implementing the Domain Trigger logic
- Implementing the custom Domain logic
- Object-orientated programming
- Testing the Domain layer
- Calling the Domain layer

## Introducing the Domain layer pattern

The following is Martin Fowler's definition of the Domain layer (<http://martinfowler.com/eaaCatalog/domainModel.html>):

*"An object model of the domain that incorporates both behavior and data".*

Like the Service layer, this pattern adds a further layer of Separation of Concerns and factoring of the application code, which helps manage and scale a code base as it grows.

*"At its worst business logic can be very complex. Rules and logic describe many different cases and slants of behavior, and it's this complexity that objects were designed to work with. A Domain Model creates a web of interconnected objects, where each object represents some meaningful individual, whether as large as a corporation or as small as a single line on an order form."*

Martin's reference to objects in the preceding quote is mainly aimed at objects created from instantiating classes that are coded in an object-orientated programming language, such as Java or .NET. In these platforms, such classes act as a logical representation of the underlying database-table relationships. This approach is typically referred to as **Object Relational Mapping (ORM)**.

In contrast, a Force.com developer reading the term object will tend to first think about Standard or Custom Objects rather than something resulting from a class instantiation. This is because Salesforce has done a great job in binding the data with behavior through their declarative definition of an object, which as we know is much more than just fields. It has formulas, filters, referential integrity, and many other features that we have discussed in earlier chapters, available without writing any code.

Taking into consideration that these declarative features are essentially a means to enable certain behaviors, a Force.com Custom or Standard Object already meets some of the encapsulation concerns of the Domain layer pattern.

## Encapsulating an object's behavior in code

Apex Triggers present a way to write code to implement additional behavior for Custom Objects (or Standard Objects for that matter). They provide a place to implement more complex behavior associated with database events, such as **create**, **update**, and **delete**.

However, as an Apex Trigger cannot have `public` methods, it does not provide a means to write code that logically belongs with the object but is not necessarily linked with a database event. An example of this would be logic to calculate **Contestants** championship points or checking compliance against the many *Formula 1 rules and regulations*, which we will look at later in this chapter. Furthermore, they do not present the opportunity to leverage **object-orientated programming (OOP)** approaches, also discussed later in this chapter.

As a result, developers often end up putting this logic elsewhere, sometimes in a controller or helper class of some kind. Thus, the code implementing the behavior for a given object becomes fragmented and there is a breakdown of *Separation of Concerns*.

Lifting your Apex Trigger code out of the body of the trigger and into an **Apex Class**, perhaps named by some convention based on the object name, is a good start to mitigating this fragmentation, for example `RaceTriggerManager` or `RaceTriggerHandler`. Using such approaches, it then becomes possible to create other methods and break up the code further. These approaches are only the start in seeking a more complete interpretation of the domain model concept described in this chapter.

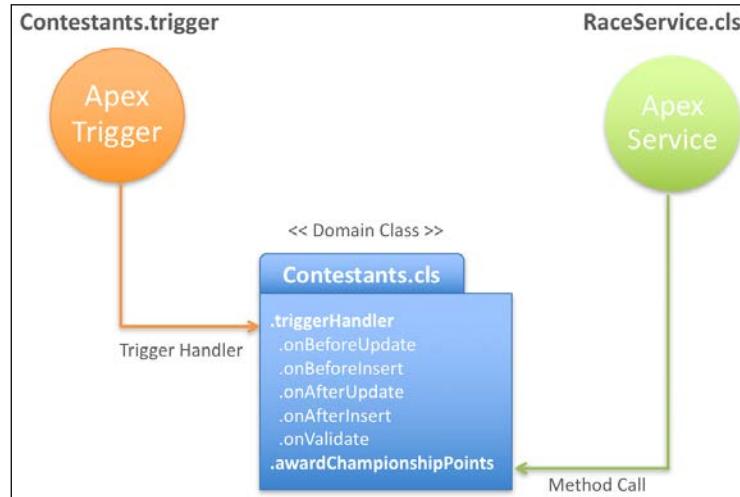
Using the Manager or Handler approach tends to attract logic relating to the Apex Trigger event model and nothing else, leaving other object-related logic to find less obvious locations in the code base.

## Interpreting the Domain layer in Force.com

In this chapter, we look at the Force.com interpretation of the Domain layer pattern, one which ensures behavior invoked both through Apex Trigger events and through direct Apex method calls (from the Service layer and other Domain classes) are considered.

A single Domain class can be created to encapsulate all of the behavior and will begin to leverage OOP principles, such as interfaces, to further enrich the code for reuse and Separation of Concerns, which we will explore later in this chapter.

The following diagram illustrates two consumers of the Domain layer classes – the code from the **Service layer** and also direct interactions with objects resulting in **Apex Trigger** events, which will also be routed to the same Domain layer class:



## Domain classes in Apex compared to other platforms

As we have seen in earlier chapters, a Standard or Custom Object is exposed within the Apex runtime as a **concrete type** that can be instantiated to populate record fields for insertions in the database, or to determine which types are used to return records queried from it.

When considering the Domain pattern, the first inclination is perhaps to extend the applicable SObject such as Account or Race\_\_c through **Apex inheritance** with the extends keyword. Unfortunately, the **Apex compiler** does not support this approach. Even if it were to support this, given best practices of bulkification, writing code that deals with a single record instance at a time will quickly lead to governor issues.

Instead, the Domain class implementation covered here uses the **composition** approach to combine record data and behavior. This is sometimes known as the **wrapper class** approach; it is so named because it wraps the data that it relates to as a class member variable.

The Apex implementation of the wrapper class is no different, except that we choose to wrap a list of records to enforce **bulkified implementations** of the logic within. The following pseudocode illustrates the instantiation of an **Apex Domain class**:

```
Race__craceRecords =
[select Id, Name from Races__c where Id in :raceIds];

Races races = new Races(raceRecords);
```

Another implementation difference compared to other platforms, such as Java and .NET, is the creation of accessor methods to obtain related parent and child records. Though it is possible to write such methods, these are not recommended, for example, `Contestants.getRaces` or `Races.getContestants`.

This implementation avoids coding these types of accessors, as the `sObject` objects in Apex already provide a means to traverse relationships (if queried) as needed. The bulk nature of Apex Domain classes also makes these types of methods less useful and more appropriate for the caller to use the `Selector` classes to query the required records as and when needed, rather than as a result of invoking an accessor method.

To summarize, the Apex Domain classes described in this chapter focus on wrapping lists of records and methods that encapsulate the object's behavior and avoid providing accessor methods for query-related records.

## Implementation design guidelines

As in the previous chapter, this section provides some general design and best practice guidelines around designing a **Domain layer class** for a given object. Note that some of these conventions are shared by the **Service layer**, as it also calls the Domain layer because conventions such as bulkification apply to the logic written here as well.

## Naming conventions

The key principle of the Domain layer pattern is to lay out the code in such a way that it maps to the business domain of the application. In a Force.com application, this is typically supported by the Custom Objects. As such, it's important to clearly indicate which Domain layer class relates to which Standard or Custom Object:

- **Avoid acronyms:** As per the previous chapter, try to avoid these unless it makes your class names unworkably long.

- **Class names:** Use the plural name of your Custom Object for the name of your Domain class. This sets the tone for the scope of the record that the class deals with as clearly being bulkified, as described in the following subsection.
  - Some bad examples are `Race.cls` and `RaceDomain.cls`
  - Some good examples are `Races.cls` and `Teams.cls`
- **Method names:** Methods that relate to the logic associated with database operations or events should follow the `onEventName` convention. Other method names should be descriptive and avoid repeating the name of the class as part of the name.
  - Some bad examples are `Races.checkInserts` and `Races.startRace`
  - Some good examples are `Races.onBeforeInsert` and `Races.start`
- **Parameter Names and Types:** Much of what was described in the previous chapter applies here. Though passing in a list of records to the Domain class methods is not required, this is available as a class member variable to all the domain class methods, as you will see later in this chapter.
  - Some bad examples are:

```
Races.onBeforeInsert(  
    List<Race__c>racesBeingInserted)  
Races.start(  
    List<Id>raceIds)
```

- Some good examples are:

```
Races.onBeforeInsert()  
Races.start()
```

- **Inner classes and interfaces:** Much of what was described in the previous chapter also applies here. As the data being managed is expressed in terms of the actual Custom Object themselves and that information is available as a class member variable, there is typically less of a need for inner classes representing data to be passed in and out of a Domain class.

The following diagram shows how the Domain classes that are used in this chapter map to their respective **Custom Objects**. Each Domain class receives the records that its methods act on in its constructor. The methods shown in the Domain classes are described in more detail as we progress through this chapter.



## Bulkification

As with the Service layer, code written in the Domain layer is encouraged to think about records in a bulk context. This is important when Domain class methods are being called from an Apex Trigger context and the Service layer code, both of which carry the same bulkification requirement.

Instead of enforcing bulkification through passing parameters and ensuring that parameter types are bulkified, as with the Service layer, the information in the Domain class logic acts on and is driven by its member variables, which are bulkified. In this case, the `Records` class property returns a `List<SObject>` object:

```
public void onValidate() {
    for(Contestant__c race : (List<Contestant__c>) Records) {
    }
}
```

## Defining and passing data

Most methods on Domain classes already have the information they need through the `Records` property (the state the Domain class was constructed with). As such, there is little need to pass data information on the methods themselves. However, for some custom behavior methods (those not reflecting the Apex Trigger logic), you might want to pass other domain objects and/or a **Unit Of Work** as additional parameters. Examples later in this chapter help illustrate this.

## Transaction management

For Domain class methods that perform database operations, there are two design guidelines: utilize a transaction context (Unit Of Work) passed as a parameter to the method or create one for the scope of the Domain class method execution.

## Domain class template

The Domain class implementation in this chapter utilizes the **FinancialForce.com Apex Enterprise Patterns** library, which is open source and is included in the sample code of this chapter. In this library, the Apex base class, `fflib_SObjectDomain`, is provided to help implement the Domain layer pattern.

A basic template for a Domain class utilizing this base class is shown in the following code snippet:

```
public class Races extends fflib_SObjectDomain {
    public Races(List<Race__c> races) {
        super(races);
    }

    public class Constructor
        implements fflib_SObjectDomain.IConstructable {
        public fflib_SObjectDomain construct(
            List<SObject>sObjectList) {
            return new Races(sObjectList);
        }
    }
}
```

The first thing to note is that the **constructor** for this class takes a list of `Race__c` records, as per the guidelines described previously. The code implemented in a domain class is written with bulkification in mind. The base class constructor initializes the `Records` base class property.



The inner class, `Constructor`, is present to permit the dynamic creation of the `Domain` class in an Apex Trigger context. This is actually working around the lack of full reflection (the ability to reference the class constructor dynamically) in the Apex language. The name of this inner class must always be `Constructor`.

By extending the `fflib_SObjectDomain` class, the `Domain` class inherits properties and methods it can override to implement its own methods, such as the `Records` property, which provides access to the actual record data. There are virtual methods provided to make the **Apex Trigger** behavior implementation easier, as well as some specialized events such as `onValidate` and `onApplyDefaults`. The following class overview illustrates some of the key methods in the base class that the `Domain` classes can override:

```

● fflib_SObjectDomain(List<SObject>, SObjectType)
● onApplyDefaults() : void
● onValidate() : void
● onValidate(Map<Id, SObject>) : void
● onBeforeInsert() : void
● onBeforeUpdate(Map<Id, SObject>) : void
● onBeforeDelete() : void
● onAfterInsert() : void
● onAfterUpdate(Map<Id, SObject>) : void
● onAfterDelete() : void
● onAfterUndelete() : void
● handleBeforeInsert() : void
● handleBeforeUpdate(Map<Id, SObject>) : void
● handleBeforeDelete() : void
● handleAfterInsert() : void
● handleAfterUpdate(Map<Id, SObject>) : void
● handleAfterDelete() : void
● handleAfterUndelete() : void

```

## Implementing Domain Trigger logic

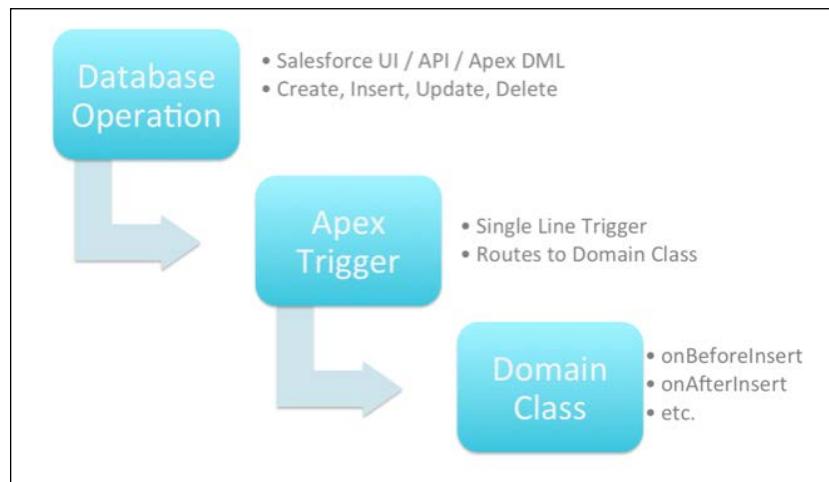
The most common initial use case for a `Domain` class is to encapsulate the Apex Trigger logic. In order to enable this, a small Apex Trigger is required to invoke the `triggerHandler` method. This will route the various Trigger events to the appropriate methods in the `Domain` class (as shown in the preceding screenshot), avoiding the need for the usual `if/else` logic around `Trigger.isXXXX` variables.

The name of this trigger can be anything, though it makes sense to match it with that of the corresponding Domain class. Once this is in place, you can ignore it and focus on implementing the Domain class methods as follows:

```
trigger Seasons on Season__c {  
    after delete, after insert, after update,  
    before delete, before insert, before update) {  
        fflib_SObjectDomain.triggerHandler(Seasons.class);  
    }  
}
```

## Routing trigger events to Domain class methods

The following diagram illustrates the flow of execution from the Apex Trigger to the Domain class, `triggerHandler`, to the individual methods:



To help you understand how traditional Apex Trigger events are mapped to the various virtual methods in the base class, this table describes the code path taken from when the base class's `fflib_SObjectDOMai.triggerHandler` method is invoked through the specific event-based methods that can be overridden by a Domain class:

Trigger context	Base class Records property value	Base class handle method called (refer to the following note)	Base class event method(s) called (refer to the following note)
<code>Trigger.isBefore</code>			
<code>Trigger.isInsert</code>	<code>Trigger.new</code>	<code>handleBeforeInsert()</code>	<code>onApplyDefaults()</code> <code>onBeforeInsert()</code>
<code>Trigger.isUpdate</code>	<code>Trigger.new</code>	<code>handleBeforeUpdate( Map&lt;Id, SObject&gt; existingRecords)</code>	<code>onBeforeUpdate( Map&lt;Id, SObject&gt; existingRecords)</code>
<code>Trigger.isDelete</code>	<code>Trigger.oldMap</code>	<code>handleBeforeDelete()</code>	<code>onBeforeDelete()</code>
<code>Trigger.isAfter</code>			
<code>Trigger.isInsert</code>	<code>Trigger.new</code>	<code>handleAfterInsert()</code>	<code>onValidate()</code> <code>onAfterInsert()</code>
<code>Trigger.isUpdate</code>	<code>Trigger.new</code>	<code>handleAfterUpdate( Map&lt;Id, SObject&gt; existingRecords)</code>	<code>onValidate( Map&lt;Id, SObject&gt; existingRecords)</code> <code>onAfterUpdate( Map&lt;Id, SObject&gt; existingRecords)</code>
<code>Trigger.isDelete</code>	<code>Trigger.oldMap</code>	<code>handleAfterDelete()</code>	<code>onAfterDelete()</code>

**Note:** Handle methods can also be overridden if you wish to implement your own handling. The `existingRecords` parameter represents the value of `Trigger.oldMap`.



The base class uses the template method pattern ([http://en.wikipedia.org/wiki/Template\\_method\\_pattern](http://en.wikipedia.org/wiki/Template_method_pattern)). This ensures that when overriding the `onXXX` methods from the base class, you do not need to worry about calling the base class version of the method, as is the typical developer requirement when overriding methods in OOP.

## Enforcing object security

Salesforce requires developers to implement the **Object CRUD (Create, Read, Update, and Delete) security** and **Field Level security** checks using the methods on the `SObjectDescribe` and `SObjectFieldDescribe` Apex runtime types.

By default, the preceding handle methods in the `fflib_SobjectDomain` base class used in this chapter automatically perform the Object CRUD security on behalf of the developer's Domain class logic.



Note that currently the base class still leaves implementing Field Level security to the developer to implement.

A developer controlled configuration option provided by the base class allows each Domain class to control whether this default behavior is enabled or not. For example, objects that are typically maintained by the application code on behalf of the user may not wish to have this check enforced, such as the awarding of championship points. This type of access is sometimes referred as *system level* access, as the system performs an operation on behalf of the user. Thus by accepting the default to enforce this check, it would require users to be granted access which would not be appropriate elsewhere in the application. Another motivation for not leveraging the default enforcement would be a preference to code these checks in your controller logic more explicitly. Consider carefully the default enforcement is what you need in each case.

## Default behavior

The handler method checks the required security before calling the preceding event methods and throws a `DomainException` exception if the user does not have the required access (forcing the entire trigger context to stop). For example, when the `handleAfterInsert` method is invoked, the `SObjectDescribe.isCreatable` method is used.

## Overriding the default behavior

To make it easier to configure the `fflib_SObjectDomain` class throughout the application, as well as to provide a means to establish shared or common Domain logic code, a new base class is created as follows.

```
/**
 * Application specific Domain base class,
 * customisefflib_SObjectDomain and add common behavior
 */
public abstract class ApplicationDomain extends
    fflib_SObjectDomain {
    public ApplicationDomain(List<SObject> records) {
        super(records);
        // Disable CRUD security enforcement at the Domain class level
        Configuration.disableTriggerCRUDSecurity();
    }
}
```

Thus Domain classes in this application extended this class instead.

```
public class Contestants extends ApplicationDomain {
    public Contestants(List<Contestant__c> contestants) {
        super(contestants);
    }
}
```



Note that this approach requires that the developer takes over exclusive responsibility for implementing Object CRUD security checking them.



## Apex Trigger event handling

The upcoming sections illustrate some Apex Trigger examples with respect to the FormulaForce application. They utilize the `Drivers` and `Contestants` Domain classes included in the sample code for this chapter along with the following new fields:

- In the `Driver__c` object, a new field called `ShortName__c` as a **Text** type, with a maximum size of 3 characters, has been created.
- In the `Race__c` object, there is a new field called `Status__c` as a **Picklist** type, with the **Scheduled**, **In Progress**, **Red Flagged**, and **Finished** values. The default value is scheduled by ticking the **Use first value as default** value checkbox.

## Defaulting field values on insert

Although the `onInsertBefore` method can be overridden to implement logic to set default values on record insert, the following code, added to the `Contestants` Domain class, has chosen to override the `onApplyDefaults` method instead. This was used as it is more explicit and permits a *Separation of Concerns* between the defaulting code and the record insert code, although both are fired during the insert phase:

```
public override void onApplyDefaults() {
    for(Driver__c driver : (List<Driver__c>) Records) {
        if(driver.ShortName__c == null) {
            // Upper case first three letters of drivers last name
            String lastName = driver.Name.substringAfterLast(' ');
            driver.ShortName__c = lastName.left(3).toUpperCase();
        }
    }
}
```

The preceding code attempts to populate the **Drivers** short name, which is typically made up of the first three characters of their second name in upper case, so **Lewis Hamilton** will become **HAM**.

## Validation on insert

The following validation logic applies during record creation. It has been added to the `Contestants` Domain class and ensures that contestants are only added when the race is in the **Scheduled** state.

It also demonstrates the use of a **Selector** pattern class to bulk load records from the `Race__c` Custom Object, and this pattern will be covered in detail in the next chapter:

```
public override void onValidate() {
    // Bulk load the associated races
    Set<Id> raceIds = new Set<Id>();
    for(Contestant__c contestant : (List<Contestant__c>) Records) {
        raceIds.add(contestant.Race__c);
    }
    Map<Id, Race__c> associatedRaces =
        new Map<Id, Race__c>(
            new RacesSelector().selectById(raceIds));
    // Only new contestants to be added to Scheduled races
    for(Contestant__c contestant :
        (List<Contestant__c>) Records) {
        Race__c race = associatedRaces.get(contestant.Race__c);
```

```

        if(race.Status__c != 'Scheduled') {
            contestantaddError(
                'Contestants can only be added to scheduled races');
        }
    }
}

```



By overriding the `onValidate` method, the logic always invokes the after phase of the Apex Trigger. As no further edits can be made to the record fields, this is the safest place to perform the logic. Always keep in mind that your Apex Trigger might not be the only one assigned to the object. For example, once your package is installed in a subscriber org, a subscriber-created custom trigger on your object might fire before yours (the order of trigger invocation is non-deterministic) and will attempt to modify fields. Thus, for managed package triggers, it is highly recommended that validation be performed in the after phase to ensure complete confidence and security, as the data will not be modified further after validation.

## Validation on update

An alternative method, `override`, is provided to implement the validation logic applicable to record updates. It is an overload of the `onValidate` method shown in the preceding example, used to pass in the current records on the database for comparison if needed:

```

public override void onValidate(
    Map<Id, SObject>existingRecords) {
    // Bulk load the associated races
    Map<Id, Race__c>associatedRaces = queryAssociatedRaces();
    // Can only change drivers in scheduled races
    for(Contestant__c contestant : (List<Contestant__c>) Records) {
        Race__ccontestantRace =
            associatedRaces.get(contestant.Race__c);
        Contestant__coldContestant =
            (Contestant__c) existingRecords.get(contestant.Id);
        if(contestantRace.Status__c != 'Scheduled' &&
            contestant.Driver__c != oldContestant.Driver__c) {
            contestant.Driver__c.addError(
                'You can only change drivers for scheduled races');
        }
    }
}

```

The preceding code leverages a new custom Domain class method to share the code responsible for loading associated **Race** records for **Contestants** across the `onValidate` method shown in the previous example. This method also uses the `Records` property to determine **Contestants** in scope:

```
private Map<Id, Race__c> queryAssociatedRaces() {
    // Bulk load the associated races
    Set<Id> raceIds = new Set<Id>();
    for(Contestant__c contestant : (List<Contestant__c>) Records) {
        raceIds.add(contestant.Race__c);
    }
    return new Map<Id, Race__c>(
        new RacesSelector().selectById(raceIds));
}
```



The preceding method is marked as `private`, as there is currently no need to expose this functionality to other classes. Initially, restricting methods this way is often considered best practice and permits easier internal refactoring or improvements in the future. If a need arises that needs access to this functionality, the method can be made `public`.

## Implementing custom Domain logic

A Domain class should not restrict itself to containing logic purely related to Apex Triggers. In the following example, the code introduced in the previous chapter to calculate championship points has been refactored into the **Contestants** Domain class. This is a more appropriate place for it, as it directly applies to the **Contestant** record data and can be readily shared between other Domain and Service layer code (which we will look at later in this chapter):

```
public void awardChampionshipPoints(fflib_ISObjectUnitOfWork uow) {
    // Apply championship points to given contestants
    Map<Integer, ChampionshipPoint__mdt> pointsByTrackPosition =
        new ChampionshipPointsSelector().selectAllByTrackPosition();
    for(Contestant__c contestant : (List<Contestant__c>) Records) {
        // Determine points to award for the given position
        ChampionshipPoint__mdt pointsForPosition =
            pointsByTrackPosition.get(
                Integer.valueOf(contestant.RacePosition__c));
        if(pointsForPosition!=null) {
            // Apply points and register for update with uow
            contestant.ChampionshipPoints__c =
                pointsForPosition.PointsAwarded__c;
            uow.registerDirty(contestant);
        }
    }
}
```

{}  
{}  
{}}

Note that the **Unit Of Work** is passed as a parameter here so that the method can register work (record updates) with the calling Service layer method responsible for committing the work. Once again, as with the previous Domain class methods, the **Records** property is used to access the **Contestant** records to process.

# Object-oriented programming

One of the big advantages of using Apex classes is the ability to leverage the power of **OOP**. OOP allows you to observe commonalities in data or behavior across your objects to share code or apply common processing across different objects.

An example of such a commonality in the Formula1 world are rules; every aspect of the sport has a set of rules and regulations to comply with, such as **drivers** owning a **FIA Super License**, the weight of the car they drive should be at least above a defined minimum, and ensuring that a **team** has not exceeded the maximum distance in testing their cars. Such compliances are checked regularly, both before and after a race.

# Creating a compliance application framework

In our FormulaForce application, we want to create a compliance framework that will check these regulations across the different objects while also providing a consistent user interface experience for the end user to verify compliance. The initial requirement is to place a **Verify Compliance** button on the **Detail Pages** on all applicable objects.

The **Visualforce Controller** and **Service** code that perform the verification process should be generic and reusable across these objects, while the actual compliance-checking logic associated with each object will be specific. By using an **Apex Interface**, we can define this common requirement for the applicable Domain classes to implement.

In this section, we will implement this requirement using an Apex interface and a generic service that can be passed record IDs for different Domain objects across the application. Creating such a service avoids code duplication by having to repeat the logic of handling the results within the code of each Domain class and provides a centralized service for the controller to consume regardless of the object type in scope.

By using an Apex interface and a generic service, we separate the functional concerns of implementing compliance functionality as follows:

- The Service layer code is concerned solely with executing the compliance-checking process through the interface
- The Controller code is concerned with calling the service class method to execute the compliance check and then presenting the results to the user consistently
- The Domain layer classes that implement the interface focus solely on validating the record data against the applicable rules according to the type of the object

Having this Separation of Concerns makes it easy to significantly modify or extend the ways in which the checking is invoked and presented to the user without having to revisit each of the Domain layer classes or conversely, modify the compliance logic of one object without impacting the overall implementation across the application.

## An Apex interface example

Interfaces help express common attributes or behaviors across different domain classes. In this section, we will use an Apex interface to help expose the compliance-checking logic encapsulated in each of the applicable Domain classes.

In order to exercise and implement the compliance framework, the FormulaForce application has gained a few extra fields and objects. These objects, additional classes, and Visualforce pages are all included in the code samples of this chapter.

To summarize, the following steps have been taken to implement the compliance framework requirement. You can follow along with these or simply refer to the sample code of this chapter:

1. Create a new **Car** object and tab.
2. Create a new **Weight** field of type **Number** and length **6** on the **Car** object.
3. Create a new **FIA Super License** field to the **Driver** object.
4. Create a new **Cars** Domain class and **CarsSelector** Selector class.
5. Create a new **ComplianceService** class and **ICompliant** interface.
6. Create new **Cars** and **Drivers** Domain classes and implement the **ICompliant** interface.
7. Update the **Application** class to implement a Domain class factory

8. Create a new `ComplianceService.verify` method that utilizes the Domain factory.
9. Create a user interface to access the service from the various objects that implement the interface.

 The last step will create two user interfaces, one for Salesforce Classic and one for Lightning Experience. The `ComplianceController` class provides a generic controller class for each specific Visualforce page per object. In addition the `ComplianceChecker` bundle provides a generic Lightning Component called **Compliance Checker**, which can be dropped on any object page.

The following sections describe in further detail the Apex coding from *Step 5* onwards.

## Step 5 – defining a generic service

The aim is to develop a common service to handle all compliance verifications across the application. So, a new `ComplianceService` class has been created with a `verify` method on it, which is capable of receiving IDs from various objects. If there are any verification errors, they will be thrown as part of an exception. If the method returns without throwing an exception, the given records are compliant. The following code snippet shows the creation of a new `ComplianceService` class with a `verify` method:

```
public class ComplianceService {
    /**
     * Provides general support to verify compliance in the
     * application
     * @throws ComplianceException for any failures
     */
    public static void verify(Set<Id>recordIds) {
        // Query the given records and delegate to the
        // corresponding Domain class to check compliance
        // and report failures via ComplianceException
    }
}
```

Before we look further into how this service method can be implemented, take a look at the new `ICompliant` interface and the `verifyCompliance` method that will be implemented by the `Drivers` and `Cars` Domain classes:

```
public class ComplianceService {  
    /**  
     * Interface used to execute compliance checking logic  
     * in each domain class  
     */  
    public interface ICompliant {  
        List<VerifyResult> verifyCompliance();  
    }  
  
    /**  
     * Results of a compliance verification for a given record  
     */  
    public class VerifyResult {  
        public Id recordId;  
        public String complianceCode;  
        public Boolean passed;  
        public String failureReason;  
    }  
}
```

## Step 6 – implementing the domain class interface

The `Drivers` Domain class implements the interface as follows (only a portion of the class is shown). It checks whether the **FIA Super License** field is checked and reports an appropriate compliance code and failure message if not:

```
public class Drivers extends ApplicationDomain  
    implements ComplianceService.ICompliant {  
    public List<ComplianceService.VerifyResult> verifyCompliance() {  
        List<ComplianceService.VerifyResult> compliances =  
            new List<ComplianceService.VerifyResult>();  
        for(Driver__c driver : (List<Driver__c>) Records) {  
            ComplianceService.VerifyResult license =  
                new ComplianceService.VerifyResult();  
            license.ComplianceCode = '4.1';  
            license.RecordId = driver.Id;  
            license.passed = driver.FIASuperLicense__c;  
            license.failureReason =  
                license.passed ? null :  
                    'Driver must have a FIA Super License.';  
            compliances.add(license);  
        }  
    }  
}
```

```
    }  
    return compliances;  
}  
}
```

The `Cars` domain class (of which only a portion of the class is shown) implements the `verifyCompliance` method as follows, checking whether the car is over the specified weight:

```
public class Cars extends ApplicationDomain
    implements ComplianceService.ICompliant {
    public List<ComplianceService.VerifyResult> verifyCompliance() {
        List<ComplianceService.VerifyResult> compliances =
            new List<ComplianceService.VerifyResult>();
        for(Car__c car : (List<Car__c>) Records) {
            // Check weight compliance
            ComplianceService.VerifyResult license =
                new ComplianceService.VerifyResult();
            license.ComplianceCode = '4.1';
            license.RecordId = car.Id;
            license.passed =
                car.Weight__c !=null && car.Weight__c>= 691;
            license.failureReason = license.passed ? null :
                'Car must not be less than 691kg.';
            compliances.add(license);
        }
        return compliances;
    }
}
```

## Step 7 – the domain class factory pattern

The next step is to dynamically construct the associated Domain class based on the record IDs passed into the `ComplianceService.verify` method. This part of the implementation makes use of a **Factory pattern** implementation for Domain classes.

The implementation uses the Apex runtime `Id.getObjectType` method to establish `ObjectType`, and then via the `Maps` (shown in the following code), it determines the applicable Domain and Selector classes to use (to query the records).

The Apex runtime `Type.newInstance` method is then used to construct an instance of the Domain and Selector classes. The factory functionality is invoked by calling the `Application.Domain.newInstance` method. The Domain field on the Application class is implemented using the `fflib_Application.DomainFactory` class as follows:

```
public class Application {  
    public static final fflib_Application.DomainFactory Domain =  
        new fflib_Application.DomainFactory(  
            Application.Selector,  
            // Map SObjectType to Domain Class Constructors  
            new Map<SObjectType, Type> {  
                Race__c.SObjectType => Races.Constructor.class,  
                Car__c.SObjectType => Cars.Constructor.class,  
                Driver__c.SObjectType => Drivers.Constructor.class );  
    }  
}
```

 As a developer you can of course instantiate a specific Domain class directly. However, this Domain factory approach allows for the specific Domain class to be chosen at runtime based on the SObjectType associated with the ID passed to the `newInstance` method. This is key to implementing the generic service entry point as shown in the next step. The preceding initialization of the Domain factory also passes in `Application.Selector`; this is another factory relating to classes that are able to query the database. The next chapter will cover the Selector pattern and the Selector factory in more detail.

## Step 8 – implementing a generic service

The `Application.Domain.newInstance` method used in the following code is used to access the Domain instance factory defined in the last step.

This method returns `fflib_ISObjectDomain`, as this is a common base interface to all Domain classes. Then, using the `instanceof` operator, it determines whether it implements the `ICompliant` interface, and if so, it calls the `verifyCompliance` method. The following code shows the implementation of a generic service:

```
public class ComplianceService {  
    public static void verify(Set<Id>recordIds) {  
        // Dynamically create Domain instance for these records  
        fflib_ISObjectDomain domain =  
            Application.Domain.newInstance(recordIds);  
        if(domain instanceof ICompliant) {  
            // Ask the domain class to verify its compliance  
            ICompliantcompliantDomain = (ICompliant) domain;
```

```
        List<VerifyResult> verifyResults =
            compliantDomain.verifyCompliance();
        if(verifyResults!=null) {
            // Check for failed compliances
            List<VerifyResult> failedCompliances =
                new List<VerifyResult>();
            for(VerifyResult verifyResult : verifyResults) {
                if(!verifyResult.passed) {
                    failedCompliances.add(verifyResult);
                }
            }
            if(failedCompliances.size()>0) {
                throw new ComplianceException(
                    'Compliance failures found.', failedCompliances);
                return;
            }
        }
        throw new ComplianceException(
            'Unable to verify compliance.', null);
    }
}
```



Note that, if the `verify` method is passed IDs for an object that does not have a corresponding Domain class, an exception is thrown from the factory. However, if a domain class is found but does not implement the interface, the preceding code simply returns without an error, though what the developer will do in this case is up to them.

## Step 9 – using the generic service from a generic controller

In this step we will utilize the same `ComplianceService.verify` method from a Visualforce Controller and a Lightning Component controller. These user interfaces are also highly generic and thus easier to apply to new objects in future releases.

## Generic Compliance Verification UI with Visualforce

A generic Visualforce Controller, `ComplianceController`, has been created with a `verify` action method that calls the service. Note that at no time have we yet referred to a specific Custom Object or Domain class, ensuring that this controller and the service are generic and able to handle objects of different types. The following code shows how the generic `ComplianceService.verify` method is being called from the `ComplianceController.verify` method:

```
public PageReference verify() {
    try {
        // Pass the record to the compliance service
        ComplianceService.verify(
            new Set<Id> { standardController.getId() });
        // Passed!
        ApexPages.addMessage(
            new ApexPages.Message(
                ApexPages.Severity.Info, 'Compliance passed'));
    }
    catch (Exception e) {
        // Report message as normal via apex:pageMessages
        ApexPages.addMessages(e);
        // Display additional compliance failure messages?
        if(e instanceof ComplianceService.ComplianceException)
        {
            ComplianceService.ComplianceException ce
                (ComplianceService.ComplianceException) e;
            for(ComplianceService.VerifyResult verifyResult :
                ce.failures) {
                ApexPages.addMessage(new ApexPages.Message(
                    ApexPages.Severity.Error,
                    String.format('{0} ({1})',
                        verifyResult.failureReason,
                        verifyResult.complianceCode }));
            }
        }
    }
    return null;
}
```

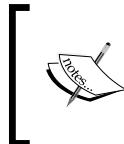
Visualforce pages are then created to bind this generic controller to Custom Buttons on the **Driver** and **Car** detail pages. This is the only specific reference made to objects that implement the `ComplianceService.ICompliant` interface and is only needed in order to create the Custom Buttons in Salesforce Classic. The following page for the **Driver** object defines a button that uses the generic `ComplianceController.verify` method:

```
<apex:pagestandardController="Driver__c"
  extensions="ComplianceController" action="{!!verify}">
  <apex:pageMessages/>
  <apex:form>
    <apex:commandButton value="Cancel" action="{!!cancel}" />
  </apex:form>
</apex:page>
```

## Generic Compliance Verification UI with a Lightning Component

The component described in this section can be placed on a Lightning Experience or Salesforce1 Mobile record pages for any object without any further configuration.

The component utilizes the same Service as the previous Visualforce example to dynamically invoke the appropriate Domain class and apply the applicable verification process.



Lightning Components will be covered in more detail in a later chapter. This component demonstrates one of the many places where components can be used to extend Lightning Experience and other aspects of the platform.

The following code shows the Apex Controller for the component:

```
public with sharing class ComplianceCheckerComponent {
  @AuraEnabled
  public static List<String> verify(Id recordId) {
    try {
      // Verify the given record for compliance
      ComplianceService.verify(newSet<Id> { recordId });
      // Success, all good!
      Return null;
    } catch (Exception e) {
      // Report message as normal via apex:pageMessages
      List<String> messages = new List<String> { e.getMessage() };
      // Display additional compliance failure messages?
    }
  }
}
```

```
    If(e instanceof ComplianceService.ComplianceException) {
        ComplianceService.ComplianceExceptionce =
            (ComplianceService.ComplianceException) e;
        for(ComplianceService.VerifyResultverifyResult : ce.failures) {
            messages.add(String.format('{0} ({1})',
                new List<String> {
                    verifyResult.failureReason,
                    verifyResult.complianceCode }));
        }
    }
    return messages;
}
}
```

The following code shows the component markup, JavaScript controller and helper:

ComplianceChecker.cmp:

```
<aura:component implements="force:hasRecordId, flexipage:availableForRecordHome" controller="ComplianceCheckerComponent" access="global">
    <aura:dependency resource="markup://force:editRecord"
        type="EVENT" />
    <aura:attribute name="category" type="String"
        default="success" />
    <aura:attribute name="messages" type="String[]" />
    <aura:handler name="init" value="{!this}"
        action=" {!c.onInit}" />
    <aura:handler event="force:refreshView"
        action=" {!c.onRefreshView}" />
    <div class="{'!slds-box slds-theme-' + v.category}">
        <aura:iteration items=" {!v.messages}" var="message">
            <p><ui:outputText value=" {!message}" /></p>
        </aura:iteration>
    </div>
</aura:component>
```



The preceding code handles the `force:refreshView` event sent by the Lighting Experience framework when the user edits records. Because the `flexipage:availableForRecordHome` interface is specified, this component can only be placed on record pages.

ComplianceCheckerController.js:

```
{
  {
    onInit : function(component, event, helper) {
      helper.verifyCompliance(component, event, helper);
    },
    onRefreshView : function(component, event, helper) {
      helper.verifyCompliance(component, event, helper);
    }
  }
}
```

ComplianceCheckerHelper.js:

```
{
  {
    verifyCompliance : function(component) {
      var action = component.get("c.verify");
      action.setParams({ "recordId" :
        component.get("v.recordId") });
      action.setCallback(this, function(response) {
        if(response.getState() === 'SUCCESS') {
          var messages = response.getReturnValue();
          if(messages!=null) {
            component.set("v.category", "error");
            component.set("v.messages", messages);
          } else {
            component.set("v.category", "success");
            component.set("v.messages", ["Verified compliance"]);
          }
        }
      });
      $A.enqueueAction(action);
    }
  }
}
```

Unlike the Visualforce page, no specific reference to an object is made, allowing the component to be used on any page.

 If you wanted to restrict the visibility of the component within the Lightning App Builder tool where users customize Lightning Experience and Salesforce1 Mobile, you can utilize the `sfdc:objects` tag in your `.design` file.

```
<sfdc:objects>
  <sfdc:object>Driver__c</sfdc:object>
  <sfdc:object>Car__c</sfdc:object>
</sfdc:objects>
```

## Summarizing compliance framework implementation

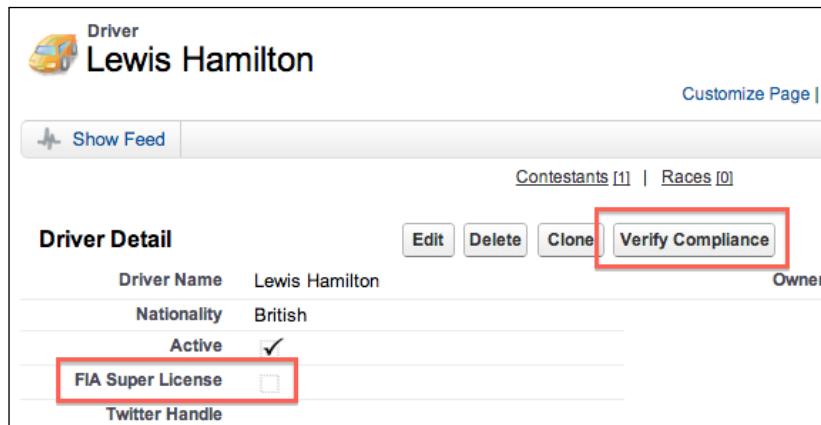
Using an Apex Interface and the Factory pattern, a framework has been put in place within the application to ensure that the compliance logic is implemented consistently. This is a simple matter of implementing the Domain class interface and creating the Visualforce page or using the generic Lightning component, to enable the feature for other applicable objects in the future.



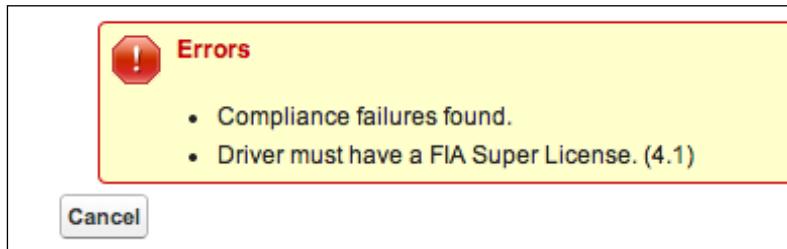
As this has been implemented as a service, it can easily be reused from a Batch Apex or Scheduled context as well.



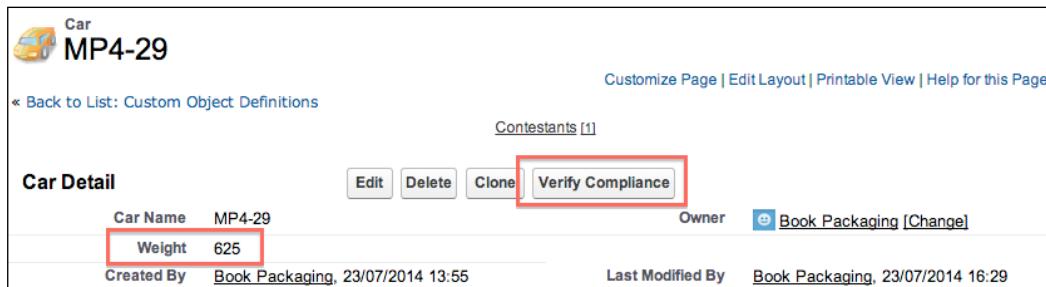
The following screenshot illustrates the **Verify Compliance** button on the **Driver** object. Ensure that the **FIA Super License** field is unchecked before pressing the button.



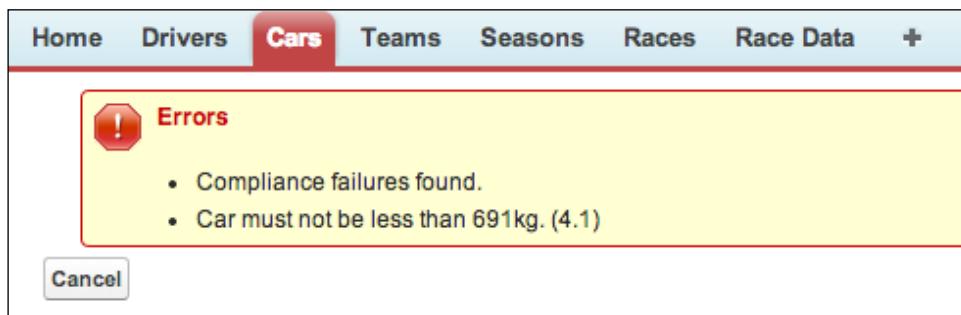
The following errors should be displayed:



The following screenshot shows the **Verify Compliance** button on the **Car** object:



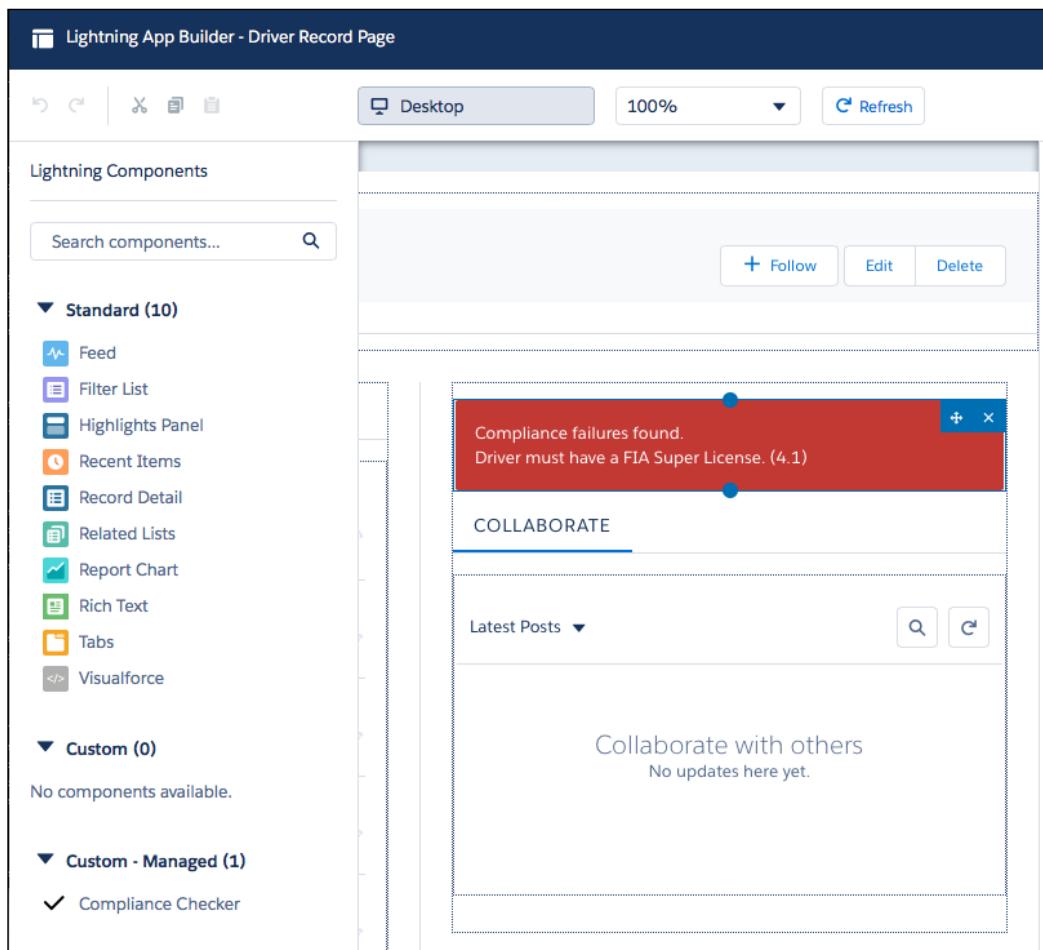
The following errors are shown by the generic controller defined/created previously:



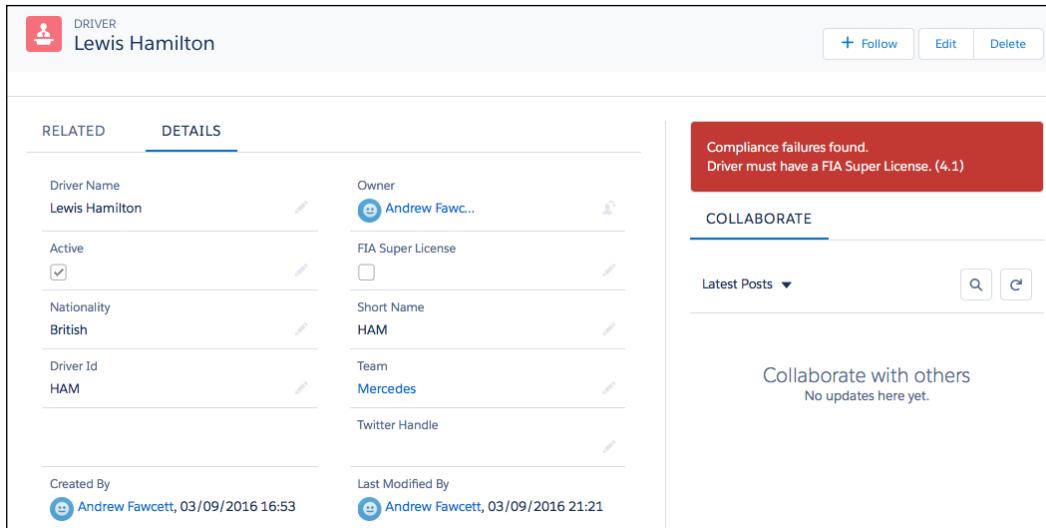
## *Application Domain Layer*

---

The following shows the **Compliance Checker** Lightning Component within the **Lightning App Builder** tool being placed on the **Driver** page:



The following shows the **Compliance Checker** component in place on the **Driver** page. In Lightning Experience, there is no button, the component is embedded in the page and reacts to the field updates the user makes. So, the verification is performed immediately.



## Testing the Domain layer

Testing your Domain code can be accomplished in the standard Force.com manner. Typically, test classes are named by suffixing `Test` at the end of the Domain class name, for example, `RacesTest`. Test methods have the option to test the Domain class code functionality either directly or indirectly.

Indirect testing is accomplished using only the DML and SOQL logic against the applicable Custom Objects and asserting the data and field errors arising from these operations. Here, there is no reference to your Domain class at all in the test code.

However, this only tests the Apex Trigger Domain class methods. For test methods that represent custom domain behaviors, you must create an instance of the Domain class. This section will illustrate examples of both indirect and direct testing approaches.

## Unit testing

Although developing tests around the Service layer and related callers (controllers, batch, and so on) will also invoke the Domain layer logic, it is important to test as many scenarios specifically against the Domain layer as possible, passing in different configurations of record data to test both success and failure code paths and making sure that your Domain layer logic is as robust as possible. Wikipedia describes the definition of a **unit test** as follows ([http://en.wikipedia.org/wiki/Unit\\_testing](http://en.wikipedia.org/wiki/Unit_testing)):

*In computer programming, unit testing is a method by which individual units of source code, sets of one or more computer program modules together with associated control data, usage procedures, and operating procedures are tested to determine if they are fit for use. Intuitively, one can view a unit as the smallest testable part of an application. In procedural programming, a unit could be an entire module, but it is more commonly an individual function or procedure. In object-oriented programming, a unit is often an entire interface, such as a class, but could be an individual method. Unit tests are short code fragments created by programmers or occasionally by white box testers during the development process.*

Testing of the Domain layer falls into this definition. The following sections illustrate the traditional and still very much valid approach to testing your Domain class code through setting up test data using DML and executing the code. In a later chapter, we will review an Apex Mocking framework (similar to **Mockito** in Java), which provides a much leaner and more targeted means to test your Domain code.

## Test methods using DML and SOQL

To test the Apex Trigger methods of the Domain class, the traditional use of DML and SOQL can be applied alongside the use of the Apex runtime `DMLException` methods to assert not only the error message but also other details. The following Apex test method illustrates how to do this:

```
@IsTest
private static void testAddContestantNoneScheduled() {
    // Test data
    Season__c season =
        new Season__c(Name = '2014', Year__c = '2014');
    insert season;
    Driver__c driver =
        new Driver__c(
            Name = 'Lewis Hamilton', DriverId__c = '42');
    insert driver;
    Race__c race =
```

```

new Race__c(Name = 'Spa',
    Status__c = 'In Progress',
    Season__c = season.Id);
insert race;

Test.startTest();
try {
    // Insert Contestant to In Progress race
    Contestant__c contestant =
        new Contestant__c(
            Driver__c = driver.Id,
            Race__c = race.Id);
    insert contestant;
    System.assert(false, 'Expected exception');
}
catch (DMLException e) {
    System.assertEquals(1, e.getNumDml());
    System.assertEquals(
        'Contestants can only be added to Scheduled Races.',
        e.getDmlMessage(0));
    System.assertEquals(
        StatusCode.FIELD_CUSTOM_VALIDATION_EXCEPTION,
        e.getDmlType(0));
}
Test.stopTest();
}

```

The preceding error is a record-level error; the `DMLException` class also allows you to assert field-level information for field-level errors. The following code shows such a test assertion; the data setup code is not shown:

```

Test.startTest();
Try {
    contestant.Driver__c = anotherDriver.Id;
    update contestant;
    System.assert(false, 'Expected exception');
}
catch (DmlException e) {
    System.assertEquals(1, e.getNumDml());
    System.assertEquals(
        'You can only change drivers for scheduled races',
        e.getDmlMessage(0));
    System.assertEquals(Contestant__c.Driver__c,
        e.getDmlFields(0)[0]);
    System.assertEquals(

```

```
    StatusCode.FIELD_CUSTOM_VALIDATION_EXCEPTION,
    e.getDmlType(0));
}
Test.stopTest();
```

## Test methods using the Domain class methods

In order to test custom Domain class methods, an instance of the Domain class should be created in the test method, using test records created in memory or queried from the database having been inserted as shown in the previous tests.

The following example shows the `Contestants.awardChampionship` method being tested. Note that the test creates a temporary Unit Of Work but does not commit the work. This is not strictly needed to assert the changes to the records, as the `Records` property can be used to access the changes and assert the correct value that has been assigned:

```
@IsTest
private static void testAddChampionshipPoints() {
    // Test data
    ChampionshipPoints__c championShipPoints =
        new ChampionshipPoints__c(
            Name = '1', PointsAwarded__c = 25);
    insert championShipPoints;
    Season__c season =
        new Season__c(Name = '2014', Year__c = '2014');
    insert season;
    Driver__c driver =
        new Driver__c(
            Name = 'Lewis Hamilton', DriverId__c = '42');
    insert driver;
    Race__c race =
        new Race__c(
            Name = 'Spa', Status__c = 'Scheduled',
            Season__c = season.Id);
    insert race;
    Contestant__c contestant =
        new Contestant__c(
            Driver__c = driver.Id, Race__c = race.Id);
    insert contestant;
    race.Status__c = 'Finished';
    update race;
    contestant.RacePosition__c = 1;
```

```

update contestant;

Test.startTest();
Contestants contestants =
    new Contestants(new List<Contestant__c> { contestant });
contestants.awardChampionshipPoints(
Application.UnitOfWork.newInstance());
System.assertEquals(25, ((Contestant__c)
    contestants.Records[0]).ChampionshipPoints__c);
Test.stopTest();
}

```

 Performing SOQL and DML in tests is expensive in terms of CPU time and adds to the overall time it takes to execute all application tests, which becomes important once you start to consider **Continuous Integration** (covered in a later chapter). For example, whether it is always necessary to commit data updates from the Domain layer, as Service layer tests might also be performing these types of operations and asserting the results.

## Calling the Domain layer

The Domain layer is positioned with respect to visibility and dependency below the Service layer. This in practice means that Domain classes should not be called directly from the execution context code, such as Visualforce Controllers, Lightning Component Controllers or Batch Apex, as it is the Service layer's responsibility to be the sole entry point for business process application logic.

That being said, we saw that the Domain layer also encapsulates an object's behavior as records are manipulated by binding Apex Trigger events to methods on the Domain class. As such, Apex Triggers technically form another point of invocation.

Finally, there is a third caller type for the Domain layer, and this is another Domain class. Restrict your Domain class callers to the following contexts only:

- **Apex Triggers:** This calls via the `fflib_SObjectDomain.handleTrigger` method.
- **Service layer:** This layer directly creates an instance of a Domain class via the `new` operator or through the Domain factory approach seen earlier in this chapter. Typically, the Domain class custom methods are called in this context.
- **Domain layer:** Other Domain classes can call other Domain classes, for example, the `Races` Domain class can have some functionality it implements that also requires the use of a method on the `Contestants` Domain class.



Note that it is entirely acceptable to have a Domain class with no Service class code referencing it at all, such as in the case where the Domain class solely implements the code for use in an Apex Trigger context and doesn't contain any custom Domain methods. Then, the only invocation of the Domain class will be indirect via the trigger context.

## Service layer interactions

While implementing the compliance framework earlier in this chapter, we saw how a Domain class can be dynamically created within a generic service method. Typically, Domain classes are created directly. In this section, we will see a couple of examples of these.

The following code shows the Domain class constructor being passed records from a Selector class, which returns `List<Contestant__c>` for the purposes of this chapter. Notice that the Unit Of Work is created and passed to the Domain class custom method so that this method can also register work of its own to be later committed to the database:

```
public class ContestantService {  
    public static void awardChampionshipPoints(  
        Set<Id>contestantIds) {  
        fflib_SObjectUnitOfWork uow =  
            Application.UnitOfWork.newInstance();  
  
        // Apply championship points to given contestants  
        Contestants contestants =  
            new Contestants(  
                new ContestantsSelector().selectById(contestantIds));  
        contestants.awardChampionshipPoints(uow);  
  
        uow.commitWork();  
    }  
}
```

You might have noticed that this example reworks the Service example from the previous chapter by refactoring the code and calculating the points closer to the object for which the code directly applies by basically moving the original code to the Domain class.

This following second example also reworks the code from the previous chapter to leverage the Domain layer. In this case, the `RaceService` class also implements an `awardChampionshipPoints` method. This can also benefit from the `Contestants` Domain class method. Note how easy it is to reuse methods between the Service and Domain layers, as both ensure that their methods and interactions are bulkified.

```
public class RaceService {
    public void awardChampionshipPoints(Set<Id>raceIds) {
        fflib_SObjectUnitOfWork uow =
            Application.UnitOfWork.newInstance();

        List<Contestant__c> contestants =
            new List<Contestant__c>();
        for(Race__c race :
            new RacesSelector().selectByIdWithContestants(raceIds)) {
            contestants.addAll(race.Contestants__r);
        }

        // Delegate to Contestant Domain class
        new Contestants(contestants).awardChampionshipPoints(uow);

        // Commit work
        uow.commitWork();
    }
}
```

## Domain layer interactions

In the following example (also included in the sample code for this chapter), a new Custom Object is created to represent the teams that participate in the races. The **Driver** object has gained a new **Lookup** field called **Team** to associate the drivers with their teams.

Leveraging the compliance framework built earlier, a **Verify Compliance** button for the **Team** records is also added to provide a means to check certain aspects of the team that are compliant (such as the maximum distance cars can cover during testing) as well as whether all the drivers in this team are also still compliant (reusing the existing code).

 This will be done by adding the compliance verification code in the new `Teams` Domain class call and by delegating to the `Drivers` Domain class method to implement the same for drivers within the team.

The following components have been added to the application to support this example:

- A new **Team** object and tab
- A new **Testing Distance** number field with a length of **6** on the **Team** object
- A new **Team** lookup field on the **Driver** object
- A new Teams Domain class



You don't always have to create an Apex Trigger that calls the `fflib_SObjectDomain.triggerHandler` method if you don't plan on overriding any of the Apex Trigger event handler methods.

Being able to call between the Domain layer classes permits the driver compliance-checking code to continue to be reused at the **Driver** level as well as from the **Team** level. This Domain class example shows the Teams Domain class calling the Drivers Domain class:

```
public class Teams extends fflib_SObjectDomain
    implements ComplianceService.ICompliant {
    public List<ComplianceService.VerifyResult> verifyCompliance() {
        // Verify Team compliance
        List<ComplianceService.VerifyResult> teamVerifyResults =
            new List<ComplianceService.VerifyResult>();
        for(Team__c team : (List<Team__c>) Records) {
            ComplianceService.VerifyResult testingDistance =
                new ComplianceService.VerifyResult();
                testingDistance.ComplianceCode = '22.5';
                testingDistance.RecordId = team.Id;
                testingDistance.passed = team.TestingDistance__c!=null ?
                    team.TestingDistance__c <= 15000 : true;
                testingDistance.failureReason = testingDistance.passed ?
                    null : 'Testing exceeded 15,000km';
                teamVerifyResults.add(testingDistance);
        }

        // Verify associated Drivers compliance
        teamVerifyResults.addAll(
            new Drivers(
                new DriversSelector().selectDriversByTeam(
                    new Map<Id, SObject(Records).keySet())))
                .verifyCompliance());
    }
}
```

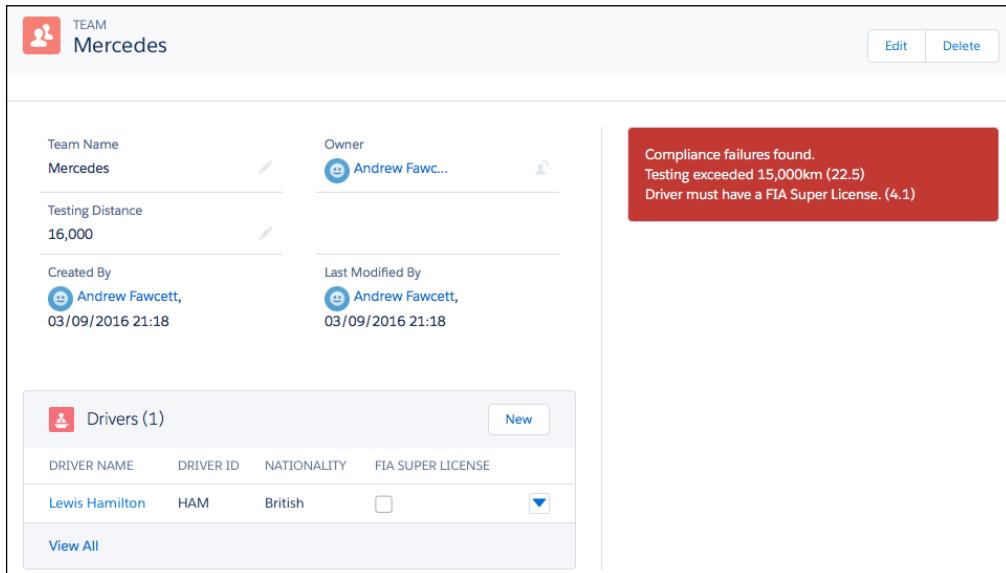
```

        return teamVerifyResults;
    }
}

```

 The bulkification guideline applied to the Domain layer is being leveraged in the preceding code, as the Drivers Domain class logic was reused directly, with no changes, from the Teams Domain class. Also note that the implementation of the Drivers Domain class was and is still unaware of the split of drivers by team.

The following screenshot shows the new **Team** object and **Compliance Checker** component added to the **Team** page using **Lightning App Builder**. The team record and related driver record have compliance issues. For the team record an invalid **Testing Distance** value greater than **15,000 km**. The **FIA Super License** field on the **Driver** record for **Lewis Hamilton**, which is unchecked, is not shown.



## Updating the FormulaForce package

As before, utilize the source code provided with this chapter to update your packaging org and upload a new version of the package. Make sure that you check for any components not automatically added to the package, such as Apex classes, objects, tabs, and Lightning Components tabs.

Remove any Lightning Components added to pages via **Lightning App Builder** before packaging. If you package **Lightning Pages** with your components on them, this will require your users to have the **My Domain** feature enabled and thus potentially limit the number of customers your package can be installed with. This is true, especially for those that have not yet fully adopted Lightning Experience.



Note that the new **Verify Compliance** button has been added to the **Driver** layout since the last release of the package in the previous chapter. However since layouts are non-upgradable components, this will need to be added manually after installation in the test org when upgrading, as will any new custom fields added throughout this chapter. You would typically notify users of these steps through your upgrade and installation guide. You will also have to ensure users are made aware of any Lightning Components as part of your solution. As previously noted, packaging Lightning pages creates a dependency on the My Domain feature having been enabled by the customer.

## Summary

In this chapter, you've seen a new way to factor business logic beyond encapsulating it in the Service layer— one that aligns the logic— implementing the validation changes, and interpretation of an object's data through a Domain class named accordingly. As with the Service layer, this approach makes such code easy to find for new and experienced developers working on the code base.

A Domain class combines the traditional Apex Trigger logic and custom Domain logic— such as the calculation of championship points for a contestant or the verification of compliance rules against the cars, drivers, and teams.

By utilizing Apex classes, the ability to start leveraging OOP practices emerges, using interfaces and factory methods to implement functional subsystems within the application to deliver not only implementation speed, consistency, and reuse, but also help support a common user experience. Domain classes can call between each other when required to encompass the behavior of related child components, such as drivers within a team.

Finally, when testing the Domain layer, keep in mind the best practice used for unit testing is to test as much of the code in isolation with varied use cases and data combinations despite the fact that other tests, such as those from the Service layer, and other callers will also exercise the code paths, though likely with less variation.

In the next chapter, we will complete the trio of patterns from Martin Fowler by taking a deeper look at the Selector pattern. This has been utilized a few times in this chapter when reading data from the various Custom Objects used in the application.



# 7

## Application Selector Layer

Apex is a very expressive language to perform calculations and transformations of data entered by the user or records read from your Custom Objects. However, **SOQL** also holds within it a great deal of expressiveness to select, filter, and aggregate information without having to resort to Apex. SOQL is also a powerful way to traverse relationships (up to five levels) in one statement, which would otherwise leave developers on other platforms performing several queries.

Quite often, the same or similar SOQL statements are required in different execution contexts and business logic scenarios throughout an application. Performing these queries inline as and when needed, can rapidly become a maintenance problem as you extend and adapt your object schema, fields, and relationships.

This chapter introduces a new type of Apex class, the **Selector**, based on **Martin Fowler's Mapper pattern**, which aims to **encapsulate** the SOQL query logic, making it easy to access, maintain, and reuse such logic throughout the application.

The following aspects will be covered in this chapter:

- Introducing the Selector layer pattern
- Implementation design guidelines
- The Selector class template
- Implementing the standard query logic
- Implementing the custom query logic
- Introducing the Selector factory

## Introducing the Selector layer pattern

The following is Martin Fowler's definition of the **Data Mapper layer** on which the **Selector layer** pattern is based (<http://martinfowler.com/eaaCatalog/dataMapper.html>):

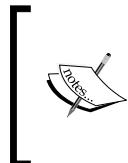
*"A layer of Mappers (473) that moves data between objects and a database while keeping them independent of each other and the Mapper itself."*

In Martin's definition, he is referring to objects as those resulting from the instantiation of classes within an OO language such as Java or Apex. Of course, in the Force.com world, this has a slightly ambiguous meaning, but is more commonly thought of as the Standard or Custom Object holding the record data.

One of the great features of the Apex language is that it automatically injects object types into the language that mirror the definition of the Custom Objects you define. These so-called **SObjects** create a type-safe bond between the code and the database schema, though you can also leverage **Dynamic Apex** and **Dynamic SOQL** to change these references at runtime if needed.

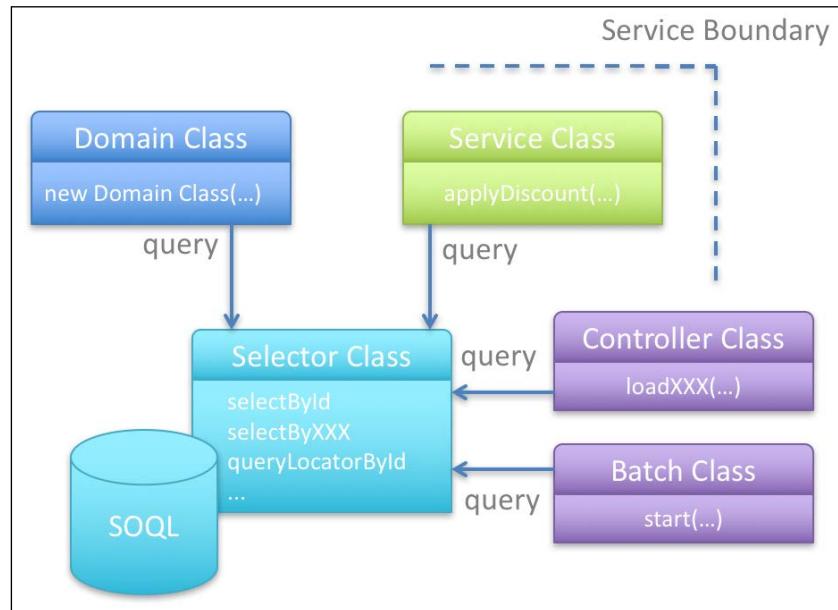
Essentially, SObjects are the native in-memory representation of the data read from the database. Thus, a traditional **Plain Old Java Object (POJO)** approach in Apex is not strictly required to expose the record field data. Additionally, through relationship fields such as `Race__c.Drivers__r`, related records can be accessed without the need for the usual POJO relationship accessor methods or properties.

For this reason, the role of **Apex classes** that represent the Selector layer code described in this chapter is much more focused on encapsulating the application's SOQL queries, promoting **reuse** and **data consistency** rather than mapping information from the database into memory.



One might consider the Domain classes as data wrappers around SObject, as they contain a list of SObjects. However, this is not the intent; the Domain class methods purely expose behavioral methods. The Records property exposes the SObject list so that callers can access the field data in the usual manner.

The following diagram illustrates where Apex classes implementing the Selector layer fit in terms of its interaction and reuse within the Service and Domain layers as well as other execution contexts such as **Batch Apex**. For the most part, it is a layer that exists conceptually below the Service layer (under the Service boundary), though it can be reused from execution contexts that perform database queries, such as Batch Apex and Controllers.



## Implementing design guidelines

The methods in the Selector classes encapsulate common SOQL queries made by the application, such as `selectById`, as well as more business-related methods, such as `selectByTeam`. This helps the developers who consume the Selector classes identify the correct methods to use for the business requirement and avoids replication of SOQL queries throughout the application.

Each method also has some standard characteristics, such as the `sobject` fields selected by the queries executed, regardless of the method called. The overall aim is to allow the caller to focus on the record data returned and not how it was read from the database.

## Naming conventions

By now, you're starting to get the idea about naming conventions. The Selector classes and methods borrow guidelines from other layers with a few tweaks. Consider the following naming conventions when writing the Selector code:

- **Class names:** in naming a Selector class, it typically follows the same convention as a Domain class, taking the plural name of the object it is associated with and appending the word Selector at the end; though you can group common cross object queries into a single module scoped class:
  - Some bad examples are `RaceSOQLHelper` and `SOQLHelper`
  - Some good examples are `RacesSelector`, `DriversSelector` and `RacingAnalyticsSelector`
- **Method names:** the `select` prefix is a good way to express the shared purpose of the Selector methods, followed by a description of the primary criteria and/or relationships used. As with the Service and Domain methods, avoid repeating terms already used in the class name:
  - Some bad examples are `getRecords`, `getDrivers`, `loadDrivers`, `selectDriversById`, and `selectRacesAndContestants`.
  - Some good examples are `selectById`, `selectByTeam`, `selectByIdWithContestants`, and `selectByIdWithContestantsAndDrivers`.
- **Method signatures:** Selector methods typically return a `Map`, `List`, or `QueryLocator` exposing the resulting SObjects, thus supporting the bulkification needs of the platform and other layers such as the Domain class constructors and Batch Apex. Method parameters reflect the parameterized aspects of the `WHERE` clause; again, these should also be bulkified where applicable to do so:
  - Some bad examples are:

```
selectById(Id recordId)
DriverSelector.select(Set<Id>teamIds)
Database.QueryLocatorqueryForBatch(Set<Id> ids)
```
  - Some good examples are:

```
selectById(Set<Id>raceIds)
selectByTeam(Set<Id>teamIds)
```

## Bulkification

As you can see, based on the method naming and signature convention examples, as with the Service and Domain layers, it's important to consider that in most cases the caller will want to honor the bulkification best practices. Make sure that the method return types and parameter types are list types—those such as `Set`, `List`, `Map`, `QueryLocator`, or `Iterator` can be used.

## Record order consistency

Quite often, the `order by` clause is overlooked when writing SOQL queries, and this can lead to client/controller developers implementing this themselves. The default ordering of the platform is non-deterministic, though it sometimes appears to reflect the insert order, so the absence of an `order by` clause can often go unnoticed in testing. By using a Selector, you can apply a default ordering to all Selector methods.



Returning `Map<Id, SObject>` instead of `List<SObject>` might seem like a good way to help callers process the information. Maps in Apex have a predictable iterator order, however it is not clear from the documentation if this is the order in which items are added to the map. If you're concerned about this, keep in mind the result of using the `order by` clause in the Selector might be affected if a Map is used. Given the ease with which maps by SObject ID are created by passing the list into the Map constructor, it's often best to leave this option to wrap or not wrap the list returned up to the calling code.

## Querying fields consistently

It is a good practice to avoid re-querying the same record(s) more than once within the same Apex execution if it can be avoided. Rather than repeating queries for the same record solely to query different fields, it becomes desirable to factor code such that it can pass the queried data as parameters from one method to another, for example from a Service method to a Domain method.

However, this practice can become problematic as when using SOQL, the developer must explicitly list the fields needed at the time the statement is executed, typically stating only the fields needed by the most immediate code path ahead.

Later, as the code evolves, the `SObject` data is passed between methods, particularly shared code. Runtime exceptions can occur if an attempt is made to read from a field that was not originally included in the initial SOQL. This result in the same code executing successfully in one scenario but failing in another, due to SOQL statements for the same data being inconsistently expressed.

For example, consider that the `Contestants.awardChampionshipPoint` Domain class method is updated to utilize the `RaceTime__c` field as well as the `RacePosition__c` field. This method is called from the `ContestantService` and `RaceService` classes. Ignoring the Selector concept for a moment, the following change to `ContestantService` will work just fine to meet this new requirement:

```
Contestants contestants =
    new Contestants(
        [select Id, RacePosition__c, RaceTime__c
         from Contestant__c order by RacePosition__c]);
    contestants.awardChampionshipPoints(uow);
```

However, if left unchanged, the following code from the `RaceService` class will cause the same method to fail with an `Object row was retrieved via SOQL without querying the requested field: Contestant__c.RaceTime__c` exception:

```
List<Contestant__c> contestants = new List<Contestant__c>();
for(Race__c race :
    [select Id,
        (Select RacePosition__c from Contestants__r)
        from Race__c where Id in :ids])
    contestants.addAll(race.Contestants__r);
new Contestants(contestants).awardChampionshipPoints(uow);
```

Also note that the `order by` clause is missing from this example, but specified in the previous one thus, in this case the order of the records returned is non-deterministic. These last two examples illustrate that the records passed to the shared Domain class `Contestants` have the potential to vary in order by caller. This could give rise to unexpected behavior, if the Domain class logic is dependent on the order.

These are the two possible ways to fix these inconsistencies, though neither is ideal:

- Update the `awardChampionshipPoints` method to have it perform its own SOQL query, and ensure that it always gets the information it needs regardless of what was initially passed into the Domain class constructor. While this is arguably more contained, it is wasteful in regards to SOQL queries and performance.
- Search for SOQL statements across the application code and update the corresponding SOQL logic in each area (including relationship sub selects).

Of course, ensuring that both areas have adequate unit and integration testing also somewhat reduces the risk, but neither really helps increase the performance or encourage SOQL reuse. One of the benefits of the Selector pattern is to encapsulate a list of commonly used fields such that all the methods on the Selector return sObjects populated with a consistent set of fields which can be relied on throughout the application code, as long as the Selector is used to query the records.

 Querying more fields can generally be at odds with the desire to maintain a low **heap** and/or **viewstate size** when querying a large number of records in a single execution context, particularly if the Selector is returning queried data for display on a Visualforce page. In a later section of this chapter, we will see how it is possible to use an Apex data class to represent only the field data queried.

## The Selector class template

A Selector class, like the Domain class, utilizes inheritance to gain some standard functionality; in this case, the base class delivered through the **FinancialForce.com Enterprise Apex Patterns** library, `fflib_SObjectSelector`.

A basic example is as follows:

```
public class RacesSelector extends fflib_SObjectSelector {

    public List<Schema.SObjectField> getsObjectFieldList() {
        return new List<Schema.SObjectField> {
            Race__c.Id,
            Race__c.Name,
            Race__c.Status__c,
            Race__c.Season__c,
            Race__c.FastestLapBy__c,
            Race__c.PollPositionLapTime__c,
            Race__c.TotalDNFs__c };
    }

    public Schema.SObjectType getsObjectType() {
        return Race__c.sObjectType;
    }
}
```



The base class uses Dynamic SOQL to implement the features described in this chapter. One potential disadvantage this can bring is that references to the fields are made without the Apex compiler knowing about them, and as such, when you attempt to delete or rename fields, no warning is given that the given field is already referenced. To avoid this, the `SObjectField` reference to the field is used, which is obtained by stating the `SObject` name followed by the field name separated by a period. This is somewhat like a static property on the `SObject` type. This approach ensures that the platform knows the class is referencing the fields, even though they are being used in a dynamic SOQL context.

With this minimal example, the following standard query can be made by leveraging the `selectSObjectsById` base class method. This method takes the information provided by the preceding methods and constructs a SOQL query dynamically and executes it via `Database.executeQuery`:

```
List<Race__c> races = (List<Race__c>)
    new RacesSelector().selectSObjectsById(raceIds);
```

Note that the `fflib_SObjectSelector.selectSObjectsById` base class method performs a number of features, described later in this chapter. Also, note that an instance of the Selector was created but was not actually stored using an instance permits base class behavior to be inherited. Additional benefits of using instances of Selectors are covered later in this chapter when we discuss **Selector factories** and testing.

The preceding Selector method example dynamically creates the following SOQL. As we progress through this chapter, how this is done will become more clear:

```
SELECT
    Name, TotalDNFs__c, Status__c, Season__c, Id,
    PollPositionLapTime__c, FastestLapBy__c
    FROM Race__c
    WHERE id in :idSet ORDER BY Name
```

The following table shows some of the key base class methods of the `fflib_SObjectSelector` class available to your Selector methods and also those that can be overridden. Note that the `getSObjectType` and `getSObjectFieldList` methods are abstract and thus must be implemented as minimum, as per the previous example.

Method	Modifier	Purpose
<code>getSObjectType</code>	abstract	Tells the base class which SObject is being described
<code>getSObjectFieldList</code>	abstract	Returns a list of common fields used when build queries used in this selector class
<code>selectSObjectsById</code>	public	Executes a dynamically generated SOQL query that selects the fields specified by the <code>getSObjectFieldList</code> method.
<code>getOrderBy</code>	virtual	Optionally override this to change the default order by applied to queries generated or executed by the base class.
<code>getSObjectFieldSetList</code>	Virtual	Optionally provide a list of Field Sets for the base class query generator to consider when generating a list of fields to query.
<code>newQueryFactory</code>	public	Provides an object orientated means to further customize the queries generated by the base class before executing them.

The following sections describe these methods in further detail. Do also take some further time to explore further methods and associated code comments in the base class code.

## Implementing the standard query logic

The previous Selector usage example required a cast of the list returned to a list of `Race__c` objects, which is not ideal. To improve this, you can easily add a new method to the class to provide a more specific version of the base class method, as follows:

```
public List<Race__c> selectById(Set<Id>raceIds) {
    return (List<Race__c>) selectSObjectsById(raceIds);
}
```

Thus, the usage code now looks like this:

```
List<Race__c> races =  
    new RacesSelector().selectById(raceIds);
```

## Standard features of the Selector base class

The `fflib_SObjectSelector` base class contains additional functionality to provide more query consistency and integration with the platform. These apply to the aforementioned `selectSObjectsById` method as well as your own. The following sections highlight each of these features.

 You can, of course, extend the standard features of this base class further. Perhaps there is something you want all your queries to consider, a common field or aspect to your schema design, or a feature that is common to most of your selectors. In this case, create your own base class and have your selectors extend that, as follows.

```
public abstract class ApplicationSelector  
    extends fflib_SObjectSelector  
{  
    // Add your common methods here  
}  
public class RacesSelector  
    extends ApplicationSelector  
{  
    // Methods using methods from both base classes  
}
```

## Enforcing object and field security

Salesforce requires developers to implement the **object read security** and **field level read security** checks when querying. Typically using the methods on the `SObjectDescribe` and `SObjectFieldDescribe` Apex runtime types. The following sections describe the `fflib_SObjectSelector` base class support in respect to this.

### Default behavior

By default, the base class methods in the `fflib_SObjectSelector` base class automatically perform Object read security. The ability of the base class to enforce Field level read security is also available but is not enforced by default.

In both cases, if enforcement is enabled and user object or field level read permissions have not been granted for the object or fields referenced in the `getSObjectType` and `getSObjectFieldSetList` methods, an exception will be thrown.

## Overriding the default behavior

You may wish to disable the aforementioned default enforcement in cases where objects are read by the application code on behalf of the user. For example, reading the race data to update other areas of the application on behalf of the user. Such access is often referred to as *system level* access. In these cases, you may not wish to have this check enforced.

Allowing this enforcement check to execute in some cases may not be desirable since, as given in the preceding example, it then requires users to be granted access to the underlying race data object in order to use aspects of the application that read but do not display race data to the user. Another motivation for disabling the selector default behavior would be a preference to code these checks in your controller logic more explicitly.

Constructor parameters provided by the `SObjectSelector` class allow each Selector class to control whether security enforcement is enabled or not. This is also available to any code instantiating a Selector class, allowing this decision to be made on a per use case basis, for example, when the selector is used within a Controller class.

To make it easier to configure the `fflib_SObjectSelector` class throughout the application as well as to provide a means to establish a place for shared or common Selector logic code, a new base class can be created as follows:

```
public abstract class ApplicationSelector
    extends fflib_SObjectSelector {

    public ApplicationSelector() {
        this(false);
    }

    public ApplicationSelector(Boolean includeFieldSetFields) {
        // Disable the default base class read security checking
        // in preference to explicit checking elsewhere
        this(includeFieldSetFields, false, false);
    }

    public ApplicationSelector(
        Boolean includeFieldSetFields,
        Boolean enforceCRUD,
```

```
        Boolean enforceFLS) {  
    // Disable sorting of selected fields to aid debugging  
    // (performance optimisation)  
    super(  
        includeFieldSetFields, enforceCRUD, enforceFLS, false);  
}  
}
```

 The preceding sample also leverages another configuration parameter of the `fflib_SObjectSelector` base class, the `sortSelectFields` parameter. This has been added to allow disablement of the sorting of the field names while building the SOQL queries. While this can aid debugging, it does have a performance overhead. For backwards compatibility the base class retains this behavior, but allows for it to be disabled optionally.

Thus Selector classes in this application extended this class instead:

```
public class RacesSelector extends ApplicationSelector {
```

 Note that this approach requires that the developer takes over exclusive responsibility for implementing object and field level security checking themselves. This will be discussed in further detail a later chapter.

## Ordering

As mentioned in the conventions, having a default order to records is important to avoid the random non-deterministic behavior of the platform SOQL engine. The `selectsObjectById` base class method calls the `getOrderBy` method to determine which field(s) to use to order the records returned from the Selector.

The default behavior is to use the `Name` field (if available, otherwise `CreatedByDate` is used). As such, the previous usage is already ordering by `Name` without further coding. If you wish to change this, override the method as follows. This example is used by the `ContestantsSelector` class to ensure that contestants are always queried in the order of season, race, and their race position:

```
public override String getOrderBy() {  
    return 'Race__r.Season__r.Name, Race__r.Name, RacePosition__c';  
}
```

Later in this chapter, you will see how custom Selector methods can be constructed; these have the option of using the `getOrderBy` method. This allows some methods to use a different `order by` clause other than the default if you wish to do so.

## Field Sets

As was discussed in a previous chapter, utilization of the Field Sets platform feature is the key to ensuring that your application is strongly aligned with the customization capabilities that your application's users expect. However, you might be wondering what it has to do with querying data? Well, even though most of our discussions around this feature will focus on the use of it in a UI context, the additional custom fields added in the subscriber org still need to be queried for them to be displayed; otherwise, an exception will occur just the same as if you had failed to query a packaged field.

To use this feature, you need to override the `getSObjectFieldSetList` method and construct the Selector with the `includeFieldSetFields` parameter. The default constructor sets this parameter to false so that in general, the **Field Sets** fields are not included. The following example assumes a field set on the **Race** object called `SeasonOverview` (included in the code of this chapter):

Field Sets			
Action	Field Label	API Name	Where is this used?
Edit   Del	Season Overview	fforce_SeasonOverview	Used when displaying Race details on the Season overview page.

The following code illustrates the configuration of this feature (note that the logic in the base class also ensures that if the subscriber adds your own packaged fields to the Field Set, such fields are only added to the SOQL statement field list once):

```
public RacesSelector() {
    super();
}

public RacesSelector(Boolean includeFieldSetFields) {
    super(includeFieldSetFields);
}

public override List<Schema.FieldSet>getSObjectFieldSetList() {
    return new List<Schema.FieldSet>
    {
        SObjectType.Race__c.FieldSets.SeasonOverview
    };
}
```

## Multi-Currency

As discussed in *Chapter 2, Leveraging Platform Features*, enabling and referencing certain platform features can create dependencies on your package that require your customers to also enable those features prior to installation, and this might not always be desirable. One such feature is **Multi-Currency**. Once this is enabled, every object gains a `CurrencyIsoCode` field; it then also appears on layouts, reports, and so on. Salesforce ensures that subscribers are fully aware of the implications before enabling it.

If you want to leverage it in your application (but do not think it will be something that all your customers will require), you have the option to reference this field using Dynamic Apex and Dynamic SOQL. It is in this latter area that the `fflib_SObjectSelector` base class provides some assistance.



You might want to consider the approach described here when working with Personal Accounts, as certain fields on the **Account** object are only present if this feature is enabled.

If you explicitly listed the `CurrencyIsoCode` field in your `getSObjectFieldList` method, you will therefore bind your code and the package that contains it to this platform feature. Instead, what the base class does is use the `UserInfo.isMultiCurrencyOrganization` method to dynamically include this field in the SOQL query that it executes. Note that you still need to utilize **Dynamic Apex** to retrieve the field value, as shown in the following code:

```
List<Team__c> teams = (List<Team__c>)
    new TeamsSelector().selectSObjectsById(teamIds);
for(Team__c team : teams) {
    String teamCurrency =
        UserInfo.isMultiCurrencyOrganization() ?
            (String) team.get('CurrencyIsoCode') :
            UserInfo.getDefaultCurrency();
}
```

For Domain logic, you might want to put a common method in your own Domain base class (such as the `ApplicationDomain` class described in the last chapter). This way, you can encapsulate the preceding turnery operation into a single method. The sample code for this chapter contains the `ApplicationDomain.getCurrencyCodes` method, which can be used as follows:

```
public override onBeforeInsert() {  
    Map<Id, String> currencies = getCurrencyCodes();  
    for(Team__c team : (List<Team__c>) Records) {  
        String teamCurrency = currencies.get(team.Id);  
    }  
}
```

## Implementing custom query logic

If we take a look at the implementation of the `selectSObjectById` base class method we have been using so far in this chapter, the `buildQuerySObjectById` method code shown as following, gives an indication of how we implement custom Selector methods; it also highlights the `newQueryFactory` base class method usage:

```
public List<SObject> selectSObjectsById(Set<Id>idSet) {  
    return Database.query(buildQuerySObjectById());  
}  
private String buildQuerySObjectById() {  
    return newQueryFactory().  
        setCondition('id in :idSet').  
        toSOQL();  
}
```

The `newQueryFactory` method exposes an alternative object orientated way to express a SOQL query. It follows the **fluent** design model with its methods making the configuration less verbose. For more information on this approach see [https://en.wikipedia.org/wiki/Fluent\\_interface](https://en.wikipedia.org/wiki/Fluent_interface).

The instance of `fflib_QueryFactory` returned by this method is preconfigured with the object, fields, order by and any field set fields expressed through the selector methods discussed previously. As described earlier it will also enforce security enabled. So in general all you need to do is provide an SOQL where clause via the `setCondition` method, as shown in the last code. Finally, the `toSOQL` method returns the actual SOQL query string that is passed to the standard `Database.query` method.



The `fflib_QueryFactory` class methods provide an alternative to using the standard string concatenation or `String.format` approaches when building dynamic SOQL queries. The original author of the `fflib_QueryFactory` class, **Chris Peterson**, was motivated in creating it to avoid the fragility that string-based methods can give as well as to provide a more readable means of understanding what such code was doing. In addition because the class supports using `SObjectField` references, as opposed to field name references in strings, such code is less prone to **SOQL-injection vulnerabilities**.

## A basic custom Selector method

Let's look first at a basic example, which queries `Driver__c` based on the team they are assigned to. As per the guidelines, the parameters are bulkified and allow you to query for drivers across multiple teams if needed.

```
public List<Driver__c>selectByTeam(Set<Id>teamIds) {
    return (List<Driver__c>)
        Database.query(
            newQueryFactory().
                setCondition('Team__c in :teamIds').
                toSOQL());
}
```

By using the `newQueryFactory` method, the `fflib_QueryFactory` instance is already populated with knowledge of the field list, object name, and `order by` clause specified by the selector. Thus this Selector method behaves consistently in terms of the fields populated and the order of the records returned.

## A custom Selector method with subselect

In the following example, the querying being made uses a **sub-select** to also include child records (in this case, **Contestants** within **Race**). The key thing here is that the `RacesSelector` method (shown in the following code) reuses an instance of the `ContestantsSelector` class to access its field list and perform security checking:

```
public List<Race__c>selectByIdWithContestants(Set<Id>raceIds) {
    fflib_QueryFactoryracesQueryFactory = newQueryFactory();

    fflib_QueryFactorycontestantsSubQueryFactory =
        new ContestantsSelector().
            addQueryFactorySubselect(racesQueryFactory);

    return (List<Race__c>) Database.query(

```

```
    racesQueryFactory.setCondition('Id in :raceIds').toSOQL();
}
```

The preceding code uses the `fflib_SObjectSelector` method `addQueryFactorySubselect`. This method creates a new `fflib_QueryFactory` instance and passes it on to the query factory passed into the method, in this case, the `racesQueryFactory`. When the `toSOQL` method is called on the outer query factory it automatically generates sub-queries for any contained query factories.

By reusing an instance of the `ContestantsSelector`, it is ensured that no matter how a list of `Contestant__c` records are queried (directly or as part of a sub-select query), the fields are populated consistently. The `getOrderBy` method on `ContestantSelector` is also used to ensure that even though the records are being returned as part of a sub-select, the default ordering of **Contestant** records is also maintained.

Let's take another look at the example used earlier to illustrate how this pattern has avoided the dangers of inconsistent querying. Although the `Contestant__c` records are queried from two different selectors, `RacesSelector` and `ContestantsSelector`, the result in terms of fields populated is the same due to the reuse of the `ContestantsSelector` class in the preceding implementation.

The following example shows the standard `selectById` method being used to query **Contestants** to pass to the `Contestants` Domain class constructor, as part of the Service layer implementation to award championship points:

```
List<Contestant__c> contestants =
    new ContestantsSelector().selectById(contestantIds);
    new Contestants(contestants).awardChampionshipPoints(uow);
```

The following alternative example shows the custom `selectByIdWithContestants` method on `RaceSelector` being used to query **Races** and **Contestants** to pass to the `Contestants` Domain class constructor to achieve the same result:

```
List<Contestant__c> contestants = new List<Contestant__c>();
for(Race__c race :
    new RacesSelector().selectByIdWithContestants(raceIds)) {
    contestants.addAll(race.Contestants__r);
}
new Contestants(contestants).awardChampionshipPoints(uow);
```

In either of these two examples, the fields and ordering of the records are consistent, despite the way in which they have been queried, either as a direct query or sub-select. This gives the developer more confidence in using the most optimum approach to query the records needed at the time.

The `selectByIdWithContestants` method generates the following SOQL:

```
select
    Name, TotalDNFs__c, Status__c, Season__c, Id,
    PollPositionLapTime__c, FastestLapBy__c,
    (select
        Qualification1LapTime__c, ChampionshipPoints__c,
        Driver__c, GridPosition__c, Qualification3LapTime__c,
        RacePosition__c, Name, DNF__c, RaceTime__c,
        Id, DriverRace__c, Qualification2LapTime__c, Race__c
    from Contestants__r
    order by Race__r.Season__r.Name, Race__r.Name,
        RacePosition__c)
    from Race__c where id in :raceIds order by Name
```

## A custom Selector method with related fields

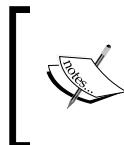
In addition to querying child records, related records can also be queried using the SOQL field dot notation. This provides an additional way to optimize the querying of additional record information, along with having to make an additional query.

The following is an example of a custom Selector method for the `ContestantsSelector` class, where `Contestant` records are queried along with the related `Driver` record fields. The resulting `Contestant__c` objects expose the `Driver__r` field, which provides an instance of `Driver__c` populated with the `Driver__c` fields specified in `DriversSelector`:

```
public List<Contestant__c>selectByIdWithDriver(Set<Id>driverIds) {
    fflib_QueryFactorycontestantFactory = newQueryFactory();

    new DriversSelector().
        configureQueryFactoryFields(
            contestantFactory,
            Contestant__c.Driver__c.getDescribe().getRelationshipName());

    return Database.query(
        contestantFactory.setCondition('Id in :driverIds').toSOQL());
}
```



The `fflib_SObjectSelector.configureQueryFactoryFields` method adds the selector fields to the query factory passed as the first parameter, utilizing the relationship prefix specified in the second parameter.

Due to the reuse of `DriversSelector` in the `ContestantsSelector` classes method in the last code, the following examples return consistently populated `Driver__c` records. This is important to the logic contained within the Domain class's `Drivers.verifyCompliance` method. This flexibility allows for the most optimum way of querying `Driver__c` records and safer reuse of the Domain class method regardless of how the records were queried.

This first example constructs the `Drivers` domain class with results from the standard `selectById` method on the `DriversSelector` class:

```
List<Driver__c> drivers =
    new DriversSelector().selectById(driverIds);
List<ComplianceService.VerifyResult> results =
    new Drivers(drivers).verifyCompliance();
```

This second example achieves the same, but queries the `Drivers` records via the custom Selector method, `selectByIdWithDriver`, on the `ContestantsSelector` class:

```
List<Driver__c> drivers = new List<Driver__c>();
List<Contestant__c> contestants =
    new ContestantsSelector().selectByIdWithDriver(contIds);
for(Contestant__c contestant : contestants)
    drivers.add(contestant.Driver__r);
List<ComplianceService.VerifyResult> results =
    new Drivers(drivers).verifyCompliance();
```

Again, both of these examples have shown that even when using related fields in SOQL, the resulting records can be kept in alignment with the desired fields as expressed by the selectors. The `selectByIdWithDriver` method generates the following SOQL:

```
SELECT
    Qualification1LapTime__c, ChampionshipPoints__c, Driver__c,
    GridPosition__c, Qualification3LapTime__c, RacePosition__c,
    Name, DNF__c, RaceTime__c, Id, DriverRace__c,
    Qualification2LapTime__c, Race__c,
    Driver__r.FIASuperLicense__c, Driver__r.Name,
    Driver__r.Id, Driver__r.Team__c
FROM Contestant__c
WHERE Id in :driverIds
ORDER BY Name
```

## A custom Selector method with a custom data set

SOQL has a very rich dot notation to traverse relationship (lookup) fields to access other fields on related records within a single query. To obtain the following information in a tabular form, it needs to traverse up and down the relationships across many of the objects in the FormulaForce application object schema:

- The season name
- The race name
- The race position
- The driver's name
- The car name

First, let's consider the following SOQL and then look at how it and the data it returns can be encapsulated in a `ContestantsSelector` class method. Note that the common `order by` clause is also applied here as was the case in the previous example:

```
select
    Race__r.Season__r.Name,
    Race__r.Name, RacePosition__c,
    Driver__r.Name,
    Driver__r.Team__r.Name,
    Car__r.Name
from
    Contestant__c
where
    Race__c in :raceIds
order by
    Race__r.Season__r.Name, Race__r.Name, RacePosition__c
```

This query will result in partially populated `Contestant__c` objects, not only that, but relationship fields will also expose partially populated `Season__c`, `Car__c`, and `Driver__c` records. Thus, these are highly specialized instances of records to simply return into the calling code path.

The following code shows an alternative to the preceding query, using a new `ContestantsSelector` method. The biggest difference from the previous ones is that it returns a **custom Apex data type** and not the `Contestant__c` object. You can also see that it's much easier to see what information is available and what is not:

```
List<ContestantsSelector.Summary> summaries =
    new ContestantsSelector().
        selectByRaceIdWithContestantSummary(raceIds).values();
for(ContestantsSelector.Summary summary : summaries) {
    System.debug(
        summary.Season + ' ' +
        summary.Race + ' ' +
        summary.Position + ' ' +
        summary.Driver + ' ' +
        summary.Team + ' ' +
        summary.Car);
}
```

Depending on your data, this would output something like the following debug:

```
USER_DEBUG| [26] |DEBUG| 2016 Spa 1 Lewis Hamilton Mercedes MP4-29
USER_DEBUG| [26] |DEBUG| 2016 Spa 2 Rubens Barrichello Williams FW36
```

The Selector method returns a new **Apex inner class** that uses Apex properties to explicitly expose only the field information queried, thus creating a clearer contract between the Selector method and the caller.

It is now not possible to reference the information that has not been queried and would result in runtime errors when code attempts to reference fields that are not queried. The following shows an Apex inner class that the Selector uses to explicitly expose only the information queried by a custom Selector method:

```
public class Summary {
    private Contestant__c contestant;
    public String Season {
        get { return contestant.Race__r.Season__r.Name; } }
    public String Race {
        get { return contestant.Race__r.Name; } }
    public Decimal Position {
        get { return contestant.RacePosition__c; } }
    public String Driver {
        get { return contestant.Driver__r.Name; } }
    public String Team {
        get { return contestant.Driver__r.Team__r.Name; } }
    public String Car {
        get { return contestant.Car__r.Name; } }
```

```
private Summary(Contestant__c contestant)
  { this.contestant = contestant; }
}
```

The Summary class contains an instance of the query data privately, so no additional heap is used up. It exposes the information as read only and makes the constructor private, indicating that only instances of this class are available through the ContestantsSelector class.

Shown in the following code is the Selector method that performs the actual query:

```
public Map<Id, List<Summary>>
selectByRaceIdWithContestantSummary(Set<Id>raceIds) {
  Map<Id, List<Summary>>summariesByRaceId =
    new Map<Id, List<Summary>>();

  for(Contestant__c contestant :
    Database.query(
      newQueryFactory(false) .
        selectField(Contestant__c.RacePosition__c) .
        selectField('Race__r.Name') .
        selectField('Race__r.Season__r.Name') .
        selectField('Driver__r.Name') .
        selectField('Driver__r.Team__r.Name') .
        selectField('Car__r.Name') .
        setCondition('Race__c in :raceIds') .
        toSOQL())){
    List<Summary> summaries =
      summariesByRaceId.get(contestant.Race__c);
    if(summaries==null) {
      summariesByRaceId.put(
        contestant.Race__c, summaries = new List<Summary>());
      summaries.add(new Summary(contestant));
    }
  }
  return summariesByRaceId;
}
```



You can utilize the Apex Describe API to add compile-time checking and referential integrity into the preceding relationship references. For example, instead of hardcoded `Race__r.Name` you can use the following:

```
Contestant__c.Race__c.getDescribe().  
getRelationshipName() + '.' + Race__c.Name
```

The preceding code shows the `newQueryFactory` method being passed `false`. This instructs the base class not to configure the query factory returned with the selector fields. This allows the caller to use the `selectField` method to specify particular fields as required.



If you are implementing an Apex interface which references custom Selectors method using custom datasets, as described in this section, you should consider creating the class as a top-level class. This avoids potential circular dependencies occurring between the interface and selector class.

## Combining Apex data types with SObject types

It is possible to combine Apex data types with SObject data types in responses from Selector methods. So long as when you return SObject data types, they are populated according to the fields indicated by the corresponding Selector.

For example, let's say we want to return an entire `Driver__c` record associated with the **Contestant** object, instead of just the **Driver** name. The change to the `Summary` Apex class will be to expose the queried `Driver__c` record, which is safe as it has been populated in accordance with the `DriversSelector`. The following code shows how the `Summary` class can be modified to expose the `Driver__c` record as queried in the custom Selector method:

```
public class Summary {  
    public Driver__c Driver {  
        get { return contestant.Driver__r; } }  
    ...  
}
```

In this example a `DriversSelector` instance is used to obtain the field list, which is injected into the query factory along with other specific fields:

```
fflib_QueryFactory contestantQueryFactory =
    newQueryFactory(false).
        selectField(Contestant__c.RacePosition__c).
        selectField('Race__r.Name').
        selectField('Race__r.Season__r.Name').
        selectField('Car__r.Name').
        setCondition('Race__c in :raceIds');

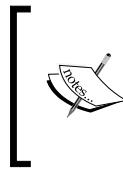
new DriversSelector().
    configureQueryFactoryFields(
        contestantQueryFactory,
        Contestant__c.Driver__c.getDescribe().getRelationshipName());

Map<Id, List<Summary>> summariesByRaceId =
    new Map<Id, List<Summary>>();
for(Contestant__c contestant :
    Database.query(contestantQueryFactory.toSOQL())) {
    ...
```

## SOSL and Aggregate SOQL queries

SOQL is not the only way to query information from the database. Force.com also provides a power **Salesforce Object Search Language (SOSL)** facility. Like SOQL, this returns SObjects. While this chapter has not covered this variation in depth, the use of Selector methods encapsulating SOSL is appropriate and in fact provides a good abstract from the caller, allowing the developer of the Selector to use SOQL or SOSL in future without impacting the callers.

Likewise, **Aggregate SOQL** queries are also good candidates to encapsulate in Selector methods. However, in these cases, consider using Apex native data types (for example, a list of values) or lists of custom Apex data types to expose the aggregate information.



The consolidated source code for this book, available in the master branch of the GitHub repository, contains a `RaceDataSelector` class. Within this class is a custom Selector method, `selectAnaysisGroupByRaceName`, that demonstrates the use of a SOQL aggregate query.

## Introducing the Selector factory

The last chapter introduced the concept of a **Domain factory**, which was used to dynamically construct Domain class instances implementing a **common Apex Interface** in order to implement the compliance framework.

The following code is used in the `ComplianceService.verify` method's implementation, making no reference at all to a Selector class to query the records needed to construct the applicable Domain class:

```
fflib_SObjectDomain domain =
    Application.Domain.newInstance(recordIds);
```

So, how did the Domain factory retrieve the records in order to pass them to the underlying Domain class constructor? The answer is that it internally used another factory implementation called the **Selector factory**.

As with the Domain factory, the Selector factory resides within the `Application` class as a static instance, exposed via the `Selector` static class member, as follows:

```
public class Application
{
    // Configure and create the SelectorFactory for this Application
    public static final fflib_Application.SelectorFactory Selector =
        new fflib_Application.SelectorFactory(
            new Map<SObjectType, Type> {
                Team__c.SObjectType => TeamsSelector.class,
                Race__c.SObjectType => RacesSelector.class,
                Car__c.SObjectType => CarsSelector.class,
                Driver__c.SObjectType => DriversSelector.class,
                Contestant__c.SObjectType => ContestantsSelector.class });

    // Configure and create the DomainFactory for this Application
    public static final fflib_Application.DomainFactory Domain =
        new fflib_Application.DomainFactory(
            Application.Selector,
            // Map SObjectType to Domain Class Constructors
            new Map<SObjectType, Type> {
                Team__c.SObjectType => Teams.Constructor.class,
                Race__c.SObjectType => Races.Constructor.class,
                Car__c.SObjectType => Cars.Constructor.class,
                Driver__c.SObjectType => Drivers.Constructor.class,
                Contestant__c.SObjectType =>
                    Contestants.Constructor.class});
}
```

Notice that the Selector factory is passed to the Domain factory in the preceding example. The following sections outline the methods on the factory and relevant use cases.

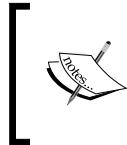
## SelectorFactory methods

The `SelectorFactory` class has two methods on it: `newInstance` and `selectById`. The following code illustrates both these methods by showing two equivalent usage examples to retrieve records given a set of IDs:

```
List<Contestant__c> contestants =
    Application.Selector.selectById(contestantIds);

List<Contestant__c> contestants =
    Application.Selector.newInstance(Contestant__c.SObjectType)
        .selectSObjectsById(contestantIds);
```

As you can see from the preceding code, the `selectById` method provides a shortcut to access the generic `selectSObjectById` method from the `fflib_ISObjectSelector` interface and as seen earlier in this chapter is implemented by the `fflib_SObjectSelector` base class. As such all Selector classes are guaranteed to provide it. It offers a cleaner way of querying records in the standard way without having to know the Apex class name for the Selector. This effectively is how the Domain Factory can dynamically instantiate a Domain class instance loaded with records on behalf of the developer.



The method internally uses `Id.getSObjectType` (on the first ID that is passed in) to look up the Selector class through the map defined previously and instantiate it (via `Type.newInstance`).

You would use the `newInstance` method instead of just instantiating directly via the `new` operator in the Selector class when you are writing generic code which handles different types of objects. In other cases you can continue to instantiate Selector classes in the normal manner using the `new` operator.

## Writing tests and the Selector layer

When writing tests specifically for a Selector class method, the process is almost as per the standard Apex testing guidelines; insert the data you need to support the queries, call the Selector methods, and assert the results returned. You can review some of the Selector tests included in this chapter.



If you have implemented Selector methods that return `QueryLocator` instances (for use by Batch Apex callers), you can still assert the results of these methods. Use the `iterator` method to obtain `QueryLocatorIterator`, then call the `next` and `hasNext` methods to return the results to pass to your assert statements.

Of course, other Apex tests around the **Controllers**, **Batch Apex**, **Domain**, and **Service** layers might also invoke the Selector methods indirectly, thus providing code coverage, but not necessarily testing every aspect of the Selector classes.



Try to ensure that your Apex tests test the layers and functional components of the application as much as possible in isolation to ensure that the existing and future callers don't run into issues.

As highlighted previously, often writing more isolated Apex tests can be made harder due to the fact that the code being tested often requires records to be set up in the database. By leveraging the Selector factory option described earlier, a **mocking** approach can be taken to the Selector methods, which can help make writing more isolated and varied component or class level tests easier. We will revisit this topic in a later chapter.

## Updating the FormulaForce package

Review the updated code supplied with this chapter and update your **packaging** org. Perform another upload and install the package in your testing org. During install you should observe that the new Field Set component added in this chapter is shown as one of the new components included in the upgrade.

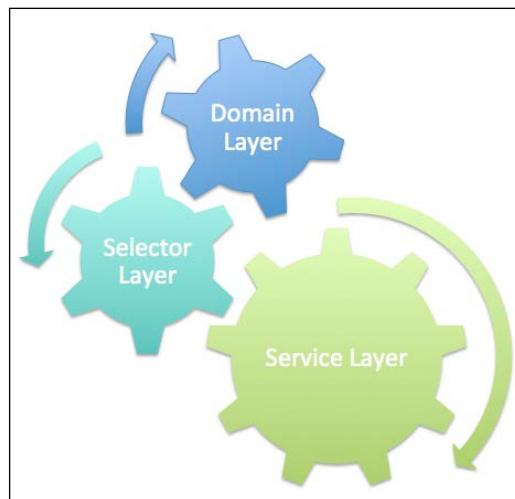
## Summary

The Selector pattern provides a powerful layer of encapsulation for some critical logic in your application. It can help with enforcing best practices around security and provides a more consistent and reliable basis for code dealing with the `sObject` data.

Selectors can also take on the responsibility and concern for platform features such as **Multi-Currency** and **Field Sets**. Ultimately allowing the caller – be that the Service, Domain, or even Apex Controllers, or Batch Apex – to focus on their responsibilities and concerns, this leads to cleaner code which is easier to maintain and evolve.

With the introduction of the Selector factory, we provide a shortcut to access this layer in the form of the `Application.Selector.selectById` and `Application.Selector.newInstance` methods, opening up potential for more dynamic scenarios such as the compliance framework highlighted in the last chapter.

I'd like to close this set of chapters with a simple but expressive diagram that shows how the Service layer code turns with the help of the Domain and Selector layers. These three patterns on Force.com help add value to the developer through consistency and also support best practices around bulkification and code reuse.



While this is the last chapter focusing on a Force.com implementation of Martin Fowler's Enterprise Application Architecture patterns, we will revisit the role of the Selector in a later chapter and focus on Batch Apex as well as continuing to leverage our Service layer in later chapters that discuss the application integration.

# 8

# User Interface

If I were to list all the technologies that have come and gone most often in my career, I would say it has to be those that impact the end user experience. Being a UI technology developer is a tough business; the shift from desktop to web to mobile to device agnostic has shaken things up, and this situation is still ongoing! This means that the investment in this part of your application architecture is important, as is the logic you put into it. Putting the wrong kind of logic in your client tier can result in inconsistent behavior and, at worst, an expensive rework if you decide to shift client technology in the future.

This chapter discusses the aspects of delivering a user interface for Force.com-based applications, getting the most from the Salesforce standard UIs and building custom UIs with Lightning versus Visualforce. It also discusses using third-party-rich client frameworks, contrasting their architecture's pros and cons with respect to platform features and performance. The chapter also covers how to use the **Service layer** and the **Domain layer** patterns, to ensure that your users' interaction with your application is consistent, regardless of the user interface approach. We will cover the following topics in this chapter:

- Which devices should you target?
- Leveraging the Salesforce standard UIs
- Generating downloadable and printable content
- Translation and localization
- Client server communication
- Managing limits
- Object- and Field-Level security
- Managing and monitoring UI response times
- Considerations for using third party JavaScript libraries

- Creating websites and external facing pages for communities
- Mobile applications
- Custom Reporting and the Analytics API

## Which devices should you target?

One of the first questions historically asked when developing a web-based application is *Which desktop browsers and versions shall we support?* These days, you should not be thinking so much about the software installed on the laptops and desktops of your users, but rather the devices they own.

The answer will still likely include a laptop or desktop, though no longer is it a safe assumption that these are the main devices your users use to interact with your application. Mobile phones, tablets, watches or skills for voice recognition devices such as **Alexa** could all be used, or depending on your target market, larger devices such as cars or even a vending machine! So, make sure that you think big and understand all the types of devices your customers and their customers might want to interact with your application.



For your desktop and laptop users interacting with your Force.com application, it is a combination of using the standard Salesforce UI and any custom UIs you might have built with HTML and JavaScript. Given this fact, it is a good idea to base your supported browser matrix on that supported by Salesforce. You can find this by searching for *Salesforce supported browsers* in Google. At the time of writing this, a PDF listing supported browsers can be found at [https://help.salesforce.com/apex/HTViewHelpDoc?id=getstart\\_browser\\_overview.htm&language=en](https://help.salesforce.com/apex/HTViewHelpDoc?id=getstart_browser_overview.htm&language=en).

Developing against multiple devices can be expensive, not only in terms of developing the solution but also performing the testing across multiple devices. In this chapter, we will take a look at a range of options, ranging from those provided by Salesforce at no additional development cost to building totally customized user interfaces using Visualforce, Lightning and other technologies.

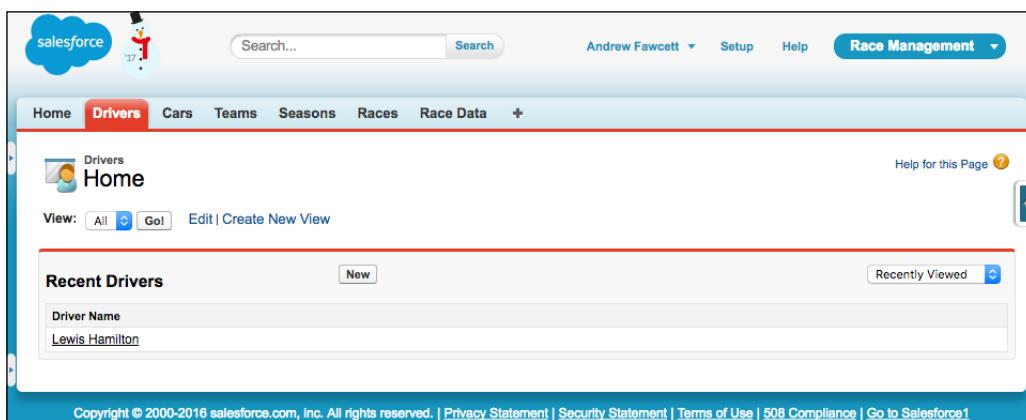
# Introducing Salesforce Standard UIs and Lightning

Choice can be a good thing, but sometimes, the choices are not very clear, especially when new technologies emerge and overlapping with existing ones. In this chapter and the next, we will be exploring features that help you make the choice between **standard UIs** provided by Salesforce, or building your own **custom UIs** or, in fact, balancing the use of both. With the advent of the new Lightning technology from Salesforce, deciding what technology to use for a given custom UI requires some consideration.

Salesforce has historically provided Visualforce as the recommended technology for building custom UIs. To some developers, it resembles Java Server Pages or .NET Active Server Pages, and is very powerful and stable. They also provide a great number of ways to extend their standard UIs with custom UIs built with Visualforce, allowing you to make the choice at a more granular function-by-function level, depending on what works best for your particular user personas.

To further complicate things, Salesforce's standard UIs now come in different variants for users to choose from. There is the Salesforce1 application, for mobiles and now two options for desktop users. The two desktop UIs from Salesforce are now known as **Salesforce Classic** and **Salesforce Lightning Experience**.

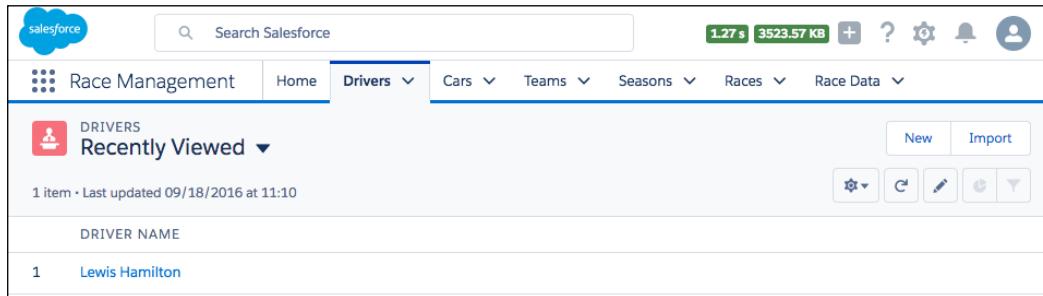
The FormulaForce application in the Salesforce Classic standard UI is shown here:



## User Interface

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This is how it is shown in the Salesforce Lightning Experience standard UI:



The screenshot shows the Salesforce Lightning Experience interface. At the top, there is a navigation bar with the Salesforce logo, a search bar, and various system icons. Below the navigation bar, a main menu is visible with items like 'Race Management', 'Home', 'Drivers' (which is currently selected), 'Cars', 'Teams', 'Seasons', 'Races', and 'Race Data'. The main content area is titled 'DRIVERS Recently Viewed'. It displays a single item: 'Lewis Hamilton'. There are buttons for 'New' and 'Import' at the top of the list, and a set of standard list management buttons (New, Import, Delete, Edit, etc.) below the list. A note at the bottom of the list indicates '1 item · Last updated 09/18/2016 at 11:10'.



There are more options to brand your application in Lightning Experience. We will cover this further in the next chapter.



**Lightning Experience** (or **LEX** for short) brings with it an entirely new **client side architecture**, which departs from the **server-side rendering** for its predecessor (Salesforce Classic) and Visualforce provided. For backwards compatibility, Visualforce UIs can still be used within Lightning Experience, although, using Visualforce in LEX will not offer the level of extensibility or visual appeal as custom UIs built using the Lightning framework.



LEX provides much more integration points for developers to extend the standard UI, reducing the need to build an entirely new replacement page from scratch. This chapter and the next will explore in more detail the ways in which Lightning Components can be used to extend LEX features with your own, thereby reducing the development costs for you, and giving your customers even more value from the Salesforce standard UIs and customization tools.



For the first time, developers can now use the same technology and theme Salesforce have used to build their LEX based applications, known as the **Lightning Framework**. Salesforce has also chosen to open source their styling framework used by Lightning, which is known as the **Lightning Design System (LDS)**. This is built into the platform and is available as a set of CSS files if you want to use it in Visualforce or externally (<https://www.lightningdesignsystem.com/>).

## Why consider Visualforce over the Lightning Framework?

So why is Visualforce still a consideration? At the time of writing this book, the Lightning framework is taking some big steps forward in providing the same facilities and components that Visualforce already has. But it's not quite there yet; there are some gaps to be aware of.

If you're reading this having already developed a Force.com application prior to Lightning, you will still very much be very interested in leveraging Visualforce until you can migrate. In this case, you will also no doubt be interested in ways to combine both technologies, so that you can perhaps start to develop new features in Lightning framework.

In the next chapter, we will go into more detail on ways to balance both technologies. For now, and likely for the next couple of years, while adoption builds, Salesforce Classic and Lightning Experience are going to co-exist.

## Leveraging the Salesforce standard UIs

Salesforce puts a lot of effort into its desktop and mobile based UIs. These declarative UIs are the first to see advancements, such as the ability to embed reporting charts. These standard user interfaces are also the primary method by which your subscribers will customize your application's appearance. Furthermore, the UI will evolve with Salesforce's frequent updates. In some cases, new features are available to your users, even without you updating your application.



In general, aspects of your application that had already leveraged the standard UI in Salesforce Classic will just work fine in Lightning Experience without change, and will also automatically adopt the new look and feel. However, if you have utilized Visualforce extensively, and/or used unsupported features such as JavaScript Custom Buttons, you will have to make some changes. Carefully test and explore your application in Lightning Experience to understand what changes you need to make. In the next chapter, we will explore some key aspects of this transition and balancing the two technologies.

In general, you should ensure that for all the objects in your application, you make the best use of the standard UI by ensuring that your packaged layouts are highly polished, and make use of every last drop of the declarative features. It is even worth considering this practice for those objects that might be typically accessed through Visualforce or Lightning-based custom UIs.

Considering the standard UI as a kind of primary or default UI also ensures that the validation in your Domain classes is complete, which ensures that it is not possible to enter invalid data regardless of how that data is entered—custom UI, standard UI, or API.

Ensure that you apply the same UI review processes you undertook on your custom UIs to the standard UI layouts. Take care to review field labels, sections, button names, and general layout while also looking for options to add more related information through report charts or embedding custom UIs, as described later in this chapter. Also, consider making use of record types and different layouts to help reduce the number of fields that a user has to enter.



Keep in mind that Salesforce layouts packaged in your application are not upgradable, as they can be edited by the subscriber. So, no matter what improvements you make to your layouts in subsequent releases, these will only be available to new customers, and not to those who are upgrading to newer versions of the application. New aspects to layouts are typically expressed in your install/upgrade documentation.

## Overriding standard Salesforce UI actions

You can override the Salesforce standard UI for the following actions: **Accept**, **Tab**, **Clone**, **Delete**, **Edit**, **List**, **New**, and **View** for an object with your own Visualforce pages, completely replacing the standard UI pages. This will also appear in LEX.



When overriding the View action, it is also possible to specify a Lightning Page (or FlexiPage as it is also known) through the **Lightning App Builder** tool (under **Setup**). In this case the Visualforce page you assign will only show within Salesforce Classic, and the Lightning Page will then show in LEX.

Be aware that, if you take this option, you're taking on the responsibility of not only ensuring that new fields added to the your application are added to such pages but also that new platform features of the standard UI appear in your page as Salesforce evolves the platform. So, be sure to review the standard UI page functionality before making the decision to package and override for the applicable action and also consider a hybrid approach described in the next subsection.

If you decide to build a custom UI, the best way to keep inline is to use the Salesforce provided standard UI components. In Visualforce these are available in the `apex` namespace. In Lightning you can leverage the components in the `lightning` namespace. In either case you can style custom UI HTML elements with the Lightning Design System.

Using Salesforce-provided components is not however a complete solution; for example, **Chatter** does not automatically appear on pages unless a developer enables it. Another significant consideration is that custom fields or related lists subscribers added to your objects need special consideration in your page code to ensure that these are surfaced, through the use of the **Field Sets** and the `apex:relatedList` component, for example.

Finally, note that, although the **Custom Object Action overrides** (defined by you) can be packaged, they are nonupgradable, so changes will not apply to existing subscribers. Also, the subscriber can remove them post-installation if they prefer to access the custom object through the standard UI, so this is another reason to make sure that you consider the standard UI for all of your objects as a standard practice.

 As an alternative to overriding an existing standard action, consider creating **Custom Buttons**, placing them on the object's **Detail page** and/or **List View layouts**, and naming the button something like **Enhanced Edit** or **Enhanced New**. Custom Buttons are available in both Salesforce Classic and LEX standard UIs to invoke Visualforce pages. However, they do not support Lightning-based custom UIs you build. To invoke a Lightning Component from the standard UI in LEX, you can either embed it in the **Lightning Record Page** layout (as shown in *Chapter 6, Application Domain Layer*) or utilize **Lightning Component Actions** (discussed in *Chapter 9, Lightning*).

## Combining standard UIs with custom UIs

Unless your user experience is such that it is entirely different from that offered by the standard UIs, always try to retain as much of the standard UIs as you can. The platform provides a number of ways to do this, which we will be exploring through this chapter and the next. In this section we will explore ways to embed in specific regions of the standard UI parts of a custom UI and vice versa.

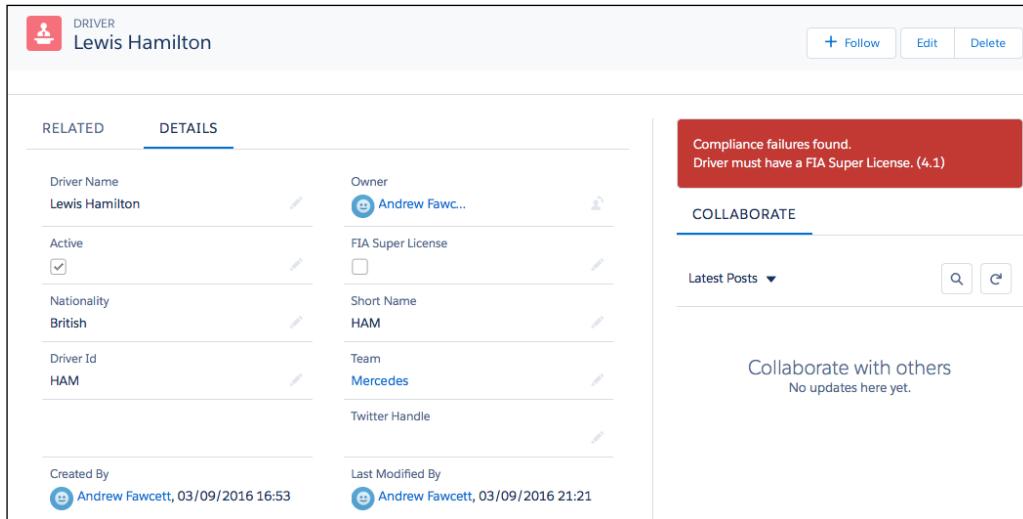
### Embedding a custom UI in a standard UI

In *Chapter 6, Application Domain Layer*, we looked at a Lightning Component which can be placed on the Lightning Record Page layout. This approach only applies to LEX, and also provides some additional benefits such as being able to listen to events LEX fires as users in-line edit the record details. This approach currently only applies when viewing the record details.

## User Interface

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The following screenshot is a reminder of what the **Compliance Verification** component looked like when placed on the LEX standard UI:



The screenshot shows a standard LEX detail page for a 'DRIVER' record. The record is for 'Lewis Hamilton'. The 'DETAILS' tab is selected. The page displays various driver details in a table format. On the right side, there is a 'COLLABORATE' section with a red callout box containing the message: 'Compliance failures found. Driver must have a FIA Super License. (4.1)'. Below this, there is a 'Latest Posts' section with a search and refresh button, and a 'Collaborate with others' section stating 'No updates here yet.'

Let's now look at an example on how to customize the standard UI that applies both to Salesforce Classic and LEX. By embedding a Visualforce page in detail **Page Layout** as shown in the following screenshot for the `Race` object. Page Layouts are leveraged in both Salesforce Classic and LEX.

The following Visualforce page uses the `$User.UIThemeDisplayed` **global variable** to style the page accordingly. It reuses the **Extension Controller** from the previous chapter:

```
<apex:page standardController="Race__c" extensions="RaceSummaryController" action="{!loadSummary}">
    <apex:slds/>
    <apex:outputPanel rendered=" {!$User.UIThemeDisplayed == 'Theme3' } " >
        <apex:pageBlock>
            <apex:pageBlockTable value=" {!Summary } " var="summaryRow" >
                <apex:column value=" {!summaryRow.Position } " >
                    <apex:facet name="header">Position</apex:facet>
                </apex:column>
                <apex:column value=" {!summaryRow.Driver } " >
                    <apex:facet name="header">Driver</apex:facet>
                </apex:column>
                <apex:column value=" {!summaryRow.Team } " >
                    <apex:facet name="header">Team</apex:facet>
                </apex:column>
            </apex:pageBlockTable>
        </apex:pageBlock>
    </apex:outputPanel>
</apex:page>
```

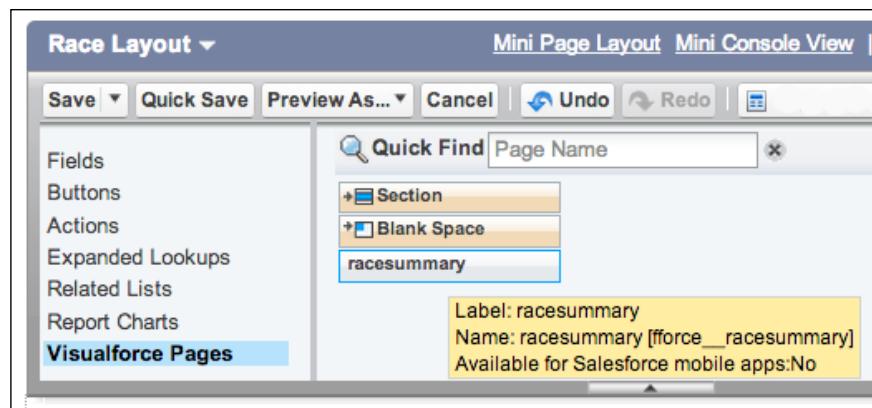
```
</apex:column>
<apex:column value="{ !summaryRow.Car }">
    <apex:facet name="header">Car</apex:facet>
</apex:column>
</apex:pageBlockTable>
</apex:pageBlock>
</apex:outputPanel>
<apex:outputPanel
    rendered=" {!$User.UIThemeDisplayed == 'Theme4d' } "
<div class="slds">
    <table
        class="slds-table slds-table--bordered
                slds-table--cell-buffer">
        <thead>
            <tr class="slds-text-title--caps">
                <th scope="col">
                    <div
                        class="slds-truncate" title="Position">Position</div>
                </th>
                <th scope="col">
                    <div class="slds-truncate" title="Driver">Driver</div>
                </th>
                <th scope="col">
                    <div class="slds-truncate" title="Team">Team</div>
                </th>
                <th scope="col">
                    <div class="slds-truncate" title="Car">Car</div>
                </th>
            </tr>
        </thead>
        <tbody>
            <apex:repeat value="{ !Summary }" var="summaryRow">
                <tr>
                    <th scope="row" data-label="Position">
                        <div
                            class="slds-truncate">{ !summaryRow.Position }</div>
                    </th>
                    <td data-label="Driver">
                        <div class="slds-truncate">{ !summaryRow.Driver }</div>
                    </td>
                    <td data-label="Team">
                        <div class="slds-truncate">{ !summaryRow.Team }</div>
                    </td>
                    <td data-label="Car">
```

## User Interface

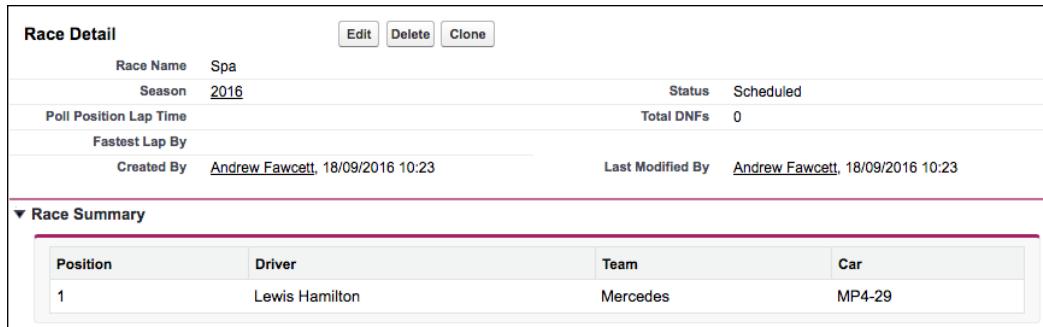
---

```
<div class="slds-truncate">{ !summaryRow.Car }</div>
</td>
</tr>
</apex:repeat>
</tbody>
</table>
</div>
</apex:outputPanel>
</apex:page>
```

As the page uses `StandardController`, it appears in the layout editor and can be positioned on the layout:



You can then drag and drop it into an existing or new section on the layout. The result will look something like the following screenshot in Salesforce Classic:



In Salesforce LEX the page looks like the following screenshot:

RELATED	DETAILS		
Race Name Spa			
Season 2016	Status Scheduled		
Poll Position Lap Time	Total DNFs 0		
Fastest Lap By			
Created By  Andrew Fawcett, 18/09/2016 10:23	Last Modified By  Andrew Fawcett, 18/09/2016 10:23		
Race Summary			
POSITION	DRIVER	TEAM	CAR
1	Lewis Hamilton	Mercedes	MP4-29

When in Salesforce Classic, this approach only applies to the layouts when users are viewing records. You can, however, provide a means for users to edit the information through such Visualforce pages even though they are rendered on the view page for the record. There is, however, no way to refresh the main page when you do so. While the width of the Visualforce page will adjust automatically, the height is fixed, so be sure to set accordingly to common data volumes. Unlike Salesforce Classic, users in Salesforce LEX will see embedded Visualforce pages in layouts when creating and editing records as well as viewing them. Ensure that your pages expect these scenarios in LEX, for example, the `StandardController.getId` method will return `null` in a record create scenario, your code should handle this accordingly.



## Embedding a standard UI in a custom UI

Depending on the custom UI technology you use, there are different options to embed the standard UI page layout. Note that when you do this, any embedded Visualforce pages are also included.

For Salesforce Classic, the `apex:detail` tag can be used on a Visualforce page to render most of the look and feel of the standard UI; note that it is not automatically restyled when the page is shown in LEX. The component is not very granular; for example, you cannot add your own buttons alongside the standard buttons it renders. This means that your page buttons need to be rendered elsewhere on the page, making the UI look inconsistent and confusing. In addition, this component only renders a read-only view of the record layout. In most cases, the hybrid approach described earlier in the chapter provides a better solution to most requirements like this.

For Salesforce LEX, the `force:recordEdit` and `force:recordView` components support both record editing and viewing within custom UIs built using Lightning Components. In contrast to the `apex:detail` component in Visualforce, action buttons are not rendered. The developer is responsible for informing the component when to save the details by firing the `recordSave` **Lightning Event**. The component responds with the `onSaveSuccess` event when the record is saved successfully.

## Extending the Salesforce standard UIs

The previous sections described a way to embed custom UIs within the standard UIs as a means of extending the Salesforce UIs with your own application functionality. The following sections outline the further options available in Salesforce Classic and LEX respectively. Some features exist in both, others have been re-envisioned in LEX through the ability to embed and invoke Lightning Components from different areas.

## Visualforce Pages

Visualforce is not only a powerful way to create entirely new pages for your application, but also augments the Salesforce user interface in multiple places. As we've seen so far, you can use it to extend the standard UI layouts and Custom Buttons. Here is a list of platform areas that accept Visualforce pages:

- Layout sections
- Custom Buttons
- Custom Tabs
- Custom Tab Splash page
- Chatter Custom Publisher Actions
- Sidebar component
- Dashboard component
- Force.com sites

Profiles and Permission Sets also reference Visualforce pages; users must be given access to a page before they can use it from these areas.

## Lightning Components

The following is a list of platform areas that accept Lightning Components:

- Record Pages
- Home Pages
- Lightning Tabs and Pages
- Lightning Component Actions
- Lightning Experience Utility Bar
- Lightning App Builder
- Lightning Community and Community Builder
- Lightning Out for Visualforce
- Lightning Out for Any App

In *Chapter 6, Application Domain Layer*, we explored adding the **Verify Compliance** Lightning Component to Record Pages. In the next chapter, we will build some new Lightning Components to allow us to take a closer look at some of the other areas in the preceding list. You should also refer to the *Lightning Developer Guide* for full details.

## Generating downloadable content

The `contentType` attribute allows you to control how the browser interprets the page output. With this attribute, you can, for example, output some CSV, JSON, or XML content. Using a controller binding, this can be dynamically generated output. This can be useful to generate content to download. The following changes have been made to the FormulaForce application and are included in the code for this chapter:

- Added a new method, `generateSummaryAsCSV`, to `RaceService`
- Added a new `getCSVContent` method to `RaceSummaryController`
- Added a new `racesummaryascsv` Visualforce page
- Added a new Custom Button, **Download Summary**, to the **Race** layout

## User Interface

---

The new method is added to the existing `RaceSummaryController` class, but is only used by the new page. Feel free to review the new Service method; note that it also uses the `ContestantsSelector.selectByRaceIdWithContestantSummary` method introduced in the previous chapter. Here is the new controller method calling it:

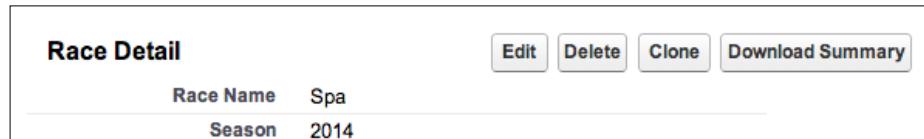
```
public String getCSVContent() {  
    return RaceService.generateSummaryAsCSV(  
        new Set<Id> { standardController.getId() });  
}
```

 The `RaceService` class contains the logic to generate the CSV file and not the controller class. Although at first you might consider this controller logic, if you think about it from a general data export perspective, there could equally be an API requirement in the future for external developers wanting to automate the CSV export process; thus, placing this logic in the Service layer facilitates this.

The new Visualforce page utilizes the `contentType` attribute as follows:

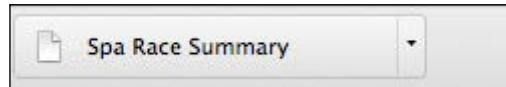
```
<apex:page  
    standardController="Race__c"  
    extensions="RaceSummaryController"  
    contentType="application/csv#{!Race__c.Name} Race  
Summary">{!CSVContent}  
</apex:page>
```

As this page uses a Standard Controller, a Custom Button can be created; once it has been clicked, instead of the page opening, the browser prompts you to download the file:



The screenshot shows a Visualforce page titled "Race Detail". The page displays two pieces of information: "Race Name" (Spa) and "Season" (2014). Below the information are four buttons: "Edit", "Delete", "Clone", and "Download Summary".

Pressing the **Download Summary** button results in the following prompt to download the resulting CSV file:



 You may have noticed in the preceding VisualForce code that the `apex:pagecontentType` attribute contained a "#" and some text. If you put a # symbol after the content type, you can specify a default filename to be presented to the user when the file downloads. Also note that the Visualforce formula can also be used in attribute values, and this is how the `Race` name appears in the filename. This also allows you to vary `contentType` dynamically if required.

 While this example works quite well to illustrate the `contentType` attribute, it should be noted that the platform-reporting engine also supports CSV exports. As such, if you are considering CSV export facilities, it is worth first considering asking users to leverage reports; thus, they have more freedom to control the output.

## Generating printable content

Salesforce has a built-in PDF generation engine that can take your HTML markup and turn it into a PDF. This is a very useful feature to generate more formal documents such as invoices or purchase orders.

You can access it using the `renderAs` attribute of the `apex:page` element on a Visualforce page, setting it to `pdf`. Note that you would typically dedicate a specific Visualforce page for this purpose rather than attempting to use this attribute on one used for other purposes.

 Make sure that you use as much vanilla HTML and CSS as possible; the Visualforce standard components do not always render well in this mode. For this reason, it is also useful to use the `standardStylesheets` attribute to disable Salesforce CSS as well.

You can also programmatically access this capability by using the `PageReference.getContentAsPDF` method and attaching the PDF generated to records for future. If you would rather generate PDF content without using a Visualforce page, you can generate the HTML programmatically and leverage the `Blob.toPDF` method. Translation and localization *Chapter 2, Leveraging Platform Features*, covered this topic, so we will not be revisiting it in further detail here. Just to reiterate, it is important to consider translation and localization requirements from the outset, as they can be expensive to retrofit afterwards.

Also, note that in the preceding example, the `$ObjectType` global variable was used in the Visualforce page to access the **Custom Field** label for the column title. Ensuring that you leverage approaches like this will reduce the number of **Custom Labels** you need to create and, ultimately, your translation costs.



Lightning Components do not currently support `$ObjectType`; as a workaround, you can use Apex Describe to expose this via your Apex Controller.



In Visualforce, you can use the `apex:inputField` and `apex:outputField` components to render and receive input from the user, which is locale sensitive. In Lightning, utilize the `lightning:formattedNumber` and `lightning:formattedDateTime` components.

## Overriding the page language

By default, the Visualforce page looks up translated text for Custom Field labels and Custom labels that you reference on your page or in your Apex code through the user's locale. However, if you wish to override this, you can specify the `<apex:page>` `language` attribute, for example, if you wish to use a Visualforce page to generate a newsletter in different languages and wish to preview them before sending them out.



There is no equivalent functionality for Lightning Components; these always leverage the language of the user.



This does not apply to any descriptive field values such as Name or any custom description fields that you add to your objects. In order to provide translation for the data entered by a user, you must develop such a feature yourself. There is no platform support for this.

## Client server communication

Fundamentally, any communication between the user's chosen device (client) and the data and logic available on the Salesforce server occurs using the **HTTP** protocol. As a Force.com developer, you rarely get involved with the low-level aspects of forming the correct HTTP POST or HTTP GET request to the server and parsing the responses.

For example, the `Visualforce apex:commandButton` and `apex:actionFunction` (AJAX) components do an excellent job of handling this for you, resulting in your Apex code being called with very little effort on your behalf apart from simply using these components. Salesforce also takes care of the security aspects for you, ensuring that the user is logged in, and has a valid session to make the request to the server. For Lightning Components, there are no direct equivalent components through the component markup. Instead, the `$A.enqueueAction` JavaScript method can be called from a component's client-side controller method to access the Apex code.

Depending on the context your client code is running in, Force.com offers a number of communication options to either perform **CRUD** operations on Standard or Custom Objects, and/or invoke your application's Apex code to perform more complex tasks.

It is important that you correctly place the logic in your Domain and Service layers to make sure that, regardless of the client communication options, the backend of your application behaves consistently and that each client has the same level of functionality available to it. The sections in this chapter will show how to ensure that, regardless of the communications approach utilized, these layers can be effectively reused and accessed consistently.

## Client communication options

Although the upcoming sections discuss the various communications in further detail, a full walk-through of them is outside the scope of this book. The Salesforce documentation and developer site offer quite an extensive set of examples on their use.

The aim of this chapter is to understand the architecture decisions behind using them, related limits, and how each interacts with the Apex code layers introduced in the previous chapters.

---

*User Interface*

This table lists the various client communication options available along with the types of user interface they are typically utilized by. It also indicates whether the API calls are governed (see the following subsection on what this means).

Communication option	Visualforce Pages (1)	Lightning Component	Custom Button or Link	Webs-ites	Native device UI (3)	API limits
Visualforce Components (apex:commandButton, apex:actionFunction)	Yes	No	No	Yes (1)	No	No
Visualforce JavaScript Remoting (Apex code)	Yes	No	No	Yes (1)	No	No
Visualforce JavaScript Remote Objects (CRUD operations)	Yes	No	No	Yes (1)	No	No
Salesforce REST/ SOAP API's(CRUD API, Apex SOAP and REST API's, Analytics)	Yes	No (5)	No	Yes (2)	Yes	Yes
Salesforce Streaming API (Read access to standard and custom objects)	Yes	No (5)	No	Yes (2)	Yes	Yes
AJAX Toolkit (4)	Yes	No	Yes	Yes (2)	No	Yes
Lightning Server Side Action @ AuraEnabled	No	Yes	No	No (6)	No	No
Lightning Data Services (CRUD access)	No	Yes	No	No (6)	No	No

The following notes apply to the preceding table:

1. As Visualforce pages are essentially dynamically rendered HTML pages output by Salesforce servers, these can also be used to build public-facing websites and also pages that adapt to various devices such as mobile phones and tablets (given the appropriate coding by the developer). The Salesforce Streaming API is currently only accessible via JavaScript.
2. Websites built using traditional off-platform languages, such as .NET, Java, Ruby, or PHP, are required to access Salesforce via the REST/SOAP and Streaming API's only.
3. A client is built using a device-specific platform and UI technology, such as a native mobile application using Xcode, Java, or a natively wrapped HTML5 application.
4. The AJAX Toolkit is a JavaScript library used to access the Salesforce SOAP API from a Visualforce or HTML page. It is the oldest way in which you can access Salesforce objects and also Apex Web Services from JavaScript. Though it is possible to utilize it from Custom Buttons and Visualforce pages, my recommendation is to utilize one of the more recent Visualforce communication options (by associating Visualforce pages to your Custom Buttons rather than JavaScript). Salesforce only supports the very latest version of this library, which is also quite telling in terms of their commitment to it.
5. Lightning utilizes the Content-Security-Policy HTTP header as recommended by W3C. This controls how (use of HTTPS) and from where (Lightning domain only) resources are loaded from the server. Since the Salesforce API's are served from a different domain, they cannot be called directly from JavaScript code inside a Lightning Component. Instead, you must call such API's server-side from the component's Apex controller.
6. Lightning Out is a technology that allows Lightning Components to be hosted on external websites. Components running within Lightning Out are still able to use Lightning Server Side and Lightning Data Services to communicate with the backend. Note that Lightning Data Services at time of writing were only in Developer Preview.

## API governors and availability

As shown in the preceding table, for some communication methods, Salesforce currently caps the amount of API requests that can be made in a rolling 24-hour period (though this can be extended through Salesforce support). This can be seen on the **Company Information** page under **Setup** and the **API Requests, Last 24 Hours** and **Streaming API Events, Last 24 Hours** fields.

Note that these are not scoped by your application's namespace unlike other governors (such as the SOQL and DML ones). As such, other client applications accessing the subscriber org can consume, and thus compete with, your application for this resource. If possible, utilize a communication approach listed in the preceding table that does not consume the **API limits**. If you cannot avoid this, ensure that you are monitoring how many requests your client is making and where aggregating them using relationship queries and/or Apex calls is possible.



If you are planning on targeting **Professional Edition**, be sure to discuss your API usage with your **Partner Account Manager**. The accessibility within this edition of Salesforce when using API's such as the Salesforce SOAP/REST API, Streaming API, and AJAX Toolkit is different from other editions. For the latest information, you can also review the *API Access in Group and Professional Editions* section in the *ISVforce Guide*, available at [https://na1.salesforce.com/help/pdfs/en/salesforce\\_packaging\\_guide.pdf](https://na1.salesforce.com/help/pdfs/en/salesforce_packaging_guide.pdf).

## Database transaction scope and client calls

As discussed in *Chapter 4, Apex Execution and Separation of Concerns*, the transaction context spans the execution context for a request made to the Salesforce server from a client. When writing the client code in JavaScript, be careful when using the **CRUD-based** communication options such as **Visualforce JavaScript Remote Objects**, **Lightning Data Service** and **Salesforce API**, as the execution scope in the client does not translate to a single execution scope on the server.

Each **CRUD** operation that the client makes is made in its own execution scope and, thus, its own transaction. This means that, if your client code hits an error midway through a user interaction, prior changes to the database are not rolled back. To wrap several **CRUD** operations in a single database transaction, implement the logic in **Apex** and call it through one of the previous means, such as **Visualforce JavaScript Remote Actions** or a **Lightning Server Side Action**. Note that this is generally a good practice anyway from a service-orientated application design perspective.

## Offline support

The **manifest** attribute on the Visualforce `apex:page` element is part of the HTML5 standard to support offline web pages. While a full discussion on its use is outside the scope of this book, one thing to keep in mind is that any information you store in the browser's local offline storage is not secure. This attribute requires the use of the `docType` attribute to indicate that the page output is HTML5-compliant.

Salesforce, however, introduced this feature mainly to support **hybrid** mobile applications, wanting to utilize Visualforce pages within a native mobile application container that supports the offline mode. It is not supported in any other context. In this case, the offline content is stored within the mobile application's own private store.

Hybrid mobile applications in the context of Salesforce Mobile SDK's are those that use a small native to the mobile device application that hosts a mobile browser that then utilizes the Salesforces login and Visualforce pages to deliver the application. In general, this would require a network connection; however, with the help of the manifest attribute, offline support can be achieved.

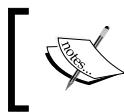
 Lightning Components cannot control this attribute currently, since they do not own the page. It is the responsibility of the Salesforce1 and Salesforce LEX standard UIs to implement this attribute. Salesforce1 Mobile does support some offline capabilities in terms of record editing; however, there is no support currently for Visualforce or Lightning-based custom UIs.

## Managing limits

Normally, the total number of records retrieved within a single controller execution context is 50,000 records (in total across all **SOQL** queries executed). In addition, Visualforce components such as `apex: dataTable` and `apex:repeat` can only iterate over 1000 items before a runtime exception is thrown.

At the time of writing this, the `readOnly` attribute (specified on the `apex:page` component) changes this to 1 million records and 10,000 iterations within Visualforce components on the page (refer to the Salesforce documentation for the latest update). As the name suggests, no updates to the database can occur, which basically means no DML at all. Note that queries are still governed by timeouts.

 If you require a more granular elevation of the SOQL query rows governor, you can apply the `@ReadOnly` Apex attribute to a JavaScript Remoting method in your controller, and not at the page level as described previously. Again, this method will not be able to use DML operations to update the database, but you will gain access to querying a higher number of query rows. Note that the iterator limit increase is not applicable in this context, as JavaScript Remoting and Visualforce iterator components cannot be used together.



At the time of writing this, Lightning Components do not provide access to this functionality. Apex Controller methods exposed via the @AuraEnabled method are subject to the standard Apex query limits.



## Object and field-level security

Visualforce pages exposing the SObject information (either via Standard, Custom, or Extension Controllers) can leverage built-in **field-level security enforcements** when using components or expressions that reference SObject fields directly; such usage will honor the user's field-level security. However, Visualforce expressions referencing SObject fields by way of a controller property are not affected, as the Visualforce engine cannot tell whether the controller property in turn refers to an SObject field.

Lightning does not currently offer components that are sensitive to object- and Field-Level security. You must, instead, inform the client side controller of the permissions via a Lightning server-side action that leverages **Apex Describe** for the information being accessed. The **Lightning Data Service** component, in Developer Preview at time of writing, does, however, support not only object and field security, but also sharing rules. *Developer Preview* status means it is not possible to package components using it.

## Enforcing security in Visualforce

When using the Visualforce `apex:inputField` and `apex:outputField` components, fields (including the label if present) will be hidden or made read only accordingly. A less well-known fact is that direct SObject field expressions are also affected by field-level security; for example, `{ !Race__c.Status__c }` will not be evaluated (no output emitted to the page) if the user has no read access to the `Status__c` field. This behavior is particularly subtle and not well documented.



The documentation states that when using components such as `apex:inputText` and `apex:outputText`, these will not enforce field security. While this is correct, security is always applied to SObject field expressions as well. So, if a field is not visible (as opposed to just read only), even the `apex:outputText` component will not display a value. However, if a field is read only and is used with `apex:inputText` (for example), it will render as an editable field. Thus, the general guideline here is that, if you have an SObject field expression, use the recommended `apex:inputField` and `apex:outputField` components.

A common confusion point is the use of the `with sharing` and `without sharing` keywords on the associated controllers. These keywords have no effect at all on the enforcement of field-level security; they purely determine record visibility, and thus effect only SOQL queries made within the controller and other Apex classes that make SOQL queries that are called by this controller.



In addition to using Apex described within your controller code, you can also determine directly a field's accessibility, using the `$ObjectType` global variable. For example, you can use the following expression to hide an entire section based on a given field's security, `{ ! $ObjectType.Race__c.fields.Status__c.Accessible }`.

The following Visualforce page and associated custom controller illustrates field-level security. In the use case shown here, two users are used, one has full access and the other has been given the following permissions via their profile:

- Read-only access to the `Status__c` field
- No access at all to the `FastestLapBy__c` field

First, review the Visualforce page; each section shows the following use case:

- **Use Case A** shows the use of `apex:inputField`
- **Use Case B** shows the use of `apex:outputField`
- **Use Case C** shows the use of `apex:inputText`
- **Use Case D** shows the use of `apex:outputText`
- **Use Case E** shows the use of an SObject field expression
- **Use Case F** shows the use of a controller property expression

To make it easier to compare, messages are shown on the page to confirm the level of field access. The `FLSDemoController` is included in the sample code for this chapter; it simply reads the first `Race__c` record in your org. It exposes two string properties indirectly exposing the `Status__c` and `FastestLapBy__c` field values. The following shows the Visualforce page used to illustrate the effects of using different Visualforce bindings and components against the permissions of the current user:

```
<apex:page controller="FLSDemoController" tabStyle="Race__c">
<apex:form>

<apex:pageMessage summary="Race__c.Status__c Accessible is
{!$ObjectType.Race__c.fields.Status__c.Accessible}"
severity="info"/>
<apex:pageMessage summary="Race__c.Status__c Updatable is
{!$ObjectType.Race__c.fields.Status__c.Updateable}"
severity="info"/>
<apex:pageMessage
summary="Race__c.FastestLapBy__c Accessible is
{!$ObjectType.Race__c.fields.
FastestLapBy__c.Accessible}"
severity="info"/>
<apex:pageMessage
summary="Race__c.FastestLapBy__c Updatable is
{!$ObjectType.Race__c.fields.
FastestLapBy__c.Updateable}"
severity="info"/>
<apex:pageBlock>

<apex:pageBlockSection
title="Use Case A: Using apex:inputField">
<apex:inputField value="{!Race.Status__c}"/>
<apex:inputField value="{!Race.FastestLapBy__c}"/>
</apex:pageBlockSection>

<apex:pageBlockSection
title="Use Case B: Using apex:outputField">
<apex:outputField value="{!Race.Status__c}"/>
<apex:outputField value="{!Race.FastestLapBy__c}"/>
</apex:pageBlockSection>

<apex:pageBlockSection
title="Use Case C: Using apex:inputText">
<apex:inputText value="{!Race.Status__c}"/>
<apex:inputText value="{!Race.FastestLapBy__c}"/>
</apex:pageBlockSection>
```

```
<apex:pageBlockSection
    title="Use Case D: Using apex:outputText">
<apex:outputText value="{!!Race.Status__c}" />
<apex:outputText value="{!!Race.FastestLapBy__c}" />
</apex:pageBlockSection>

<apex:pageBlockSection
    title="Use Case E: Using SObject Field Expressions">
<apex:pageBlockSection>
    The value of Status__c is '{!Race.Status__c}'
</apex:pageBlockSection>
<apex:pageBlockSection>
    The value of FastestLapBy__c is
    '{!Race.FastestLapBy__c}'
</apex:pageBlockSection>
</apex:pageBlockSection>

<apex:pageBlockSection
    title="Use Case F: Using Controller
    Property Expressions">
<apex:pageBlockSection>
    The value of Status__c is '{!Status}'
</apex:pageBlockSection>
<apex:pageBlockSection>
    The value of FastestLapBy__c is '{!FastestLapBy}'
</apex:pageBlockSection>
</apex:pageBlockSection>
</apex:pageBlock>

</apex:form>
</apex:page>
```

## User Interface

---

For a user with full access, this page displays as follows:

The screenshot displays a user interface with six sections, each representing a use case:

- Use Case A: Using apex:inputField**  
Status: In Progress  
Fastest Lap By: Lewis Hamilton
- Use Case B: Using apex:outputField**  
Status: In Progress  
Fastest Lap By: Lewis Hamilton
- Use Case C: Using apex:inputText**  
Status: In Progress  
Fastest Lap By: a02b0000008i13yAA/
- Use Case D: Using apex:outputText**  
Status: In Progress  
Fastest Lap By: a02b0000008i13yAAA
- Use Case E: Using SObject Field Expressions**  
The value of Status\_\_c is 'In Progress'  
The value of FastestLapBy\_\_c is 'a02b0000008i13yAAA'
- Use Case F: Using Controller Property Expressions**  
The value of Status\_\_c is 'In Progress'  
The value of FastestLapBy\_\_c is 'a02b0000008i13yAAA'

The following screenshot and explanations confirm how the page reacts and displays to a user with limited access; this page shows that some information is hidden or read-only as expected, but not all, the exceptions being use **Case C** and **Case F**:

- For **Use Case C**, the field is read only, so its value is accessible and placed in the input field. As it is an `apex:inputText` field, it does not honor the field-level security status of the field and the field is editable when it should not be.

- For **Use Case F**, the `FastestLapBy__c` field value is shown because it is not using a SObject field binding; it is using a binding to controller property, which is indirectly exposing the field value. In this case, the responsibility lies with the developer to check the field-level security in the controller code.

Race\_\_c.Status\_\_c Accessible is true

Race\_\_c.Status\_\_c Updatable is false

Race\_\_c.FastestLapBy\_\_c Accessible is false

Race\_\_c.FastestLapBy\_\_c Updatable is false

▼ Use Case A: Using apex:inputField

Status In Progress

▼ Use Case B: Using apex:outputField

Status In Progress

▼ Use Case C: Using apex:inputText

Status

▼ Use Case D: Using apex:outputText

Status In Progress

▼ Use Case E: Using SObject Field Expressions

The value of Status\_\_c is 'In Progress'

The value of FastestLapBy\_\_c is ''

▼ Use Case F: Using Controller Property Expressions

The value of Status\_\_c is 'In Progress'

The value of FastestLapBy\_\_c is 'a02b0000008i13yAAA'

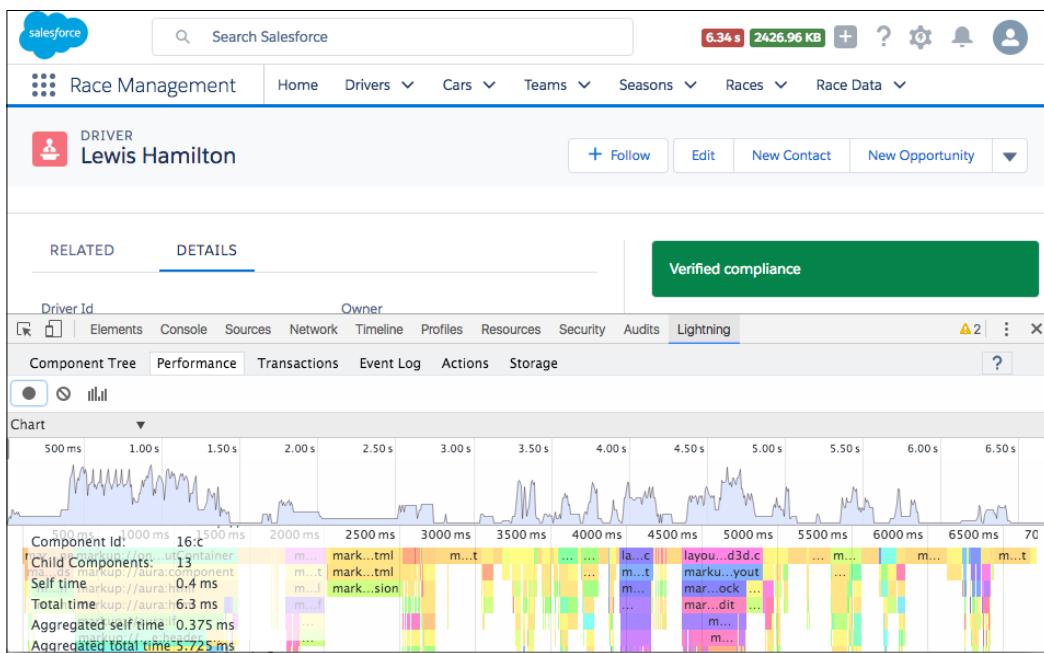
## Managing performance and response times

The response times in your solutions can make a big difference to the usability of the application. This section provides information on how to monitor and manage response times in Lightning and Visualforce.

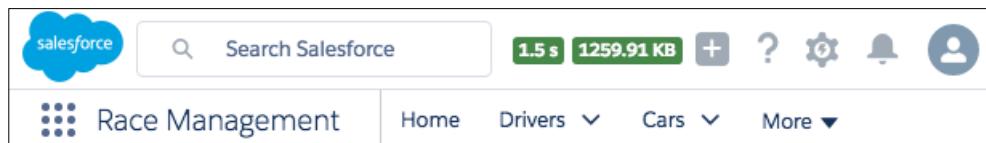
## Lightning tools to monitor size and response times

In Lightning, it is important to monitor the complexity of your component hierarchy. While it is good to componentized for reasons of separation of concerns, too much of it can result in a heavy component tree, and result in poor performance. Salesforce provides an excellent tool known as **Lightning Inspector**, which provides insight into your component hierarchy and the rendering times each component takes. You can download and install this from the Google Chrome Web store.

The following shows an example screenshot for the FormulaForce application:



You may also have noticed that LEX displays page size and response time in the header:



## Visualforce Viewstate size

*Visualforce Developer's Guide* has a section within it entitled *Best Practices for Improving Visualforce Performance*, in which it outlines some excellent ways to ensure that your pages remain responsive. I highly recommend that you take the time to read through it. There is, however, one point in that topic that I want to elaborate further on in this section:

*"If your view state is affected by a large component tree, try reducing the number of components your page depends on."*

This symptom can result in poor response times, even for pages that are properly optimized in all other regards described in the documentation. The cause stems from the internal overhead of the Salesforce Visualforce components, known as **internal view state**, which increases when you have many such components on the page, typically in tabular or apex:repeat scenarios.

Depending on your Visualforce page design, it can often represent proportionally more than the data the developer explicitly places in the view state through controller properties and member variables. Together, they both contribute to reaching the 145 KB limit on view state size, though before this is reached larger view states can effect response times.

## Considerations for managing large component trees

Here are a few considerations when designing Visualforce pages utilizing tables or repeated sections that contain the native Visualforce components:

- **View state is only generated if you have a apex:form tag on the page;** if you don't need one, then you should remove it, for example in view only pages.
- Consider if you need to use Visualforce components such as apex:outputField or if using HTML elements directly with a Visualforce expression would suffice. HTML elements consume no viewstate. However be careful to consider localization features the standard components provide when doing this, such as formatting dates and numbers; you might need to perform this in the Apex code and bind to the formatted values.
- Avoid nested apex:repeat tags that contain Visualforce components. If possible, flatten a nested structure with the Apex logic in your controller and expose a single iterable list property that results in the same output.

- Consider moving to a stateless controller mode as described in the following section.
- Consider implementing pagination in your page.

 For a further analysis, search <http://salesforce.stackexchange.com/> for 'How to reduce a large internal view state/what is in the internal view state?'

## Using the Service layer and database access

As with the Visualforce Apex controller action methods you've seen in the earlier chapters, the **Service** layer is also designed to be called from Visualforce JavaScript Remoting methods, as follows:

```
public with sharing class RaceResultsController {  
    @RemoteAction  
    public static List<RaceService.ProvisionalResult>  
        loadProvisionalResults(Id raceId) {  
        return RaceService.calculateProvisionResults(  
            new Set<Id>{ raceId }).get(raceId);  
    }  
}
```

To make Lightning Component controller server-side calls to Apex use the @AuraEnabled annotation method:

```
public with sharing class RaceResultsController {  
    @AuraEnabled  
    public static List<RaceService.ProvisionalResult>  
        loadProvisionalResults(Id raceId) {  
        return RaceService.calculateProvisionResults(  
            new Set<Id>{ raceId }).get(raceId);  
    }  
}
```

You will also need to apply the `@AuraEnabled` method to accessors for Apex types referenced by the Controller methods:

```
public class ProvisionalResult {  
    @AuraEnabled  
    public Integer racePosition {get; set;}  
    @AuraEnabled  
    public Id contestantId {get; set;}  
    @AuraEnabled  
    public String contestantName {get; set;}  
}
```

In both these cases, however, there is no `try/catch` block, as error handling is done by the client code to render the messages. When exceptions are thrown, the platform takes care of catching the exception and passing it back to the calling JavaScript code for it to display accordingly. In short, there is no need to invent your own error message handling system; just let the platform handle pass it back to the client JavaScript code for you. Remember though that you still need to handle the error message in your client side JavaScript logic; this will not be done by Visualforce for you.

## Considerations for client-side logic and Service layer logic

With the addition of more complex logic in the client via JavaScript, more attention needs to be given to **Separation of Concerns**. The following points provide some guidelines for this:

- **Single service method per remoting method:** A single Service layer method invocation rule should still be observed when developing remoting methods on the controller. If multiple Service layer methods are being called, this becomes a sign that a new aggregate Service layer method should be created and called instead.
- **Avoid remoting client bias:** Do not be tempted to design your Service layer solely around your JavaScript Remoting controller method needs (the needs of your JavaScript client). Always consider the Service layer as client-agnostic; this becomes particularly important if you also want to also later expose your Service layer as an API to your application.

- **Apex enum types:** If you utilize Enum types in your Service layer design (to be honest, why would you not?), they are very expressive and self-documenting! However, they unfortunately at this time are not supported by the JavaScript Remoting JSON de-serializer, which means that you can return Apex data structures containing them, but cannot receive them from the client (a platform exception occurs).

The workarounds are to either not use enum's and drop back to using string data types or create Apex class data types within the controller class and perform your own marshaling between these types and service types (leveraging the `Enum.name()` method to map Enum's to string values). The choice is between your desire to protect your Service layer's use of Enum's (especially if it is your public-facing API) and the effort involved. Hopefully, at some point, Salesforce will fix this issue.

## When should I use JavaScript for database access?

JavaScript Remote Objects and the Lightning Data Service are designed to expose a "SOQL- and DML-like API" for use by the JavaScript code embedded within a Visualforce page or Lightning Component. Providing a way to query and update the database without having to go through the traditional AJAX Toolkit or Salesforce REST API's that incur charges to the daily API limit.

*Visualforce Developer's Guide* has an excellent topic that describes the best practices around using this feature, entitled *Best Practices for Using Remote Objects*, which I highly recommend that you read and digest fully. *The Lightning Component developer Guide* also has samples describing the Lightning Data Service. The main aspect from this section which I would like to highlight is the one that relates to transactional boundaries in close conjunction with maintaining a good Separation of Concerns.

Resist the temptation to invoke multiple database operations within a single JavaScript code block as each will be executed in its own Salesforce execution context and thus transaction. This means that, if an error occurs in your JavaScript code, previous operations will not be rolled back.

If you find yourself in this situation, it is also likely that you should be positioning such code in your application's Service layer and thus using JavaScript Remoting to call that Service layer method, which will then occur within a single transactional scope.

That said, if you have use cases that result in a single database operation then you can of course consider using this feature, safely assured that your Apex Trigger and Domain layer code will continue to enforce your data validation and integrity.

Finally, note that querying records from JavaScript does not invoke your Selector code. So the fields queried and populated in the resulting SObject records on the client will not always be the same in all cases throughout your JavaScript code.

## Considerations for using JavaScript libraries

As discussed, the more you move towards a stateless controller and JavaScript Remoting client architecture, the more you need to invest in providing or obtaining client-side components not presently provided by Salesforce.

Consider this decision carefully on a per-case basis (not all of your application UI has to use the same approach) and make sure that you appreciate the value of the platform features that you are leaving behind. Expect to adjust your expectations around your client developer's velocity to be more in alignment with those on other platform developers.

Libraries such as JQuery provide a great deal of convenience, flexibility, and components available in the community to provide some alternatives and improvements over the Visualforce components, in addition to larger components such as grids and trees. Taking things a step further, larger commercially available libraries such as **Sencha ExtJS** are also usable from within a Visualforce page, including mobile variants such as JQuery Mobile and Sencha Touch.

 Lightning implements a security layer around your components, known as the **Locker Service**. This blocks eval, enforces use of strict mode, and restricts access to the DOM outside your components own boundaries. Check that the third-party libraries you intend to use in Lightning Components are compatible with this type of security context.

All of these libraries require a good deal of JavaScript programming knowledge, including its OOP style of programming. Some provide the **Model View Controller (MVC)** frameworks as well, such as **AngularJS**. If you search on Google for Salesforce and for example AngularJS, you will find many examples and articles from the community and the Salesforce Developer Evangelists team.

Here are some aspects of developing with such libraries, which you should consider:

- **Developer flow:** What is the process from storing the client code in source control, pushing it into an org for development, editing code, debugging it, and pushing it back into Source Control? Likewise when it comes to packaging, consider whether you should compress your JavaScript or not. The Developer flow has to be fast; editing JavaScript files, rebuilding zip files, and uploading new static resources is not fast. Consider whether you can support a loose file development flow for client developers, such as using Visualforce components, page, or static resources for each file (**MavensMate** has good support for this), and then combine these into a single static resource for packaging and deployment.
- **Security:** Salesforce takes a great deal of care with their Visualforce and Lightning components to ensure that the escape values are displayed by the components to prevent attacks such as HTML injection for example. Check your components' escape values that they inject into the DOM from your database records, or you could find yourself open to attack and delays getting through the Salesforce Security Review.
- **Testing frameworks:** There are a number of approaches when testing rich clients, ranging from unit testing frameworks that have the developer write a JavaScript code to testing commercial applications that actually drive the web browser and assert the state of the page. Make sure that you invest according to the amount of JavaScript code your application contains.

## Custom Publisher Actions

In a previous chapter, we created a **Publisher Action** to mark a **Contestant** as a **DNF** (Did not Finish) object easily from a Chatter feed. This leveraged the declarative approach to creating Publisher Actions, based on creating or updating a related record. If your use case does not fit into these type of operations, you can use Lightning Component to develop a Custom Publisher Action.

## Creating websites and communities

Salesforce provides the following two ways to create public-facing web content:

- **Force.com:** This offers a means to create public-facing authenticated or public websites using Visualforce pages. Due to this, it can access Standard and Custom objects using the approaches described in this chapter, reusing components and services from your application as needed. The Force.com site configurations cannot be packaged, though the pages and controllers you create to support them can be. This feature is available in the **Enterprise** and **Developer Edition** orgs. It is possible to use Lightning Components via Lightning Out for Visualforce pages.
- **Sites.com:** This is a declarative website product that is targeted at nontechnical users. Visualforce pages cannot be used directly with Site.com though components available with Site.com can access your application's Custom Objects and as such will invoke your Apex Trigger and thus Domain logic code. It is possible to use Lightning Components with Sites.com via Community Builder.

## Mobile application strategy

Mobile application development using Salesforce has been a hot topic for the last few years, starting with the use of various well-known mobile frameworks such as jQuery Mobile, AngularJS along with Salesforce's own API's, including **oAuth** for authentication, and **Salesforce REST API** to access Standard and Custom Object records, leading up to the current development around the latest Salesforce1 mobile application.

The interesting thing about this is that it has evolved in a different way to the browser UI, which started with the standard declarative-driven UI and could then be augmented with a more developer-driven solution such as Visualforce. For a mobile UI, up until the release of Salesforce1, we only had the option of building something with a developer.

As things stand today, we now have both options available for building mobile UI's. As such, make sure that you understand first and foremost the capability of the Salesforce1 mobile application and its ability to surface your objects through its standard UI. **Publisher Actions** provide an excellent way to enhance the **Chatter** feed presence of your application and also add the same actions to your users' Salesforce1 experience.

Salesforce1's user interface model is not for everyone; it is, like the browser UI, mostly data-centric if you wish to expose a more fine-tailored process-driven user experience for a very specific mobile application. If this is something you feel you need, you can review Salesforce Mobile Packs to choose the architecture and API's that suite your needs the best (<https://developer.salesforce.com/mobile>).

## Custom reporting and the Analytics API

Sometimes, the standard output from the **Salesforce Reporting** engine is just not what your users are looking for. They require formatting or a layout not supported by Salesforce, but the way in which they have defined the report is appealing to them.

The **Salesforce Analytics API** allows you to build a Visualforce page or mobile application that can execute a given **tabular**, **summary**, or **matrix report** and return its data into your client code to be rendered accordingly. The API is available directly to Apex developers and as a **REST API** for native mobile applications.



You might want to consider using a report to drive an alternative approach to selecting records for an additional process in your application by leveraging the flexibility of the **Report Designer** as a kind of record selection UI.

## Updating the FormulaForce package

Apply the code included in this chapter into your package org. Apart from the `RaceResultsController` Apex class, all components provided with the sample code for this chapter will be included in the package automatically as they are additions to or referenced from components that are already packaged.

## Summary

Salesforce provides a great standard UI experience that is highly customizable and adaptable to new features of the platform without you necessarily releasing new revisions of your application. At its core, it is a data-centric user experience, which means that most tasks come down to creating, editing, or deleting records of some kind. Having a strong focus on your Domain layer code ensures that it protects the data integrity of your application.

If you want to express a more complex process or a series of tasks, Visualforce and Lightning allows you to be more expressive using components or other HTML libraries to create the user experience needed for the task at hand. While this is very powerful, it is important to always consider the standard UI, and, wherever possible, augment or complement it with the Visualforce page and/or Lightning components rather than making this the only way of interacting with your application.

Equally important is to observe best practices around engineering custom UIs for performance and security. Consider carefully and choose wisely the degree to which you depart from the standard UI and/or standard components, as the further you move away from these, the more responsibility and complexity you have to deal with as a developer. Look for opportunities to create hybrid standard UI and custom UI combinations to get the best of both worlds.

Reporting can be a personal thing for your users; the Salesforce Analytics API allows you to harness the power of the Salesforce Report Designer and engine with a more tailored rendering of the reporting data returned.

At present, there are numerous combinations of technologies and approaches to build a mobile user experience for your users. As with the standard UI in the browser, start with what Salesforce provides you and your users with out of the box as standard. The Salesforce1 Mobile application is effectively a platform feature that users expect to be able to use with your application objects like any other.

Building custom UIs for use within Salesforce1 mobile is best accomplished using Lightning Components. However, if you choose to build your own mobile application, you can choose to develop it using one of the Salesforces Mobile SDK's as a starting point; alternatively, if you have the skills and experience, use them as a guide on how to call the various Salesforce API's.



# 9

## Lightning

**Lightning** is a rich client side framework for developing device agnostic and responsive user experiences as well as supporting mobile, tablet and desktop. Unlike **Visualforce** it was built from the ground up with today's multi-device rich client demands in mind. It is used by Salesforce themselves and is also available to developers to build their own standalone or platform integrated UIs. Using **Lightning Out** developers can also integrate UIs built with Lightning into **external sites** and applications. An emphasis on componentization is at the heart of its architecture, and plays a key part in providing a means to implement reuse, separation of concerns and extensibility.

This chapter provides an architectural overview of the Lightning component architecture, while contrasting it with its predecessor Visualforce. New **Lightning Components** called **Race Calendar**, **Race Results**, **Race Standings** and **Race Setup** will allow us to explore and development process and styling using **Lightning Design System**.

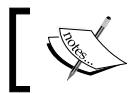
Using the new components, we will explore the options and benefits of integrating components into **Lightning Experience**, **Salesforce1 Mobile**, **Lightning Communities**, as well as an existing Visualforce pages. **Lightning Out for Visualforce** allows existing solutions to continue to support Salesforce Classic while moving towards Lightning.

We will cover the following topics in this chapter:

- Overview of the Lightning component framework
- Understanding of the various component containers
- Building components your end users can customize
- Using components to extend Lightning Experience and Salesforce1 Mobile
- Understanding how to write secure JavaScript code
- Styling your Lightning UIs

## Building a basic Lightning user interface

Before we dive into the more complex components included in the sample code for the FormulaForce application, let's first create a simple **Lightning Application** to better understand the architecture of Lightning. Think of a Lightning Application as a **container** for your UI, essentially your HTML markup. Containers are effectively things you can navigate to in the browser, they get their own URL based on the name you give them.



As we will explore later in the chapter, **Lightning Experience** and **Salesforce1 Mobile** are also containers built by Salesforce in the same way as the example that follows.



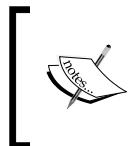
If you want to follow along with the next few steps, ensure you have installed the **Force.com IDE** with support for Lightning Components. We will be taking a closer look at the Force.com IDE features around Lightning later in this chapter.

Follow these steps to create your first Lightning Application:

1. Ensure that you are using a **Developer Edition** org with **My Domain** enabled. This can be enabled under the **Setup** menu by searching for **My Domain**. Ensure that you have completed all the My Domain steps.
2. Create **Force.com IDE** project for your org from the **New** menu by selecting **Force.com Project**.
3. Once the project is created, right click on the project in the **Package Explorer** and select the **Force.com** sub-menu then **Work Online**. This ensures when saving a file it gets automatically uploaded to Salesforce.
4. From the **File** menu, select **Lightning Bundle** from the **New** sub-menu.
5. In the **Create new Lightning Component** dialog, select **Lightning Application** from the **Type** field.
6. Give your application the name `myapp` and click **Finish**.
7. A **Lightning Bundle** in source form is a folder that contains one or more files depending on the type. In this case you will have a `.app` file, `.css` file and three `.js` files. Open the `myapp.app` file and enter the markup below, then save the file.

```
<aura:application>
  <h2>Success your first Lightning App</h2>
</aura:application>
```

8. As described in the preceding code, containers are essentially pages you can navigate to with your browser. These work outside of the standard UIs from Salesforce but still require you to login. Login to your Developer Edition org and enable **Lightning Experience** from under the Setup menu (if it is not already enabled).
9. Switch to **Lightning Experience** and take note of the URL in the browser. This might be something like the following for the Lightning Experience container (<https://yourdomain.lightning.force.com/one/one.app>).
10. To launch your first Lightning Application, modify the URL as follows, substituting yourdomain for your orgs domain (<https://yourdomain.lightning.force.com/c/myapp.app>).



The c in the preceding URL represents the default namespace of your org. If your org has a namespace or you're attempting to launch a Lightning Application from an installed package with a namespace of coolapps, for example, exchange it with the namespace /coolapps/myapp.app.

You should see in your browser the following message:

### Success your first Lightning App

This type of Lightning Application is known formally as a **Standalone Lightning App** in the *Lightning Components Developer Guide* (you can refer to [https://developer.salesforce.com/docs/atlas.en-us.lightning.meta/lightning/intro\\_framework.htm](https://developer.salesforce.com/docs/atlas.en-us.lightning.meta/lightning/intro_framework.htm)).

## Introduction to Lightning Design System

Lightning brings with it a rich and sophisticated CSS library for styling the look and feel of your HTML. This has been previously referenced as Salesforce **Lightning Design System (LDS)**. While you can include its CSS as a static resource in your application, for native Lightning UIs such the ones featured in this chapter that is not required.

By using the `extends` attribute in the following code, we can ask the framework to always include the latest platform version and start using its CSS classes to brighten up our output:

```
<aura:application extends="force:slds">
  <div class="slds-notify_container">
    <div class="slds-notify slds-notify--alert slds-theme--success
      slds-theme--alert-texture" role="alert">
      <span class="slds-assistive-text">Success</span>
```

```
<h2>Success! Your first Lightning App</h2>
</div>
</div>
</aura:application>
```

 Note the use of the `role` attribute and the `slds-assistive-text` class in the preceding code. While these are not required technically, they are present to ensure compatibility with users that require assistance in reading the screen. Lightning includes and encourages support for **HTML5** standards around **Accessibility**. We will discuss this further later in the chapter.

If you refresh your browser, you will now see what is shown in the following screenshot. The preceding HTML code was based on that provided on the LDS website:

Success your first Lightning App

The Lightning Design System (<https://www.lightningdesignsystem.com>) website is full of great sample HTML markup allowing you to explore, design, and test statically what you want your UIs to look like. Using a simple Lightning Application like the previous one, you can continue to copy and paste examples to try different combinations out.

 Keep in mind however to be productive as a developer. What you really need is a component library with components that encapsulate the preceding HTML code, so that, you can define once and reuse, rather than copy and pasting HTML over and over. You can build your own components as we will see later and leverage SLDS within them as well. Fortunately, for the simpler and more basic component requirements, the platform provides a growing number of basic components already styled with SLDS for you, known as the **Lightning Base Components**. We will explore these later in the chapter (<https://developer.salesforce.com/blogs/developer-relations/2017/01/base-lightning-components.html>).

## Building your first component

Finally, let us create a Lightning Component to encapsulate our success message, a component that could, for example, be the basis of a more reusable one for general informational messages:

1. Within the **Force.com IDE**, navigate to **File | New | Lightning Bundle**.
2. In the **Create new Lightning Component** dialog, select **Lightning Component** from the **Type** field.
3. Give your component the name `mycomponent` and click **Finish**.
4. Take the markup contained with `aura:application` tag in the `myapp.app` file and paste the contents to your new `aura:component` tag shown as follows, in the new `mycomponent.cmp` file, while also modifying the message:

```
<aura:component>
    <div class="slds-notify_container">
        <div class="slds-notify slds-notify--alert
            slds-theme--success
            slds-theme--alert-texture" role="alert">
            <span class="slds-assistive-text">Success</span>
            <h2>Success your first Lightning Component</h2>
        </div>
    </div>
</aura:component>
```

5. Finally modify the `myapp.app` file to use your new component:

```
<aura:applicationextends="force:slds">
    <c:mycomponent/>
</aura:application>
```

Refresh the browser and you will see the following:

Success your first Lightning Component

The preceding code is the basic introduction to Lightning development, intended to help you understand the high level architecture of Lightning and how it fits into the standard HTML page model used by the internet, as well as providing introduction to the styling and design framework known as Salesforce Lightning Design System.

## How does Lightning differ from other UI frameworks?

So far things might feel quite familiar if you have developed in other UI frameworks such as Salesforce's own Visualforce or others such as **Java Server Pages (JSP)** or **ASP .NET**. We have defined some markup, used CSS, and seen how we can encapsulate reusable portions of HTML. When the user navigates to the URL, the Lightning platform server side code served up the appropriate HTML to launch the specified application and render referenced components. If you are a Visualforce developer, you might be thinking that this is not all that different from the use of Visualforce Pages and Visualforce Components.

While there are other similarities to other frameworks, such as the use of expressions for example, the biggest departure from those technologies is the lifecycle of the page itself. A server-side architecture often requires that the whole page be refreshed when the user performs an action. The information on the page, the *state* of the page, is transmitted back and forth between the client and the server each time the user performs an action. Server side controller code controls validations, loading of data and conditional display of the UI.

Increasingly, user interface designs result in HTML pages that represent a single application or workspace users open and keep open. They access different modules and perform various operations within. This is typically known as **Single-Page Application (SPA)** architecture. The traditional server side page refresh model is not responsive enough to meet these needs, for example when only a portion of the page needs updating. Even when the traditional **Asynchronous JavaScript and XML (AJAX)** approach is deployed, often the entire state of the page needs transmitting back to the server side controller. Server-side UI frameworks are also not well-suited to developing user experiences that tolerate lack of connectivity in temporary offline scenarios.

In contrast, Lightning applications are long lived in the browser and depend on JavaScript code to manipulate the DOM of the page to load new content and functionality. The state of the operation the user is performing is stored in the browser and only transmitted when needed by the server to retrieve and update the database.

## Lightning architecture

In this section, we will discuss key layers of the Lightning architecture that will allow you to have a better framework of understanding as you go deeper.

A key aspect that took me by surprise at first is the need to write **client-side controllers** in JavaScript. This can be particularly puzzling at first if you are Visualforce developer, but is vital part of being a Lightning developer and is a reflection of its client side architecture. As we saw in the previous chapter, Apex server side controllers still play a part but are mainly for accessing your backend Apex Services and Selectors.

In general, Lightning development is much more componentized. In terms of how the UI is designed and how the code is factored, the two are much more aligned, making it easier to maintain and navigate code. This also gives a much greater emphasis on separation of concerns within the UI tier.

## Containers

As we saw in the previous section, we created a basic container called `myapp` using a standalone Lightning app. It contained a single instance of our `mycomponent` component. It may not have looked like much but `<aura:application>` provided a number of services for its components and you as the developer.

- It constructed the page `<HTML>` tag and loaded appropriate JavaScript, CSS resources, such as SLDS and the Lightning JavaScript runtime that allows your components to react to user interactions through client side controller code.



The `extends` attribute allows for inheritance from other `<aura:application>` based applications. The preceding example extending the platforms `force:slds` application to inject the CSS for SLDS.

- It loaded the components within its body, namely the `mycomponent` component, but also any HTML markup that is present is also injected into the page. Each component started its own life cycle within the container. Much like an object in Apex, it was constructed, initialized, tracked, and can be destroyed.



**Component management** is an important service since it helps avoid a common pitfall when developing rich client applications and that is resource management. Each HTML tag and associated data takes up memory in the browser and throughout the life time of the page can easily climb and cause issues if not properly managed.

- **URL-parameters** are mapped automatically to `aura:attribute` components specified in the body of the `aura:application`. For example:

```
/c/myapp.app?myparam=myvalue
```

```
<aura:application extends="force:slds">
  <aura:attribute name="myparam" type="String"/>
  <h2>The value of myparam is '{!v.myparam}'</h2>
</aura:application>
```

Results in the following text being displayed in the browser:

**The value of myparam is 'myvalue'**

- **URL centric navigation** is an important aspect of the user experience and an expectation when users are bookmarking or sharing links to records or certain pages in your web application. Since the application is designed to be long lived and changing the URL causes the entire page to reload, an alternative is needed.

Modifying the bookmark portion of a URL does not reload the page. As such, Lightning applications leverage this to add more contexts to links stored by users, as well as using it during the applications own navigation.

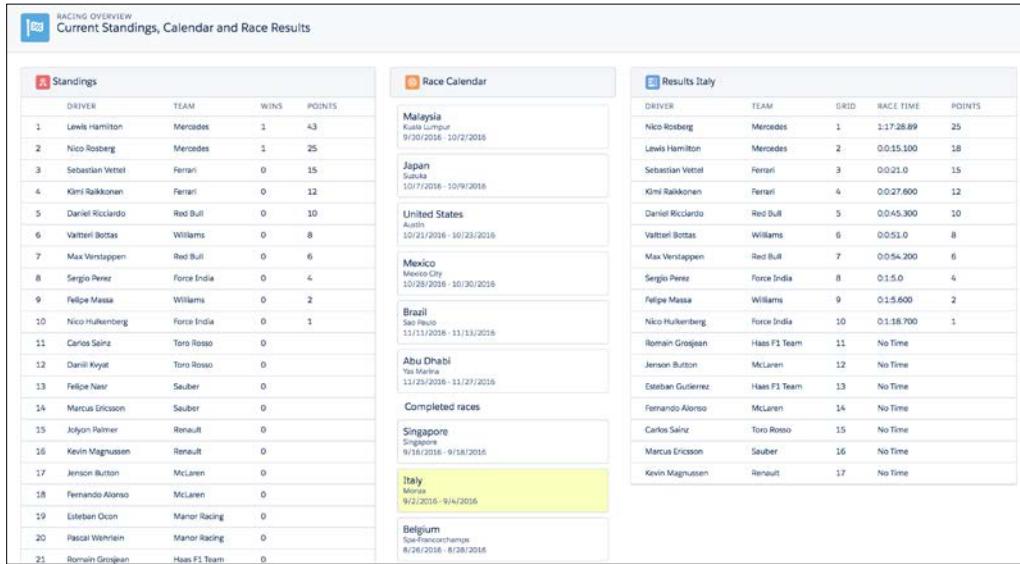
You can see this in action as you navigate through Lightning Experience. The framework provides the `aura:locationChange` event your client side logic can listen to determine when changes are made.

Here is simple example of the URL convention used: `/c/myapp.app#showraceresults-2016`

You can read more about the attributes of the `aura:application` in the *Lightning Components Developer Guide*. Not all these services may be relevant depending on the container you're using. However, it is good to have a basic understanding of how things work even if you only ever leverage the Salesforce containers.

## Introducing the Racing Overview Lightning app

The **Racing Overview** Lightning standalone app is contained in the sample code for this chapter. It can be accessed through `/c/RacingOverview`. The following screenshot shows what it looks like and gives a first look at the Lightning Components we will be covering in more detail throughout the rest of this chapter:



The sample record data shown in the preceding screenshot can be injected into your developer org by running the following script in **Developer Console** or **Execute Anonymous** in Force.com IDE:



```
PageReference sampleData =
    new PageReference('/resource/sampledadata');

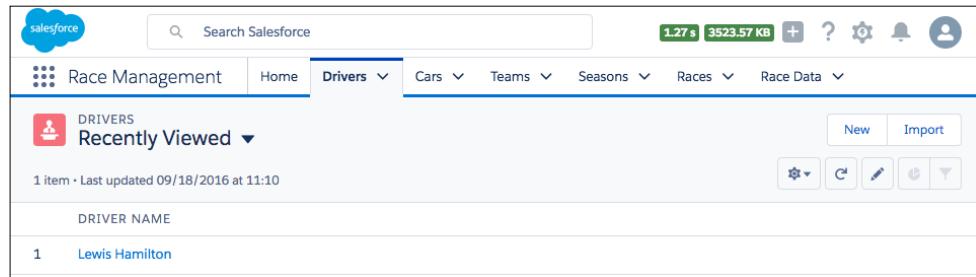
String sampleDataJSON =
    sampleData.getContent().toString();

String orgNameSpace =
    SObjectDataLoader.class.toString().
        removeEnd('SObjectDataLoader').removeEnd('.');

SObjectDataLoader.deserialize(
    sampleDataJSON.replace('ns__', orgNameSpace+'__'));
```

## Lightning Experience and Salesforce1

Salesforce has created its own standard UI containers for its own products and partner applications through the Lightning Application containers, known as **Lightning Experience** and **Salesforce1 Mobile**. Both are served up via the /one/one.app URL:



As we have seen in the previous chapters, Salesforce does not restrict loading of its own components in these containers. They provide various ways in which developers can load components they write in order to integrate and extend the standard user experience in respect of their specific application objects and processes.

Salesforce also allows developers to leverage some components they have built and tested for external developer consumption. For example, the `force:recordView` is used to display a record. The `force:showToast` component can be used to display popup notifications. We will look at the various ways in which both of these components and Salesforce containers can be used and extended later.

## Components

Page level design is no longer the focus in Lightning; thinking component-first is the focus you should have. This does not dismiss the need for good user experience design however. Rather it involves a closer collaboration between UX designer and developer.

Creating one huge component to serve your needs is not recommended and will not embrace the Salesforce UI customization facilities in the way your users will expect. From a coding perspective it will be hard to maintain and not reusable, as it will likely not fit everyone's need.

A better approach is to work with your UX designer on the mockups and think about how you can break up the UI into reusable or distinct elements. Later in this chapter, I will explain how I approached this thinking when devising the components for the FormulaForce application.



Having a good knowledge of the extensibility points within the Salesforce UIs is also important when designing your user experience. The standard UI may offer most of the user experience required, leaving the developer to focus on one or two single components that add the remainder.

## Separation of concerns

Lightning Components are built with separation of concerns in mind from the ground up. Note the use of a **Lightning Bundle** and the contents as we know them thus far are split into separate files for, the **markup** (view) and **JavaScript** code (controller). They are all grouped under a single subfolder. This is a clever way in which Salesforce wants us to really consider the way we engineer our Lightning code and how components interact.

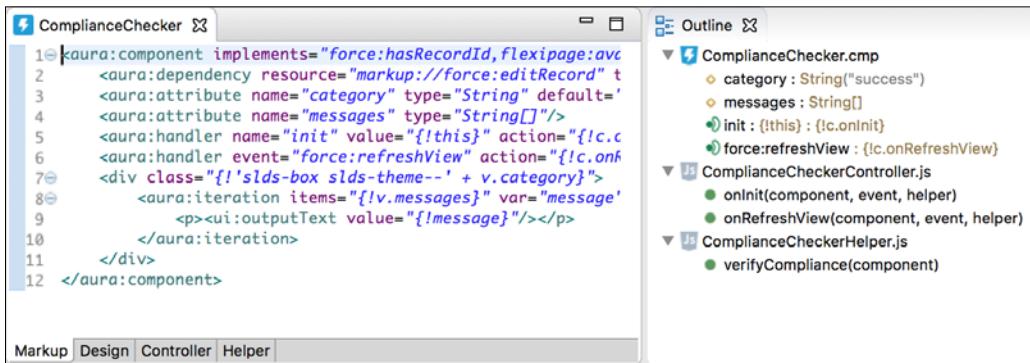
As with most things in engineering, separation of concerns is not a given by just using the technology alone. Some aspects are enforced for you; other things are subject to guidelines and good component design. If you get it right, you will not only get reusable, robust and enduring UI components within your own application UI, but also within the evolving Salesforce containers, as well as the ever increasing number of mobile devices and even integration with third party websites if needed.

Keeping in mind the tenets of separation of concern are as vital when developing a rich client application as they are when engineering your applications backend business logic.

## Encapsulation during development

An important aspect of a component's implementation is encapsulation. Its ability to keep its implementation from impacting the operation of other components on the page is a critical aspect of what makes the container model work—especially since in reality all components occupy the same HTML DOM for the page.

As previously mentioned, **Lightning Bundles** (also known as **Aura Definition Bundles**) are used to collect together the source files needed to implement each of the specific aspects the Lightning artifact you are creating. The following screenshot shows **Compliance Checker** component included in this book as shown with in the Force.com IDE:



The screenshot shows the Force.com IDE interface. On the left, the 'Markup' tab is selected, displaying the component's markup code. The code includes attributes like `force:hasRecordId` and `flexipage:ave`, and a `aura:iteration` block. On the right, the 'Outline' tab is selected, showing the component's structure: `ComplianceChecker.cmp` (with attributes `category` and `messages`, and methods `init` and `force:refreshView`), `ComplianceCheckerController.js` (with methods `onInit` and `onRefreshView`), and `ComplianceCheckerHelper.js` (with a method `verifyCompliance`).

 Also see Aura Definition Bundle type in the *Metadata API Developers Guide* ([https://developer.salesforce.com/docs/atlas.en-us.api\\_meta.meta/api\\_meta/meta\\_auradefinitionbundle.htm](https://developer.salesforce.com/docs/atlas.en-us.api_meta.meta/api_meta/meta_auradefinitionbundle.htm)).

The following sections discuss the contents of a Lightning Component bundle.

## Component markup (.cmp)

Component markup contains the **XHTML markup** for the components appearance. Its root element is `aura:component`. It can include references to valid HTML elements and/or other components, as we have seen in the `mycomponent` example earlier.

Amongst the markup you can also specify **attribute bindings**, for dynamic aspects of the component, such as a table or field values. Unlike Visualforce these are not bindings to Apex class properties. Bindings refer to attributes defined via the `aura:attribute` component (typically at the top of this file) or those provided by the platform.

The framework ensures that when the value of an attribute changes (through JavaScript controller code) any markup that references it via a binding expression is refreshed. This is a very powerful feature and avoids the need for extensive coding around the page DOM. In fact, this is generally discouraged in all but advanced scenarios, such as custom component rendering or use of third-party libraries.

The following is a simple example of an attribute definition and usage. When the controller changes the attribute value, the **<b>** tag will be automatically refreshed:

```
<aura:attribute name="myattr" type="String"/>

<b>The value of myattr is '{!v.myattr}'</b>
```

 The **v** prefix denotes a **value provider**. This one provides access to a component's attributes or more specifically its *view*. Other value providers are available that provide similar functionality to that of Visualforce for accessing Custom Fields and Static Resources through `$Label` and `$Resource`. Consult the **Lightning Components Developer Guide** for more information on these.

## Component controller (...Controller.js)

The `Controller.js` is a JavaScript file that contains the **client-side controller** code for the component. You must have one of these to define dynamic behavior in your component, including any dynamic initialization. The only way to call code in an **Apex controller** is from the client side controller code; unlike Visualforce there is no direct way to do so from the markup.

Functions defined relate to corresponding **action bindings** or `aura:handler` references in the `.cmp` file. Actions are events that occur in the browser, such as clicking a button, hovering over an element, scrolling or an event from the container or another component. We will discuss **Events** in a later section.

Though not enforced, it is recommended that it contains only functions that relate to actions referenced in the `.cmp` file. More extensive controller code and utility functions should be placed in the `Helper.js` file described as following. Another motivation for this separation of concerns is that the framework replicates the controller per instance of your component; however there is only ever one instance of the helper.

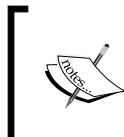
The following is a simple button markup in `.cmp` file using the `c` value provider in an expression to reference a client side controller function:

```
<lightning:button label="Add Drivers"
  onclick=" {!c.onAddDrivers}"/>
```

The framework automatically handles the setup of the HTML event listeners for you and routing them to the specified controller method. The `component`, `event` and `helper` parameters are always injected by the framework:

```
onAddDrivers :function(component, event, helper) {
```

```
    helper.addDrivers(component, event);  
}
```



The **c value provider (controller provider)** can also be used within JavaScript to obtain a reference to an **Apex Controller method** the client code wishes to call. We will review an example of this scenario later in the chapter.



## Component Helper (...Helper.js)

A JavaScript file that defines functions are used by the `Controller.js` and `Renderer.js` (described as following) files. The framework creates a single instance of these methods which is shared between all component instances. Thus it is recommended you do not store any state and instead leverage the component attributes instead.

This example shows an action binding as referenced by an `aura:handler` specifying a platform event fired during the initialization of a component. In this case it allows the component to load data from the server dynamically:

```
<aura:handler  
    name="init" value="{!this}"  
    action="{!c.onInit}" />
```

The controller function is fired and delegates to the helper class:

```
onInit :function(component, event, helper) {  
    helper.getCalendar(component, event);  
}
```

The helper function makes a server side call out to the Apex Controller, which is specified through `controller` attribute within the `.cmp` file? The **c value provider** is used here again, but this time to access server side controller methods:

```
getCalendar :function(component, event) {  
    var action = component.get("c.getRaceCalendar");  
    action.setCallback(this,  
        function(response) {  
            if(response.getState() === 'SUCCESS') {  
                component.set("v.calendar", response.getReturnValue());  
            }  
        });  
    $A.enqueueAction(action);  
}
```

The `$A` variable used in the preceding code provides access to Lightning JavaScript API.

## Component CSS (.css)

When styling your component, you should leverage the designs and CSS provided by the Lightning Design System, as shown in the `mycomponent` example earlier. This will ensure your UI continues to stay in line with the Salesforce containers it resides in, as well as, any further advancement in respect to supporting new devices and layout types.



Using Salesforce base components from the `lightning` namespace, such as `lightning:button`, `lightning:input` and `lightning:tabSet` automatically ensures you are using SLDS.

However, if you do need to define your own styles, do so via custom CSS classes added to the components `.css` file. The framework will ensure that these will be encapsulated within the component and will not affect other components on the page.



You should not attempt to modify the `.style` attribute of the element. If you need to control this you may need to implement a Component Render. The framework provides `$A.util.addClass` and `$A.util.removeClass` methods to dynamically manipulate the style of your components markup safely.

The `THIS` identifier in component CSS must be used to scope the CSS to your component. The following example is used in the **Race Calendar** component to highlight a race when the user clicks on it:

```
.THIS .selectedRace{
  background-color:token(colorBackgroundHighlight);
}
```

The corresponding component markup uses a conditional expression to apply the CSS class (in addition to the SLDS styles). The controller method simply updates the value of the `.Selected` property from the `race` binding:

```
<li class="{'slds-item' + (race.Selected ? 'selectedRace' : '')}">
  onclick="{!c.onRaceClicked}">
```



**Tokens** are a feature of the Lightning framework that allows you to reuse colors and font values expressed by Salesforce in your own styles. The preceding example reuses a token from SLDS that defines what color a selected item is. To include the standard SLDS tokens for use in your components you must create an `aura:tokens` Lightning Bundle, called `defaultTokens`. This has already been included in the sample code for this chapter. In this you can also define your own tokens via the `aura:token` element.

## Component Render (...Renderer.js)

In most cases utilizing the component markup, attributes and bindings to manipulate the appearance of the component is the intended way in which to develop your components. You are also discouraged from manipulating the DOM within your helper or controller methods, as the framework will overwrite the changes when it responds to attribute changes. However, in some cases, for example when using a third party JavaScript library you may wish to take control of the DOM directly. In these cases, utilize a component render. Consult the *Lightning Components Developer Guide* for more information on this facility.

## Component Design (.design) and Component SVG (.svg)

These XML based files allow you to customize the appearance of your component when exposing it through the **Lightning App Builder** and **Lightning Community Builder** tools, such as configuring the icon used to identify it in the sidebar, allowing your users to use these drag and drop tools to configure Salesforce UIs with the introduction of your packaged components. See *Making components customizable* later in this chapter for further discussion and examples of this capability.

## Component Documentation (.auradoc)

Lightning provides its own documentation framework that is built dynamically based on the components in the org, including those from Salesforce. If you plan to allow other developers to use your packaged components, you can use this file to place documentation that describes the purpose and features of the component.



You should also leverage the `description` attribute available on `aura:component`, `aura:attribute`, `aura:method`, `aura:event`, `aura:interface` and `aura:registerEvent`.

Developers can access documentation expressed this way via the URL, <https://<myDomain>.lightning.force.com/auradocs/reference.app>. See *Making components customizable* later in this chapter for an example and more discussion on how to expose your components for use outside your package.

## Enforcing encapsulation and security at runtime

JavaScript code on a page can traverse the entire page content via the HTML DOM API and obtain information or modify other aspects of the page. This breaks encapsulation at runtime and also breaks **security best practices** for container architectures such as Lightning. Imagine as an admin you installed a component that you placed on your Home page and it obtained important data and transmitted it back to another server.

While it is unlikely such a component would pass through the **Salesforce Security Review** and onto **AppExchange**. There is another reason why in Lightning this type of component is not permitted. **Lightning Locker Service**, a service designed to physically block this type of logic from executing at runtime, either intentionally or unintentionally has been created by Salesforce. You may unintentionally write code that is considered not secure, by using features that do not comply with the industry standard **Content Security Policy (CSP)**. Features like use of `eval` and access to the `window` object are also not supported within the security context the Locker Service creates.



Locker Service may be activated by default in your org or your customers org. We are thus strongly encouraged to develop and test our code with it enabled if it is not already switch on for your develop and test orgs. There is also a command line utility, Salesforce Lightning CLI, that scans your code for security vulnerabilities. This is well worth investigating and if you have a Continuous Integration process integrating it.

## Expressing behavior

Now that we know how Lightning allows us to encapsulate our implementation. It is important to keep in mind the vision behind components is sharing and reusability, not just within your own application, but by other consumers of your application. As with an Apex class exposing an API, it is important to carefully manage what ways consumers of your components are permitted to interact with them.

### Access Control

Apex uses the visibility keywords to control what classes, properties and methods are visible, within the scope of the class, within a package and outside of it.

The same level of control is available for the Lightning artifacts you define, such as `aura:application`, `aura:component`, `aura:attribute`, `aura:method`, `aura:event` and `aura:interface`. The default access level in all cases is `public`, which can be increased to `global`. For attributes, you can also use `private`.



As with Apex, it is actually best practice to mark something as the lowest level of access unless you have good reason to increase it. Thus the samples in this book mostly utilize `private` attributes, as these represent the internal state of the component and should not be accessible even to any other components, including those within the package. As with general Apex coding, this best practice helps manage coupling and allows for greater factoring freedom.

JavaScript functions within the controller, helper and renderer files are `private`. You can however use `aura:method` in your component markup to expose controller functions. The next section goes into more details on the use of methods, events and interfaces.



As with Apex classes, consider carefully the implications on your components evolution between package releases when specifying the `global` access control. To support backwards compatibility between upgrades, changes are limited to artifacts that have this access control applied.

## Methods, events and interfaces

In Lightning, the method and interface concepts are similar to equivalent concepts in Apex, but apply to components defined in the client. Unlike Apex, interfaces do not express methods, only attributes and events to be implemented by the component.



Like Apex and Java, interfaces that have no attributes or events are known as **marker interfaces**, as we will discover later in this chapter. The platform makes extensive use of marker interfaces, such as the `force:hasRecordId`, you can apply to your components to let the Salesforce containers known that your components are ready to be used in various contexts.

It can sometimes be difficult to decide when to use a method in place of an event or vice versa, both provide a means for communicating between components:

- An event can be quite an overused term in Lightning; it can refer to something sent from an HTML element in the browser or something that occurs during the component's lifecycle, such as the `init` event. These are known as browser and system level events respectively.

- As a component author you can also define your own **component events** and **application events**. Component events can be fired and handled within the component and by its child components only, whereas application events follow the **publish and subscribe** model, allowing a component to broadcast to any component on the page an event that wants to listen (subscribe) to the event. Refer to developer's guide for more information relating to event handling when considering owner components versus container ([https://developer.salesforce.com/docs/atlas.en-us.lightning.meta/lightning/events\\_application\\_handling\\_phases.htm](https://developer.salesforce.com/docs/atlas.en-us.lightning.meta/lightning/events_application_handling_phases.htm)).
- Methods while easier to implement, tend to create tighter coupling between components, so should be used sparingly, for example to optimize the setup or configuration of child components.

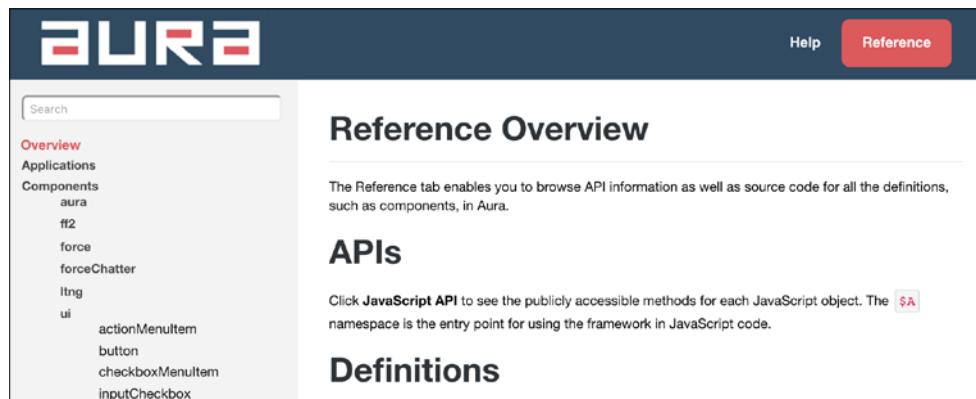
## Platform namespaces

Lightning leverages namespaces to segregate layers and functionality. Namespaces are used in the same way as other parts of the platform with a prefix ahead of the artifact you wish to reference, such as a component or interface. The following table lists some of the core namespaces provided with the platform.

Namespace	Purpose
aura	Based on the core framework used to build Lightning, Aura. This remains an open source framework managed by Salesforce. Core components and markup is defined in this namespace. Aspects of this namespace are designed to be agnostic of the hosting platform. You can run Aura on a Java stack if you wanted to!
force	Contains aspects that relate to the Force.com platform, such as knowledge of SObjects and components that replicate the Custom Object Layout UI in Lightning. The <code>force:inputField</code> and <code>force:outputField</code> components mimic those found in Visualforce under the apex namespace. It contains interfaces that are used when integrating into the Lightning Experience and Salesforce1 mobile containers. The sample components in this chapter implement these interfaces.

forceCommunity	Represents interfaces used to integrate components into the Lightning Community container.
ui	Includes reusable UI components for basic form based user experiences. These components predate SLDS and thus are not styled with it by default, though you can apply SLDS styles yourself. In terms of roadmap, Salesforce is focusing on the lightning namespace going forward.
lightning	Also known as the Base Lightning Components, these are discussed in further detail in the following section.

The following screenshot of the **Aura Documentation** page illustrates a good way to discover all of the supported namespaces and the interfaces, components, and API's within them, including those exposed from packages installed in the org:



The screenshot shows the Aura Documentation interface. At the top, there is a dark header with the 'AURA' logo on the left and 'Help' and 'Reference' buttons on the right. Below the header, on the left, is a sidebar with a 'Search' input field and a 'Overview' section. The 'Overview' section lists 'Applications' and 'Components'. Under 'Components', there is a list of namespaces: 'aura', 'ff2', 'force', 'forceChatter', 'ltng', 'ui', and several sub-components: 'actionMenuItem', 'button', 'checkboxMenuItem', and 'inputCheckbox'. The main content area is titled 'Reference Overview'. It contains a sub-section titled 'APIs' with a note about the \$A namespace being the entry point for JavaScript code. Below the APIs section is another sub-section titled 'Definitions'.

## Base components

The components in the lightning namespace are recommended by Salesforce as they provide functionally rich and styled UI components using SLDS. They have stated that they will continue to receive updates as SLDS evolves. Thus they are recommended to ensure components stay in alignment with the look and feel of the rest of the platform.

At time of writing they have not fully replaced those within the ui namespace. However, Salesforce have stated that they will continue to expand them on each release. Meanwhile continue to check first the lightning namespace before the ui namespace, and check both before building your own.

## Data services

**Lightning Data Services** are at the time of writing in **Developer Preview**, which means that there is a possibility they will change once fully released for production usage. As described in the previous chapter, these can be used as an alternative to writing an Apex Controller in scenarios where you simply wish to create, read, update or delete a record. You can consider them much like the role of the **Standard Controller** in Visualforce, but instead they exist in the client tier and are interacted with by code in the client controller.



Be careful not to allow such client side facilities to allow business logic to leak into the client tier. In all but the simplest cases, you will likely still want to delegate to an Apex Service to perform business logic. Also keep in mind the transactional scope; multiple updates from the client will likely each have their own transaction.

## Object-oriented programming

Lightning components are in many ways similar to classes and objects used by traditional object-oriented programming languages like Apex, Java and C#. There are many benefits to leveraging OOP techniques with components.

In respect to inheritance consider the following:

- We have already seen an example inheritance through the `extends` attribute on the `myapp` Lightning Application extended `force:slds` (which is itself an `aura:application`) to inject SLDS into the application.
- The `defaultTokens` token component used in this chapter's sample code to import the SLDS tokens extended the `force:base` component (which is itself an instance of `aura:tokens`).
- You don't have to leverage only the platform provided base components; you can define your own, marking them extensible via the `extensible` attribute on the `aura:component` element.

Interfaces also provide a means for our components to integrate with Salesforce containers. The **Race Results** component implements the following interfaces so that it can be used on the Lightning Experience **Home** and **Record** pages:

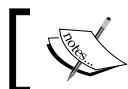
```
<aura:component controller="RaceResultsComponentController"
  implements="force:hasRecordId,
  flexipage:availableForAllPageTypes"
  access="global">
```

## Object-Level and Field-Level security

It is the developer's responsibility to enforce object and field security within Lightning. This can be done with the traditional **Apex Describe** approaches within Apex Controllers. Enforcement should be done at the server end, otherwise unauthorized data can be transmitted to the client and the user could use browser debug tools to inspect the JSON payloads sent from the server.

It is up to the developer as to how the UI manifests to the user. This might simply result in message indicating the user requires more permission or you may choose to dynamically hide (which should include omitting values from the server response) or disallow edit to certain fields or table rows for example.

You might expect that the `ui:inputField` and `ui:outputField` components respect field level security, like their Visualforce counterparts. This is not the case, due to the aforementioned reason; enforcement must happen at the server end.



**Lightning Data Services** are expected to honor object and Field-Level security.



## FormulaForce Lightning Components

In designing the Lightning Components for the FormulaForce sample application contained in this book, I wanted to try to demonstrate some key integration points within the Salesforce UIs, while also ensuring the use cases fit with the application domain.

I focused on Lightning Experience and Salesforce1 Mobile. It is also good practice to think platform-first, before embarking on any extensive development. I started with the following use cases and then devised a set of components to deliver the functionality.

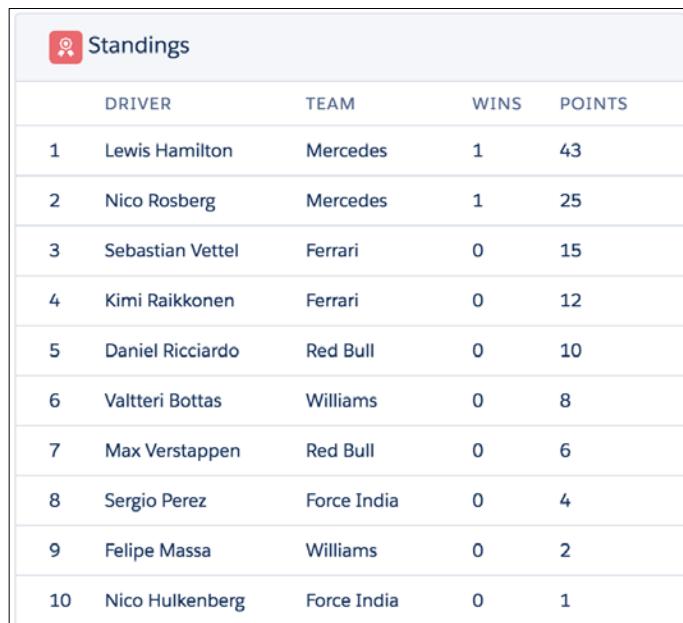
- **Race Overview:** while the standalone Lightning Application we looked at earlier was a good means to get started with the components, it's not a Salesforce integrated solution. What I wanted to do was integrate the **Lightning Experience Home Page**, through the **Lightning App Builder** customization tool. Not only to show the overall standings (leaderboard), but to allow users to **filter information** through the race calendar to show the results from each completed race.

- **Race Calendar accessibility:** The race calendar is a key piece of information users will likely want at hand when using other parts of the application. The **Lightning Experience Utility Bar** (or footer) is specific to your application and contain components you want to be always accessible.
- **Race Setup assistance:** There is a junction object between Race records and Drivers called Contestants. This can make setting up a race overly complex from a user experience perspective. As such I wanted to leverage **Lightning Component Actions** to provide a custom UI to add drivers to a race.
- **Race Results overview.** Race results are the combined result of information from the Contestants, Driver, Team and Car objects. I wanted to provide an easy and contextual way of viewing the race results from the **Home Page** and **Race Record Page** through the **Lightning App Builder** customization tool.

Let's take a closer look at the components that I came up with.

## RaceStandings component

The following screenshot shows the top most portion of the c:RaceStandings component:



The screenshot shows a table titled "Standings" with a red icon of a person in a box next to it. The table has columns: DRIVER, TEAM, WINS, and POINTS. The data is as follows:

	DRIVER	TEAM	WINS	POINTS
1	Lewis Hamilton	Mercedes	1	43
2	Nico Rosberg	Mercedes	1	25
3	Sebastian Vettel	Ferrari	0	15
4	Kimi Raikkonen	Ferrari	0	12
5	Daniel Ricciardo	Red Bull	0	10
6	Valtteri Bottas	Williams	0	8
7	Max Verstappen	Red Bull	0	6
8	Sergio Perez	Force India	0	4
9	Felipe Massa	Williams	0	2
10	Nico Hulkenberg	Force India	0	1

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The following component markup is a simplified HTML `<table>` styled using SLDS:

```
<aura:component controller="RaceStandingsComponentController" implements="flexipage:availableForAllPageTypes" access="global">
    <!-- Attributes -->
    <aura:attribute name="standings" type="Object[]" access="private"/>
    <!-- Event handlers -->
    <aura:handler name="init" value="{!this}" action=" {!c.onInit}"/>
    <!-- Component markup -->
    <lightning:card>
        <aura:set attribute="title">
            <lightning:icon iconName="standard:reward" size="small"/>
            &nbsp;Standings
        </aura:set>
        <table class="slds-table slds-table-bordered
                    slds-table--cell-buffer">
            <thead>
                <tr class="slds-text-title--caps">
                    <th scope="col"></th>
                    <th scope="col">Driver</th>
                    <th scope="col">Team</th>
                    <th scope="col">Wins</th>
                    <th scope="col">Points</th>
                </tr>
            </thead>
            <tbody>
                <aura:iteration items=" {!v.standings}" var="standing">
                    <tr>
                        <th scope="row" data-label="Position">
                            {!standing.Position}</th>
                        <td data-label="Driver">{!standing.Driver}</td>
                        <td data-label="Team">{!standing.Team}</td>
                        <td data-label="Wins">{!standing.Wins}</td>
                        <td data-label="Points">{!standing.Points}</td>
                    </tr>
                </aura:iteration>
            </tbody>
        </table>
    </lightning:card>
</aura:component>
```

Other notable aspects of the `RaceStandings` component are:

- It implements the `flexipage:availableForAllPageTypes` interface that permits the component to be dropped on to the Lightning Experience Home page or any other page edited by the Lightning App Builder.
- The `aura:iteration` is similar to the Visualforce `apex:repeat` component, in that it will iterate over a bound list and repeat the markup defined within.
- It uses two **Base Lightning Components**, `lightning:card` and `lightning:icon`, SLDS styling is implemented by these components.
- The client controller function `onInit` calls a helper function that makes a call to the Apex Controller to load the information from the server. The response updates the `standings` attribute which in turn causes the framework to refresh the HTML table with the records:

```
getStandings :function(component, event ) {
    var action = component.get("c.getStandings");
    action.setCallback(this, function(response) {
        if(response.getState() === 'SUCCESS') {
            component.set("v.standings",
            response.getReturnValue());
        }
    });
    $A.enqueueAction(action);
}
```

- The **Apex Controller** method uses the `ContestantsSelector` class. In the following example the members of the Selector class `ContestantsSelector.Standing` do not support the `@AuraEnabled` attribute, so this class was not used directly in the response. The alternative `RaceStanding` class, allows the response to the client to be more focused on the needs of the client code:

```
public with sharing class RaceStandingsComponentController {
    @AuraEnabled
    public static List<RaceStanding> getStandings() {
        List<RaceStanding>raceStandings =
            new List<RaceStanding>();
        for(ContestantsSelector.Standing standing :
            newContestantsSelector() .
                selectStandingsForCurrentSeason()) {
            RaceStandingraceStanding = newRaceStanding();
            raceStanding.Position = standing.Position;
            raceStanding.Driver = standing.Driver;
            raceStanding.Team = standing.Team;
            raceStanding.Wins = standing.Wins;
            raceStanding.Points = standing.Points;
```

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```
        raceStandings.add(raceStanding);
    }
    return raceStandings;
}

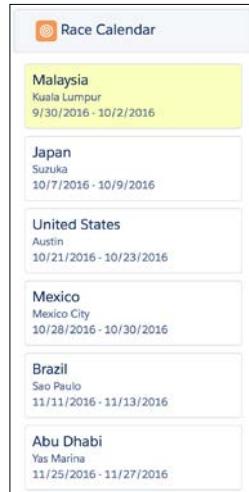
public class RaceStanding {
    @AuraEnabled
    public Integer Position;
    @AuraEnabled
    public String Driver;
    @AuraEnabled
    public String Team;
    @AuraEnabled
    public Integer Wins;
    @AuraEnabled
    public Integer Points;
}
}
```



The `@AuraEnabled` annotation is similar to the `@RemoteAction` annotation used with Visualforce. Both require the method to be static and thus stateless. They can also be used together on the same method thus helping with migration from Visualforce to Lightning.

## RaceCalendar component

The following shows the topmost portion of the `c:RaceCalendar` component:



When the user clicks on a race, the selected race is highlighted and a component application event `c:RaceSelected` is fired. This event will later be received by the `c:RaceResults` component. This event is defined as follows:

```
<aura:event type="APPLICATION"
  description="Fired when the user selects a race" access="global">
  <aura:attribute name="raceId" type="string"/>
  <aura:attribute name="raceName" type="string"/>
</aura:event>
```

The following component markup uses a HTML unordered list `<ul>`. The list and items are styled using SLDS to show a list of *tiles* as specified by the SLDS design guidelines:

```
<aura:component controller="RaceCalendarComponentController" implements
  s="flexipage:availableForAllPageTypes" access="global">
  <!-- Attributes -->
  <aura:attribute name="calendar" type="Object" access="private"/>
  <!-- Event handlers -->
  <aura:handler name="init" value="{!this}" action=" {!c.onInit}"/>
  <!-- Component markup -->
  <lightning:card>
    <aura:set attribute="title">
      <lightning:icon iconName="standard:campaign" size="small"/>
      &nbsp;Race Calendar
    </aura:set>
  </lightning:card>
  <div class="slds-p-around--small">
    <ul class="slds-has-dividers--around-space">
      <aura:iteration items=" {!v.calendar.Remaining}" var="race">
        <li class="{'!slds-item ' + (race.Selected ? 'selectedRace' :
        '')}" onclick=" {!c.onRaceClicked}" data-raceid=" {!race.Id}" data-
        racename=" {!race.Name}">
          <div class="slds-tile slds-tile--board">
            <h4 class="slds-text-heading--small">{!race.Name}</h4>
            <div class="slds-tile__details slds-text-body--small">
              <p>{!race.Location}</p>
              <p>{!race.RaceDate}</p>
            </div>
          </div>
        </li>
      </aura:iteration>
      <li class="slds-p-around--small">
        <div class="slds-text-heading--small">Completed races</div>
      </li>
      <aura:iteration items=" {!v.calendar.Completed}" var="race">
```

```
<li class="{'!slds-item' + (race.Selected ? 'selectedRace' : '')}" onclick="{!c.onRaceClicked}" data-raceid=" {!race.Id}" data-racename=" {!race.Name}">
    <div class="slds-tile slds-tile--board">
        <h4 class="slds-text-heading--small">{!race.Name}</h4>
        <div class="slds-tile__details slds-text-body--small">
            <p>{!race.Location}</p>
            <p>{!race.RaceDate}</p>
        </div>
    </div>
</li>
</aura:iteration>
</ul>
</div>
</aura:component>
```

Other new and notable aspects of this component are as following:

- The CSS class for the `<li>` elements is driven by an expression that evaluates the value of the `Selected` property from the `race` binding. This indicates which race is currently selected by the user.
- **HTML5 data attributes** `data-raceid` and `data-racename` are used to assign useful information to the `<li>` elements. This information can later be referenced by the following controller code.
- The `onclick` attribute on the `<li>` elements calls the `c.onRaceClicked` method. The helper `selectRace` function is invoked and uses the HTML5 data attributes to determine the Salesforce record Id for the race the user clicked on. A utility method updates the `Selected` property on items held in the `calendar` attribute. This update in turn causes the `class` attribute on the `<li>` elements to be refreshed and thus the selected race item shown. Finally the `c:RaceSelected` event is fired so that other components can respond accordingly:

```
selectRace :function(component, event ) {

    // Establish the selected race via HTML5 data attributes
    var selectedRaceId =
        event.currentTarget.dataset.raceid;
    var selectedRaceName =
        event.currentTarget.dataset.racename;

    // Mark the race as selected and deselect any selected
    var calendar = component.get('v.calendar');
    this.updateSelectedRace(calendar.Remaining,selectedRaceId);
    this.updateSelectedRace(calendar.Completed,selectedRaceId);3
```

```

        component.set("v.calendar", calendar);

        // Fire the RaceSelected event
        varcompEvent = $A.get("e.c:RaceSelected");
        compEvent.setParams({ "raceId" :selectedRaceId } );
        compEvent.setParams({ "raceName" :selectedRaceName } );
        compEvent.fire();
    }
}

```

- The Apex Controller method (not shown) to load the race calendar splits and correctly orders the races into two lists (based on whether or not the race has been completed already) which are then sent to the component. This reduces the amount of JavaScript needed in the controller and helper files.

## RaceResults component

The following shows the topmost portion of the `c:RaceResults` component:

Results Italy				
DRIVER	TEAM	GRID	RACE TIME	POINTS
Nico Rosberg	Mercedes	1	1:17:28.89	25
Lewis Hamilton	Mercedes	2	0:0:15.100	18
Sebastian Vettel	Ferrari	3	0:0:21.0	15
Kimi Raikkonen	Ferrari	4	0:0:27.600	12
Daniel Ricciardo	Red Bull	5	0:0:45.300	10
Valtteri Bottas	Williams	6	0:0:51.0	8
Max Verstappen	Red Bull	7	0:0:54.200	6
Sergio Perez	Force India	8	0:1:5.0	4
Felipe Massa	Williams	9	0:1:5.600	2
Nico Hulkenberg	Force India	10	0:1:18.700	1

The `c:RaceResults` component follows a similar implementation approach to the `c:RaceStandings` component, so the full source code is not shown here. You can review the full code through the sample code associated with this chapter:

```
<aura:component controller="RaceResultsComponentController" im-
plements="force:hasRecordId,flexipage:availableForAllPageTypes"
access="global">
<!-- Attributes -->
<aura:attribute name="recordName" type="String" access="private"/>
<aura:attribute name="results" type="Object[]" access="private"/>
<!-- Event handlers -->
<aura:handler name="init" value="{!this}" action=" {!c.onInit}"/>
<aura:handler event="c:RaceSelected"
action=" {!c.handleRaceSelectedEvent}"/>
```

The following code fragments from the component are notable:

- The `flexipage:availableForRecordHome` interface, states the component is available for dropping on **Record pages** via Lightning App Builder.
- The `flexipage:availableForAllPageTypes` interface, states the component is available for dropping on the **Home page** via Lightning App Builder.
- The `force:hasRecordId` interface, lets the container, Lightning Experience or Salesforce1 know that the component wants to know the record ID. This is placed by the container in the `recordId` attribute (added by the interface), when the component is placed on a **Record** page.
- The `c.onInit` method checks the value of the `recordId` attribute; if it is not null it will load the applicable race results and display them. Since the component can be dropped on the home page this can be null in that context:

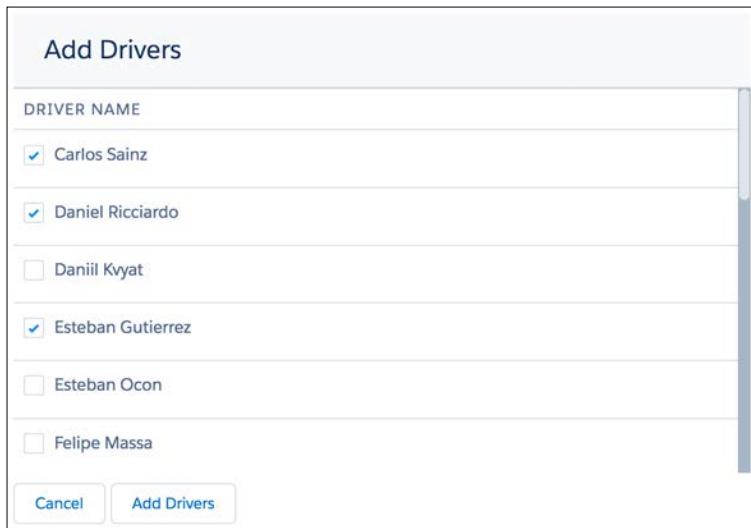
```
onInit :function(component, event, helper) {
    // If we have a recordId context load the race results
    varrecordId = component.get('v.recordId');
    if(recordId!=null) {
        helper.getRaceResults(component, event);
    }
}
```

- The `c.handleRaceSelected` is called when the `c:RaceSelect` event is fired. The method extracts the `raceId` and `raceName` from the event parameters and refreshes the race results. This approach allows the component to exist on both the Record and Home pages and still be contextual:

```
handleRaceSelectedEvent :function(component, event, helper) {
    // Update race record Id and Name attributes from Event
    component.set('v.recordId', event.getParam('raceId'));
    component.set('v.recordName', event.getParam('raceName'));
    // Retrieve race results
    helper.getRaceResults(component, event);
}
```

## RaceSetup component

The following shows the `c:RaceSetup` component:



This component leverages a HTML table to display a table with a list of drivers. The `lightning:input` component is used to bind checkboxes to the list items. The full markup is not shown; the following code fragments are notable:

```
<aura:component controller="RaceSetupComponentController"
    implements="force:lightningQuickActionWithoutHeader,
    force:hasRecordId" access="global">

    <lightning:input
        value="{!driver.Selected}" type="checkbox"
```

```
checked=" {!driver.Selected}" label=" {!driver.Name}" />

<lightning:button label="Cancel" onclick=" {!c.onCancel}" />
<lightning:button label="Add Drivers"
    onclick=" {!c.onAddDrivers}" />
```

The following code fragments from the component are notable:

- The `force:lightningQuickActionWithoutHeader` is used to indicate that this component can be used when creating an **Action** on an object definition. When the user invokes the action the component will show in a popup without the default header and cancel button, which is the preference here since the component is rendering its own buttons. Otherwise the component would have implemented `force:lightningQuickAction`.
- The `c.onCancel` function sends the `force:closeQuickAction` event to instruct the container to close the popup by executing the following code:  
`$.A.get("e.force:closeQuickAction").fire();`
- The `c.onAddDrivers` function calls a helper function. The helper function passes back the list of drivers to the server. The list contains the selected drivers. The Lightning framework automatically keeps the checked status of the `lightning:input` component in sync with the bound `.Selected` property on the items in the list. The Apex Controller calls the `RaceService.addDrivers` method. After a successful response the client controller code fires the `force:showToast` event (shown as following) to display a notification and the `force:closeQuickAction` event to close the popup:

```
addDrivers :function(component, event ) {
    var action = component.get("c.addDrivers");
    action.setParam('raceId', component.get('v.recordId'));
    action.setParam('driversToAdd',
        component.get('v.drivers'));
    action.setCallback(this, function(response) {
        if(response.getState() === 'SUCCESS') {
            // Refresh the view to show the recently added drivers
            $.A.get('e.force:refreshView').fire();
            // Display Toast message to confirm drivers
            var resultsToast = $.A.get("e.force:showToast");
            resultsToast.setParams({
                "title": "Add Drivers",
                "message": "Added " + response.getReturnValue() +
                " drivers." });
            resultsToast.fire();
            // Close the action panel
            $.A.get("e.force:closeQuickAction").fire();
        }
    });
}
```

```

    });
    $A.enqueueAction(action);
}

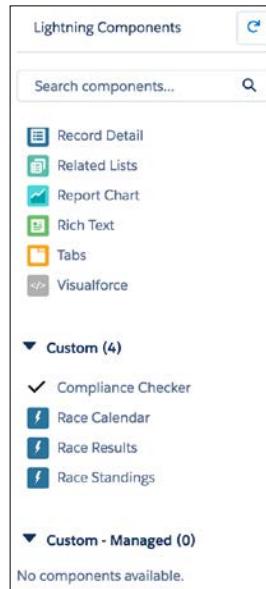
```



 In the preceding example, literal text is used. Best practice is to use a **Custom Label**. In this case the message text would look something like this Add {0} drivers. The client controller code would use the \$A.util.format function to format the message.

## Making components customizable

The components included in this chapter will appear in Lightning App Builder and are thus available for the developer and consumers of the package to drag and drop them onto pages. Because they are *global* they can also use them in their own component code:



This is due to the following aspects:

- The `access` attribute on the components is set to `global`.
- They implement applicable `flexipage` and `force` interfaces.
- Though not required, the `.design` files specify a component label:

```
<design:component label="Race Calendar">  
</design:component>
```

- The `.svg` file for the `c:CheckCompliance` component defines a custom icon that is displayed next to the component in the Lightning App Builder.
- Though not required, the **Race Result** component also includes additional markup to indicate to Lightning App Builder, the component is only relevant to the `Race__c` custom object:

```
<design:component label="Race Results">  
<sfdc:objects>  
<sfdc:object>Race__c</sfdc:object>  
</sfdc:objects>  
</design:component>
```

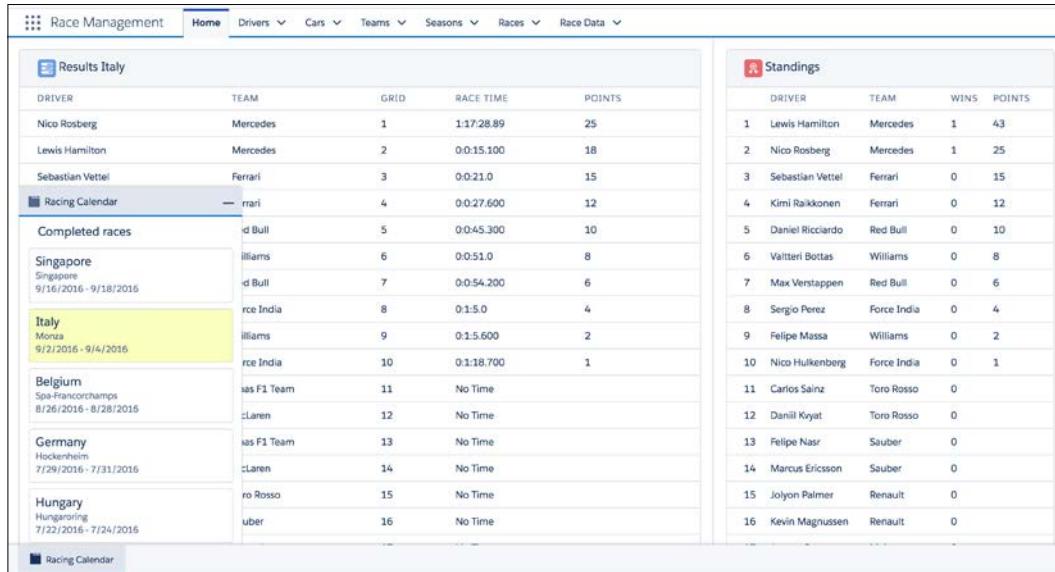


The components can also declare attributes that appear in the configuration panel to the right of the Lightning App Builder design surface. These are expressed using the `design:attribute` element within the `.design` file. These must match those expressed in the component markup. Any attributes exposed this way must also have an access level of `global`.

## Integrating with Lightning Experience

The following screenshots highlight the various points at which the components have now been integrated with Lightning Experience. These components are still available to the Race Overview standalone app we started this chapter with, though additional interfaces and events now support more advanced containers through Lightning App Builder.

This screenshot shows the **Race Results** and **Race Standing** components on the **Home page**, with the **Race Calendar** component accessible via the **Utility Bar**. The race results are updated as the user selects races from the **Race Calendar**:



The screenshot displays the Home page of the Race Management application. At the top, there is a navigation bar with tabs: Race Management, Home, Drivers, Cars, Teams, Seasons, Races, and Race Data. The Home tab is currently selected. Below the navigation bar, there are two main components: 'Results Italy' and 'Standings'.

**Results Italy:** This component displays race results for the Italian Grand Prix. It includes a table with columns: DRIVER, TEAM, GRID, RACE TIME, and POINTS. The results are as follows:

DRIVER	TEAM	GRID	RACE TIME	POINTS
Nico Rosberg	Mercedes	1	1:17:28.89	25
Lewis Hamilton	Mercedes	2	0:05:100	18
Sebastian Vettel	Ferrari	3	0:02:1.0	15
—	Red Bull	4	0:02:7.600	12
Completed races	Red Bull	5	0:04:5.300	10
Singapore	Williams	6	0:05:1.0	8
Singapore 9/16/2016 - 9/18/2016	Red Bull	7	0:05:4.200	6
Italy	Force India	8	0:1:5.0	4
Monza 9/2/2016 - 9/4/2016	Williams	9	0:1:5.600	2
Belgium	Force India	10	0:1:18.700	1
Spa-Francorchamps 8/26/2016 - 8/28/2016	Red Bull Team	11	No Time	
Germany	McLaren	12	No Time	
Hockenheim 7/29/2016 - 7/31/2016	Red Bull Team	13	No Time	
Hungary	McLaren	14	No Time	
Hungaroring 7/22/2016 - 7/24/2016	Toro Rosso	15	No Time	
—	Renault	16	No Time	

**Standings:** This component displays the driver standings. It includes a table with columns: DRIVER, TEAM, WINS, and POINTS. The standings are as follows:

DRIVER	TEAM	WINS	POINTS
Lewis Hamilton	Mercedes	1	43
Nico Rosberg	Mercedes	1	25
Sebastian Vettel	Ferrari	0	15
Kimi Raikkonen	Ferrari	0	12
Daniel Ricciardo	Red Bull	0	10
Valtteri Bottas	Williams	0	8
Max Verstappen	Red Bull	0	6
Sergio Perez	Force India	0	4
Felipe Massa	Williams	0	2
Nico Hulkenberg	Force India	0	1
Carlos Sainz	Toro Rosso	0	
Daniel Ricciardo	Toro Rosso	0	
Felipe Massa	Sauber	0	
Marcus Ericsson	Sauber	0	
Jolyon Palmer	Renault	0	
Kevin Magnussen	Renault	0	

At the bottom of the page, there is a 'Race Calendar' component with a table showing race details for the Italian Grand Prix (Monza, 9/2/2016 - 9/4/2016).

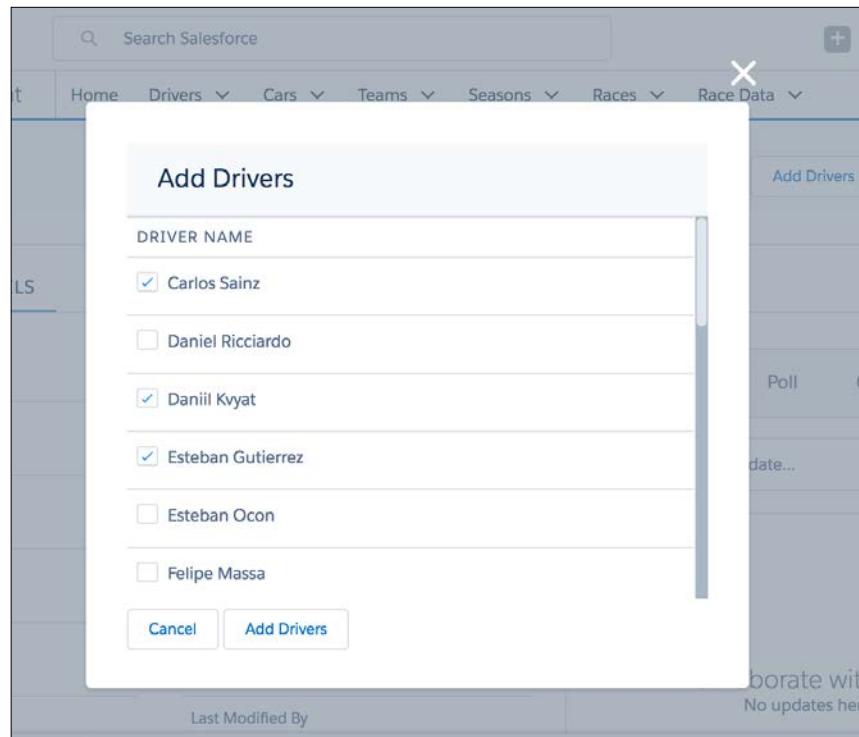
The Utility Bar is defined using a **Lightning Page** (or **FlexiPage** as it's known in **Metadata** form). The sample code in this chapter included such a page called `RaceManagementUtilityBar` in the `/flexipages` folder. This page is referenced in the **Race Management** app metadata (in the `/apps` folder).



## *Lightning*

---

This screenshot shows the **Race Setup** component appearing as a result of the user clicking the **Add Drivers** Action on the Race record page. Lightning Component Actions are configured under **Actions** from the **Race** object definition page under **Setup**:



This final screenshot shows the **Race Results** component again, but this time on the Race record page. The Lightning App builder was used to add a new tab Race Results and the Race Results tab was dragged and dropped on it. This illustrates that components can support multiple locations within Lightning Experience:

DRIVER	TEAM	GRID	RACE TIME	POINTS
Nico Rosberg	Mercedes	1	1:17:28.89	25
Lewis Hamilton	Mercedes	2	0:01:15.100	18
Sebastian Vettel	Ferrari	3	0:01:21.0	15
Kimi Raikkonen	Ferrari	4	0:01:27.600	12
Daniel Ricciardo	Red Bull	5	0:01:45.300	10
Valtteri Bottas	Williams	6	0:01:51.0	8
Max Verstappen	Red Bull	7	0:01:54.200	6

## Using Components on Lightning Pages and Tabs

**Lightning Pages** (or FlexiPages) are essentially layouts created from a blank page with the Lightning App Builder tool. Thus you or your customers can drop the preceding components and any others on them to create a new page. Unlike Visualforce pages, they do not have a URL for accessing them. **The only way to display a Lightning Page is to create a Lightning Tab for it.** This can be accessed under **Tabs** under the **Setup** menu. Lightning Tabs work in Lightning Experience and Salesforce1 Mobile.

It is also possible to implement the `force:appHostable` for a component. This permits the creation of **Lightning Component Tabs**. This historic facility is not as flexible as using the Lightning App Builder to build Lightning Pages which allow the user to place multiple components on the page.

## Lightning Out and Visualforce

**Lightning Out** is a JavaScript library that can be imported into regular HTML pages, such as Visualforce pages and other websites or other containers such as Google Apps. Once imported it exposes an API that allows the page developer to instantiate a Lightning Component and inject it into a given HTML element on that page. The host page must provide a Salesforce Session or oAuth token to allow this to happen in a secure way.

The process of using **Lightning Out for Visualforce** pages is simplified through the use of the `apex:includeLightning` component on the page which loads the JavaScript library and handles authentication. Call the `$Lightning.use` global method to begin the bootstrapping process to load the component onto the page.

 Using Lightning Components on a Visualforce page does allow you to consider ways to develop new areas of your solution with Lightning while still delivering a Salesforce Classic user experience for customers that still require it.

For more information on configuring Lightning Out, consult the applicable section in the *Lightning Developers Guide* ([https://developer.salesforce.com/docs/atlas.en-us.lightning.meta/lightning/lightning\\_out.htm](https://developer.salesforce.com/docs/atlas.en-us.lightning.meta/lightning/lightning_out.htm)).

## Integrating with communities

Lightning Community is another container for your Lightning Components; as such existing components are likely already close to being able to exist within it and the **Lightning Community Builder** tool. The most basic requirement is that your components implement the `forceCommunity:availableForAllPageTypes` interface.

The same considerations to specify a component `.design` file as described in the earlier section also apply so that the components appear correctly in the Lightning Community Builder tool, notably making the components access level `global`.

It is also possible to customize the Lightning Community container through components implementing interfaces that provide a custom theme layout, profile header, search and post publisher components and content layouts. Consult the interfaces within the `forceCommunity` namespace for more details.

## Testing

At the time of writing there is no Salesforce provided test framework for Lightning components as there is for Apex. Salesforce has not officially commented, but it is likely that they will include the Aura test framework that exists today in the open source project in a future release of the Force.com platform (<http://documentation.auraframework.org/test/runner.app>).

Meanwhile I recommend you review existing browser testing tools.

## Updating the FormulaForce package

As with previous chapters, check that all new components have been added to the FormulaForce package and upload it. Due to the inclusion of the Utility Bar the package now requires **My Domain** to be configured in orgs for installation to complete. While My Domain offers some increased security benefits for customers, it does come with the implications that need careful consideration. Consult with your customer base before making this dependency on your package.

## Summary

In this chapter, you have understood the high level architecture of the Lightning framework, both from a the perspective of a standalone page to integrating Lightning Components within Lightning Experience and Salesforce1 Mobile.

Lightning Experience is now more extensible than the original Salesforce Classic user interface. There are more options to consider before deciding your only option is to start building entirely new from the ground up page level experiences. Thinking about these integration capabilities as you consider your user experience requirements along with how aligning component thinking between developers and UX designers is a key to embracing this new of building applications on Salesforce.

The need for Separation of Concerns and good coding practices is now as important at the client tier as it is at the backend. It is also more important to monitor your architecture for encapsulation of and containment of your business logic. This should still remain firmly at the backend where different client types can access it.

Finally, it is pretty clear that Lightning is embracing the ongoing industry adoption of JavaScript, so if you need to brush up on your JavaScript skills now is the time to start!

In the next chapter we will be exploring platform features, tools and best practices for providing integration opportunities to your applications customers and partners.



# 10

## Providing Integration and Extensibility

Enterprise businesses have complex needs involving many human, device, and increasingly machine interactions, often distributed across the globe. Allowing them to work together in an efficient and secure manner is no easy task, and as such, it is no great surprise that utilizing cloud-based software over the Internet has become so popular. High-grade security, scalability, and availability is high on checklists when choosing a new application, often followed by API needs and the ability to customize.

By developing on the Force.com platform, your application already has a good start. The <http://trust.salesforce.com/> site provides a wide selection of industry strength, compliance, and encryption standards that are equally applicable to your applications. With this comes a selection of standard APIs offered in the SOAP and REST forms as well as the ability to create your own application APIs. In my view, there is not a more integration-ready cloud platform available today than Force.com.

In this chapter, we will review the integration and extensibility options provided as standard on the platform and how your application can get the most from them, in addition to developing custom application APIs. Once again the Application Enterprise Patterns will come into play, supporting the need for APIs and UIs to have a strong functionality parity, through the use of the Domain and Service layers described in earlier chapters.

This chapter will cover the following topics:

- Reviewing integration and extensibility needs
- Force.com platform APIs for integration
- Application-specific APIs

- Alignment with Force.com extensibility features
- Extending the application logic with Apex Interfaces

## Reviewing your integration and extensibility needs

Before diving into the different ways in which you can provide APIs to those integrating or extending your application, let's review these needs through the eyes of *Developer X*. This is the name I give to a persona representing a consumer of your APIs and general integration and extensibility requirements. Much like its use in designing a user interface, we can use the persona concept to sense check the design and interpretation of an API.

## Defining the Developer X persona

Asking a few people (internal and external to the project) to represent this persona is well worth doing, allowing them to provide use cases and feedback to the features and functions of your application's API strategy, as it is all too easy to design an API you think makes sense, but others with less knowledge of the application do not easily understand. A good way to develop a developer community around your API is to publish designs for feedback. Keep in mind the following when designing your API for *Developer X*:

- *Developer X* is skilled in many platforms and programming languages these days, which might not always be Force.com. Increasingly *Developer X* is also creating Mobile, JavaScript, and Heroku applications around your API.
- As the **Internet of Things (IoT)** continues to expand, there is also a shift towards device integration from consumer devices such as watches, fridges, cars, and jet engines. So, APIs that work well on-platform and off-platform are a must.
- *Developer X* might not have an in-depth knowledge of the application domain (its functional concepts), thus it's important for them to be able to communicate with those that do, meaning that your API design and application functionality terminology has to be well-aligned.

The upcoming sections outline general considerations and needs around providing both an integration API and general extensibility of your application's functionality.

## Versioning

As your product functionality grows, it is important to manage the impact this has on developers and partners who have already adopted your APIs in earlier releases of your application and not force them to make code changes unless needed. Where possible, maintain backwards compatibility such that even after your application has been upgraded in a subscriber org, existing integrations and extensions continue to work without modification (multiple versions of your application code are not stored in a subscriber org).

Without backwards compatibility you can inhibit upgrades to your application within your customer base, as the time spent by *Developer X* addressing API issues can delay upgrades and be expensive. Some subscribers might have utilized consulting services to affect the original work or be dependent on one of your partners for add-on solutions using your API.

Versioning falls into two categories: versioning the definition (or contract determined input and output of data) and the functionality (or behavior) each API represents.

### Versioning the API definition

Once you have published a specific version of an API, do not change its definition, for example the Custom Objects, fields, Apex classes, methods, or members, or equivalent REST or SOAP constructs. Even though the platform will help avoid certain changes, additions can be considered a breaking change, especially new required fields. Anything that changes the definition or signature of the API can be considered a potential breaking change.

*Developer X* should be able to modify and redeploy their existing integrations or extensions without having to recode or adjust their code using your API and without forcing them to upgrade to the latest version of your API, unless, of course, they want to access new functionality only accessible by completing new fields. Note that this is different from upgrading the package itself within the subscriber org, which must be allowed to happen.

The standard Salesforce APIs and platform help provide versioning when *Developer X* interacts with your Custom Objects and Application APIs. Versioning is implemented as follows:

- In an Apex code context, the platform retains the version of your package installed when the Apex code was first written by *Developer X*, and then only ensures that Apex classes, methods, members, Custom Objects, and fields visible in this packaged version are visible to the code. This feature is something that we will explore in further detail later in this chapter.

- In the case of the SOAP and REST APIs, by default the latest version of your Custom Objects is visible. When using the SOAP API, header values can be passed in such calls to lock a particular package version if needed (search for `PackageVersionHeader` in *Apex Developer's Guide*). Alternatively the packaged version used by these APIs can be set at an org-configuration level.

## Versioning application access through the Salesforce APIs

Under the **Setup** menu, search for **API**. You will find a setup page that allows you to download the WSDLs for one of the many Salesforce SOAP APIs. In the next section there are some versioning settings that determine which installed package version should be assumed during interactions with your packaged objects.

For example, when performing a `describeObject` web service operation via the Salesforce Enterprise or Partner APIs, these APIs will return different custom fields depending on when new fields were added, as new versions of the package have been released over time. The default behavior will return all fields as the default is the current package version.

If this is important to *Developer X* or third-party solutions when using these Salesforce APIs, the subscriber administrator can specify an explicit previous version. If they do this, new fields available in future package versions will not be available unless this is changed. The following screenshot shows how these settings can be accessed on the API page under **Setup**:

**Package Version Settings**

**Enterprise Package Version Settings**  
These version settings are used if an API call doesn't include version information for an installed package. This ensures backwards compatibility.  
[Configure Enterprise Package Version Settings](#)

**Partner Package Version Settings**  
These version settings are used if an API call doesn't include version information for an installed package.  
[Configure Partner Package Version Settings](#)



Only available if you have one or more managed packages installed.

## Versioning the API functionality

When offering new versions of your application to users through the UI, new features are accessed by the user – either by opting into the feature by configuration using a new page or button, or sometimes just seamlessly such as a new type of calculation, optimization, or improvement to existing behavior with added benefits.

As the API is just another way into your application's logic, you should think about enabling these new features through the API in conceptually the same way. If it is seamlessly available through the UI to users, it becomes so in the API regardless of the API version, and thus, solutions built around your application's API will also benefit automatically without changes to the integration or extension code. However, if there is a new field or button needed in the UI, then a new API parameter or operation will be needed to enable the new feature. It is reasonable for this to be exposed in a new version of your API definition. Thus, *Developer X* will have to modify the existing code, test it, and deploy it before the solution can leverage it.

Trying to be sophisticated in your code by providing exactly the same behavior to older callers of your API will depend on the Service and Domain layers understanding the concept of API versus UI contexts and package versioning, which will rapidly become complex for you to develop, test, support, and document.

 Agree and communicate to your customers and partners clearly how many versions of your API you will support and give warning on retirements. Always be sure to test your APIs at different versions to ensure the lack of fields that arrive later in your package, which are not provided by older callers, does not cause errors or unwanted behavior in these cases. Try to avoid adding new required fields to your applications without a way to default them.

If in your regression testing of older API versions, you notice a reduction in data volume throughput due to governors, it can be acceptable to condition newer logic (such as checks for newer fields). Again, be careful with how often you implant this type of conditional logic in your code base.

## Translation and localization

As with the guidelines around the Service layer, which can be used as a means to form your application API later in this chapter, you should ensure that any error or status messages are translated according to your use of **Custom Labels**, as described in *Chapter 2, Leveraging Platform Features* (the Apex runtime will ensure that the user locale determines the translation used).



It is not possible to override the default Org language used to look up the appropriate Custom Labels through Apex. However, if the API is called from a Visualforce page utilizing the `language` attribute as described in Chapter 8, your API code will also honor this.

Some APIs expose error codes to provide a language-neutral way to recognize a certain error use case programmatically (parsing the message text is not reliable in a translated environment). As such, one approach is to use an Apex **enum** and a custom Apex **exception** class, which captures both the translated error message and the exception code. The following enum and exception types are defined in the Application class contained within the sample code for this chapter. Note the use of the `global` keyword in Apex; this will be discussed later in this chapter in more detail:

```
global Application {  
    global enum ExceptionCode {  
        ComplianceFailure,  
        UnableToVerifyCompliance  
    }  
  
    global virtual class ApplicationException extends Exception {  
  
        global ExceptionCode ExceptionCode {get; private set;}  
  
        public ApplicationException(  
            ExceptionCode exceptionCode, String message) {  
            this(message);  
            this.exceptionCode = exceptionCode;  
        }  
    }  
}
```

While the preceding `ApplicationException` class can be used as it is, the following `ComplianceService` class has its own custom exception that can then extend this:

```
global class ComplianceException  
    extends Application.ApplicationException {  
  
    global List<VerifyResult> failures {get; private set;}  
  
    public ComplianceException(  
        Application.ExceptionCode exceptionCode,  
        String message, List<VerifyResult> failures) {  
        super(exceptionCode, message);  
        this.failures = failures;
```

```
    }  
}
```

This code can then raise exceptions specifying the enum value related to the message as follows:

```
throw new ComplianceException(  
    Application.ExceptionCode.ComplianceFailure,  
    Label.ComplianceFailuresFound,  
    failedCompliances);  
  
throw new ComplianceException(  
    Application.ExceptionCode.UnableToVerifyCompliance,  
    Label.UnableToVerifyCompliance,  
    null);
```

As with the Service layer guidelines, the API should be client agnostic, and thus you cannot assume whether the data values accepted or returned should be formatted or not. Thus, it is best to use the native Apex types for date, date/time, and number and allow the caller to decide whether or not to format the values. Returning formatted values is useful for UI callers, but for headless or automated solutions, this is not ideal.

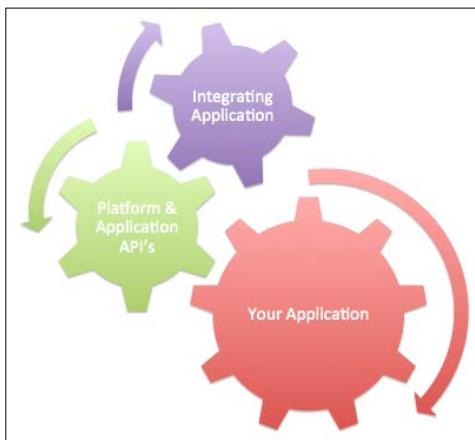
## Terminology and platform alignment

If you're following the guidelines of the Service layer when defining your classes, methods, parameters, and interfaces (as discussed later in this chapter), then any API based on this layer should already mirror the functional terms used in your application. Having a good alignment with your application terms makes your API easier to map to functional concepts in your application and thus for *Developer X* to navigate around and understand and discuss with those that know the application in more functional depth.

In addition, like the Service layer, your API should support platform concerns such as bulkification and not inhibit *Developer X* from calling your API in a bulkified way to make optimum use of the platform resources. This also includes *Developer X* utilizing Apex DML statements and thus then raises the importance of bulkified Domain layer logic as well as bulkified Service layer logic.

## What are your application's integration needs?

Typically an integration need arises from a controlling process or application that consumes the functionality of your application, effectively invoking the functionality within your application automatically on behalf of a user, or as part of an event or scheduled background process. Both, the standard Salesforce APIs and any additional application APIs that you create can support this need. The following diagram shows a controlling system driving your application through either the standard Salesforce API and/or application APIs that you have provided as part of the managed package:



Although integrations are much easier when all applications are built based on the same platform, it is a good practice to have an API strategy that covers both, on- and off-platform, *Developer X* scenarios, ideally exposing the same functionality consistently.

## Developer X calling your APIs on-platform

A Force.com Apex developer can manipulate the data stored in your application through Apex DML statements. You can think of Apex DML as your free Apex API to your application data, as this approach avoids the need for you to build your own application APIs to purely manage record data, particularly for those Custom Objects that you are already exposing through the standard Salesforce UI.



It can be a useful aid to these developers to browse your Custom Object schema through Salesforce Schema Builder, as highlighted earlier in this book. Try to avoid inconsistencies between your **Field Labels** and **Field API** names (though the Schema Builder does permit toggling of these), as this can make it harder for developers and those expressing the requirements to collaborate.

Just because Apex is being used does not mean that *Developer X* can bypass logic in your managed Apex Triggers. However, take note that they can also write Apex Triggers of their own, which can execute before yours (as the Apex Trigger order is nondeterministic). To avoid *Developer X* triggers making invalid changes to record data, ensure that you follow the best practice when you're writing the validation logic to place it in the after-phase of your application triggers. As discussed in the previous chapter, utilizing the Domain pattern will ensure this.

Later in this chapter we will discuss application APIs that expose functionality not directly related to manipulating your Custom Object records, but one that is more business logic related, for example exposing the `ComplianceService.verify` method. In this case, by making the Service class and methods `global` as opposed to `public`, you can make this same method available to *Developer X*. As an extension to your Apex API strategy, allow them to consume it in the same manner as you do within your application.

The motivation behind this approach, described further in this chapter, is to ensure that the maximum amount of your application functionality is available through your API as your application evolves. However, if you do not want to expose your full Service layer directly as your application API, you can elect to create separate Apex classes that define your API which delegate to the Service layer or selectively apply the `global` keyword to your Service methods.

## Developer X calling your APIs off-platform

*Developer X* using languages such as Java, .NET, NodeJS or Ruby uses the HTTP protocol to connect between the two platforms. Salesforce provides APIs to log in and authorize access for you as well as APIs to manipulate the data in your Custom Objects much like using Apex DML. Salesforce currently chooses to expose both SOAP- and REST-based variants of its HTTP-based APIs. So again, you need not develop your own APIs for this type of data integration.



Many third-party Salesforce integration applications leverage platform APIs and as such will also work with your application data; this fact is a key platform benefit for you and *Developer X*.

When it comes to exposing application APIs, to support SOAP and REST, you will need to develop separate Apex classes in each case for each API that you want to expose. This is because the definition and design of these types is different, though the functionality you're exposing is the same. We will discuss this further later in this chapter.

## SOAP versus REST

If you have been following the debate over SOAP versus REST or just simply Google for it, you'll know that there is currently a general trend towards REST. As it's easier to code against and consume in mobile and JavaScript-based scenarios, most major cloud services such as Facebook and LinkedIn only provide REST versions of their APIs. For ease of use and the ability to be more self-describing I prefer REST also.

## What are your applications extensibility needs?

So far we have been discussing providing facilities to build custom solutions around your application, which is one type of integration. Another is providing ways to make extensions to its existing business logic. In an extensibility use case, *Developer X* or an administrator is happy for your users to consume your application UI and functionality directly but wants to extend it in some way to add additional functionality or updates to other Custom Objects. Some examples of the type of extensions you might want to consider are as follows:

- Adding subscriber-created **Custom Fields** to **Visualforce Pages** and **Field Sets** is an easy way to achieve this
- Providing alternatives to hardcoded **Email messages** via **Email Templates**
- Extending the application Apex code logic with the subscriber-written Apex logic; this is something I call **Application Callouts**

In this chapter we will explore Application Callouts further. The following diagram shows processes in your application code making use of this approach to execute **code** written by *Developer X*. Later in this chapter we will see an example of how can implement these through the use of Apex interfaces and Custom Metadata records.



## Force.com platform APIs for integration

*Chapter 2, Leveraging Platform Features*, provided a good overview of the many platform APIs available to those integrating with your application from outside of the Force.com platform, from environments such as Java, .NET, PHP, and Ruby. It also provided the best practices to ensure that your application and developers using these APIs have the best experience.

As stated in that chapter, these APIs are mostly focused on record data manipulation and querying, often known as CRUD. Leveraging the Salesforce APIs means developers wishing to learn how to integrate with your application objects can leverage the standard Salesforce API documentation and websites such as <https://developer.salesforce.com/>.



Although the Enterprise API provides a strongly typed SOAP API for Java or .NET developers, its larger size can be problematic to load into development environments (as it includes all Custom Objects and fields present in the org). As such, more general Partner API is often a better recommendation to make to *Developer X*. Most developers are used to generic data access layers such as JDBC and ADO, and in essence to them the Partner API is similar and a lot smaller to embed in their applications. If however, you are recommending an API for mobile or JavaScript integration, the Salesforce REST APIs are even lighter, though come at the added responsibility of the developer to parse and form the correct JSON responses and requests without the aid of generated class types provided via the WSDLs of the SOAP APIs. Typically, languages that prefer more strongly typed programming principles prefer the SOAP variants over the REST variant.

For Java developers, Salesforce provides an excellent **Web Service Connector (WSC)** framework, which offers an efficient way to consume the SOAP and REST APIs without the need for any other web service stacks. They provide compiled versions of their popular Partner and Metadata APIs, with plenty of examples online. If you're familiar with it, the easiest way to download and start using this API is to use Apache Maven (<https://mvnrepository.com/artifact/com.force.api/force-wsc>). You can also download WSC from <https://github.com/forcedotcom/wsc>:

*"The Force.com Web Service Connector (WSC) is a high performing web service client stack implemented using a streaming parser. WSC also makes it much easier to use the Force.com API (Web Services/SOAP or Asynchronous/BULK API)."*

For .NET developers, Salesforce started an open source initiative to build precompiled assemblies providing access to their APIs, much in the same spirit as the WSC Java library described earlier. You can download the toolkit for .NET from <https://github.com/developerforce/Force.com-Toolkit-for-NET>:

*"The Force.com Toolkits for .NET provides an easy way for .NET developers to interact with the Force.com & Chatter REST APIs using native libraries."*

For NodeJS developers, Kevin O'Hara has contributed to the community a library known as nforce to the community. You can download this toolkit for NodeJS from <https://github.com/kevino'hara80/nforce>:

*"nforce is node.js a REST API wrapper for force.com, database.com, and salesforce.com."*

## Application integration APIs

This section describes ways in which you can expose your application's business logic functionality encapsulated within your Service layer.

 In some cases, *Developer X* is able to achieve such functionality through the standard Salesforce APIs. However, depending on the requirement, it might be easier and safer to call an API that exposes an existing business logic within the application. You can decide to do this for the same reasoning you would create a custom UI rather than expect the end users to utilize solely the standard UI (as using your objects directly requires them to understand the application's object schema in more detail).

## Providing Apex application APIs

If your Service layer is developed and tested as robustly as possible following the guidelines discussed in the earlier chapter, it is worth considering exposing it to *Developer X* by simply updating the class, methods, members, properties, and any custom Apex types such as `global`. This part of the chapter discusses the approach in more detail, though it can also be applied to dedicated Apex classes built specifically to expose an API that is delegating to your Service layer classes:

```
global class ComplianceService
{
    global static void verify(Set<Id> recordIds)
    {
```

 Make sure that you apply the `global` modifier carefully as it is not easy to deprecate it after your package has been released. Also, be sure to apply `global` to aspects of your Service layer only, avoid exposing Domain or Selector layer classes or types. If you need to expose behavior in these classes, write a Service layer method to do so. Also, note that the `ComplianceService.ICompliant` interface has not had the `global` modifier applied, as this is an internal aspect to the service.

As shown earlier in this chapter, we have also applied the `global` modifier to the Apex exception class defined within the `ComplianceService` class.

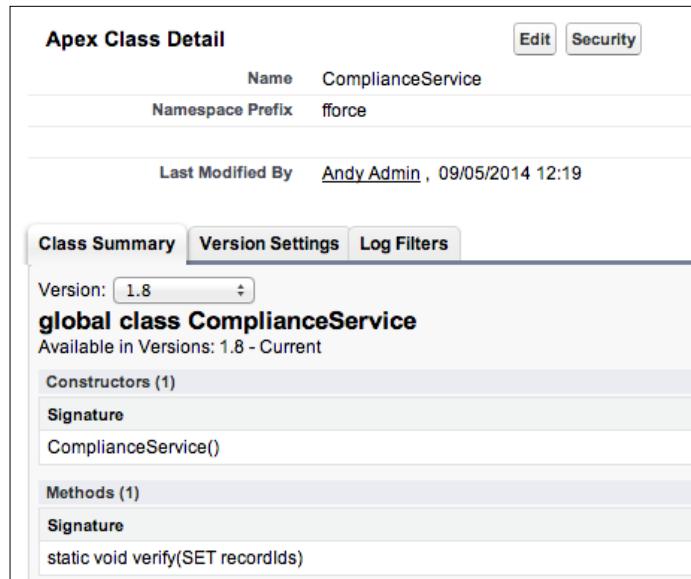
To try out this new application API, we will perform the following steps and execute the sample Apex test code introduced below in your test development org:

1. Apply the sample code for this chapter to your packaging org.
2. Comment out the `ComplianceService.report` method (we will uncomment this shortly before performing another upload).

3. Upload a release of the package and install it in your test development org.
4. Open the **Developer Console** and create an Apex class called ApplicationAPITest.

If you inspect the `ComplianceService` class in your test development org from the **Apex Classes** page under the **Setup** menu, you can see the new API methods and types you've just exposed are now visible (without the code). This provides a basic means for *Developer X* to learn about your API, in addition to any documentation you provide. A portion of how this looks for `ComplianceService` is shown in the following screenshot.

You can also see a **Version** drop-down box, which allows *Developer X* to explore different versions of the API definition. Note that the version shown might differ from yours depending on how many uploads of the package you have done at this point in the book:



The screenshot shows the 'Apex Class Detail' page for the class 'ComplianceService'. The page has a header with 'Edit' and 'Security' buttons. Below the header, the class details are listed: Name: ComplianceService, Namespace Prefix: fforce. The 'Last Modified By' field shows 'Andy Admin, 09/05/2014 12:19'. Below these details, there are three tabs: 'Class Summary' (selected), 'Version Settings', and 'Log Filters'. The 'Class Summary' tab shows the class name 'global class ComplianceService' and its availability in versions 1.8 - Current. It lists one constructor, 'ComplianceService()', and one method, 'static void verify(SET recordIds)'. The 'Version Settings' tab shows the current version as 1.8. The 'Log Filters' tab is empty.

All global Apex classes will also show the **Security** link next to them in the list of classes, in the subscriber org. This is so that the subscriber org administrator can control permissions around the execution of the API's through Profiles. Note this only applies to global controller methods custom or extension controller or Web Service calls by Developer X. You can also granted access through appropriate Permission Set's as described in an earlier chapter. Meaning if the user is assigned a Permission Set granting them access to a specific set of features in the application, accessing those through API is included as well.

If you want to control API permissions separately, create separate but functionality scoped permission sets:

Action	Name ↑	Namespace Prefix
Edit   Security	Application	fforce
Edit	Cars	fforce
Edit	CarsSelector	fforce
Edit	ComplianceController	fforce
Edit   Security	ComplianceService	fforce

## Calling an application API from Apex

The code used in this section uses Apex test methods (not included in the FormulaForce application). As an easy way to run API code examples, we will be using an Apex Test to illustrate the use of Apex APIs from the sample code included in this chapter. The two test methods we will look at call the compliance API after calling the season API to create some test data (which, of course, only exists on the database within the scope of the test execution).

In the following examples, the **Driver** records created by the `SeasonService.createTestSeason` API do not indicate that the drivers hold **FIA Super License**. Thus, the expectation is that the `ComplianceService.verify` method will throw an exception reporting this problem. The following example test code asserts this behavior purely for illustration purposes in this chapter:

```

@IsTest
private class ApplicationAPITest {
    @IsTest
    private static void demoComplianceVerifyAPI() {

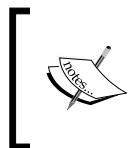
        // Create some test data via the SeasonService
        fforce.SeasonService.createTestSeason();

        // Query Drivers to test compliance against
        Map<Id, fforce__Driver__c> driversById =
            new Map<Id, fforce__Driver__c>(
                [select Id from fforce__Driver__c]);

        try {
            // Invoke the compliance engine for the drivers
            fforce.ComplianceService.verify(
                driversById.keySet());
            System.assert(false, 'Expected failures');
        }
        catch (fforce.ComplianceService.ComplianceException e) {
    }
}

```

```
// Check the results
System.assertEquals(
    '4.1', e.failures[0].complianceCode);
System.assertEquals(
    'Driver must have a FIA Super License.',
    e.failures[0].failureReason);
}
}
}
```



The namespace used in this sample is `fforce`. Your namespace will differ. Replace the namespace to get the code sample to compile (you can also find this class in the sample code for this chapter).



Run the test to confirm whether the API is working as expected.



As you have used the same Service layer method as used by the rest of the application, your existing unit and integration tests around this class should suffice in providing you confidence in the robustness of this as an API to your application. If not, improving your testing around your Service layer benefits both external and internal callers equally.

Notice that when you click on the **Show Dependencies** button in the `ApplicationAPITest` class, it shows the API and Custom Objects being referenced from the package:

Show Dependencies

### Dependency Information for Apex Class ApplicationAPITest

« Back to Apex Class: ApplicationAPITest

A dependency is created when one component references another component, permission, or preference below have dependencies. In addition, the object-level operational scope, that is, the data manipulation also listed. To see field-level detail of the operational scope, click Fields next to name of an object.

▼ Object Operational Scope

	Insert
Driver (Installed Package: FormulaForce)	<a href="#">[Fields]</a> <input type="checkbox"/>

▼ Apex Class, Trigger and Page References

<a href="#">ComplianceService (Installed Package: FormulaForce)</a>
<a href="#">SeasonService (Installed Package: FormulaForce)</a>

## Modifying and depreciating the application API

Once a `global` class method or member has been published by including it in a released package, it cannot be removed or changed. For example, try changing the `ComplianceService.verify` method by renaming it to `verification` (for example). When you attempt to save the class, you will receive the following error:

```
(ComplianceService) Global/WebService identifiers cannot be removed
from managed application: Method: void verify(SET<Id>) (Line: 1)
```



If you want to perform some testing or distribute your package while reserving the ability to make changes to your new APIs, upload your package as a beta until you are happy with your API definition. Note that you can of course change the behavior of your API (determined by the Apex code behind it) at any time, though this has to be done with care.

The `@Deprecated` annotation can be used to effectively remove from visibility the class, interface, method, or member that `global` has been applied to from the perspective of subsequent package version consumers. *Developer X* can still access the deprecated items by referencing an earlier version of the package through the class version settings shown via the **Version Settings** tab as described in more detail in the following sections:



At the time of writing this, the `@Deprecated` flag cannot be used in developer orgs that are unmanaged. In a later chapter, we will discuss a team development model that permits the development of your application through managing your code within Source Control system and separately managing developer orgs per developer. While this style of development has a number of benefits, it does exclude the use of the `@Deprecated` flag, as such orgs are effectively unmanaged.

## Versioning Apex API definitions

When saved, the `ApplicationAPITest` class, the **Version Settings** tab, and the **Dependencies** page reflects the fact that code within the class is referencing the `ComplianceService` and `SeasonService` classes from the `FormulaForce` package.

In the following screenshot, the version is shown v1.8 as this was the current version of the package when the Apex class was first created (this might be different in your case, depending on how many times you have uploaded the package so far):

Name	Version	Namespace	Type
Salesforce.com API	30.0		Salesforce.com API
FormulaForce	1.8	fforce	Installed Package

In the following steps, we will release a new version of the package with a new Compliance API to explore how the platform provides Apex API versioning:

1. In the packaging org, uncomment the `ComplianceService.report` method. This method works like the `verify` method but will not throw an exception; instead, it returns a full list of results including compliance passes and failures.
2. Upload a new release of the package and install it into your test development org.
3. In the test development org, open the Apex class `ApplicationAPITest`.

Attempt to add the following new test method and save the class:

```
@IsTest
private static void demoComplianceReportAPI() {

    // Create some test data via the SeasonService
    fforce.SeasonService.createTestSeason();

    // Query Drivers to test compliance against
    Map<Id, fforce__Driver__c> driversById =
        new Map<Id, fforce__Driver__c>(
            [select Id from fforce__Driver__c]);
}

// Update the licenses for the drivers
for(fforce__Driver__c driver : driversById.values())
```

```

        driver.fforce__FIASuperLicense__c = true;
        update driversById.values();

        // Invoke the compliance engine to verify the drivers
        List<fforce.ComplianceService.VerifyResult>
        reportResults =
            fforce.ComplianceService.report(
                driversById.keySet());

        // Check the results
        System.assertEquals('4.1',
            reportResults[0].complianceCode);
        System.assertEquals(true, reportResults[0].passed);
        System.assertEquals(null,
            reportResults[0].failureReason);
    }
}

```

You should get an error, indicating that the method does not exist:

```

Compile Error: Package Visibility: Method is not visible: fforce.
ComplianceService.report(SET<Id>) at line 21 column 13

```

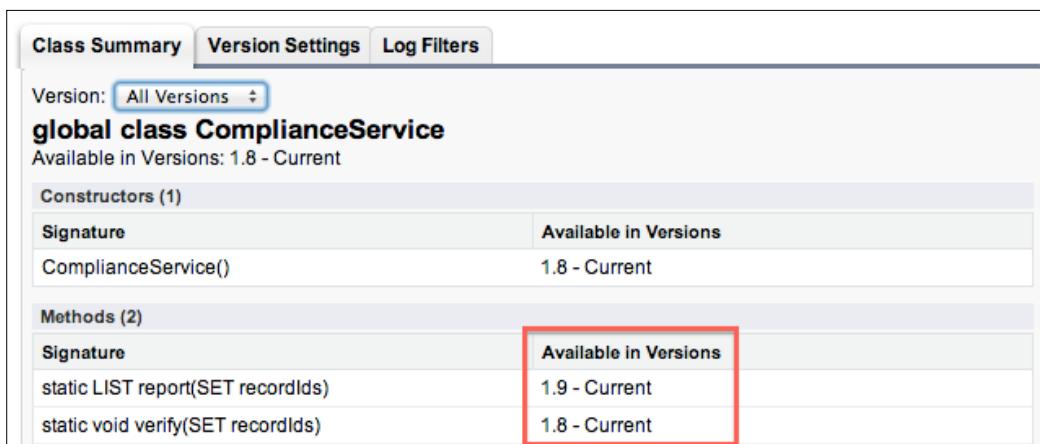
This is due to the package version information in the Apex class metadata of the test class still referencing the release of the package installed at the time the code was originally written. Upgrading the package does not change this. Open the **Version Settings** tab and change to the release you have just installed to fix this compile problem



The preceding steps have illustrated how the Apex runtime manages versioning of the Apex APIs you expose from your package. Thus, the requirement of versioning API definition described earlier has been provided by the platform for you. There is no need to manage this yourself, though you do need to be aware of how it works.

Finally, revisit the `ComplianceService` Apex class page from within your test development org and notice that the available versions of this class has also increased to include the version just uploaded. Toggle between them; you can see the changes that the API definition has undergone between the last two package releases we have just performed.

Select **All Versions** to get a full summary of which methods arrived at which package version. You can see in the following screenshot that the `verify` method was first available in v1.8 and the `report` method in v1.9; again, your version numbers might differ:



The screenshot shows the 'Class Summary' page for the `ComplianceService` class. The 'Version' dropdown is set to 'All Versions'. The class is described as a 'global class' available from version 1.8 to the current version. It lists one constructor and two methods. The 'Available in Versions' column for the methods is highlighted with a red box.

Signature	Available in Versions
<code>ComplianceService()</code>	1.8 - Current
<code>static LIST report(SET recordIds)</code>	1.9 - Current
<code>static void verify(SET recordIds)</code>	1.8 - Current

## Versioning Apex API behavior

The API definition is not the only aspect that can undergo changes between releases. Even if the definition stays the same, the code behind it can change the behavior of the API. The Apex runtime provides a means for the packaged code to determine which version the calling code written by *Developer X* is expecting. This can be obtained by calling the `System.requestVersion` method. With this information, your packaged code can modify its behavior according to the expectations of the calling code.

As you release more versions of your package and the functionality grows, the management of this type of code becomes more complex. Also note that this feature is only available in the code located within the packaging org or specifically managed code. In the standard developer org, this method will throw a runtime exception. This essentially rules out its use if you plan on relocating your code outside the packaging org, for example, by following the team development model discussed in the last chapter of this book.

Another way of versioning behavior is by considering whether changes in your application logic are something that *Developer X* would want to opt in to or be immediately available to their existing code once the package is upgraded. Changes to fix bugs or minor improvements in the way information is processed are likely things you wish to be available, regardless of the API version. However, other changes such as the way values are calculated or the addition of significantly new processing would be something that might justify a new API method or a parameter for *Developer X* to modify their code to use. Much like in the UI, you will choose to add a new tab, page, or button.

By considering when to version the API behavior, you have put the choice as to when to accept new API behaviors in the hands of *Developer X*. Critically, by considering backwards compatibility you have not blocked upgrading to the latest version of your package due to integration failures. Spotting backwards compatibility regressions caused by behavior changes will get harder the more versions you release and the more supported versions you have in your customer base. Therefore making sure that you have a strong API-testing strategy becomes all the more critical.

## Providing RESTful application APIs

So far we have focused on *Developer X* being an on-platform Apex developer and the ways in which you can provide application APIs via Apex. However, it is also possible that *Developer X* could be coding off-platform, needing to call your application APIs from Java or Microsoft .NET, or a mobile application. Perhaps they want to write a small dedicated mobile application to check the compliance for teams, drivers, or cars.

This part of the chapter will focus on exposing a REST API of the preceding compliance API for use by off-platform developers writing integrations with your application. Don't forget, as with the on-platform scenario Salesforce provides a number of standard Salesforce APIs via SOAP and REST, which by coding off-platform *Developer X* can use to create, read, update, and delete records held in your application's Custom Objects.

Apex provides support to expose the application logic via web services (SOAP), through the use of the `webservice` keyword placed in your Apex classes. If you want to expose a SOAP API, the platform can generate the appropriate WSDLs once you have applied this keyword to methods on your Service classes. The design of services designed in this book happens to align quite well with the general requirements of web services.



Note that the afore mentioned `@Deprecated` attribute cannot be used on Apex code exposed in this way. One thing to consider though is that the WSDLs generated are not versioned; they are only generated based on the code for the installed version of your package. *Developer X* cannot generate historic versions of it from previous package versions. While Apex methods that use the `webservice` keyword fall under the same restrictions as `global`, you cannot exclude new methods or fields in your web services by version.

Apex also provides support to create your own REST APIs, with some great reference documentation within the *Apex Developer's Guide*. However, what it doesn't cover are REST API design considerations, often referred to as RESTful.

Many mistakes are made in exposing REST APIs without first understanding what it means to be RESTful. Before we get into using your Service layer to deliver a REST API, let's learn more about being RESTful.

## Key aspects of being RESTful

A full discussion and overview of RESTful API design could easily take up a full chapter. The following is a summary of the key RESTful design goals and how these apply to REST APIs delivered via Apex (some guidelines are handled for you by the platform). As we discuss this topic further, the use of the term *operation* represents the methods in the application's Service layer classes. This will be used to help expose the application's REST API but should not steer its design.

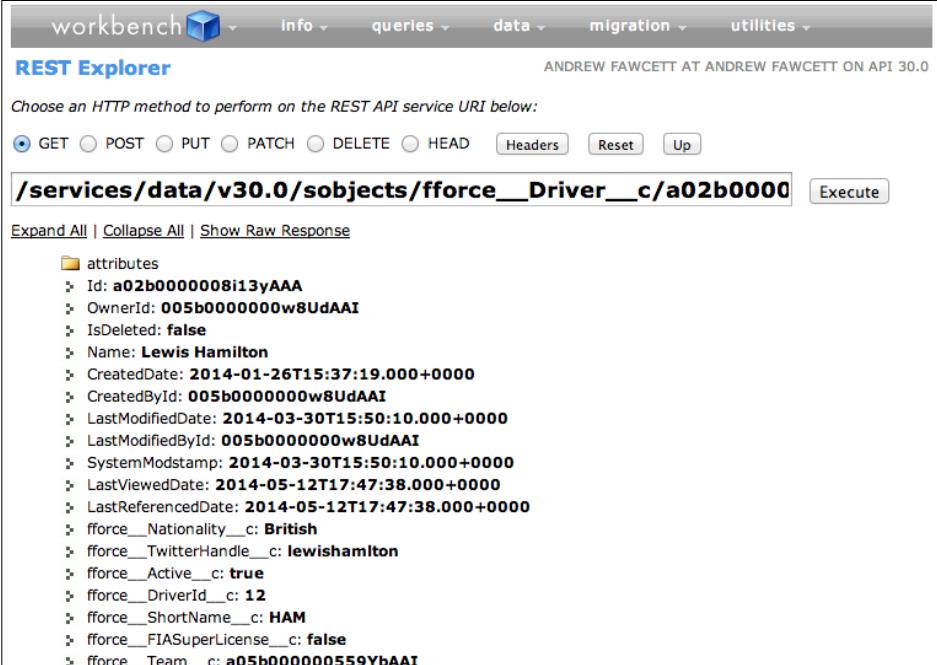


There is no one list of guidelines and some are open to interpretation. However, if you enter Designing a RESTful API in Google, you're sure to come up with some useful reading. I recommend that you focus on those articles that give insight as to how some of the larger services such as Facebook, LinkedIn, and Salesforce themselves are interpreting RESTful, such as <http://www.apigee.com/>.

## What are your application resources?

In the RESTful world, your operations are associated with a resource that is expressed via **Uniform Resource Identifier (URI)**. A resource can be a physical thing in your application such as a Custom Object, or a conceptual thing. This is different from the Service layer design that drove the Apex API we have looked at earlier, where operations are expressed by grouping them under functional areas of the application, which are then expressed by Apex Service classes and methods for each operation.

The Salesforce REST API uses Custom Objects to define physical resources the REST URI uses, allowing you to build a URI and use the various HTTP methods to perform the create, read, update, and delete operations. For example, to retrieve a record you can issue the following request via the Developer Workbench tool:



The screenshot shows the REST Explorer interface in the Developer Workbench. The URL entered is `/services/data/v30.0/sobjects/fforce__Driver__c/a02b00000`. The response is a JSON object representing a record:

```

{
  "attributes": {
    "id": "a02b0000008i13yAAA",
    "type": "fforce__Driver__c"
  },
  "fforce__Active__c": true,
  "fforce__DriverId__c": "12",
  "fforce__FIASuperLicense__c": false,
  "fforce__Name": "Lewis Hamilton",
  "fforce__Nationality__c": "British",
  "fforce__ShortName__c": "HAM",
  "fforce__Team__c": "a05b000000559YbAAI",
  "lastmodifieddate": "2014-03-30T15:50:10.000+0000",
  "lastreferenceddate": "2014-05-12T17:47:38.000+0000",
  "lastvieweddate": "2014-05-12T17:47:38.000+0000",
  "systemmodstamp": "2014-03-30T15:50:10.000+0000",
  "updatedate": "2014-01-26T15:37:19.000+0000"
}

```

In cases where you are exposing more business process or task-orientated operations that are not data-centric, it can be difficult to decide what the resource name should actually be? So it is worth taking the time to plan out and agree with the whole product team what the key REST resources are in the application and sticking to them.

One operation that falls into this category in our FormulaForce package is the compliance report. This operates on a number of different Custom Object records to report compliance, such as the driver, car, and team. Should we define a URI that applies it to each of these physical resources individually, or create a new logical compliance resource?

I chose the latter in this chapter because it feels more extensible to do it this way, as it also leverages the compliance service in the application, which already supports adding new object types to the compliance checker. Thus, the REST API will support new object types without future changes to the API, as they are added to the compliance checker.

Salesforce dictates the initial parts of the URI used to define the resource and the developer gets to define the rest. For the compliance REST API, we will use this URI:

```
/services/apexrest/compliance
```

Once you package your Apex code implementing this REST API, you will find that the preceding URI needs to be qualified by your package namespace, so it will take on the format, shown as follows, from the point of view of *Developer X*, where `fforce` is my namespace. We will use this format of URI when we test the compliance REST API later in this chapter:

```
/services/apexrest/fforce/compliance
```

## Mapping HTTP methods

Your application operations for a given resource URI should be mapped to one of the standard HTTP methods on which REST is based: GET, POST, PUT, PATCH, and DELETE. Choosing which to use and being consistent about its use throughout your REST API is vital. Again, there are many resources on the Internet that discuss this topic in much more detail. Here is a brief summary of my interpretation of those readings:

- **GET:** This method is typically for operations that query the database and whose parameters are easily expressed in the URI structure and/or whose parameters fit well with this method.
- **PUT versus POST:** These methods are typically for operations that create, update, or query the database and where parameters are more complex, for example lists or structures of information that cannot be reflected in URI parameters. There is also a consideration around the term **Idempotent** (check out Wikipedia for a full definition of this), which relates to whether or not the request can be repeated over and over, resulting in the same state in the database. As you dig deeper into the RESTful design guidelines, this term typically drives the decision over using `PUT` versus `POST`.

- **PATCH**: This method is typically for operations that solely update existing information, such as a record or some other complex dataset spanning multiple records.
- **DELETE**: This method is, of course, to delete existing information expressed in the URI.

We will use the `POST` HTTP method with the `/services/apexrest/compliance` resource URI to implement our REST API for the compliance verify operation, passing the list of records to verify as a part of the HTTP request body using the JSON data format.

## Providing Apex REST application APIs

The following Apex class follows the naming convention `[ResourceName] Resource` as the class name and then defines the appropriate methods (whose names are not as important in this case), mapping them accordingly to the HTTP method for the URL mapping. This is included in the sample code of this chapter:

```
@RestResource(urlMapping='/compliance')
global with sharing class ComplianceResource {
    @HttpPost
    global static List<ComplianceService.VerifyResult>
        report(List<Id> Ids) {
        return ComplianceService.report(new Set<Id>(Ids));
    }
}
```

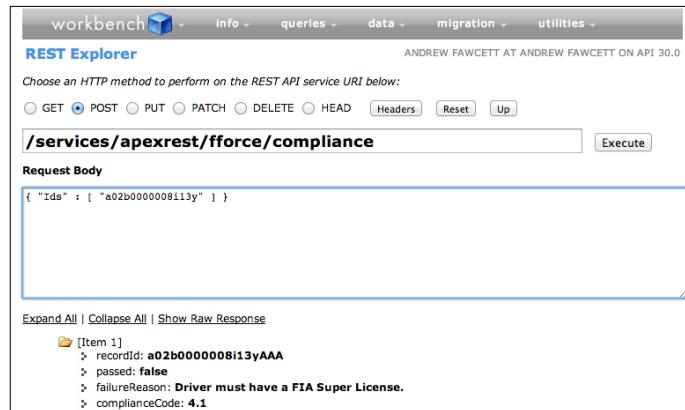
The following are some things to note about the preceding example, and in general about wrapping Service layer methods in Apex REST methods to create REST APIs:

- The preceding example uses the `VerifyResult` class from `ComplianceService`. You may wish to create your own class scoped within the `ComplianceResource` class for further isolation.
- The methods in this class should delegate to one and only one, applicable method in a Service class as per the general Service layer calling guidelines, to maintain a transaction scope and also Separation of Concerns.
- It is not recommended that you map your Apex resource classes only to a specific Service class as your earlier RESTful API design might not match your Service class design, though it should still delegate to it.
- Treat these classes like you would treat a UI controller, including only marshaling and error-handling logic as required.

- Typically you don't need to catch exceptions from the Service layer (unlike Visualforce controller action method callers), as the Apex REST runtime catches the exception and the returns appropriate REST API error code and message. Avoid implementing your own REST API error handling.
- The `global` modifier is still required. Keep in mind that the same packaging restrictions regarding changes to these methods apply.
- It is possible for the *Developer X* Apex developer to call these methods from Apex, as they are `global`. However, this should be discouraged because these methods might reference the REST API context variables, which will not be initialized in a standard Apex context.
- The `Set` Apex data type is not supported by the Apex REST methods. Unlike the standard, which has been established with the Service class methods, the `Set` Apex data type is not supported by the Apex REST methods. Therefore, you will need to convert the `List<Id>` REST method parameters to the `Set<Id>` collections for your Service method calls.
- The `ComplianceService.verify` method throws an exception with additional information about the specific compliance failures. However, information in a custom Apex exception is not automatically serialized by the platform – only the error message is included. In this case, a custom response would be required to catch the exception and return the information.

## Calling your Apex REST application APIs

The Salesforce Developer Workbench can be used to call the preceding REST API. Locate a **Driver** record without the **FIA Super License** field selected and use the following ID. Note that the URI shown in the following screenshot contains the package namespace, `fforce`. To try this out you need to replace this with your chosen package namespace:



## **Versioning Apex REST application APIs**

The generally recognized way in which REST APIs are versioned is to include the version in the URI. Notice that v30.0 (the Salesforce platform version) was included in the standard Salesforce REST API example shown earlier, but no version was included in the URI for the REST API exposing the compliance report operation. The platform does not provide a facility for versioning Apex REST APIs in the same way as its own APIs.

### **Behavior versioning**

The Salesforce REST API, and any Apex REST APIs exposed, can receive from a new HTTP header, such as x-sfdc-packageversion-fforce: 1.10. In the case of Apex REST APIs, this can be used to allow the packaged API code to implement behavior versioning. This can be used to set the version returned by `System.requestVersion` as described earlier in this chapter.

This header is optional; without it, the current package version installed is assumed. My preceding recommendations around the utilization of behavior versioning also apply here. Because the header is optional, its usefulness is diluted.

### **Definition versioning**

The preceding HTTP header does not affect the visibility of the API's definition in the same way that the platform does for Apex API's as illustrated earlier in the chapter. One option to address this is to map a versioned URI to a specific Apex resource class per version, for example, to support version v1.0 and v2.0 of the compliance REST API. This approach allows you to expose URI's with your version included:

```
/service/apexrest/fforce/v1.0/compliance  
/service/apexrest/fforce/v2.0/compliance
```

When versioning the API definition, you would need to also capture copies of the Apex data types used in the Service layer. This would isolate each REST API version from underlying changes of the Service layer as it evolves. The main coding overhead here is going to be marshaling between the Apex types defined in the Service layer (which are always the latest version) and those in the class implementing the REST API.

For example, to version the report API, we have to capture its types as inner Apex classes at the time the API class is created. The following example illustrates this for v1.0. You can see how the definition of the API can be encapsulated within the specific version of the Apex class denoted by the v1\_0 suffix:

```
@RestResource(urlMapping='/v1.0/compliance')
global with sharing class ComplianceResource_v1_0 {

    global class VerifyResult {
        global Id recordId;
        global String complianceCode;
        global Boolean passed;
        global String failureReason;
    }

    @HttpPost
    global static List<VerifyResult> report(List<Id> Ids) {

        List<VerifyResult> results = new List<VerifyResult>();
        for(ComplianceService.VerifyResult result :
            ComplianceService.report(new Set<Id>(Ids)))
            results.add(makeVerifyResult(result));
        return results;
    }

    private static VerifyResult
        makeVerifyResult(ComplianceService.VerifyResult verifyResult){
        VerifyResult restVerifyResult = new VerifyResult();
        restVerifyResult.recordId = verifyResult.recordId;
        restVerifyResult.complianceCode = verifyResult.complianceCode;
        restVerifyResult.passed = verifyResult.passed;
        restVerifyResult.failureReason = verifyResult.failureReason;
        return restVerifyResult;
    }
}
```

While the version number you use can be anything you like, you may want to consider following your package version numbering sequence.

Versioning Apex REST APIs this way is not ideal due to the manual way in which the definition has to be versioned by code and the overhead in managing that code for each release of your package. However, without this approach, it is always the latest definition of the Apex REST API in your package that is exposed.

This means that after upgrades of your package callers receive new fields in responses they do not expect. There is also no way to deprecate Apex REST APIs. However due to the deletion restrictions over the `global` class members, there is some protection over developers in accidentally removing fields that would break existing requests.

## Exposing Lightning Components

In the previous chapter, we looked at several components that are included in the `FormulaForce` package. These have all been exposed for use by tools and developers code in the subscriber org, through `global` access level.

When developers consume these components inside their own component, there is a facility through the bundle metadata for them to express what package version they want the platform to assume when their code interacts with the packaged component. This allows for definition and behavior versioning of your components. If this information is not present, the currently installed package version is assumed.

The `System.requestVersion`, `{!Version}` and `cmp.getVersion()` are available to determine the version your component needs to honor in an Apex or JavaScript.

## Extending Process Builder and Visualflow

The **Process Builder** or **Visualflow** tools allow users to create customized processes and wizard-like user experiences. Both tools offer a large selection of actions they can perform based on criteria defined by the user.

Available actions can be extended by packages installed in the org. This provides another way in which you can expose your functionality for building customized scenarios. This approach does not require the user to write any code.

The following code creates an **Invocable Method**, which is a `global` class and a single method with some specific annotations. These annotations are recognized by the tools to present a dynamic configuration UI to allow the user to pass information to and from the method you annotate:

```
global with sharing class UpdateStandingsAction {  
  
    global class UpdateStandingsParameters {  
  
        @InvocableVariable(  
            Label='Season Id'  
    }  
}
```

```
        Description='Season to update the standings for'
        Required=True)
    global Id seasonId;
    @InvocableVariable(
        Label='Issue News Letter'
        Description='Send the newsletter out
                    to the teams and drivers'
        Required=False)
    global Boolean issueNewsLetter;

    private SeasonService.UpdateStandings makeUpdateStandings() {
        SeasonService.UpdateStandings updateStandings =
            new SeasonService.UpdateStandings();
        updateStandings.seasonId = this.seasonId;
        updateStandings.issueNewsLetter = this.issueNewsLetter;
        return updateStandings;
    }
}

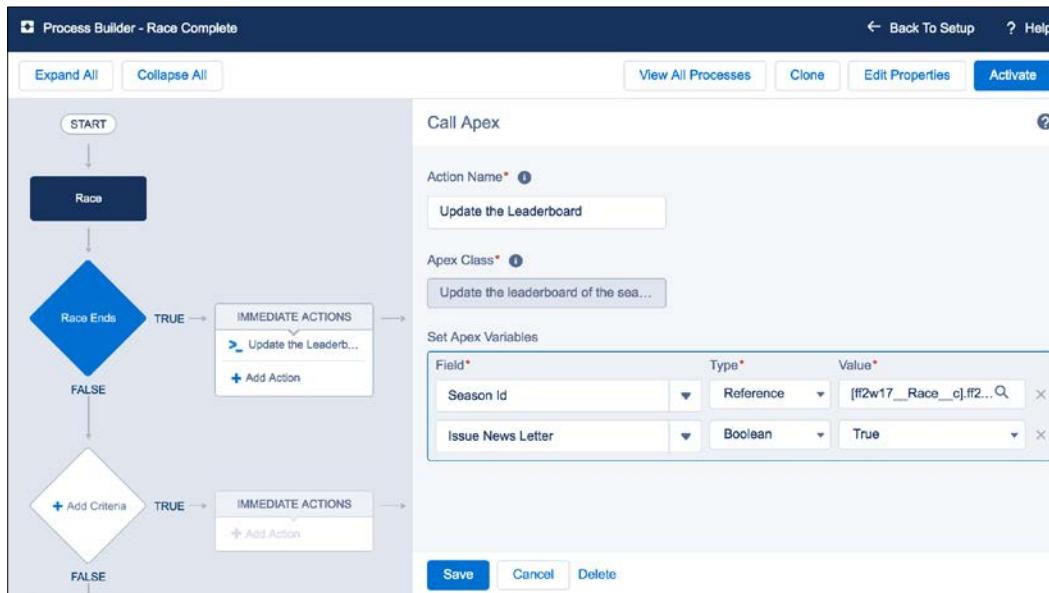
@InvocableMethod(
    Label='Update the leaderboard of the season'
    Description='Updates the standings and optionally
                sends the newsletter.')
global static void
updateStandings(
    List<UpdateStandingsParameters> parameters) {

    // Marshall parameters into service parameters
    List<SeasonService.UpdateStandings> updateStandings =
        new List<SeasonService.UpdateStandings>();
    for(UpdateStandingsParameters parameter : parameters) {
        updateStandings.add(parameter.makeUpdateStandings());
    }
    // Call the service
    SeasonService.updateStandings(updateStandings);
}
}
```

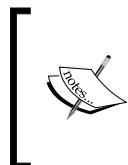


In order to isolate the parameters of this method from changes to the Service class methods, the `UpdateStandings` Apex class is used. This also allows the method to evolve in a different direction if needed.

The following shows how the preceding Invocable Method appears in Process Builder:



This method could for example be used as part of the above subscriber defined Process Builder process when a race ends. While you could perform this in Apex Trigger, this might involve some additional conditions unique to the subscriber of your package. Thus this is a good use case for Process Builder and exposing the `SeasonService.updateStandings` method via an Invocable Method.



Check the Apex Developers guide for more information on Invocable Methods and the preceding attributes. There are various restrictions around the types of parameters that can be passed, such as the parameters must be in list form. This fits well with the bulkified requirements of the Service layer.

## Versioning Invocable Methods

Neither Process Builder or VisualFlow record the package version that was used when an invocable method is referenced. Thus it is not possible to perform behavior versioning, the `System.requestVersion` returns the currently installed package version. The definition of the Invocable Method is controlled by the constraints relating to use of the `global` modifier as we have already discussed in this chapter. As a best practice avoid adding new required members (via `@InvocableVariable`) to your parameter classes.

## Alignment with Force.com extensibility features

Here are some platform features that can help ensure your application functionality is open to being extended by *Developer X* or subscriber org administrators:

- **Apex Triggers:** *Developer X* can write their own triggers against your application's managed Custom Objects. These will execute in addition to those packaged. This allows *Developer X* to implement the defaulting of fields or custom validations, for example. Salesforce does not guarantee that packaged triggers execute before or after *Developer X* triggers in the subscriber org. To ensure that all changes are validated regardless of the trigger execution order, perform your validation logic in the after-phase of your packaged triggers.
- **Field Sets:** As described in earlier chapters, be sure to leverage this feature as often as possible on your Visualforce pages to ensure that regions and tables can be extended with subscriber added fields. These can also be used with JavaScript frameworks if you're developing a mobile UI.
- **E-mail templates:** If you're writing code to emit e-mails, consider providing a means to allow the text to be customized using an e-mail template. These can be referenced through their developer name using a custom setting. Field Sets can also be leveraged here to provide an easy way to include additional custom fields added by the subscriber administrator.
- **Visualforce components:** Consider creating some Visualforce components globally, such that *Developer X* can more easily build alternative custom Visualforce pages without having to reinvent all aspects of your applications pages. Such components can be built to allow dynamic content in e-mail templates.
- **Lightning components:** Consider exposing Lightning components used in your package for use with tools such as Lightning App Builder and Lightning Community builder, as we explored in the previous chapter. This can provide administrators and developers with a great deal of flexibility to build and customize unique user experiences for their business.
- **Dynamic Apex type creation:** The `Type.forName` method can be used to create an instance of an Apex type, and from that an instance of that type at runtime. This capability can be used to allow *Developer X* to write the Apex code, which your application code can dynamically call at a specified time. This approach is discussed in further detail in the upcoming section.

# Extending the application logic with Apex interfaces

An **Apex Interface** can be used to describe a point in your application logic where custom code written by *Developer X* can be called. For example, in order to provide an alternative means to calculate championship points driven by *Developer X*, we might expose a global interface describing an application callout that looks like this:

```
global class ContestantService {
    global interface IAwardChampionshipPoints {
        void calculate(List<Contestant__c> contestants);
    }
}
```

By querying **Custom Metadata** records from the **Callouts** custom metadata type, which has been included in the source code for this chapter, code in the application can determine whether *Developer X* has provided an implementation of this interface to call instead of the standard calculation code.

Using Custom Metadata is an excellent use case for this sort of requirement, since you can declare the callouts your package supports by packaging records. Then, by making certain fields subscriber editable you can allow the subscriber (*Developer X*) to configure those callouts. This approach in contrast with Custom Settings, avoids additional configuration and risk of misconfiguration.

 Partners extending your package can also package this configuration with their Apex class. Thus administrators installing such partner extension packages have zero configuration to perform to activate the callout contained within.

This screenshot shows how the **Callouts** Custom Metadata Type is defined. Notice how the **Apex Class** and **Apex Class Namespace Prefix** fields are subscriber editable:

Custom Fields							New
Action	Field Label	API Name	Data Type	Field Manageability	Indexed	Controlling Field	Modified By
Edit   Del	Apex Class	ff2w17__ApexClass__c	Text(64)	Subscriber editable			Andrew Fawcett 10/16/2016 9:28 AM
Edit   Del	Apex Class Namespace Prefix	ff2w17__ApexClassNameSpacePrefix__c	Text(16)	Subscriber editable			Andrew Fawcett 10/16/2016 9:28 AM
Edit   Del	Interface Type	ff2w17__InterfaceType__c	Text(255) (Unique Case Insensitive)	Upgradable	✓		Andrew Fawcett 10/16/2016 9:27 AM

The following record is defined by you the packager developer to effectively declare that **Award Championship Points** callout exists and can be configured. This should also be included in your package:



Callouts						Help for this Page 
View: All  <a href="#">Edit</a>   <a href="#">Create New View</a>		New				
Action	Label 	Callout Name	Namespace Prefix	Interface Type	Protected Component	
<a href="#">Edit</a>   <a href="#">Del</a>	Award.Championship.Points	AwardChampionshipPoints	f2w17	ContestantService.IAwardChampionshipPoints	<input checked="" type="checkbox"/>	

Notice how the Custom Metadata Type fields supports *Developer X* providing a class name that is either fully qualified (perhaps from an extension package, for example, `fforceext.SimpleCalc`) or a local class (defined in the subscriber org), for example, `DeveloperXCustomCalc`.

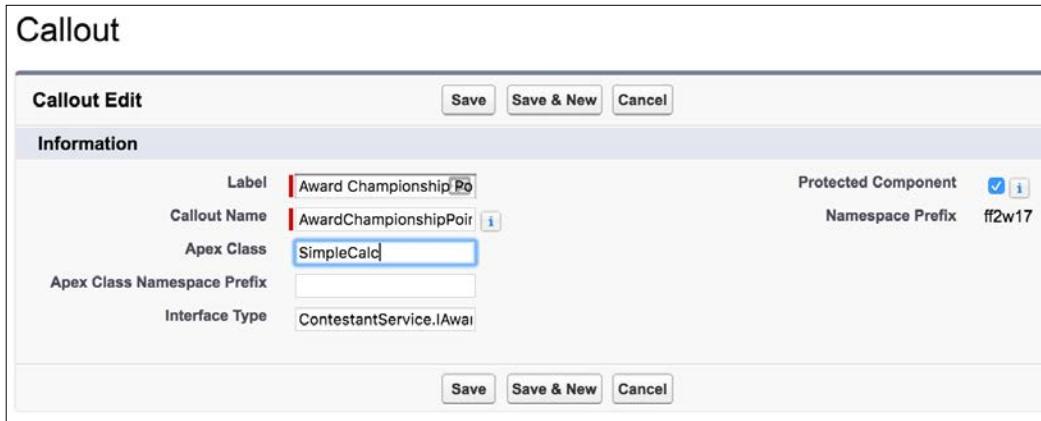
The following code is a Selector method (see `CalloutsSelector`) class that reads the registered interface implementations. It uses the `Type.forName` method to construct applicable Apex types and returns a Map of Apex classes implementing each interface:

```
public Map<Type, Type> selectAllCallouts() {
    // Query custom metadata records for callouts
    Map<Type, Type> calloutsByInterfaceType =
        new Map<Type, Type>();
    for(Callout_mdt record :
        Database.query(newQueryFactory().toSOQL())) {
        if(Callout_mdt.ApexClass__c!=null) {
            // Namespace of the interface is that
            // of the custom metadata type
            Type interfaceType =
                Type.forName(
                    record.NamespacePrefix, record.InterfaceType__c);
            // Implementing class can optionally specify
            // the namespace if needed
            Type implType =
                Type.forName(record.ApexClassNameSpacePrefix__c,
                    record.ApexClass__c);
            calloutsByInterfaceType.put(interfaceType, implType);
        }
    }
    return calloutsByInterfaceType;
}
```

The following code uses a new `Application.Callout` class factory, which is not shown here but is included in the source code of this chapter. This is a simple class factory that uses the above Selector method and exposes the `newInstance` method to provide an easy way to instantiate the classes *Developer X* has registered. The following method in the `Contestants` Domain class now looks like this:

```
public void awardChampionshipPoints(ffebl_ISObjectUnitOfWork uow)
{
    // Custom implementation configured by Developer X?
    Object registeredInterfaceImpl =
        Application.Callouts.newInstance(
            ContestantService.IAwardChampionshipPoints.class);
    if(registeredInterfaceImpl instanceof
        ContestantService.IAwardChampionshipPoints) {
        // Cast the interface to call the calculate method
        ContestantService.IAwardChampionshipPoints
        awardChampionshipPoints =
            (ContestantService.IAwardChampionshipPoints)
            registeredInterfaceImpl;
        // Invoke the custom method from Developer X
        awardChampionshipPoints.calculate(Records);
        // Mark dirty on behalf of Developer X
        for(Contestant__c contestant :
            (List<Contestant__c>) Records) {
            uow.registerDirty(contestant);
        }
        return;
    }
    // Continue with standard implementation...
```

In the subscriber org or the test development org, *Developer X* can then implement this interface as follows and configure the Apex Class field on the Callouts record corresponding to the **Award Championship Points** callout. The next time the award championship points service is called, this custom logic will be called instead:



The following is a simple Application Callout implementation that assigns points according to the race position rather than using the default calculation:

```
public class SimpleCalc
    implements fforce.ContestantService.IAwardChampionshipPoints
{
    public void calculate(List<fforce__Contestant__c> contestants)
    {
        // Very simple, points equals race position
        for(fforce__Contestant__c contestant : contestants)
            contestant.fforce__ChampionshipPoints__c =
                contestant.fforce__RacePosition__c;
    }
}
```

Some aspects to consider when exposing global Apex interfaces are as follows:

- You cannot modify global interfaces once published by uploading them within a release managed package.
- You can extend a global interface from another global interface, for example `IAwardChampionshipPointsExt` extends `IAwardChampionshipPoints`.

- From a security perspective consider carefully what you pass into an Application Callout via your Apex Interface methods, especially if the parameters are objects whose values are later referenced by the application code. Be sure that you are happy for the Application Callout to make any changes to this object or data. If you're not comfortable with this, consider cloning the object before passing it as a parameter to the interface method.

## Summary

In this chapter, we have reviewed enterprise application integration and extensibility requirements through the eyes of a persona known as *Developer X*. By using this persona, much like your UI designs, you can ensure that your API tracks real use cases and requirements from representative and ideally actual users of it.

When defining your API strategy, keep in mind the benefits of the standard Salesforce APIs and how to evangelize those and the significant investment Salesforce puts into them in order to provide access to the information stored in your Custom Objects. We have also seen that platform tools such as Lightning App Builder, Lightning Process Builder, and Visualflow can be extended with embedded functionality from your package that can be accessed without the need for code.

When needed, leverage your Service layer to create application APIs either on-and/or off-platform using Apex and REST as delivery mechanisms. Keep in mind that REST requires additional design considerations to ensure that your REST API can be considered properly RESTful and thus familiar to *Developer X* who has been using other REST APIs. Application callouts configured via Custom Metadata allow developers to extend the logic within your application.

Don't forget that while technologies such as Visualforce, Lightning and Apex provide you great flexibility as a developer and finely tuned functionality to the user, they can often lead to reduced opportunities for extensibility for the subscriber; by using Field Sets and Apex Application Extensions (leveraging `Type.forName`) you can address this balance. Also keep in mind that Field Sets provide a good extensibility tool beyond custom UI use cases. For example, they can be used to expose subscriber custom fields when building Mobile UIs using JavaScript frameworks.

There is no need to upload a new version of the FormulaForce package in this chapter if you have been following along; if not, take the latest code from the sample code provided with this chapter to update your packaging org and upload a new package.

In the next chapter we will review approaches and features that help your application scale.



# 11

## Asynchronous Processing and Big Data Volumes

This chapter covers two important aspects of developing an enterprise-level application on the Force.com platform. While asynchronous processing and Big Data volumes are not necessarily linked, the greater governor limits and processing power of the platform are mostly to be found in the async processing mode. However, making sure that your interactive user experience is still responsive when querying large volumes of data is also very important.

In this chapter, we will first review how to ensure SOQL queries are as performant as possible by understanding how to profile queries and make use of the standard and custom indexes. This will benefit both interactive and batch (or async) processes in your application as well as how they leverage native platform features such as reporting.

We will then take a look at the options, best practices, design, and usability considerations to move your application processing into the async mode, once again leveraging the **Service** layer as the shared backbone of your application, before finally understanding some thoughts and considerations when it comes to volume testing your application. We will cover the following topics in this chapter:

- Creating test data for volume testing
- Indexes, being selective, and query optimization
- Asynchronous execution contexts
- Volume testing

## Creating test data for volume testing

Throughout this chapter, we are going to use the `RaceData__c` object. We will be extending it with additional fields and running a script to populate it with some test volume data, before exploring the different ways of accessing it and processing the data held within it.

In the **Formula1** racing world, a huge amount of data is captured from the drivers and the cars during the race. This information is used to perform real-time or post race analysis in order to lead to further improvements or troubleshoot issues. Because of the huge volumes of data involved, the **FormulaForce** application considers ways to summarize this data such that it can be removed and later reloaded easily if required.

The following functionalities will be added to the **FormulaForce** application to process this information and help demonstrate the **Force.com** features described in this chapter. The Apex classes and Visualforce page for this functionality is included in the sample code for this chapter.

- A Visualforce page able to perform some *What-If* analysis on the race data
- A Batch Apex process to validate and associate race data with contestants

The sample code for this chapter also contains updates to the **Race Data** object, as follows:

1. The **Type** field represents the type of race data, for example, **Oil Pressure**, **Engine Temperature**, **Sector Time**, **Fuel Level**, **Pit Stop Times**, and so on.
2. The **Value** field is a numeric value dependent on the **Type** field.
3. The **Lap** and **Sector** fields are numeric fields that represent the lap and sector number the data was captured on.
4. The **Year**, **Race Name**, and **Driver Id** fields are text fields whose values, when later combined together, can be used to form a key to link each **Race Data** record with the appropriate **Contestant** record (which has its own relationships with the **Driver**, **Race**, and **Season** objects). In this use case, we assume that the electronic systems generating this raw data do not know or want to understand Salesforce IDs, so the **FormulaForce** application must correctly resolve the relationship with the **Contestant** record.
5. The **Contestant** lookup field references the applicable **Contestant** record. As the incoming raw data does not contain Salesforce record IDs, this field is not initially populated. The **FormulaForce** applications logic will populate this later, as will be shown later in this chapter.

6. A new **Race Data** ID external ID field has been added to the **Contestant** object. The Apex code in the **Contestants** Domain class has been updated to ensure that this field is automatically populated as **Contestants** are added and that its value can be used during the processing of new **Race Data** to correctly associate **Race Data** records with **Contestant** records.

The **Race Data** object uses an **Auto Number** field type for its **Name** field. This ensures the insert order for the data is also retained.

 Note that we have added the **Race Data** ID field to an object already released in previous versions of the package, while the **Contestants** Domain class has been updated to populate this field for new records. The records already existing in subscriber orgs will not contain this value. Force.com provides a means to execute the Apex code after installation (and uninstallation) of the package, such that you can include the code to trigger a Batch Apex job to update this field value with the appropriate value on existing records. Refer to the `System.InstallHandler` interface in the *Apex Developers Guide*.

## Using the Apex script to create the Race Data object

Just like me, I doubt if you have a real Formula1 race team or car to provide raw data input. We will be using an Apex script to generate the test data, though in reality race data may be inserted through a CSV file import or through an integration with the car itself via the Salesforce APIs.

This test script will generate 10,000 rows, which is about enough to explore the platform features described in this chapter and the behavior, Force.com SOQL **profiler**, which makes different choices dependent on row count.

Due to the volumes of data being created (and deleted if you rerun the scripts), you must run each of the following Apex statements one by one to stay within the governors via the **Execute Anonymous** prompt from your chosen IDE or developer console:

1. `Run TestData.resetTestSeason();`
2. `Run TestData.purgeVolumeData(false);`
3. `Run TestData.purgeVolumeData(true);`
4. `Run TestData.createVolumeData(2017, 'Spain', 52, 4);`

 Step 1 of the preceding steps will run a script that will clear down all other data from other FormulaForce objects in order to set up test **Season**, **Race**, and **Driver** data for the rest of the chapter. You can repeat Step 4 to generate a further 10,000 **Race Data** records for additional races—something we will do later in this chapter. This step might take a few minutes to complete.

Once the script has been executed, go to the **Race Data** tab and review the data. The values shown in the **Value** column are random values, so your results will differ.

Race Data						
All		Edit   Delete   Create New View				
New Race Data		Change Owner		A   B   C   D   E   F   G		
Action	Race Data Name	Driver Id	Lap	Sector	Type	Value
<a href="#">Edit   Del</a>	RD-000030418	44	1	1	Sector Time	4.3913
<a href="#">Edit   Del</a>	RD-000030419	44	1	1	Fuel Level	510.0000
<a href="#">Edit   Del</a>	RD-000030420	44	1	1	Oil Presure	76.3941
<a href="#">Edit   Del</a>	RD-000030421	44	1	1	Engine Temperature	11.6583
<a href="#">Edit   Del</a>	RD-000030422	44	1	1	Tyre Temperature	90.3241
<a href="#">Edit   Del</a>	RD-000030423	44	1	1	Track Temperature	7.9087
<a href="#">Edit   Del</a>	RD-000030424	44	1	2	Sector Time	2.5705
<a href="#">Edit   Del</a>	RD-000030425	44	1	2	Fuel Level	510.0000
<a href="#">Edit   Del</a>	RD-000030426	44	1	2	Oil Presure	30.4201
<a href="#">Edit   Del</a>	RD-000030427	44	1	2	Engine Temperature	3.6761
<a href="#">Edit   Del</a>	RD-000030428	44	1	2	Tyre Temperature	62.3697
<a href="#">Edit   Del</a>	RD-000030429	44	1	2	Track Temperature	36.4411
<a href="#">Edit   Del</a>	RD-000030430	44	1	3	Sector Time	16.8990
<a href="#">Edit   Del</a>	RD-000030431	44	1	3	Fuel Level	510.0000
1-25 of 2000+ <a href="#">▼</a>		0 Selected <a href="#">▼</a>				
<a href="#">◀◀ Previous</a> <a href="#">Next ▶▶</a>						

You should also see the following row count if you review the **Storage Usage** page:

Current Data Storage Usage	
Record Type	Record Count
Race Data	10,000

## Indexes, being selective, and query optimization

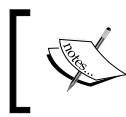
In this section, we will review when system and custom indexes maintained by the Force.com platform are used to make queries more performant and, once larger query results are returned, the ways in which they can be most effectively consumed by your Apex logic.

### Standard and custom indexes

As with other databases, Force.com maintains database indexes as record data is manipulated to ensure that, when data is queried, such indexes can be used to improve query performance. Due to the design of the Force.com multitenant platform, it has its own database index implementation (instead of using the underlying Oracle database indexes) that considers the needs of each tenant. By default, it maintains standard indexes for the following fields:

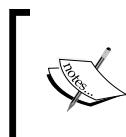
- ID
- Name
- OwnerId
- CreateDate
- CreatedById
- LastModifiedDate
- LastModifiedById
- SystemModStamp
- RecordType
- Any Master Detail fields
- Any Lookup fields
- Any fields marked as Unique
- Any fields marked as External Id

Once your application is deployed into a subscriber org, you can also request that Salesforce to consider creating additional custom indexes on fields not covered by the preceding list, such as fields used by your application logic to filter records, including custom formula fields and custom fields added to your objects by the subscriber as well.



Formula fields can be indexed so long as the formula result is deterministic, which means that it does not use any dynamic data or time functions such as TODAY or NOW, or leverage-related fields via lookup fields or any other formula fields that are non deterministic.

As creating indexes and maintaining them consumes platform resources, custom indexes cannot be packaged, as the decision to enable them is determined by conditions only found in the subscriber org.



Though objects can contain millions of records, standard indexes will only index up to 1 million records and custom indexes up to 333,333 records. These limits have a bearing on whether an index is used or not, depending on the query and filter criteria being used. This is discussed in more detail further in this chapter.

With respect to the **Race Data** object, the following fields will be indexed by default by the platform. Only through contacting Salesforce support and enabling in the subscriber org can additional custom indexes be created, for example, on the **Type\_\_c** field.

Field	Standard Index
Created_By	Yes (Lookup Field)
LastModifiedBy	Yes (Lookup Field)
Name	Yes
Owner	Yes
Contestant__c	Yes (Lookup Field)
Race__c	Yes (Lookup Field)
DriverId__c	No
Lap__c	No
RaceName__c	No
Sector__c	No
Type__c	No
Value__c	No
Year__c	No

Under **Setup**, navigate to **Objects** and locate the **Race Data** object. When viewing fields listed in the **Standard Fields** or **Custom Fields & Relationships** related lists, observe the **Index** column. This is the easiest way to determine whether a field has a standard or custom index applied to it.

Thus, if a query filters by fields covered by a system or custom index, the index will be considered by the Force.com query optimizer. This means that just because an index exists does not mean it will be used. The final decision is determined by how *selective* the query is.

 By default, Salesforce does not include rows (that contain null values) within its indexes for the respective field. In this case, although the **Contestant** field is indexed by default, it initially contains a null value and thus initially the index will be ineffective (this fact relates to why the use of nulls in filter criteria will deter the Force.com query optimizer from using an index, as discussed in the next section). You can, however, get Salesforce Support to discuss enablement of the inclusion of nulls in indexes.

## Ensuring queries leverage indexes

The process of selecting an appropriate index applies to queries made via SOQL through APIs and Apex, but also via **Reporting** and **List Views**. The use of an index is determined by the SOQL statement being selective or not. The following provides definitions of being selective and being non selective:

- Salesforce uses the term **selective** to describe queries filtering record data that are able to leverage indexes maintained behind the scenes by Salesforce, making such queries more efficient and thus returning results more quickly.
- Conversely, the term **non selective** implies a given query is not leveraging an index; thus, it will, in most cases, not perform as well. It will either time-out or, for objects with records greater than 100,000, result in a runtime exception.

In a nonselective query situation, the platform will scan all the records in the object, applying the filtering to each; this is known as a **full table scan**. However, this is not necessarily the slowest option, depending on the number of records and the filter criteria.

The main goal of this part of the chapter is to explain what it takes for Salesforce to select an index for a given query. This depends on a number of factors, both when you build your application queries and the number of records in your objects within the subscriber org.

## Factors affecting the use of indexes

There are two things that determine whether an index is used. Firstly, the **filter criteria** (or the WHERE clause in SOQL terms) of the query must comply with certain rules in terms of operators and conditions used. Secondly, the **total number of records** in the object versus the estimated number of records that will be returned by applying the filter criteria.

The filter criteria must, of course, reference a field that has either a standard or custom index defined for it. After this, unary, AND, OR, and LIKE operators can be used to filter records. However, other operators, such as negative operators, wild cards, and text comparison operators, as well as the use of null in the filter criteria, can easily disqualify the query from using an index. For example, a filter criteria that is more explicit in the rows it wants, `Type__c = 'Sector Time'`, is more likely to leverage an index (assuming that this field has a custom index enabled), than say, for example, `Type__c != 'Pit Stop Time'`, which will cause the platform to perform a full table scan, as the platform cannot leverage the internal statistics it maintains on the spread of data throughout the rows across this column.

The filtered record count must be below a certain percentage of the overall records in the object for an index to be used. You might well ask how Salesforce knows this information without actually performing the query in the first place? Though they do not give full details, they do describe what is known as a pre-query, using statistical data that the platform captures as the standard or custom indexes are maintained. This statistical data helps to understand the spread of data based on the field values. For example, the percentage of rows loaded by the execution of the scripts to load sample data where the `Type__c` field contains the **PitStop Time** value is 0.16 percent, and thus, if a custom index was in place and the queries filter criteria was selective enough (for example, `Type__c = 'PitStop Time'`), an index would be used.

A query for **Sector Time**, such as `Type__c = 'Sector Time'`, will result in 1664 records, which is 16.64 percent of the total rows being selected. So, while the filter criteria are selective, the filtered record count is above the threshold for custom index: 10 percent or 333,333 records max. Thus, in this case, an index is not used. This might result in a timeout or runtime exception. So, in order to avoid this, the query must be made more selective, for example, by enabling a custom index and adding either `Lap__c` or `Sector__c` into the filter criteria.

Salesforce provides more detailed information on how to handle large data volumes, such as fully documenting the filter record count tolerances used to select indexes (note that they differ based on standard or custom indexes) and some insights as to how they store data within the Oracle database that help make more sense of things. These are a must-read in my view and can be found in various white papers and Wiki pages. Some of them are as follows:

- *Query & Search Optimization Cheat Sheet*: [http://resources.docs.salesforce.com/rel1/doc/en-us/static/pdf/salesforce\\_query\\_search\\_optimization\\_developer\\_cheatsheet.pdf](http://resources.docs.salesforce.com/rel1/doc/en-us/static/pdf/salesforce_query_search_optimization_developer_cheatsheet.pdf)
- *Best Practices for Deployments with Large Data Volumes*: [http://www.salesforce.com/docs/en/cce/ldv\\_deployments/salesforce\\_large\\_data\\_volumes\\_bp.pdf](http://www.salesforce.com/docs/en/cce/ldv_deployments/salesforce_large_data_volumes_bp.pdf)
- *Force.com SOQL Best Practices: Nulls and Formula Fields*: <https://developer.salesforce.com/blogs/engineering/2013/02/force-com-soql-best-practices-nulls-and-formula-fields.html>
- *Developing Selective Force.com Queries through the Query Resource Feedback Parameter Pilot*: <https://developer.salesforce.com/blogs/engineering/2014/04/developing-selective-force-com-queries-query-resource-feedback-parameter-pilot.html>

## Profiling queries

As you can see, consideration for which indexes are needed and when they are used are very much determined by the rate of data growth in the subscriber org and also the spread of distinct groups of data values in that data. So, profiling is typically something that is only done in conjunction with your customers and Salesforce, within the subscriber org.

In some cases, disclosing the queries your application makes from Apex and Visualforce pages might help you and your subscribers plan ahead as to which indexes are going to be needed. You can also capture the SOQL queries made from your code through the debug logs, once you're logged in through the **Subscriber Support** feature.

Once you have a SOQL query you suspect is causing problems, you will profile it to determine which indexes are being used in order to determine what to do to resolve the issue, create a new index, and/or make the filter criteria select less records by adding more constraints. To do this, you can use a feature of the platform to ask it to explain its choices when considering which index (if any) to use for a given query. Again, it is important to use this in the subscriber org or sandbox itself.

For the purposes of this chapter, the following example utilizes the `explain` parameter on the Salesforce REST API to execute a query within the packaging org we ran the preceding script in, to populate the **Race Data** object with 10,000 records.

 **Developer Console** includes **Query Planner Tool**, which can be enabled under the **Preferences** tab. When you run queries via **Query Editor**, a popup will appear with an explanation of the indexes considered. The information shown is basically the same as that described in this chapter via the `explain` parameter.

This section utilizes the `explain` parameter when running SOQL via the **Developer Workbench** tool. Here, you can run the various queries in the explain mode and review the results. The results show a list of query plans that would have been used, had the query been actually executed. They are shown in order of preference by the platform. The following steps show how to login to the Developer Workbench to obtain a query plan for a given query:

1. Log in to **Developer Workbench**.
2. From the **Utilities** menu, select **REST Explorer**.
3. Enter `/services/data/v30.0/query?explain=` and then paste your **SOQL**. You may also use the latest Salesforce API version in the URL.
4. Click on **Execute**.

First, let's try the following example without a custom index on the `Type__c` field. Note that the `fforce` prefix is used; as the SOQL query is being executed in the namespace-enabled packaging org, you should replace this with your own chosen namespace.

```
select id from fforce__RaceData__c
  where fforce__Type__c = 'PitStop Time'
```

The following screenshot shows the Developer Workbench showing the query plan result for this query:

The screenshot shows the Developer Workbench REST Explorer interface. The top navigation bar includes 'workbench' (with a blue cube icon), 'Info', 'queries', 'data', 'migration', and 'utilities'. The main area is titled 'REST Explorer' and shows the URL `/services/data/v30.0/query?explain=select+id+from+fforce`. Below the URL, there are buttons for 'GET', 'POST', 'PUT', 'PATCH', 'DELETE', 'HEAD', 'Headers', 'Reset', and 'Up'. The 'GET' button is selected. Below the URL, there are links for 'Expand All', 'Collapse All', and 'Show Raw Response'. The main content area displays a query plan tree. The root node is 'plans' (with 1 item). The first item under 'plans' is 'fields', which has the following details: 'leadingOperationType: TableScan', 'relativeCost: 0.883333333333333', 'sobjectCardinality: 2160', and 'sobjectType: fforce\_\_RaceData\_\_c'.

You can see, as expected, the result is **TableScan**, compared to the following query:

```
select id from fforce__RaceData__c
  where CreatedDate = TODAY
```

The following screenshot shows the query plan for this query:

```
plans
  [Item 1]
    + cardinality: 648
    fields
      0: CreatedDate
      + leadingOperationType: Index
      + relativeCost: 1
      + sobjectCardinality: 2160
      + sobjectType: fforce__RaceData__c
  [Item 2]
    + cardinality: 648
    fields
      + leadingOperationType: TableScan
      + relativeCost: 1.31666666666667
      + sobjectCardinality: 2160
      + sobjectType: fforce__RaceData__c
```

This results in two plans; however, the standard **Index** was selected over **TableScan**.

The `cardinality` and `sobjectCardinality` fields are both estimates based on the aforementioned statistical information that Salesforce maintains internally relating to the spread of records (in this case, distinct records by `Type__c`). Thus, it gives the rows it thinks will be selected by the filter versus the total number of also estimated rows in the SObject.

 In this case, we can see that these are just estimates, as we know we have 10,000 records in the `RaceData__c` object; actually, 1,664 of those are **Sector Time** records. In general though, as long as these are broadly relative to the actual physical records, what the platform is doing is looking for the percentage of one from the other in order to decide whether an index will be worth using. It is actually the `relativeCost` field that is most important; basically a value greater than 1 means that the query will not be executed using the associated plan.

Now that you have a general idea of how to obtain this information, let's review a few more samples, but this time with 100,000 RaceData\_\_c records (10 races worth of data using the same distribution of records). In my org, I have also asked Salesforce Support to enable a custom index over the Type\_\_c, Lap\_\_c and Sector\_\_c custom fields. The namespace fforce prefix has been removed for clarity.

SOQL	Resulting plans
<pre>select id from RaceData__c where Type__c = 'PitStop Time'</pre> <p>The number of records relating to PitStop Time is less than 10 percent of the overall record count, so an index was used.</p>	<pre>{   "plans" : [ {     "cardinality" : 160,     "fields" : [ "Type__c" ],     "leadingOperationType" : "Index",     "relativeCost" : 0.016,     "sobjectCardinality" : 100000,     "sobjectType" : "RaceData__c"   }, {     "cardinality" : 160,     "fields" : [ ],     "leadingOperationType" : "TableScan",     "relativeCost" : 0.670133333333334,     "sobjectCardinality" : 100000,     "sobjectType" : "RaceData__c"   } ] }</pre>

SOQL	Resulting plans
<pre>select id from RaceData__c where Type__c = 'Sector Time'</pre> <p>A table scan plan was selected as the number of records relating to Sector Times was greater than 10 percent of the overall record count.</p>	<pre>{   "plans" : [ {     "cardinality" : 16640,     "fields" : [ ],     "leadingOperationType" : "TableScan",     "relativeCost" : 1.0272,     "sobjectCardinality" : 100000,     "sobjectType" : "RaceData__c"   }, {     "cardinality" : 16640,     "fields" : [ "fforce__Type__c" ],     "leadingOperationType" : "Index",     "relativeCost" : 1.664,     "sobjectCardinality" : 100000,     "sobjectType" : "RaceData__c"   } ] }</pre>

SOQL	Resulting plans
<pre>select id from RaceData__c where Type__c = 'Sector Time' and RaceName__c = 'Spa'</pre> <p>Again, a table scan was selected even though the query was made more selective by adding the race name. Adding a custom index over the race name would be advised here, as it is likely to be a common filter criteria.</p>	<pre>{   "plans" : [ {     "cardinality" : 1000,     "fields" : [ ],     "leadingOperationType" : "TableScan",     "relativeCost" : 0.688333333333334,     "sobjectCardinality" : 100000,     "sobjectType" : "fforce__RaceData__c"   }, {     "cardinality" : 16640,     "fields" : [ "fforce__Type__c" ],     "leadingOperationType" : "Index",     "relativeCost" : 1.664,     "sobjectCardinality" : 100000,     "sobjectType" : "fforce__RaceData__c"   } ] }</pre>
<pre>select id from RaceData__c where Type__c != 'PitStop Time'</pre> <p>A table scan plan was selected, as a negative operator was used.</p>	<pre>{   "plans" : [ {     "cardinality" : 100000,     "fields" : [ ],     "leadingOperationType" : "TableScan",     "relativeCost" : 2.833333333333335,     "sobjectCardinality" : 100000,     "sobjectType" : "RaceData__c"   } ] }</pre>

SOQL	Resulting plans
<pre>select id from RaceData__c where Type__c != 'PitStop' and Lap__c &gt;=20 and Lap__c &lt;=40  Even though a negative operator was used, by adding more selective criteria backed by a custom index, the platform chose to use the index over a table scan.</pre>	<pre>{   "plans" : [ {     "cardinality" : 10000,     "fields" : [ "Lap__c" ],     "leadingOperationType" : "Index",     "relativeCost" : 1.0,     "sobjectCardinality" : 100000,     "sobjectType" : "RaceData__c"   }, {     "cardinality" : 40000,     "fields" : [ ],     "leadingOperationType" :     "TableScan",     "relativeCost" : 1.533333333333334,     "sobjectCardinality" : 100000,     "sobjectType" : "RaceData__c"   } ] }</pre>

## Skinny tables

Internally, Salesforce stores Standard Object's field data and custom field data for a given record in two separate physical Oracle tables. So, while you don't see it, when you execute a SOQL query to return a mixture of both standard and custom fields, this internally requires an Oracle SQL query, which requires an internal database join to be made.

If Salesforce Support determines that avoiding this join would speed up a given set of queries, they can create a skinny table. Such a table is not visible to the Force.com developer and is kept in sync with your object records automatically by the platform, including any standard or custom indexes.

A skinny table can contain commonly used standard and custom fields that you, the subscriber, and Salesforce deem appropriate, all in the one Oracle table, thus, it avoids the join (all at the internal cost of duplicating the record data). If a SOQL, Report, or List View query utilizes the fields or a subset, the platform will automatically use the skinny table instead of the join to improve performance. As an additional benefit, the record size needed internally is smaller, which means that the data bandwidth used to move chunks of records around the platform can be better utilized.

This is obviously quite an advanced feature of the platform, but worth considering as an additional means to improve query performance in a subscriber org.

 Skinny tables are not kept in sync if you change field types or add new fields to the corresponding object in the Force.com world. Also, they are not replicated in sandbox environments. So, you or your subscriber will need to contact Salesforce Support again each time these types of changes occur. Also note that skinny tables cannot be packaged; they are configurations only for subscriber orgs.

## Handling large result sets

In most cases within Apex, it is only possible to read up to 50,000 records, regardless of whether they are read individually or as part of forming an aggregate query result. There is, however, a context parameter that can be applied that will allow an unlimited number of records to be read. However, this context does not permit any database updates. In this section, we will review the following three ways in which you can manage large datasets:

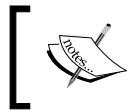
- Processing 50k maximum result sets in Apex
- Processing unlimited result sets in Apex
- Processing unlimited result sets via the Salesforce APIs

## Processing 50k maximum result sets in Apex

One of the problems with reading 50,000 records is that you run the risk of hitting other governors, such as the **heap governor**, which, although increased in an async context, can still be hit depending on the processing being performed. Take a look at the following contrived example to generate attachments on each **Race Data** record:

```
List<Attachment> attachments = new List<Attachment>();
for(RaceData__c raceData : [select Id from RaceData__c])
    attachments.add(
        new Attachment(
```

```
Name = 'Some Attachment',
ParentId = raceData.Id,
Body = Blob.valueOf('Some Text'.repeat(1000)));
insert attachments;
```



To try out the examples in this chapter, you will need the **Partner Portal Developer Edition** org, which comes with 250 MB of record and document storage.



If you try to execute the preceding code from an **Execute Anonymous** window, you will receive the following error, as the code quickly hits the **6 MB heap size limit**:

```
System.LimitException: Apex heap size too large: 6022466
```

The solution to this problem is to utilize what is known as **SOQL FOR LOOP** (as follows); it allows the record data to be returned to the Apex code in chunks of 200 records so that not all the **Attachment** records will build up on the heap:

```
for(List<RaceData__c> raceDataChunk :
    [select Id from RaceData__c]) {
    List<Attachment> attachments = new List<Attachment>();
    for(RaceData__c raceData : raceDataChunk)
        attachments.add(
            new Attachment(
                Name = 'Some Attachment',
                ParentId = raceData.Id,
                Body = Blob.valueOf('Some Text'.repeat(1000)));
        insert attachments;
}
```

Once this code completes, it will have generated over 80 MB of attachment data in one execution context! Note that, in doing so, the preceding code does technically break a bulkification rule, in that there is a DML statement contained within the outer chunking loop. For 10,000 records split over 200 record chunks, this will result in 50 chunks, and thus, this will consume 50 out of the available 150 DML statements. In this case, the end justifies the means, so this is just something to be mindful of.

## Processing unlimited result sets in Apex

In this section, a new **Race Analysis** page is created to allow the user to view results of various calculations and simulations applied dynamically to selected **Race Data**. Ultimately, imagine that the page allows the user to input adjustments and other parameters to apply to the calculations and replay the race data to see how the race might have finished differently.

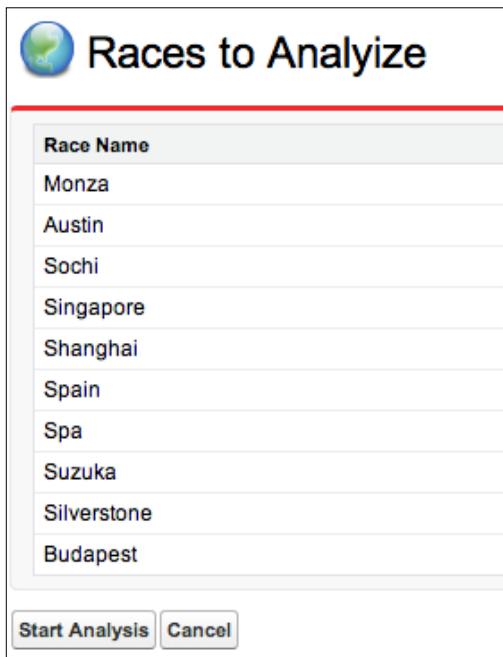
For the purposes of this chapter, we are focusing on querying the **Race Data** object only. The standard row limits 50,000 records (approximately 5 races' worth of data) to be returned from the SOQL query. The following changes have been made to the FormulaForce application to deliver this page and are present in the code samples associated with this chapter if you wish to deploy them:

- A new `analyzeData` method on the `RaceService` class has been added.
- The `RaceDataSelector` class has been created to encapsulate the query logic.
- `RaceAnalysisController` has been created for the Visualforce page.
- The `raceanalysis` Visualforce page has been created.
- A new **Race Analysis** list Custom Button has been added to the `Race__c` object. This button has been added to the list related to **Races** on the **Season** detail page.

The user can now select one or more **Race** records from the related list to process as follows:

Season Detail	
Season Name	2014
Year	2014
Current	<input type="checkbox"/>
Created By	Andrew Fawcett, 26/05/2014 10:34
<input type="button" value="Edit"/> <input type="button" value="Delete"/> <input type="button" value="Clone"/>	
Races	
<input type="button" value="New Race"/> <input type="button" value="Race Analysis"/>	
Action	Race Name
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Spain</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Spa</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Silverstone</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Singapore</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Sochi</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Austin</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Budapest</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Monza</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Suzuka</u>
<input checked="" type="checkbox"/>	<a href="#">Edit</a>   <a href="#">Del</a> <u>Shanghai</u>

The next display provides a confirmation of the selected races before starting the calculations. This button invokes the `RaceService.analyzeData` method and attempts to query the applicable `RaceData__c` records.



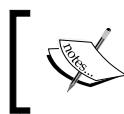
## Generating more Race Data

To demonstrate how it is possible to read more than 50,000 records, we will need to generate some more **Race Data**. To do this, we can rerun a portion of the script we ran earlier in this chapter to generate up to 100,000 records (which will nearly fill a Partner Portal Developer Edition org).

From an **Anonymous Apex** prompt, execute the following Apex code for each race; this should result in 100,000 records in the **Race Data** object (which you can verify through the **Data Storage** page under **Setup**):

```
TestData.createVolumeData(2017, 'Monza', 52, 4);
```

Run the preceding code again a further eight times, each time changing the name of the race to Austin, Sochi, Singapore, Shanghai, Spa, Suzuka, Silverstone, and Budapest (note that **Race Data** for Spain was generated earlier).



Note that to clear down the data for any reason, repeatedly call the following, then go to your **Recycle Bin** and delete all org data:

```
TestData.purgeVolumeData(false);
```

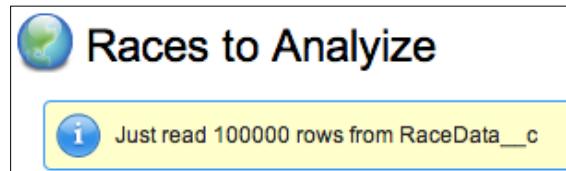


## Leveraging Visualforce and the Apex read-only mode

The **Start Analysis** button calls the service to query the race data analyze the data and for the purposes of this chapter, it outputs the total number of queried rows as follows:

```
ApexPages.addMessage(
    new ApexPages.Message(
        ApexPages.Severity.Info,
        'Just read ' + Limits.getQueryRows() +
        ' rows from RaceData__c'));
```

As per the previous screenshot, select all 10 races (click on the **Show 5 more** link to show more related list records). Click on the **Start Analysis** button to display a message, confirming the number of records processed is above the standard 50,000.



The reason this has been made possible is due to the Visualforce page enabling the read-only mode, via the `readOnly` attribute on the `apex:page` element, as follows:

```
<apex:page
    standardController="Race__c"
    extensions="RaceAnalysisController"
    recordSetVar="Races"
    readOnly="true">
```

This mode can also be enabled via the `@ReadOnly` Apex attribute on an Apex scheduled class or on an Apex Remote Action method. As the name suggests, the downside is that there can be no DML statements, so we have no means to update the database. For this use case, this restriction is not a problem. Note that, by using **JavaScript Remoting**, you can create a mix of methods with and without `@ReadOnly`. Currently this attribute cannot be used in conjunction with `@AuraEnabled`.



Note that, in this mode, other governors are still active, such as heap and CPU timeout. You might also want to consider combining this mode with the SOQL FOR LOOP approach described earlier. Also, the SOQL Aggregate queries will benefit from this (as these also count against the SOQL query rows governor).

## Processing unlimited result sets using Salesforce APIs

Salesforce does not limit the maximum number of rows that can be queried when using the Salesforce SOAP and REST APIs to retrieve record data, as in these contexts, the resources consuming and processing the resulting record data are off-platform.

One consideration to keep in mind, however, is the daily API limits – although you can read unlimited data, it is still chunked from the Salesforce servers and retrieving each chunk will consume an API call. Although less friendly, the Salesforce Bulk API is more efficient at retrieving more records while using less API calls to the Salesforce servers.

## Asynchronous execution contexts

Salesforce is committed to ensuring that the interactive user experience (browser or mobile response times) of your applications and that of its own is as optimal as possible. In a multitenant environment, it uses the governors as one way to manage this. The other approach is to provide a means for you to move the processing of code from the foreground (interactive) into the background (async mode). This section of the chapter discusses the design considerations, implementation options, and benefits available in this context.

As the code running in the background is, by definition, not holding up the response times of the pages the users are using, Salesforce can and does throttle when and how often async processes execute, depending on the load on the servers at the time. For this reason, it currently does not provide an **SLA** on exactly when an async piece of code will run or guarantee exactly when the Apex Schedule code will run at the allotted time. This aspect of the platform can at times be a source of frustration for end users, waiting for critical business processes to complete. However, there are some design, implementation, user interface, and messaging considerations that can make a big difference in terms of managing their expectations.

The good news is that the platform rewards you for running your code in `async` by giving you increased governors in areas such as Heap, SOQL queries, and CPU governor. You can find the full details in their documentation (attempting to document them in a book is a nonstarter as they are constantly being improved and removed in some cases).

**Understanding Execution Governors and Limits:** [http://www.salesforce.com/us/developer/docs/apexcode/Content/apex\\_gov\\_limits.htm](http://www.salesforce.com/us/developer/docs/apexcode/Content/apex_gov_limits.htm).

## General `async` design considerations

The platform provides some straightforward ways in which you can execute code in `async`. What is often overlooked though is error handling and general user experience considerations. This section presents some points to consider functionally when moving a task or process into `async` or the background to use a more end user-facing term:

- **Type of background work:** I categorize work performed in the background in two ways, application and end user:
  - **Application** is something that the application requires to support future end user tasks, such as periodic recalculation, major data manipulation, or the on boarding of data from an external service, for example.
  - **End user** is something that is related (typically initiated) to an end user activity that just happens to require more platform resources than are available in the interactive (or foreground) context. The latter can be much harder to accept for business analysts and end users, who are constantly demanding real-time response times. If you do find that this is your only route, focus hard on the user interaction and messaging aspects as follows.

- **User experience:** A well-crafted user experience around the execution of background work can make all the difference when the platform is choosing to queue or slow the processing of work. Here are some considerations to keep in mind:
  - **Starting the background work:** Decide how the user starts the background process. Is it explicitly, via a button or indirectly, via a scheduled job or as a side effect of performing another task? Starting the background work explicitly from a user interface button gives you the opportunity to set expectations. A critical one being whether the work is queued or it has actually started; if they didn't know this, they might be inclined to attempt to start the work again, thus resulting in potentially two jobs processing in parallel! If you decide to start the process indirectly, make sure that you focus on error handling and recovery to ensure that the user has a way of being notified of any important failures at a later point in time.
  - **Progress bar indicators:** These can be used to allow the user to monitor the progress of the job from start to finish. Providing messages during the progress of the work can also help the user understand what is going on.
  - **Monitoring:** Ensuring that the user can continue to monitor the progress between sessions or other tasks can also be important. Often, users might close tabs or get logged out and so consider providing a means to revisit the place where they started the job and have the user interface recognize that the job is still being processed, allowing the user to resume monitoring of the job.
- **Messaging and Logging:** Think about the ways in which your background process communicates and notifies the end user of the work it has done and any errors that occurred. While e-mails can be the default choice, consider how such e-mails can get lost easily, look for alternative notification and logging approaches that are more aligned with the platform and the application environment. Here are some considerations to keep in mind:
  - **Logging:** Ideally, persist log information within the application through an associated log (such as a logging Custom Object) with other Custom Objects that are associated with records being processed by the job, such that the end users can leverage related lists to see log entries contextually.

- **Unhandled exceptions:** They are caught by the platform and displayed on the **Apex Jobs** page. The problem with this page is that it's not very user-friendly and also lacks the context as to what the job was actually doing with which records (the Apex class name might not be enough to determine this alone). Try to handle exceptions, routing them via your end user-facing messaging. Some Apex exceptions cannot be handled and will still require admins or support consultants to check for these. Your interactive monitoring solutions can also query `AsyncApexJob` for such messages.
- **Notifications:** Notifications that a job has completed or failed with an error can be sent via an e-mail; however, also consider creating a child record as part of the logging alternative. A user-related task or a chatter post can also work quite well. The benefit of options that leverage information stored in the org is that these can also be a place to display Custom Buttons to restart the process.
- **Concurrency:** Consider what would happen if two or more users attempted to run your jobs at the same time or if the data being processed overlaps between two jobs. Note that this scenario can also occur when scheduled jobs execute. You might want to store the Apex job ID during the processing of the job against an appropriate record to effectively lock it from being processed by other jobs until it is cleared.
- **Error recovery:** Consider whether the user needs to rerun the job processing that has only failed records or whether the job can simply be designed in a way which is re-entrant, which means that it checks whether executions of a previous job might have already been made over the same data and cleans up or resets as it goes along.

## Running Apex in the asynchronous mode

There are three ways to implement the asynchronous code in Force.com; all run with the same default extended governors compared to the interactive execution context.

As stated previously, there is no guarantee when the code will be executed. Salesforce monitors the frequency and length of each execution, adjusting a queue that takes into consideration performance over the entire instance and not just the subscriber org. It also caps the number of async jobs over a rolling 24-hour period. See the *Understanding Execution Governors and Limits* section for more details. Salesforce provides a detailed white paper describing the queuing.

**Asynchronous Processing in Force.com:** [https://developer.salesforce.com/page/Asynchronous\\_Processing\\_in\\_Force\\_com](https://developer.salesforce.com/page/Asynchronous_Processing_in_Force_com).



Apex Scheduler can be used to execute code in an async context via its execute method. This also provides enhanced governors. Depending on the processing involved, you might choose to start a Batch Apex job from the execute method. Otherwise, if you want a one-off, scheduled execution, you can use the Database.scheduleBatch method.

## @future

Consider the following implementation guidelines when utilizing @future jobs:

- Avoid flooding the async queue with many @future jobs (consider Batch Apex).
- Methods must execute quickly or risk platform throttling, which will delay the execution.
- It is easier to implement as they require only a method annotation to be added.
- Typically, the time taken to dequeue and execute the work is less than Batch Apex.
- You can express, via a method annotation, an increase in a specific governor to customize the governor limits to your needs.
- Parameter types are limited to simple types and lists.
- Be careful when passing in list parameters by ensuring that you volume test with large lists.
- There is no way to track execution as the **Apex Job ID** is not returned.
- Executing from an Apex Trigger should be considered carefully; @future methods should be bulkified, and if there is a possibility of bulk data loading, there is a greater chance of hitting the daily per user limit for @future jobs.
- You cannot start another @future, Batch Apex or Queueables job. This is particularly an issue if your packaged code can be invoked by code (such as that written by developer X) in a subscriber org. If they have their own @ future methods indirectly invoking your use of this feature, an exception will occur. As such, try to avoid using these features from a packaged Apex Trigger context.



I would recommend **Queueables** over `@future` since they have additional flexibility in terms of the type of information that can be passed to them and they are more easily tracked once submitted.

## Queueables

Consider the following implementation guidelines when utilizing Queueables:

- Avoid flooding the async queue with many jobs (consider Batch Apex).
- Methods must execute quickly or risk platform throttling, which will delay the execution.
- Implement the interface `Queueables` and the `execute` method. Then, use the `System.enqueueJob` method to start your job:
 

```
public void execute(QueueableContext context)
```
- The object implementing `Queueables` can contain serializable state that represents the work to be undertaken. This can be complex lists, maps, or your own Apex types.
- Typically, the time taken to dequeue and execute the work is less than Batch Apex.
- Be careful while processing lists, ensuring that you volume test with large volumes of lists to ensure that the job can complete with maximum data.
- You can track execution as the **Apex Job ID** is returned.
- Executing from an Apex Trigger should be considered carefully. Use of `Queueables` should be bulkified, and if there is a possibility of bulk data loading, there is a greater chance of hitting the daily per user limit for `@future` jobs.
- You can start up to 50 queueables jobs in a sync context.
- You can start only one queueable job within an existing queueable job; this is known as chaining. The depth of the chain is unlimited, though the platform will slow the gaps between jobs as the depth grows. Also Developer Edition orgs are limited to a depth of 5.
- If code attempts to issue more than 1 queueable job within an existing queueable context, an error occurs. This can be particularly an issue if your packaged code can be invoked by code (such as that written by developer X) in a subscriber org. If they have their own async methods indirectly invoking your use of this feature, an exception will occur. As such, try to avoid using these features from a packaged Apex Trigger context.

- It is possible to run more queueables jobs concurrently than Batch Apex. The exact limit is not documented. However be sure to avoid flooding the system, by putting in place logic that controls how chaining and concurrency are used.

## Batch Apex

In our scenario, the **Race Data** records loaded into Salesforce do not by default associate themselves with the applicable **Contestant** records. As noted earlier, the **Contestant** record has a **Race Data Id** field that contains an Apex-calculated unique value made up from the **Year**, **Race Name**, and **Driver Id** fields concatenated together.

The following Batch Apex job is designed to process all the **Race Data** records, calculate the compound **Contestant Race Data Id** field, and update the records with the associated **Contestant** record relationship. The following example highlights a number of other things in terms of the Selector and Service layer patterns usage within this context:

- The `RaceDataSelector` class is used to provide the `QueryLocator` method needed, keeping the SOQL logic (albeit simple in this case) encapsulated in the Selector layer.
- The `RaceService`.`processData` method (added to support this job) is passed in the IDs of the records rather than the records passed to the `execute` method in the `scope` parameter. This general approach avoids any concern over the record data being old, as Batch Apex serialized all record data at the start of the job.
- As per the standard practice, the Service layer does not handle exceptions; these are thrown to the caller and it handles them appropriately. In this case, `a new LogService class is used to capture exceptions thrown and log them to a Custom Object, utilizing the Apex job ID as a means to differentiate log entries from others jobs.` Note that the use of `LogService` is for illustration only; it is not implemented in the sample code for this chapter.
- `In the finish method, new NotificationService encapsulates logic, which is able to notify end users (perhaps via e-mail, tasks, or Chatter as considered earlier) of the result of the job, passing on the Apex job ID, such that it can leverage the information stored in the log Custom Object and/or ApexAsyncJob to form an appropriate message to the user.` Again, this is for illustration only.

The following code shows the implementation of the Batch Apex job to process the race data records:

```

public class ProcessRaceDataJob
    implements Database.Batchable<SObject> {
    public Database.QueryLocator start(
        Database.BatchableContext ctx) {
        return
            RaceDataSelector.newInstance().selectAllQueryLocator();
    }

    public void execute(
        Database.BatchableContext ctx, List<RaceData__c> scope) {
        try {
            Set<Id> raceDataIds =
                new Map<Id, SObject>(scope).keySet();
            RaceService.processData(raceDataIds);
        }
        catch (Exception e) {
            LogService.log(ctx.getJobId(), e);
        }
    }

    public void finish(Database.BatchableContext ctx) {
        NotificationService.notify(
            ctx.getJobId(), 'Process Race Data');
    }
}

```

Note that even the code to start the Apex job is implemented in a **Service** method; this allows for certain pre-checks for concurrency and configuration to be encapsulated. To run this job, a list view Custom Button has been placed on the **Race Data** object in order to start the process. The controller calls the Service method to start the job as follows:

```
Id jobId = RaceService.runProcessDataJob();
```

Consider the following implementation guidelines when utilizing Batch Apex:

- A maximum of 5 active Apex Jobs can run in the org.
- **Apex Flex Queue** (available under **Setup**) can queue up to 100 jobs. The platform automatically removes items from this queue when jobs complete. You can also reorder items in the queue through the UI or via an API. Jobs in the queue have a special holding status.

- An exception is thrown if 100 jobs in an org are already enqueued or executing.
- It is more complex to implement Batch Apex, which requires three methods.
- Typically, the time taken to dequeue and execute can be several minutes or hours.
- Typically, the time taken to execute (depending on the number of items) can be hours.
- Up to 50 million database records or 50 thousand iterator items can be processed.
- Records or iterator items returned from the `start` method are cached by the platform and passed back via the `execute` method as opposed to being the latest records at that time from the database. Depending on how long the job takes to execute, such information might have changed on the database in the meantime.
- Consider re-reading record data in each `execute` method for the latest record state.
- You can track Batch Apex progress via its Apex job ID.
- Executing from an Apex Trigger is not advised from a bulkification perspective, especially if you are expecting users to utilize bulk data load tools.
- You can start another Batch Apex job from another (from the `finish` method).
- Calibrate the default scope size (the number of records passed by the platform to each `execute` method call) to the optimum use of governors and throughput.
- Provide a subscriber org configuration (through a protected Custom Setting or Custom Metadata) to change the default scope size of 200.



Note that the ability to start a Batch Apex job from another can be a very powerful feature in terms of processing large amounts of data through various stages or implementing a clean-up process. This is often referred to as **Batch Apex Chaining**. However, keep in mind that there is no guarantee the second job will start successfully, so ensure you have considered error handling and recovery situations carefully.

## Performance of Batch Apex jobs

As stated previously, the platform ultimately controls when and how long your job can take. However, there are a few tips that you can use to improve things:

- **Getting off to a quick start:** Ensure that your `start` method returns as quickly as possible by leveraging indexes.
- **Calibrating:** Calibrate the scope size of the records passed to the `execute` method. This will be a balance between the maximum number of records that can be passed to each `execute` (which is currently 2000) and the governors required to process the records. The preceding example uses 2000 as the operation itself is fairly inexpensive. This means that only 50 chunks are required to execute the job (given the test volume data created in this chapter), which in general, allows the job to execute faster as each burst of activity gets more done at a time. Utilize the `Limits` class with some debug statements when volume testing to determine how much of the governors your code is using, and if you can afford to do so, increase the scope size applied. Note that if you get this wrong (as in the data complexity in the subscribers orgs is more than you calibrated for your test data), it can be adjusted further in the subscriber org via a protected Custom Setting.
- **Frequency of Batch Apex jobs:** If the use of your application results in the submission of more Batch Apex jobs more frequently, perhaps because they are executed from an Apex Trigger (not recommended) or a user interface feature used by many users, your application will quickly flood the org's Batch Apex queue and hit the concurrent limit of 5, leaving no room for your Batch Apex jobs or those from other applications. Consider carefully how often you need to submit a job and whether you can queue work up within your application to be consumed by a Batch Apex Scheduled job at a later time. The Summer'14 **Batch Apex Flex Queue** will help reduce this problem.

## Using external references in Apex DML

The `RaceService.processData` service method demonstrates a great use of external ID fields when performing DML to associate records. Note that in the following code, it has not been necessary to query the `Contestant__c` records to determine the applicable record ID to place in the `RaceData__c.Contestants__c` field. Instead the `Contestants__r` relationship field is used to store an instance of the `Contestant__c` object with only the external ID field populated, as it is also unique and it can be used in this way instead of the ID.

```
public void processData(Set<Id> raceDataIds)
{
    fflib_SObjectUnitOfWork uow =
        Application.UnitOfWork.newInstance();
```

```
for(RaceData__c raceData :  
    (List<RaceData__c>)  
        Application.Selector.selectById(raceDataIds))  
{  
    raceData.Contestant__r =  
        new Contestant__c(  
            RaceDataId__c =  
                Contestants.makeRaceDataId(  
                    raceData.Year__c,  
                    raceData.RaceName__c,  
                    raceData.DriverId__c));  
    uow.registerDirty(raceData);  
}  
uow.commitWork();  
}
```

If the lookup by external ID fails during the DML update (performed by the **Unit Of Work** in the preceding case), a DML exception is thrown, for example:

```
Foreign key external ID: 2014-suzuka-98 not found for field  
RaceDataId__c in entity Contestant__c
```



This approach of relating records without using or looking up the Salesforce ID explicitly is also available in the Salesforce SOAP and REST APIs as well as through the various **Data Loader** tools. However, in a data loader scenario, the season, race, and driver ID values will have to be pre-concatenated within the CSVfile.

## Volume testing

In this chapter, we have used the Apex code to generate additional data to explore how the platform applies indexes and the use of Batch Apex. It is important to always perform some volume testing even if it is just with at least 200 records to ensure that your Triggers are bulkified. Testing with more than this gives you a better idea of other limitations in your software search, such as query performance and any Visualforce scalability issues.

One of the biggest pitfalls with volume testing is the quality of the test data. It is not often that easy to get hold of actual customer data, so we must emulate the spread of information by varying field values amongst the records to properly simulate how the software will not only behave under load with more records, but under load with a different dispersion of values. This will tease out further bugs that might only manifest if the data values change within a batch of records. For example, the Apex script used in this chapter could be updated to apply a different PitStop strategy across the drivers, varying those types of records per race per driver.

The second challenge is to understand how long a process will take, for example, a Batch Apex job. As it is a multitenant environment, this can vary a lot. This does not mean to say that you should not try a few times during different times of the day and get a rough guide on how long jobs take with different data volumes. You should also experiment with your Batch Apex scope size during your volume testing. The higher the scope size, the fewer chunks of work to perform and, typically, the jobs need to execute for a reduced elapsed time.

As we have seen in this chapter, it only takes 100,000 records to fill a Partner Developer Edition org near to a capacity of 250 MB. The Partner Portal test orgs offer an increase to 1 GB so that you can push volume testing further. You should also encourage relationships with your larger customers to utilize Beta package versions of your application in their sandboxes.

Finally, consider other ways to generate volume data; bulk loading CSV files can work, but can lead to less varied data as CSV files are typically static and not so easy to edit. It can be well worth investing in some off-platform code that either generates dynamic CSV files or directly invokes the Salesforce API or Bulk API to push data into an org directly. Also, remember that, while you're doing this, you're also testing your Apex Trigger code.

## Summary

In this chapter, we have learned that understanding not just the volume of records, but also how data within them is dispersed can affect the need for indexes to ensure that queries perform without having to resort to expensive table scans or, in the case of Apex Trigger, runtime exceptions. Ensuring that you and your customers understand the best way to apply indexes is critical to both interactive and batch performance.

Asynchronous execution contexts open up extended and flexible control over the governors available in the interactive context, but need to be designed from the beginning with careful consideration for the user experience, such that the user is always aware of what is and is not going on in the background. Messaging is the key when there is no immediate user interface to relay errors and resolve them. Don't depend on the **Apex Jobs** screen; instead, try to contextualize error information through custom log objects related to key records in your application that drive background processes, allowing related lists to help relay information in context about the state and result of jobs.

Execution of background processes is not scoped to your application but affects the whole subscriber org, so the frequency in which your application submits processes to the background needs to be carefully considered. Understand the difference between application and end user jobs; the latter are more likely to flood an org and cause delays or, worse, result in end users having to retry requests. Consider leveraging Apex Scheduler to implement your own application queue to stage different work items for later processing. Salesforce allows up to Batch Apex 100 jobs to queue, giving the ability for the subscriber to control priority. Queueables offer more flexibility than `@future` and thus recommended. Queueables support more concurrent jobs and dequeues faster, though are less elastic in terms of variables volumes than Batch Apex.

In the next chapter, we will be moving out of the packaging org as the primary development environment and moving into a place that supports multiple developers and an application development life cycle backed by Source Control and Continuous Integration to ensure that you have a real-time view on test execution and auditability over your application's source code.

# 12

## Unit Testing

**Unit testing** is a key technique used by developers to maintain a healthy and robust code base. The approach allows developers to write smaller tests that invoke more varied permutations of a given method or a unit of code. Treating each method as a distinct testable piece of code means that not only current usage of that method is safer from regression, future usage is protected as well. It frees the developer to focus on more permutations, such as error scenarios and parameter values beyond those currently in use.

Unit testing is different from **integration testing** where many method invocations are tested as a part of an overall business process. Both have a place on Force.com. In this chapter we will explore when to use one over the other.

To understand how to adopt unit testing we first need to understand **dependency injection**. This is the ability to dynamically substitute the behavior of a dependent class' s methods with test or stub behavior. Using a so-called **mock** implementation of dependent methods (such as reading from the database) avoids the need for the repeated process intensive setup of test data. We will explore the ways in which dependency injection can be implemented, including the use of the **Apex stub API** that is included with the Force.com platform.

Finally, this chapter shows how unit testing can be applied to the Apex Enterprise Patterns introduced earlier in this book. Using the popular open source **ApexMocks mocking framework** with the Apex stub API, developers can write unit tests for controller, service, domain and selector classes.

This chapter will cover the following aspects of unit testing:

- Exploring the difference between unit and system testing
- Understanding dependency injection and how to implement it
- Leveraging the Apex stub API
- Applying the ApexMocks mocking framework to FormulaForce

## Comparing Unit testing and Integration Testing

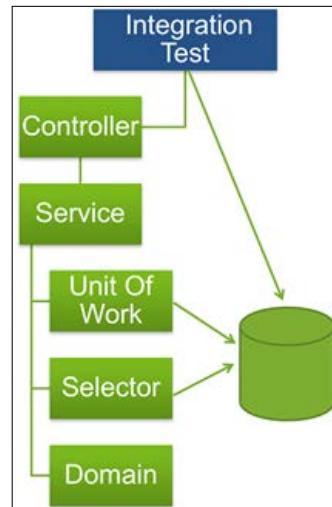
Much of the difference between unit and integration testing relates to the scope of the code being tested and the goals of the test. Chances are you have been mixing a combination of the two on Force.com without realizing it.

First, let's consider this definition of **Integration testing** by Wikipedia:

*Integration testing (sometimes called integration and testing, abbreviated I&T) is the phase in software testing in which individual software modules are combined and tested as a group. It occurs after unit testing and before validation testing. Integration testing takes as its input modules that have been unit tested, groups them in larger aggregates, applies tests defined in an integration test plan to those aggregates, and delivers as its output the integrated system ready for system testing.*

In general, most published guidance on writing Apex tests falls into this integration testing category. Indeed, the only way to cover Apex Trigger code is to physically write to the database. There is also the need to test declarative aspects of your solution (unit test only tests code) and how these affect the broader application processes.

When I read the preceding Wikipedia description, it described the Apex tests I had been writing before discovering how to write true unit tests on this platform (more on this later). Visually my tests would look like the following diagram.



I would write Apex test code to set up my records or execute my controller code or Service layer code (to test the API). This code would update or query the database accordingly.

Then I would write test code to query the results records to assert the behavior was what I was expecting. This approach would ensure that all the classes involved in the functionality: such as service, domain, unit of work, selector and domain—got executed. It also ensured that they did just what they needed to in the scenario I was testing to result in the overall goal of completing the end user or API process being tested.

Integration tests are still necessary to test your key processes and indeed to obtain code coverage on Apex Triggers required to package your solution. However, they do have some downsides:

- **Execution time:** Since each test method needs to set up, update, and query the database executing them, all or individual test methods can start to take increasingly longer to execute, slowing the developer's productivity.
- **Scenario coverage:** Introducing more varied scenarios can become less practical due to the preceding performance concern. This discourages developers from doing thorough testing (we hate waiting!). This in turn reduces code coverage and the value of the tests. And this ultimately increases the risk of bugs being left undiscovered by the developer.
- **Code coverage challenges:** Obtaining 100% code coverage is the desirable goal, but it can be impossible to achieve in certain scenarios. For example, error handling for some system events cannot be emulated in an integration test.
- **Ensuring future proofing and reliability to other developers:**  
Methodologies like Scrum teach us to write code incrementally and just in time for market needs. However, developers are often aware of future needs and wish to build frameworks, engines or libraries to support both current and future needs. It may not be possible to write integration tests that ensure that when that time comes such code is robust and reliable for other developers.

## Introducing Unit Testing

As we will discover throughout this chapter, unit testing helps address the preceding challenges. When used in combination with integration tests, the resulting test suite creates a much stronger and more efficient set of Apex tests for your application.

Learning about and writing unit tests can often seem difficult because it requires you to learn other concepts, some of which determine how you write your application code. Things such as Separation of concerns, Dependency Injection, Mocking, and Test Driven Development are concepts you will come across when Googling about unit tests. We will be looking into these throughout this chapter. Of course, you are already by now quite familiar with SOC and how this is applied to Apex Enterprise Patterns.

Consider this definition of unit tests by Wikipedia:

*Intuitively, one can view a unit as the smallest testable part of an application. In procedural programming, a unit could be an entire module, but it is more commonly an individual function or procedure. In object-oriented programming, a unit is often an entire interface, such as a class, but could be an individual method. Unit tests are short code fragments created by programmers or occasionally by white box testers during the development process.*

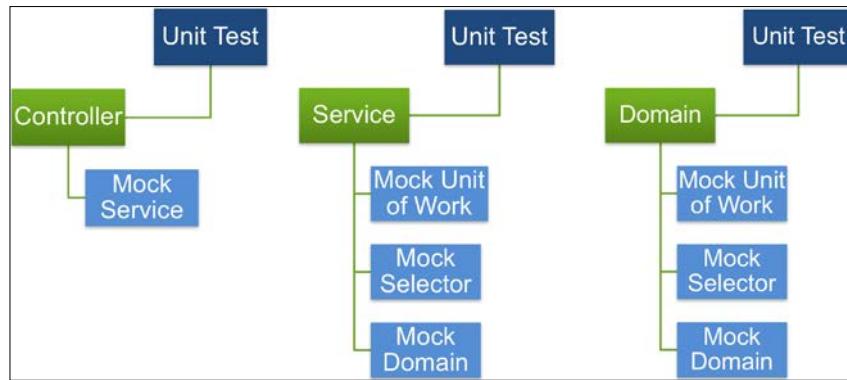
The biggest difference between unit and integration testing is evident through this definition. Unit tests may cover methods on potentially any class in your codebase, not just the outer controller classes or service classes. Furthermore, the goal is to test the execution and behavior of only the code in the chosen method and nothing else.

The hard part can be preventing the execution of other methods that the method being unit tested calls. This is done by substituting parts of the real production code (within the test context only) with stubbed code, or what is referred to as *mocked code*, that emulates the behavior of those methods. Then the method you're unit testing can still execute. Ideally, the method should be unaware of this substitution, or *injection* as it's known.

For example, a unit test for a Controller method should test the behavior of that method only, such as interaction with the view state or the handling of UI request and response with the Service layer calls. What the service layer method does is not of interest. Developers should not have to consider any requirements of dependent methods like this (for example, database setup) in the unit test code.

Likewise, when testing the Service layer logic, its use of the unit of work, selector and domain classes are not of interest or concern. However, these dependencies need to be resolved. The next section discusses how to inject dependencies.

The following diagram shows a series of unit tests focusing on a specific class and using mock alternatives of the dependent class methods to avoid having to concern themselves with their needs:



A mock version of a dependent class should emulate the expectations of the calling method (the method you are testing), by returning a value or throwing an exception for example. Configuring mocking is a key setup aspect of a unit test you need to master. It can allow you to write some very sophisticated and varied tests. We will go into more detail on mocking later in the chapter.

 Meanwhile, if you're not familiar with the mocking approach when developing the test code, this [http://en.wikipedia.org/wiki/Mock\\_object](http://en.wikipedia.org/wiki/Mock_object) link is a useful introduction. Though naturally there are many other sites on the Internet describing its benefits. The following is an extract from the Wikipedia page:

*'In object-oriented programming, mock objects are simulated objects that mimic the behavior of real objects in controlled ways. A programmer typically creates a mock object to test the behavior of some other object, in much the same way that a car designer uses a crash test dummy to simulate the dynamic behavior of a human in vehicle impacts.'*

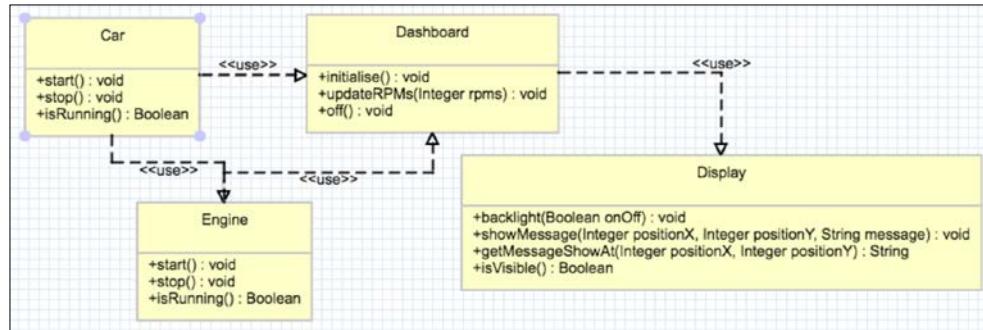
*'In a unit test, mock objects can simulate the behavior of complex, real objects and are therefore useful when a real object is impractical or impossible to incorporate into a unit test. If an actual object has any of the following characteristics, it may be useful to use a mock object in its place.'*

The more developers invest in unit tests; the less likely integration tests and your end users are to find defects. Keep in mind, however, that proving methods work in isolation does not prove your application works as designed. Integration tests are still a critical tool in testing your application.

## Dependency Injection, Mocking, and Unit Testing

At this stage, you're probably wondering just how is it technically possible, using code, to substitute or *inject* (to use the correct term) different compiled code during a test execution. To illustrate the various options for Dependency Injection let's start with a simple code example. We will explore how unit testing can be applied to Apex Enterprise patterns later in this chapter.

The following diagram shows the **Unified Modeling Language (UML)** for a Car class model, which has been designed with SOC in mind. Responsibilities such as engine, dashboard, and the digital readout display have been separated. This is a pure Apex code example to illustrate how dependencies between classes can be managed with Dependency Injection (DI):



The following code is for the Car class. It has a dependency on methods from the Dashboard and Engine classes. The caller must set up and provide instances of these classes for the methods to function correctly:

```
public class Car {  
  
    private Engine engine;  
    private Dashboard dashboard;  
    private Boolean isRunning;  
  
    public Car(Engine engine, Dashboard dashboard) {  
        this.dashboard = dashboard;  
    }  
}
```

```
        this.engine = engine;
    }

    public void start() {
        dashboard.initialise();
        engine.start();
    }

    public void stop() {
        engine.stop();
        dashboard.off();
    }

    public Boolean isRunning() {
        return engine.isRunning();
    }
}
```

The `start` and `stop` methods contain functionality that ensures that `dashboard` and `engine` are initialized accordingly. The following code for the `Dashboard` class requires an instance of the `Display` class, which handles the display of information:

```
public class Dashboard {

    private Display display;

    public Dashboard(Display display) {
        this.display = display;
    }

    public void initialise() {
        display.backlight(true);
        display.showMessage(10, 20, 'Hello Driver!');
    }

    public void updateRPMs(Integer rpms) {
        display.showMessage(10, 10, 'RPM: ' + rpms);
    }

    public void off() {
        display.backlight(false);
    }
}
```

The methods on the `Dashboard` class integrate with the `Display` class to show messages on the digital display of the car at various locations. The `Display` class has no dependencies, so for simplicity is not shown here. (If you want to view its code you can refer to the sample code for this chapter). Finally, the `Engine` class is shown as following:

```
public class Engine {  
  
    private Dashboard dashboard;  
    private Boolean isRunning;  
  
    public Engine(Dashboard dashboard) {  
        this.dashboard = dashboard;  
    }  
  
    public void start() {  
        dashboard.updateRPMs(1000);  
        isRunning = true;  
    }  
  
    public void stop() {  
        dashboard.updateRPMs(0);  
        isRunning = false;  
    }  
  
    public Boolean isRunning() {  
        return isRunning;  
    }  
}
```

The methods in the `Engine` class call methods on the `Dashboard` class to update the driver on the **Revolutions per Minute (RPM)** of the engine.



This is sample code. Real code would likely include classes representing various hardware sensors.



First let's take a look at what an integration test looks like for the Car:

```
@IsTest  
private class CarTest {  
  
    @IsTest  
    private static void integrationTestStartCar() {
```

```
// Given
Display display = new Display();
Dashboard dashboard = new Dashboard(display);
Engine engine = new Engine(dashboard);

// When
Car car = new Car(engine, dashboard);
car.start();

// Then
System.assertEquals(true, car.isRunning());
System.assertEquals(true, engine.isRunning());
System.assertEquals(true, display.isVisible());
System.assertEquals('Hello Driver!',
    display.getMessageShowAt(10,20));
System.assertEquals('RPM:1000',
    display.getMessageShowAt(10,10));
}
```

The setup for this test looks simple, but imagine if each of the classes constructed required other configuration and data to be created, the setup logic can grow quickly. This integration test is perfectly valid and useful in its own right. However, as I mentioned earlier, you cannot assume just because you have fully unit tested methods that everything still works when you put it all together!

The preceding test code is split into three main sections, *Given*, *When*, and *Then*. This type of approach and thinking originates from another practice known as **Behavior Driven Development (BDD)**. You can read more about this from Martin Fowlers web site. <https://martinfowler.com/bliki/GivenWhenThen.html>

## Deciding what to test and what not to test for in a Unit test

In this section let's review what type of unit tests we would want to write and what these tests should assert for some of the methods in the preceding example.

Let's consider what we would assert in writing a unit test that just tested the following logic in the `Car.start` method. (Remember we are not interested in testing the `dashboard.initialise` or `engine.start` methods yet):

```
public void start() {  
    dashboard.initialise();  
    engine.start();  
}
```

For this method, we would assert that the `dashboard.initialize` and `engine.start` methods actually got called. So in a unit test for this method, we are testing the behavior of the `start` method only. In separate unit tests, we would also test the `Dashboard.initialise` and `Engine.start` methods themselves.

 Solely testing the behavior or implementation of a method (for example, which methods it called), might seem odd, compared to asserting values. But sometimes asserting that certain methods were called (and how many times they were called) and any parameters that may exist were passed to them is a key validation that the code is working as expected. Asserting values returned from methods, as a means of testing correct behavior, is also valid in a unit test.

In the case of the `Engine.start` method, shown again in the following code, we want to assert that the `dashboard.updateRPMs` method was called with the correct idle RPM's value and that the state of the engine was correctly setup as running:

```
public void start() {  
    dashboard.updateRPMs(1000); // Idle speed  
    isRunning = true;  
}
```

We are not interested in testing whether the method updated the display; that's the concern of another unit test which tests the `Dashboard.updateRPMs` method directly.

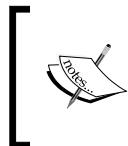
Here is the `Dashboard.updateRPMs` method code again. When writing a unit test for this method, we should validate that any value passed to the `rpms` parameter was correctly passed to the `Display.showMessage` method:

```
public void updateRPMs(Integer rpms) {  
    display.showMessage(10, 10, 'RPM: ' + rpms);  
}
```

In order to write unit tests for these methods and these methods alone, we need the dashboard, display and engine variables to reference something the compiler will recognize as having the required methods. But it also needs to allow us to make a substitution of the real implementation of these methods with special test-only versions so we can record when the methods are called in order to assert behavior. What we need is mock implementations of the Dashboard, Engine and Display classes.

## Constructor Dependency Injection

The preceding code makes explicit hard coded dependencies between classes. To work around this, CDI can be applied. This has been used in other languages such as Java. In the following examples **Apex Interfaces** are utilized to express the dependencies between various units of code that you want to test in isolation.



It is not required to apply this to all method-to-method calling dependencies; only those that you want to apply unit testing to. The Apex Enterprise patterns focuses mainly on Services, Domain, Selector and Unit of Work classes.

By leveraging the ability to have multiple implementations of a given interface we can vary which implementation gets executed. We can execute the real implementation of a method (this is provided by the preceding classes) or the test only the mock behavior of it, typically defined in the test itself. Thus depending on the type of test being written, integration or unit test, you then pass the appropriate implementations constructor of the Car class.

To support this type of injection, the following three things must be changed:

Firstly, interfaces are created to reflect the methods on the Engine, Dashboard, and Display classes. The following code shows how these interfaces are defined:

```
public interface IEngine {
    void start();
    void stop();
    Boolean isRunning();
}

public interface IDashboard {
    void initialise();
    void updateRPMs(Integer rpms);
    void off();
}

public interface IDisplay {
    void backlight(Boolean onOff);
```

```
void showMessage(  
    Integer positionX, Integer positionY, String message);  
String getMessageShowAt(  
    Integer positionX, Integer positionY);  
Boolean isVisible();  
}
```

Second, the real implementation of the classes must implement the interfaces, since the interfaces are based on their methods. This typically just requires stating the class implements the interface:

```
public class Engine implements IEngine {  
  
public class Dashboard implements IDashboard {  
  
public class Display implements IDisplay {
```

Finally, references to the interface types and not the concrete classes must be made throughout the codebase. For example, the `Car` constructor now takes the interface types, as does the member types `engine` and `dashboard` used to call the methods:

```
public class Car {  
  
    private IEngine engine;  
    private IDashboard dashboard;  
    private Boolean isRunning;  
  
    public Car(IEngine engine, IDashboard dashboard) {  
        this.dashboard = dashboard;  
        this.engine = engine;  
    }
```



Notice that, the integration test shown earlier in this chapter for the `Car` class still works without modification, since the real implementation it uses implements the interfaces.



## Implementing Unit tests with CDI and Mocking

The mock implementations of the interfaces can now also be implemented. These mock classes can be as simple or as complex as you desire, depending on what behavior you need to emulate and what it is you're asserting. Note that, you do not have to fully implement all methods; stubs are fine. Implement what is needed for your test scenarios:

```
private class MockDashboard implements IDashboard {
```

```

public Boolean initialiseCalled = false;
public Boolean updateRPMSCalled = false;
public Integer updateRPMSCalledWith = null;
public void initialise() { initialiseCalled = true; }
public void updateRPMS(Integer rpms) {
    updateRPMSCalled = true;
    updateRPMSCalledWith = rpms;
}
public void off() { }
}

private class MockEngine implements IEngine {
    public Boolean startCalled = false;
    public void start() { startCalled = true; }
    public void stop() { }
    public Boolean isRunning() { return true; }
}

private class MockDisplay implements IDisplay {
    public Boolean showMessageCalled = false;
    public String showMessageCalledWithMessage = null;
    public void backlight(Boolean onOff) { }
    public void showMessage(
        Integer positionX, Integer positionY, String message) {
        showMessageCalled = true;
        showMessageCalledWithMessage = message;
    }
    public String getMessageShowAt(
        Integer positionX, Integer positionY) { return null; }
    public Boolean isVisible() { return false; }
}

```



You can keep the implementation of these mock classes contained and scoped within your Apex test classes or a single as class, as inner classes, if needed.

After making the preceding changes and introduction of the mocking classes, the implementation of the `Car` class object model now supports unit testing through CDI.

Each of the following unit tests resides in the corresponding test class within the sample code for this chapter, for example, `CarTest`, `EngingeTest` and `DashboardTest`.

The following is a unit test for the `Car.start` method:

```
@IsTest
private static void
whenCarStartCalledDashboardAndEngineInitialised () {

    // Given
    MockDashboard mockDashboard = new MockDashboard();
    MockEngine mockEngine = new MockEngine();

    // When
    Car car = new Car(mockEngine, mockDashboard);
    car.start();

    // Then
    System.assert(car.isRunning());
    System.assert(mockDashboard.initialiseCalled);
    System.assert(mockEngine.startCalled);
}
```



Notice the method naming approach used by the test method. This is deliberate, as unit testing often results in the creation of many small unit test methods. Having a naming convention such as the examples shown in this section helps make it clearer at a glance what the test is covering. Once again this convention is borrowed from the BDD principles referenced earlier in this chapter.

Notice that the test did not need any setup to fulfill the setup requirements of the engine and dashboard dependencies, such as constructing an instance of the `Display` class.

Mock classes can also record the values passed as parameters for later assertion. The following is a unit test for the `Engine.start` method:

```
@IsTest
private static void whenStartCalledDashboardUpdated() {

    // Given
    MockDashboard mockDashboard = new MockDashboard();
```

```

// When
Engine engine = new Engine(mockDashboard);
engine.start();

// Then
System.assert(engine.isRunning());
System.assert(mockDashboard.updateRPMsCalled);
System.assertEquals(1000,
    mockDashboard.updateRPMsCalledWith);
}

```

It uses the mock implementation of the dashboard to confirm the `Dashboard.updateRPMs` method was correctly passed the corresponding value.

Finally, the following unit test is for the `Dashboard.updateRPMs` method:

```

@IsTest
private static void whenUpdateRPMsCalledMessageIsDisplayed() {

    // Given
    MockDisplay mockDisplay = new MockDisplay();

    // When
    Dashboard dashboard = new Dashboard(mockDisplay);
    dashboard.updateRPMs(5000);

    // Then
    System.assert(mockDisplay.showMessageCalled);
    System.assertEquals('RPM:5000',
        mockDisplay.showMessageCalledWithMessage);
}

```

It uses the mock implementation of the display to validate the correct behavior and the display value is calculated and passed to the display when the method is called:

Using interfaces to achieve Dependency Injection has an overhead in the development and use of interfaces in the production code. This is something Salesforce has improved on with the introduction of the Apex Stub API described later in this chapter. As the Stub API is still quite new, you may still see the DI accomplished with interfaces. The **Apex Enterprise Patterns** library utilized it prior to the arrival of the Stub API.

Also keep in mind, as we have seen in previous sections in this book, Apex Interfaces also have many other uses in providing flexibility in your architecture's evolutions and reduce coupling between clearly defining boundaries such as those in this book and your logic can also define.

## Other Dependency Injection approaches

A variation on the constructor pattern is to use **setter methods** to inject references into the instance of a class being unit tested. These should use the `@TestVisible` annotation so that these methods do not get used to override the instance setup to point to the real instances of dependent classes, which might be setup in the constructor.

The **factory pattern** discussed earlier in this book can also be used to inject alternative implementations of the mock implementations. The factory approach does not require constructors to be declared with a list of dependencies for each class. Instead, instances of the interfaces are obtained by calling factory methods.

 The use of factory dependency injection over CDI can be a matter of preference regarding whether the dependencies need to be declared up front or not. The Apex Enterprise pattern library chose to use a factory pattern for injection over CDI since layers such as service, domain, and selector are well defined and consistently applied throughout an applications code base.

The Application class factories used in the preceding chapters of this book allow you to implement runtime injection of services, domain, or selector implementations by calling the respective methods on each of the corresponding factories.

The following Application class factory methods allow you to obtain an instance of an object implementing the specified service, unit of work, domain, or selector class. These are the same methods that have been used in earlier chapters to implement various dynamic configuration behaviors at runtime:

You must cast the result to the applicable Apex class or interface.

```
Application.Service.newInstance  
Application.Domain.newInstance  
Application.Selector.newInstance  
Application.UnitOfWork.newInstance
```

The following methods can be used to register an alternative implementation during test setup of a given service, domain or selector class.

```
Application.Service.setMock  
Application.Domain.setMock  
Application.Selector.setMock  
Application.UnitOfWork.setMock
```

The preceding `newInstance` methods will then return these in preference to instances of the real classes you configured in the `Application` class.

In an earlier chapter the `RaceService` created and implemented the `IRaceService`. The following unit test for the `RaceController` class leverages this interface and the `Application.Service.setMock` method. To register with the factory a mock implementation of the `IRaceService` interface. In order to implement a unit test that validates the controllers, record `Id` is correctly passed to the called service method:

```
@IsTest
private static void whenAwardPointsCalledIdPassedToService() {

    // Given
    MockRaceService mockService = new MockRaceService();
    Application.Service.setMock(IRaceService.class, mockService);

    // When
    Id raceId = fflib_IDGenerator.generate(Race__c.SObjectType);
    RaceController raceController =
        new RaceController(
            new ApexPages.StandardController(
                new Race__c(Id = raceId)));
    raceController.awardPoints();

    // Then
    System.assert(mockService.awardChampionshipPointsCalled);
    System.assertEquals(new Set<Id> { raceId },
        mockService.awardChampionshipPointsCalledWithRaceIds);
}
```

The `MockRaceService` is not shown here for brevity, but it follows the same pattern as the other mock classes shown so far in this chapter. Refer to it within the `RaceControllerTestMockingDemo` class included in the sample code of this chapter. Also recall that the `RaceService.service` method utilizes the `Application` service factory to create an instance of the service to execute.

## Benefits of Dependency Injection Frameworks

So far we have discussed ways in which you can achieve dependency injection by using factories or constructors and implementing Apex Interfaces to inject alternative mock implementations of classes you wish to mock. DI frameworks offer ways for developers to access certain underlying language runtime features that can provide more direct ways to implement these aspects.

Thus DI frameworks tend to help developers gain easier access to the benefits of DI with much less boilerplate coding such as utilizing interfaces, especially in older code bases. However the developer may still have to write the mock implementations such as those we have seen above and manage dependencies between classes carefully via SOC.

Java for example leverages its reflection API to allow the injection at runtime without the need for interfaces. The Java Spring framework extends this feature by allowing configuration via XML files to allow for different runtime configurations. Some frameworks will also intercept the use of the native new operator. This avoids the need to implement factory- or constructor based injection approaches outlined in the preceding code.

A relatively recent addition to the Apex runtime is the **Apex Stub API**. This is one such DI framework provided by Salesforce as part of their platform. It does not override the new operator. The developer still needs to implement an injection approach such as those described earlier. However, it does make it easier to adopt mocking in legacy code bases (where interfaces have not been applied). The rest of this chapter will continue to explore this API in more detail and frameworks will be built on top of it.

## Writing Unit Tests with the Apex Stub API

The **Apex Stub API** applies only within an Apex test context. So it cannot be used to implement DI outside of tests. For this you still need to leverage Apex interfaces.

Utilizing the APIs requires an understanding of the following:

- **Implementing the Stub Provider interface:** The `System.StubProvider` system-provided Apex interface is effectively a callback style interface. It allows your mocking code to be informed when method calls are against classes you are mocking in your test. You can implement this interface multiple times, once per class you're mocking, or a single implementation for building sophisticated generalized mocking frameworks. The Apex Mocks open source framework from FinancialForce.com is one such framework that we will be reviewing later.

- **Dynamic Creation of Stubs for Mocking:** The platform automatically creates instances of classes you wish to mock through the `Test.createStub` method. You do not need to create Apex interfaces to perform DI when using the Stub API. The only requirement is that you provide the platform with an implementation of the `Test.StubProvider` interface to callback on when methods on the created stub instance are called during test execution.

## Implementing Mock classes using Test. StubProvider

Implementing mock handling code with the `System.StubProvider` requires only one method to be implemented as opposed to each of the methods being mocked individually. This is because this interface is a generic interface for all possible method signatures.

As you can see from the following implementation of the `MockDashboard` class, the `handleMethodCall` method on this interface passes all the information your mocking code needs in order to identify which method on which object has been called.

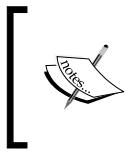
```
private class MockDashboard implements System.StubProvider {

    public Boolean initialiseCalled = false;

    public Object handleMethodCall(
        Object stubbedObject,
        String stubbedMethodName,
        Type returnType,
        List<Type> listOfParamTypes,
        List<String> listOfParamNames,
        List<Object> listOfArgs) {

        // Record method call
        if(stubbedMethodName == 'initialise') {
            initialiseCalled = true;
        }
        return null;
    }
}
```

Once again this mock implementation implements only the minimum needed to satisfy the mocking requirements of the test being performed. It simply validates that the `initialise` method was called.



Salesforce has provided a rich set of parameters to allow more generic implementations of this method to occur. We will review these later in this chapter through the Apex Mocks framework.

## Creating dynamic stubs for mocking classes

Having implemented the `System.StubProvider` it is still not possible to pass an instance of the `MockDashboard` class to the `Car` class since it cannot be cast to an instance of `dashboard`. To make this possible the platform-provided `Test.createStub` method must be called. This internally creates an instance of the `Dashboard` class but routes method calls to the provided stub provider instead of the real code.

A convention I decided to follow in these samples is to wrap the call to this method through a `createStub` method of my own on the mocking class. This reduces the amount of repetition when calling it (boiler plate code) and makes it easier to use when writing the unit testing code, as you will see in the next section.

```
private class MockDashboard implements System.StubProvider {  
  
    public Boolean initialiseCalled = false;  
  
    public Object handleMethodCall( ... ) {  
        ...  
    }  
  
    public Dashboard createStub() {  
        return (Dashboard) Test.createStub(Dashboard.class, this);  
    }  
}
```

## Mocking Examples with the Apex Stub API

After implementing the `MockDashboard` class, we can use it in a unit test. The resulting unit test is similar to those illustrated using Apex Interfaces:

```
@IsTest  
private static void  
whenCarStartCalledDashboardAndEngineInitialised() {  
  
    // Given  
    MockDashboard mockDashboard = new MockDashboard();
```

```

MockEngine mockEngine = new MockEngine();

// When
Car car = new Car(
    mockEngine.createStub(),
    mockDashboard.createStub());
car.start();

// Then
System.assert(car.isRunning());
System.assert(mockDashboard.initialiseCalled);
System.assert(mockEngine.startCalled);
}

```

 The sample unit test code and mocks used for this unit test are implemented in the `CarTestApexStubAPIDemo` class.

The main difference from the Apex interface approach is the creation of the stub instances of the classes being mocked using the applicable `createStub` methods.

The following code shows the `handleMethodCall` method in the `MockEngine` class used in the preceding unit test. It illustrates how a mock response can be returned for the `Engine.isRunning` method:

```

public Object handleMethodCall(
    Object stubbedObject,
    String stubbedMethodName,
    Type returnType,
    List<Type> listOfParamTypes,
    List<String> listOfParamNames,
    List<Object> listOfArgs) {

    // Record method call
    if(stubbedMethodName == 'isRunning') {
        isRunningCalled = true;
        return true;
    } else if(stubbedMethodName == 'start') {
        startCalled = true;
    }
    return null;
}

```

The following code shows the `handleMethodCall` method from the `MockDisplay` class (see the `DashboardTestApexStubAPIDemo` class for full code) and the use of the `listOfArgs` parameter:

```
public Object handleMethodCall(
    Object stubbedObject,
    String stubbedMethodName,
    Type returnType,
    List<Type> listOfParamTypes,
    List<String> listOfParamNames,
    List<Object> listOfArgs) {

    // Record method call and parameter values
    if(stubbedMethodName == 'showMessage') {
        showMessageCalled = true;
        showMessageCalledWithMessage = (String) listOfArgs[2];
    }
    return null;
}
```

The preceding mock handler code monitors the `showMessage` method being called by the `Dashboard.updateRPMs` method. It then stores parameter values for later assertion, in addition to the fact the method itself was called.

The following unit test code leverages this to test that the correct information is passed to the display when the `updateRPMs` method is called:

```
@IsTest
private static void whenUpdateRPMsCalledMessageIsDisplayed() {

    // Given
    MockDisplay mockDisplay = new MockDisplay();

    // When
    Dashboard dashboard = new Dashboard(mockDisplay.createStub());
    dashboard.updateRPMs(5000);

    // Then
    System.assert(mockDisplay.showMessageCalled);
    System.assertEquals('RPM:5000',
        mockDisplay.showMessageCalledWithMessage);
}
```

## Considerations when using the Apex Stub API

The following are some general notes and considerations for the Apex Stub API:

- The Apex new operator still creates the real type when used in your application code. Therefore, you still need to leverage a Dependency Injection convention, such as one of them described in this chapter, to inject the alternative implementation of any dependent class you wish to mock in your unit tests.
- Explicitly defined interfaces between the dependency boundaries of your classes are not strictly required, but might be a useful means of further enforcing SOC boundaries or for further configuration of your application.
- Not all methods and classes can be stubbed using the `Test.createStub` method. Examples include inner classes and get/set accesses. Also methods returning `Iterator`. For a full list consult the *Apex Developers Guide*.
- Static methods are also not able to be stubbed, this is by design, since these methods are not open to dependency injection. Although the Service layer design convention utilizes static methods, the actual implementation of those methods goes through the service factory to access the actual service implementation via instance methods. This can be seen in the `RaceService` included in the sample code.
- Other restrictions over what can be mocked, such as private methods and constructors, might seem like an omission. However, in principle you should be testing the public behavior of your classes in your unit test only anyway. Once you mock an object method the constructor used to instantiate the object is not significant, as your mocking code determines what each method returns.
- Keep in mind that, changes to method signatures can break the late bound references to parameters and return types made in your mock implementations. In this respect, explicit interface-based mock implementations have an advantage as a compilation error will occur if you make breaking changes. Mocking frameworks can help mitigate this risk as we will discuss in the next section.

## Using Apex Stub API with Mocking Frameworks

Implementing mock classes for small code bases or as an aid to get a better understanding of the concept of unit testing, as we have done in this chapter is fine. However, it can quickly become onerous and a maintenance overhead for larger code bases. The Apex Stub API was designed to handle any class shape for a reason.

The `stubbedObject` parameter can be used to determine from what type the method being called belongs. This allows for the creation of a single `System.StubProvider` implementation that can implement more advanced services that can be leveraged by unit tests without the need to write their own mock classes over and over. Playback of preconfigured responses to mocked methods and recording of each method call it receives for later assertion is an example of this.

The concept of a **mocking framework** is not new. There are many well established frameworks such as the popular **Mockito** framework for Java or **Jasmine** for JavaScript/NodeJS applications. However, mocking is a relatively new concept and capability in Apex, so the space is still emerging for Apex-based mocking frameworks.

**FinancialForce.com** has published an open source mocking framework known as **ApexMocks**. While it predates the arrival of the Apex Stub API it has been updated to work with this API. The advantage is that the code generator used to create the mock classes for use with Apex Mocks is no longer required; nor is the explicit use of Apex interfaces.

In the remainder of this chapter we will review the benefits of a mocking framework through the use of the ApexMocks framework (now included in the sample code of this chapter). We apply it first to our sample `Car` class model and then to unit test scenarios from the FormulaForce application. A full walkthrough is worthy of an entire book in my view. You can read more about ApexMocks through the various blog and documentation links on its `README` file, <https://github.com/financialforcedev/fflib-apex-mocks/blob/master/README.md>.



Credit should be given to Paul Hardaker for the original conception and creation of ApexMocks. As an experienced Java developer coming to the platform and used to using Mockito he was quickly driven to find out whether a similar unit testing facility could be created on the platform. Thus, ApexMocks inherits much of its API design from Mockito. Since then the framework has gone from strength to strength and received several other submissions and support from the community including presentations at Dreamforce. Much of what I know about the area of unit testing is also due to Paul's tutoring. Thank you!

## Understanding how ApexMocks works

The `whenCarStartCalledDashboardAndEngineInitialised` unit test method in the `CarTestApexMocksDemo` test class uses the ApexMocks library. The structure of this unit test is similar to those we have looked at so far in this chapter. It creates the mocks, runs the method to test, and asserts the results.

The big difference is that you do not need to write any code for classes you wish to mock. Instead you use the ApexMocks framework to configure your mock responses and to assert which methods were recorded. Then through its integration with the Apex Stub API it creates a stub that wraps itself around any class you wish to mock.

The main class within the ApexMocks framework is `fflib_ApexMocks`. This class implements the `System.StubProvider` interface for you. It automatically echoes any mock responses to mocked methods called and records that they got called and with what parameters. This applies to all public methods on the classes you ask it to mock for you.

Much of the skill in using ApexMocks is knowing how to configure the mocked responses it gives when mocked methods are called and how to write matching logic to assert not only when a method was called, but how many times and with what parameters. This later facility is incredibly powerful and opens up some sophisticated options for verifying the behavior of your code.

The following code initializes the ApexMocks framework (every test method needs this):

```

@IsTest
private static void
whenCarStartCalledDashboardAndEngineInitialised() {
    fflib_ApexMocks mocks = new ffib_ApexMocks();
}

```

Next create the mock implementations that you need:

```
// Given
Dashboard mockDashboard =
    (Dashboard) mocks.factory(Dashboard.class);
Engine mockEngine =
    (Engine) mocks.factory(Engine.class);
```

The following code replaces the need for you to write mock methods that return test values during the execution of code being tested. In ApexMock terms this configuration code is known as a **stubbing** code. You must surround stubbing code in `startStubbing` and `stopStubbing` method calls as shown here:

```
mocks.startStubbing();
mocks.when(mockEngine.isRunning()).thenReturn(true);
mocks.stopStubbing();
```

 The syntax gets a little tricky to understand at this stage, but you will get used to it, I promise! As I stated earlier, much of the inspiration for the ApexMocks API is taken from the Java Mockito library. So much so that articles and documentation around the Internet should also aid you in learning the API, as well as the documentation provided on the GitHub repo.

Your eyes are not deceiving you; the preceding code is calling the method you're attempting to mock a response for. First of all, this is a compile time reference, so it is much safer than a late bound string reference we used when using the Apex Stub API raw.

Secondly, because the `mockEngine` points to a dynamically generated stub, it is not calling the real implementation of this method. Instead it is registering in the framework that the next method call, `thenReturn`, should store the given value as a response to this method. This will be given back at a later point in the test when that mocked method is called again, this time in the test case context. In this case when the `Car.isRunning` method calls `engine.isRunning` (refer to the `Car` code if you need to refresh your memory as to what the implementation does) it returns the value `true`.

The next part of the unit test, the actual code being tested, is more familiar:

```
// When
Car car = new Car(mockEngine, mockDashboard);
car.start();
```

Asserting that the `Dashboard.initialise` and `Engine.start` methods have been called, as well as the value returned by the `Car.isRunning` is as expected, is also a little different from when calling the hand written mock class methods:

```
// Then
System.assertEquals(true, car.isRunning());
((Dashboard) mocks.verify(mockDashboard, 1)).initialise();
((Engine) mocks.verify(mockEngine, 1)).start();
}
```

 Due to the explicit casting requirements of Apex, the last two lines do not quite match what you would see in an equivalent Java Mockito example. This can make the syntax harder to read. In Java Mockito it would look like:

```
mocks.verify(mockDashboard, 1).initialise();
mocks.verify(mockEngine, 1).start();
```

The assertion code is a mixture of traditional `System.assert` and calls to the `fflib_ApexMocks.verify` method, followed by a call to the methods being mocked. Once again this compiler-checked reference is preferable to late bound string references.

The `verify` method takes an instance of the mocked object and number. This number allows you to assert that the method was called once and only once. Once the `verify` method exits and the mocked method is called, the expected result passed to the `verify` method is checked. If it is not met, either because the method was not called, or it was called more than once, the framework actually has the mocked method use `System.assert` to halt the test with an exception message describing why.

Another example is the `whenUpdateRPMsCalledMessageIsDisplayed` test method in the `DashboardTestApexMocksDemo` class. This utilizes a more advanced form of asserting that the desired mocked method was called. This approach not only validates that it was called but with specific parameter values:

```
@IsTest
private static void whenUpdateRPMsCalledMessageIsDisplayed() {

    fflib_ApexMocks mocks = new fflib_ApexMocks();

    // Given
    Display mockDisplay = (Display) mocks.factory(Display.class);

    // When
    Dashboard dashboard = new Dashboard(mockDisplay);
```

```
dashboard.updateRPMs(5000);

// Then
((Display) mocks.verify(mockDisplay, 1)).
    showMessage(10, 10, 'RPM:5000');
}
```

The preceding use of the `verify` method is no different from the previous test. However, the following mocked method call illustrates a very cool feature of ApexMocks verification logic. The parameters passed in the call to the mocked method are used by the framework to compare with those recorded during prior execution of the method during the preceding test. If any differences are detected an assertion is thrown and the test is stopped.



Some of the preceding examples include a `System.assert` method call inline. Other unit tests you write may not require use of this statement as they solely assert the correct dependent methods have been called through the `verify` method. This can lead to a false positive in the **Salesforce Security Review** scanner, since the `verify` method is not recognized as a method asserting quality. If this happens you can add a comment neutral assert to pacify the scanner, or record the reason why in the false positive document you attach to the review.

## ApexMocks Matchers

As you can see there are two key parts to using ApexMocks—setting up the mocked responses through stubbing, and asserting the behavior through verifying. Both these facilities support the ability customize what mocked values are returned or what parameters are matched during verify.

For example, if the code you're unit testing calls a mocked method several times with different parameters, you can vary the mocked value returned using a convention known as a matcher during the stubbing phase of your test code.



It is also possible to configure the framework's throwing of exceptions when mocked methods are called, if that is the desired test case you want to cover.

When asserting behavior, if you wish to check that a mocked method is called twice—once with a certain set of parameter values and a second time with a different set of parameters—then matchers can be used to express this desired outcome.

Matchers is an advanced feature, but well worth further investment of your time to learn.

## ApexMocks and Apex Enterprise Patterns

As we saw earlier, the supporting library or **Apex Enterprise patterns** provides methods that provide a Dependency Injection facility through the factories in the Application class. This facility is also compatible with the use of ApexMocks and Apex Stub API. The following sections contain examples of the use of ApexMocks to unit test the layers within the application architecture introduced in earlier chapters.

## Unit Testing a Controller Method

The following test can be found in the `RaceControllerTest` class and demonstrates how to mock a service layer class:

```
@IsTest
private static void whenAwardPointsCalledIdPassedToService() {

    fflib_ApexMocks mocks = new fflib_ApexMocks();

    // Given
    RaceServiceImpl mockService =
        (RaceServiceImpl) mocks.factory(RaceServiceImpl.class);
    Application.Service.setMock(RaceService.class, mockService);

    // When
    Id raceId = fflib_IDGenerator.generate(Race__c.SObjectType);
    RaceController raceController =
        new RaceController(
            new ApexPages.StandardController(
                new Race__c(Id = raceId)));
    raceController.awardPoints();

    // Then
    ((RaceServiceImpl) mocks.verify(mockService, 1)).
        awardChampionshipPoints(new Set<Id> { raceId });
}
```

Consider the following notable aspects from the above test code:

- Controllers in general use only service or selector classes. It could be considered a code review discussion point if other classes are used. Perhaps the separation of concerns within the controller needs further review?
- This test simply creates a mock instance of the Service class and confirms the method was called with the correct parameter value from the controller. There is no mock response required. However, the ApexMocks framework does permit for exceptions to be mocked. Thus another test could be written to confirm the error handling in the controller is working.

## Unit Testing a Service Method

The following test method can be found in the `RaceServiceTest` class and demonstrates how to mock classes implementing the unit of work, domain, and selector layers:

```
@isTest
private static void
whenAwardChampionshipPointsCallsDomainAndCommits() {

    fflib_ApexMocks mocks = new fflib_ApexMocks();

    // Given - Create mocks
    fflib_SObjectUnitOfWork mockUow = (fflib_SObjectUnitOfWork)
        mocks.factory(fflib_SObjectUnitOfWork.class);
    RacesSelector mockSelector = (RacesSelector)
        mocks.factory(RacesSelector.class);
    Contestants mockDomain = (Contestants)
        mocks.factory(Contestants.class);

    // Given - Configure mock responses
    Id testRaceId =
        fflib_IDGenerator.generate(Race__c.SObjectType);
    Id testContestantId =
        fflib_IDGenerator.generate(Contestant__c.SObjectType);
    List<Race__c> testRacesAndContestants = (List<Race__c>)
        fflib_ApexMocksUtils.makeRelationship(
            List<Race__c>.class,
            new List<Race__c> { new Race__c ( Id = testRaceId) },
            Contestant__c.Race__c,
            new List<List<Contestant__c>> {
                new List<Contestant__c> {
                    new Contestant__c (Id = testContestantId) } });
}
```

```

mocks.startStubbing();
mocks.when(mockSelector.SObjectType()) .
    thenReturn(Race__c.SObjectType);
mocks.when(mockSelector.selectByIdWithContestants(
    new Set<Id> { testRaceId })) .
    thenReturn(testRacesAndContestants);
mocks.when(mockDomain.SObjectType()) .
    thenReturn(Contestant__c.SObjectType);
mocks.stopStubbing();

// Given - Inject mocks
Application.UnitOfWork.setMock(mockUow);
Application.Selector.setMock(mockSelector);
Application.Domain.setMock(mockDomain);

// When
RaceService.awardChampionshipPoints(
    new Set<Id> { testRaceId });

// Then
((RaceSelector) mocks.verify(mockSelector, 1)) .
    selectByIdWithContestants(new Set<Id> { testRaceId });
((Contestants) mocks.verify(mockDomain, 1)) .
    awardChampionshipPoints(mockUow);
((fflib_SObjectUnitOfWork) mocks.verify(mockUow, 1)) .
    commitWork();
}

```

Consider the following notable aspects from the preceding test code:

- The `fflib_ApexMocksUtils.makeRelationship` method is used to construct in memory a list of records containing child records. This utility method (part of `ApexMocks`) works around a platform limitation in mocking this data construct. This method is very useful for returning more complex record sets returned from selector methods your tests are mocking.
- Prior to calling the `Application.Selector.setMock` and `Application.Domain.setMock` methods to inject the mock implementations of the `RaceSelector` and `Contestants` domain classes, the mocking framework is used to mock responses to the `SObjectType` methods for the mocked instances of these classes, which is called by the `setMock` methods. Mocking this method ensures that the mocked selector instance gets correctly registered with the Selector factory.

- The `fflib_IDGenerator.generate` method (part of `ApexMocks`) is used to generate an in memory ID that is used to populate the mock records returned from the mock selector. These same ID's are used to confirm what was passed into the Selector as the same ID's were passed to the Service method.
- The `Contestants` domain class gained a default constructor as required by the `Test.createStub` method, used by the `fflib_ApexMocks.factory` method.

## Unit Testing a Domain method

The following test method can be found in the `ContestantsTest` class and demonstrates mocking selector method responses to return database rows created in memory. it also shows that asserting the same records are subsequently passed to a mocked unit of work for update:

```
@IsTest
private static void whenAwardChampionshipPointsUowRegisterDirty() {

    fflib_ApexMocks mocks = new fflib_ApexMocks();

    // Given
    fflib_SObjectUnitOfWork mockUow = (fflib_SObjectUnitOfWork)
        mocks.factory(fflib_SObjectUnitOfWork.class);
    Application.UnitOfWork.setMock(mockUow);
    Id testContestantId =
        fflib_IDGenerator.generate(Contestant__c.SObjectType);
    List<Contestant__c> testContestants =
        new List<Contestant__c> {
            new Contestant__c (
                Id = testContestantId,
                RacePosition__c = 1 )};

    // When
    Contestants contestants = new Contestants(testContestants);
    contestants.awardChampionshipPoints(mockUow);

    // Then
    ((fflib_SObjectUnitOfWork)
        mocks.verify(mockUow, 1)).registerDirty(
            fflib_Match.sObjectWith(
                new Map<SObjectField, Object>{
                    Contestant__c.Id => testContestantId,
                    Contestant__c.RacePosition__c => 1,
                    Contestant__c.ChampionshipPoints__c => 25} ));
```

}

Consider the following notable aspects from the preceding test code:

- An in memory list of records is created in the test code and passed to the domain classes constructor. The awardChampionshipPoints method being unit tested is then called to determine if it correctly interacts with the unit of work.
- A custom ApexMocks matcher is used to check that the `sObject` passed to the mocked `fflib_SObjectUnitOfWork.registerDirty` method is the expected method. The matcher is also helping the test code confirm that the correct championship points have been calculated. For more information about ApexMock maters refer to the earlier section.
- As this test is using a mocked unit of work, no DML is performed.

## Unit Testing a Selector Method

The main logic to be tested by selector methods is that of constructing SOQL strings dynamically. Ideally it would be good if it were possible to mock the `Database.query` method and thus unit tests could be written around complex selector methods to assert the SOQL strings generated. As this is currently not possible, there is little benefit in mocking selector classes. Your selector classes can instead obtain coverage and validation through their executions as part of your integration tests.

## Summary

Integration testing focuses on the scope of controller methods or APIs exposed via your services to test the full stack of your code. It requires setting up the database, executing the code to be tested and querying the database. These tests are critical to ensuring all the components of your application deliver the expected behavior.

In order to make the individual code components, classes and methods as robust and future proof as possible, developers can test each method in isolation without incurring the overhead of setting up the database or updating it. As such, unit tests run more quickly. Unit tests can increase coverage, as more corner cases testing scenarios can be emulated using mocking of scenarios that would otherwise be impossible or difficult to setup on the database.

Unit Testing requires an understanding of some other patterns such as Dependency Injection and mocking. Dependency Injection can be implemented in a number of ways, using constructors, factories and setter methods. The approach you use of Dependency Injection will depend on your personal preference and/or the preference of the libraries you're using. Multiple approaches to dependency injection can be mixed if needed.

One approach to implementing mocking is to use Apex interfaces. Utilizing multiple implementations of interfaces that represent the boundaries between the dependencies of your code base allows you to implement the real code and test code separately.

Mocking is most effective when the code being tested is not aware which implementation is being used. The Apex Stub API allows for the creation of dynamic mocks for classes without using Apex interfaces. This is good for existing code bases or scenarios where using Apex interfaces don't make sense or adds overhead.

ApexMocks is a mocking framework library that reduces the work involved in building mock objects, removing the need to physically code them. Based on Mockito it offers advanced facilities to configure mocked method responses or throw exceptions to help test error handling. This framework also records the mock methods invoked and provides a sophisticated matching syntax to assert what methods were called.

The Apex Commons open source library used in this book utilizes the factory pattern to provide built in methods for injecting mock implementations of services, unit of work, domain, and selector layers.

In the end unit testing and its associated prerequisites make it a difficult concept to master and requires a lot of work up front. Start with a few simple examples at first and continue leveraging your existing Apex testing approaches until you're ready to expand. Once you have mastered the API's and concepts, it becomes second nature and can help open up access to other development coding practices such as test-driven development.

In the final chapter of this book, we will take a step back and look at how to scale your development around multiple developers and setup continuous and automated execution of your tests whenever changes are made.

# 13

## Source Control and Continuous Integration

So far we have been making changes in the packaging org for the **FormulaForce** application. This has worked well enough, as you're the sole developer in this case. However, when you add more developers and teams other considerations come into play, mainly traceability of code changes and also the practical implications of conflicts when more than one developer is working in a development org at a time.

This chapter sees the packaging org take on more of a **warehouse**-only role, accessed only when there is a need to create a beta or release package and no longer for day-to-day development as we have been doing. This principle can become quite important to you and your customers if they desire that you demonstrate compliance and auditability with respect to controls around your software development process and life cycle.

As the code base grows and the number of contributions to it at any given time increases, it's important to monitor the quality of the code more frequently. Finding out that your Apex tests are failing prior to an upload is frustrating and costly when you're trying to release the software to your customers. **Continuous Integration** works with a **Source Control** system to validate the integrity and quality (through your tests) of your application on an automated basis, often triggered by developers committing changes to Source Control.

In this chapter, you will learn the following:

- Developer workflow
- Developing with Source Control
- Hooking up to Continuous Integration

- Releasing from Source Control
- Automated regression testing

## Development workflow and infrastructure

A development workflow describes the day-to-day activities of a developer in order to obtain the latest build, make changes, and submit them back to a repository that maintains the current overall state of the source code. Having a solid well-defined developer workflow, supporting tools, and infrastructure is critical to the efficiency of any development team.

The first thing a developer will want to know is where the source code is, basically a source control system, such as Git. The next would be how to get it into a form so that they can start executing it. Salesforce provides a toolkit known as the **Migration Toolkit** that helps write scripts to deploy to a Salesforce org using the popular developer scripting language known as **Ant**. We will be building such a script in this chapter. Such scripts are also used by Continuous Integration build servers described later in this chapter.

The Migration Toolkit also provides a means to extract from Salesforce org source that has all the components needed to represent your application, not just the Apex and Visualforce source files, but XML files describing Custom Objects, fields, tabs, and practically any other component that can be packaged. We will use this facility to extract the current state of our packaging org in order to initially populate a Git repository with all the component files needed to maintain further changes to the source code outside of the packaging org that we have been developing within so far.

## Salesforce Developer Experience (DX)

At the time of writing, Salesforce announced Salesforce DX. It's a new developer experience focused on enterprise developer needs. The goal is to provide additional tools and APIs that better facilitate source control-based development with a full development life cycle:

- **Scratch orgs:** These are special types of orgs that can be created and deleted on demand. Thus it is not necessary to clean an org (think of this as your workspace in the cloud). You can also provide JSON configuration file to set various configurations for the org, such as multi-currency and even namespace (despite your packaging org also using the same).

- **Heroku flow:** The Heroku command line has been extended with additional facilities, such as the creation of Scratch orgs and the ability to synchronize the contents of your local folder structure with that of an attached org.

Details are limited to what was announced at the annual Salesforce Dreamforce event. The preceding points are aimed at giving you an idea of some of the things they announced and that will start to arrive over the next few years.

Meanwhile the following sub-sections provide you with a means to achieve source control development with today's tools, both from Salesforce and the community. It is also likely that some of the approaches here will still be needed as Salesforce DX continues to mature over several releases.

## Packaging org versus sandbox versus developer org

As mentioned previously, it can rapidly become impractical to have a number of developers within one org. They might accidentally overwrite each other's changes, make Custom Object or setup changes that others might not want to see, and consume daily API limits for that org more rapidly, eventually blocking everyone from making changes.

When it comes to the packaging org there is another more important reason, and that is the ability to know exactly what changes have been applied to your application code between one version and the next. This is something you and your customers want to have confidence in being able to know at any given time.

There is also the ability to be able to control the release of features or rollback changes, which becomes harder if those changes have already been made in the packaging org. For these reasons, it is typically a good idea to limit access to your packaging org to those responsible for making releases of your packages, thus treating your packaging org conceptually as a warehouse only.



Sandbox orgs are often attributed to development of custom solutions within an Enterprise organization, where the sandbox has been initialized with a copy of the production org. This can include data, installed packages, and other customizations. At the time of writing, sandbox orgs are available from Partner Portal-provisioned Enterprise Edition orgs (maximum of five). A sandbox can be used as an alternative to a developer org. One advantage is the ability to configure the parent org to a default blank state and then leverage the sandbox refresh process to effectively clean the org ready for a new build deployment. Note that the upcoming Salesforce DX scratch orgs are similar to sandbox orgs in some of these aspects. Note that if you are using Field Sets, sandbox orgs do not currently allow the definition of **Available Fields**.

## Creating and preparing your developer orgs

In the *Required and recommended organizations* section of *Chapter 1, Building, Publishing, and Supporting Your Application*, I recommended that you create a developer org. If you have not done already, visit the Partner Portal or <https://developer.salesforce.com/> and obtain a new developer org (or DE org for short) or Salesforce DX scratch org if you have that facility available to you.



Since this application utilizes Lightning Components and FlexiPages that references these components, you will need to enable **My Domain** on your Development Org for the deployments in this chapter to succeed.

Once you have this, you might want to take some time to further clean out any sample packages, Apex code, or configuration that Salesforce has put in such orgs, as these components will be merged with your own components later in the developer workflow process and you would want to avoid committing them to Source Control, or worse, getting them added to your package. Salesforce DX scratch orgs are empty by design.

Cleaning DE orgs is not something that Salesforce natively supports, yet most developers are familiar with the ability to clean their working environment (their DE orgs in the case of Force.com development) before taking new builds from Source Control. This avoids unwanted classes, objects, and fields building up during the course of development, for example when implementation strategies change or functionality is redefined, causing previously committed components to be renamed or deleted. This can leak back into your code base accidentally. Fortunately, there is an open source solution that leverages the Migration Toolkit to clean a DE org, which we will explore later. Salesforce DX scratch orgs have the same problem, but can more easily be deleted and replaced with a new org.



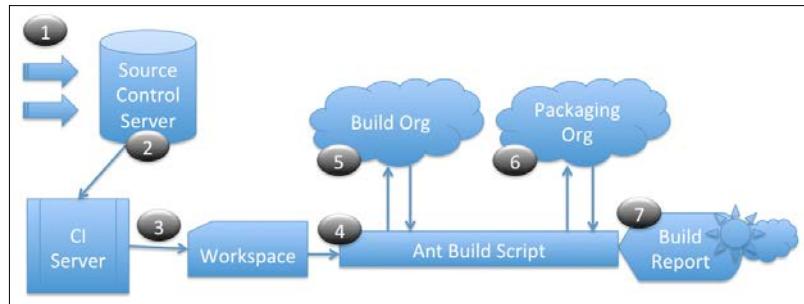
Due to the overhead of creating and managing installation of packages. Typically, DE orgs are also used by test engineers and other members of the team to test or preview features being developed. That being said, it can be worth considering the creation of a beta package from a stable build of your code at various intervals throughout your release development cycles, for additional sanity and smoke testing ahead of your final upload process. The uploading and installation of packages can be automated via the Tooling and Metadata APIs.

In this chapter, we are going to extract our application's components from the packaging org as files that we can later upload into a GitHub repository to allow tracking and auditability of changes in a more robust way than is permitted within a Salesforce org. We will then use this repository to populate the DE org created, make some changes, and commit those changes back to the repository. This is known as **developer workflow**.

## The developer workflow

There are many options when it comes to choosing an appropriate Source Control system to store your application code within. In this book, we will use GitHub as a remote Source Control store and local Source Control repository.

The aim here is not to prescribe which tools to use but to give a general walk-through of a Force.com developer flow that you can adapt and explore different options within later. The following diagram illustrates the developer workflow that we will be walking through in this chapter:



The following points relate to the preceding diagram:

1. Choosing a Source Control product and server is an important decision in which you should consider security, accessibility, and durability. The source code to your application needs to be securely managed for only authorized personnel, which is managed ideally through clear processes in your business when employees arrive and leave. Where you choose to store your Source Control server also adds further importance to this. If for accessibility reasons you choose to use one of the many cloud-based Source Control hosting services or indeed manage your own, for example via **Amazon EC2**. Perform durability tests from each location, ensuring that the server operates efficiently (developers hate waiting!). Finally, make sure that you have a backup and recovery process that is defined and tested, focusing on minimizing the downtime of your developers should the worst happen. The next section in this chapter will walk through populating a GitHub repository from the contents of our packaging org.
2. Populating a local repository with files stored in your Source Control server is the initial activity that most developers will perform. As described previously, this should be as efficient as possible. If you are using a cloud-based server, the amount of bandwidth needed to synchronize the remote and local repository is important. Some Source Control products offer more efficient implementations in this regard than others. Git is especially tailored for this kind of scenario, giving the ability to clone the whole or specific branches of the repository locally, complete with file history, followed by incrementally updating it as desired. Most common Source Control products offer excellent choices for GUI as well as the standard command-line interfaces. In this chapter we will use GitHub's GUI to clone the repository to a local folder ready for the next step in the developer flow.

3. The **Apache Ant** open source tool offers a good OS platform-neutral solution for making a standard build (deploy) script and other custom development tools you might want to build.
4. In its most basic form, an Ant build script simply leverages the Salesforce Migration Tool Ant task, `sf:deploy`, to deploy the contents of the local repository to a designated developer org. However, as we will discuss in a later section, it also forms a part of your Continuous Integration solution.
5. Once deployed to a developer org, the tools used to develop on Force.com range from using combinations of the **Setup** menu, **Schema Builder** (often overlooked), **Developer Console**, Force.com IDE (Eclipse) to other third-party IDEs that have emerged.
6. The key requirement is that once the developer is ready to submit to Source Control, there is an ability to synchronize the component files stored locally with the contents of the developer org. Most desktop based IDEs provide a means to do this, though you can also leverage an Ant build script via the `sf:retrieve` Ant Task supplied with the Migration Toolkit. I will cover how I do this later in this chapter.
7. Once files have been synchronized from the developer org, the developer can use standard Source Control commit processes to review their changes and commit changes to the Source Control server (Git requires developers to commit to their local repository first). We will use the GitHub GUI for this. Later in this chapter, we will see how this action can be used to automatically trigger a build that confirms that the integration of the developer's changes with the current state of Source Control has not broken anything, by automatically executing all Apex unit tests.



More advanced developer flows can also utilize Continuous Integration to pre-validate commits before ultimately allowing developer changes (made to so-called feature branches) to be propagated or merged with the main branch. One such advanced flow is known as **GitFlow**, describing a staged processing for code flowing from developer/feature branches to release branches. Search via Google for this term to read about this more advanced developer flow.

Note that it is only after step 4 that a developer can actually start being productive, so it's worth ensuring that you check regularly with your developers that this part of the developer flow is working well for them. Likewise, step 5 is where most of their time is spent. Try to allow as much freedom for developers as possible to choose the tools that make each of them the most efficient but still work within the boundaries of your agreed development flow.



**Debugging** still remains one of the most time-consuming aspects of developing on Force.com. Make sure that all developers are fully up-to-date with all the latest tools and approaches from Salesforce as well as your chosen IDE environment. Making effective use of the **debug log filters** can also save a lot of time sorting through a large debug log, as debug logs are capped at 2 MB. Often, developers resort to `System.debug` to gain the insight they need. Do ensure that these are removed before **Security Review**. Though genuine supporting debug entries can be discussed and permitted (it is recommended that you utilize the appropriate debug levels), ad hoc debug entries should be removed as a part of general practice anyway. Salesforce's interactive Apex Debugger is available through the Force.com IDE leveraging the Eclipse debugger UI. This can be enabled through conversations with Salesforce on certain orgs.

## Developing with Source Control

Now that we understand the general developer flow a bit more, let's take a deeper dive into using some of the tools and approaches that you can use.

In this case, we will be using the following tools to populate and manage the content of our chosen Source Control repository, in this case, Git. To provide an easy means to explore the benefits of a more distributed solution, we will use GitHub as a hosted instance of Git (others are available, including broader developer flow features):

- **GitHub:** Ensure that you have a GitHub account. Public accounts are free, but you can also use a private account for the purposes of this chapter. Download the excellent GitHub GUI from either <https://desktop.github.com/>. This chapter will use the Mac edition, though not to the level that it will not be possible find and perform equivalent operations in the Windows edition; both clients are really easy to use!
- **Apache Ant v1.9 or greater:** To determine if you have this already installed; type in `ant -version` at the terminal prompt to confirm. If not, you can download it from <http://ant.apache.org/>.
- **Force.com Migration Toolkit:** This can be downloaded from <https://developer.salesforce.com/page/Tools>. The instructions in the read me file recommend that you copy the `ant-salesforce.jar` file into your Apache Ant installation folder. I do not recommend this and instead prefer to capture build tools like this in a `/lib` folder located within the source code. This makes it easier to upgrade for all developers in a seamless way, without having to perform the download each time.

- **Force.com IDE:** The Force.com IDE is an open source project run by Salesforce. It gets regular updates and improvements, such as support for developing Lightning Components and the only interactive Apex Debugger (talk to your Salesforce contact for access). For more information and download instructions visit [https://developer.salesforce.com/page/Force.com\\_IDE](https://developer.salesforce.com/page/Force.com_IDE).

## Populating your Source Control repository

A key decision when populating your Source Control repository is the folder structure.

The following table shows one structure that you might want to consider:

Folder	Purpose
/	Keep the content of the root as clean as possible, and typically, the only file here will be the <code>Ant build.xml</code> file. You might also have a <code>README.md</code> file, which is a common Git convention to provide important usage and documentation links. This is a simple text file that uses a simple notation syntax (known as <b>MarkDown</b> ) to represent sections, bold, italics, and so on.
/lib	This folder contains any binary, configuration, or script files that represent build tools and dependencies needed to run the Ant build script, typically placed in the root. This is an optional folder but is used in this chapter to store the <code>ant-salesforce.jar</code> file, as opposed to having developers install it.
/src	This folder contains Force.com source files, structured in alignment with the folder structure returned by the Ant <code>sf:retrieve</code> task and expected by IDEs such as Force.com IDE.
/source (alternative)	Note that if your application contains other Source Control artifacts from other platforms, you might want to consider having a more general <code>/source</code> folder, permitting paths such as <code>/source/salesforce/src</code> and then <code>/source/heroku</code> .

If you want to follow through the steps in this chapter, follow on from the source code as contained within the `chapter-12` branch. If you would rather review the end result, skip to the `chapter-13` branch in the sample code repository to review the `build.xml` and `package.xml` files.

Perform the following steps to create the new repository and clone it, in order to create a local repository on your computer to populate with initial content:

1. Log in to your GitHub account from your web browser and select the option from the dropdown next to your user to create a new repository. Also select the option to create a default README file.



If you plan to try out the Continuous Integration steps later in this chapter, the easiest option with respect to configuration at this point is to create a **public repository**. An in-depth walk-through on how to configure Jenkins authentication with GitHub is outside the scope of this chapter.

2. From the web browser project page for the new repository, locate the **Clone or download** button on the right-hand side bar towards the bottom of the page. Click the **Open in Desktop** button on it to open the GitHub desktop client and begin cloning the repository, or open the GitHub desktop client manually and select the **Clone to Computer** option.
3. The preceding clone process should have prompted you for a location on your hard drive in which the local repository is to be stored. Make a note of this location, as we will be populating this location in the following steps.
4. Create a `/lib` folder in the root of the repository folder.
5. Copy the following files from the `/lib` sample code folder from this chapter into the new `/lib` folder created in the previous step:
  - Copy the `ant-salesforce.jar` file
  - Copy the `ant-salesforce.xml` file
  - Copy the `ant-contrib-1.0b3.jar` file
6. Create a `/src` folder in the root of the repository folder.
7. Copy the `build.xml` file that you have been using from the previous chapters into the root of the repository folder.

In this chapter, we will update the Ant `build.xml` script file to allow it to deploy the application source code into new Developer Edition orgs as needed. Before this, we will use the Ant `sf:retrieve` task provided by the `salesforce-ant.jar` file to retrieve the latest content of our FormulaForce package, which you have been developing so far, in the form of component source files, which we will migrate to Source Control.

 Note that we are performing this step due to the approach we have taken in this book, which is starting with development in the packaging org. If you are not starting from this point, you can create a `/src` folder and the `package.xml` file as described manually. That being said, you might want to make some initial inroads within the packaging org to establish a package and namespace with some initial objects.

The following `build.xml` target retrieves the content of the package defined in the packaging org and populates the `/src` folder. Make sure that your **Package** name is called **FormulaForce**. If not, update the `packageName` attribute as follows:

```
<target name="retrieve.package">
  <sf:retrieve
    username="${sf.username}"
    password="${sf.password}"
    retrieveTarget="${basedir}/src"
    packageName="FormulaForce"/>
</target>
```

 You can see the name of your package shown in the black banner in the top-right corner of the Salesforce page header when logged into the packaging org.

Perform the following command (all on one command line) with your own username, password, and token to execute the `retrieve` target. Ensure that you have changed the location to the root folder of your local repository first:

```
ant retrieve.package
-Dsf.username=yourusername
-Dsf.password=yourpasswordyourtoken
```

You should see something like the following in your local repository folder:

Folders	Folders	Documents
src bin .git  Documents build.xml README.md	applications classes labels layouts objects pages permissionsets quickActions tabs triggers  Documents package.xml	Application.cls Application.cls-meta.xml Cars.cls Cars.cls-meta.xml CarsSelector.cls CarsSelector.cls-meta.xml ComplianceController.cls Compliance...ls-meta.xml ComplianceService.cls Compliance...ls-meta.xml ComplianceServiceTest.cls Compliance...ls-meta.xml ContestantController.cls ContestantC...ls-meta.xml

 You might find references to the package namespace present in the code and metadata files retrieved. These should be removed, otherwise the files might not deploy or execute within an unmanaged developer org. You can use file search utilities to find such references. For example, open the /layouts/Contestant\_c-Contestant Layout.layout file and search for QuickActionName, then remove the namespace reference.

Before we are ready to commit this to your local repository (required before you can upload or push to the GitHub remote repository), open the package.xml file created by the retrieve operation and convert it to a more generic form. The one created by the preceding process contains explicit lists of each of the components in the package.

This means that if developers add new component files within the subfolders such as /classes, /pages, and /objects for example, they will not be subsequently deployed automatically without first having to update the package.xml file.

To avoid the developer from having to remember to do this, the package.xml file can be updated to use wildcards instead. For example, open the package.xml file and replace explicit references with wildcard characters, as shown in the following examples:

```
<types>
  <members>*</members>
  <name>ApexClass</name>
</types>
<types>
  <members>*</members>
  <name>ApexPage</name>
</types>
```

```

<types>
  <members>*</members>
  <name>ApexTrigger</name>
</types>

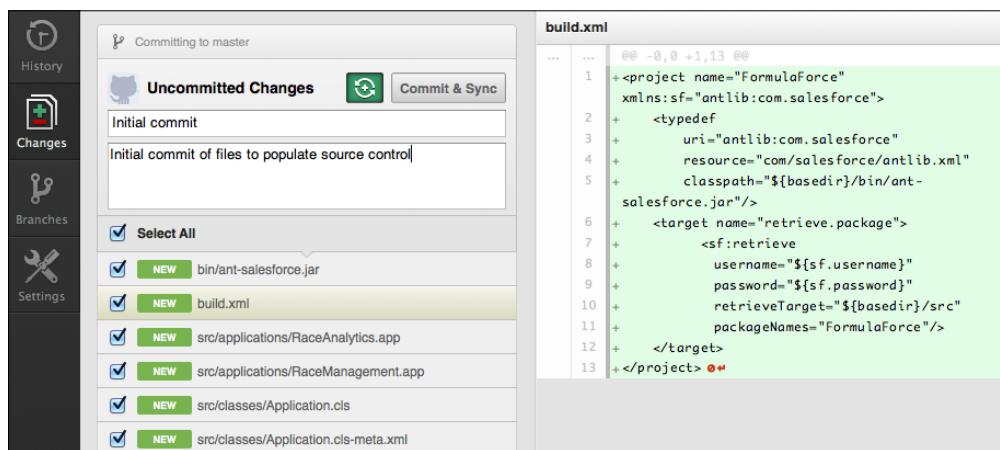
```

Also remove the `fullName`, `apiAccessLevel` and `namespacePrefix` tags from the `package.xml` file. Repeat the preceding approach for most of the component types in the `package.xml` file, not just the ones shown earlier as examples, with the exception of those that are known as **child components**.

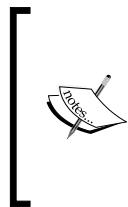
If you compare the preceding example with the `package.xml` file created previously, you will note that some of the components in the original `package.xml` file are child components of the `CustomObject` component, such as `FieldSet`, `WebLink`, `CustomField` and `Listview`. Also multiple entries for `CustomLabel` are not needed. Thus, they don't need wildcard entries at all as they will be deployed through their parent file, for example, via the `CustomObject` component's `.object` file, which contains fields.

Note that the actual list of components contained within the `FormulaForce` package still resides in the packaging org. The role and purpose of the `package.xml` file within Source Control is different and is more optimized for developer org deployments.

Finally, commit and sync the preceding changes to your local repository using the GitHub UI tool and upload or push (to use the correct Git term). If you run the tool, you should see that it is already reporting that new files have been detected in the repository folder on your hard disk, as shown in the following screenshot of the Mac version of the tool. Simply enter a summary and description and click on **Commit & Sync**.



Note that this will both commit to the local repository and be pushed to the remote repository in one operation. Typically, developers would work on a set of changes and commit locally in increments, before deciding to push all changes as one operation to the remote repository.



If you're not familiar with Git, this might seem a bit confusing, as you have already physically copied or updated files in the repository folder. However, in order to push to the remote Git repository stored on the GitHub servers, you must first update a local copy of the state of the repository held in the `.git` folder, which is a hidden folder in the root of your repository folder. You should never edit or view this folder as it is entirely managed by Git.

## The Ant build script to clean and build your application

Now that we have our initial Source Control content for the application created, let's deploy it to a developer org. Before we do this, we will update the `build.xml` file to clean the org (in case it has been used to develop an earlier build of the application).

Salesforce does not provide an Ant task to completely clean a developer org of any previously deployed or created components. However, it does provide a means via its Force.com Migration Toolkit to deploy what is known as a `destructivePackage.xml` file, which has a list of components to delete. Unfortunately, this needs a little help when there are component dependencies present in the org. **FinancialForce.com** has provided an open source solution to this via an `undeploy.xml` Ant script, which wraps this process and resolves the dependency shortcomings.

Download the following files from the `/lib` folder of the **FinancialForce.com** repository (<https://github.com/financialforcedev/df12-deployment-tools>), and place them in the `/lib` folder created earlier, along with the `ant-salesforce.jar` file:

- `exec_anon.xml`
- `undeploy.xml`
- `xmlltask.jar`
- `ml-ant-http-1.1.3.jar`
- `ant-contrib-1.0b3.jar`

Next, the Ant script is updated to default by executing the existing `deploy` target (used to deploy the sample source code from previous chapters). Then, by importing the preceding tasks into the build file, the `undeploy` target becomes available as a dependent target to the `deploy` target, which means that it will be called before that target is executed. The following sample build script highlights these changes:

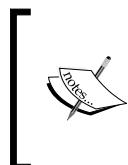
```
<project name="FormulaForce"
  xmlns:sf="antlib:com.salesforce" default="deploy">
  <property name="sf.server"
    value="https://login.salesforce.com"/>
  <import file="${basedir}/lib/exec_anon.xml"/>
  <import file="${basedir}/lib/undeploy.xml"/>

  <target name="deploy" depends="undeploy">
    <sf:deploy
      username="${sf.username}"
      password="${sf.password}"
      serverurl="${sf.server}"
      runAllTests="true"
      deployRoot="${basedir}/src"/>
  </target>

</project>
```

Execute the following command (all on one command line) to run the preceding script (make sure that you use your developer org username, password, and token):

```
ant
-Dsf.username=yourdevusername
-Dsf.password=yourdevpasswordyourdevtoken
```



It appears to output quite a lot of messages to the console due to the complexity of the `undeploy` target being executed. After a few moments, it will begin executing the `deploy` target. Once you receive confirmation that the entire script is successfully complete, you can confirm that the application has been deployed by logging into the org.

Once you're happy that the `build.xml` file is working fine, go back to the GitHub UI application and, as before, use the **Commit and Sync** button to commit your changes and push to the GitHub server's remote repository.

Congratulations! You have now left home (the packaging org) and moved out into your own brand new developer org. This also means that you can now allow other developers to start work independently on your code base by following the same developer flow using their own developer orgs.



Salesforce does not automatically grant access to applications, tabs, pages, objects, and fields deployed using the Migration Tool. So, you will find that before you can see these components, you need to assign your Permission Sets to your developer org user. Doing this is a good way to ensure that these are kept up to date with new components and are valid. In general, testing as a **system administrator** is not a reliable confirmation of your application working in an end-user scenario. This is why Salesforce has adopted this policy—to make the developer think about which permissions need to be applied, even in a developer org.

## Developing in developer orgs versus packaging orgs

Now that you have moved out of the packaging org and into a developer org, you will no longer be developing or executing code within the associated namespace context that it provides. If you recall back to the chapter around execution contexts, remember that the debug logs from Apex code executed in the packaging org had two namespaces referenced: the packaging org one and the default one. While everything runs in this namespace implicitly in the packaging org, nothing would ever run in the default namespace.

As you will have noticed, when writing the Apex code in the packaging org, you don't have to prefix Custom Objects or fields with that namespace the way you would have to in a subscriber org where your package was installed. Instead, in the packaging org, this is done implicitly on the whole, which made it easier to export into Source Control, as the target developer org environments do not have the namespace assigned to them (because it can only be assigned once).

When developing and executing code in a developer org, everything runs in the default namespace. Keep in mind the following differences when developing in a developer org:

- Apex features that can help implement Application Apex APIs such as the `@deprecated` annotation and the `Version` class that are not supported outside of the packaging org and results in compilation failures in the developer org. The main downside here is the lack of ability to use the `@deprecated` attribute as you want to retire old Apex APIs. Behavior versioning using the `Version` class is not something I would recommend for the reasons outlined in *Chapter 9, Providing Integration and Extensibility*.

- Apex tests that utilize Dynamic Apex to create and populate SObject instances and fields will need to dynamically apply the namespace prefix by autosensing, whether the Apex test is running in a namespace context or not. The following code snippet is a good way to determine whether the code is running in a namespace context or not. You can place this in a test utility class:

```
DescribeSObjectResult seasonDescribe =
    Season__c.SObjectType.getDescribe();
String namespace =
    seasonDescribe.getName().
    removeEnd(seasonDescribe.getLocalName()).
    removeEnd('__');
```

- Apex tests that utilize `Type.forName` to create instances of Apex classes (for example, a test written for an application plugin feature) will also need to dynamically apply the namespace prefix to the class name given to the plugin configuration (such as the custom metadata type featured in *Chapter 9, Providing Integration and Extensibility*).

Later in this chapter, we will discuss Continuous Integration. This process will automatically perform a test deployment and execution of Apex tests in the packaging org and thus continue to ensure that your tests run successfully in the namespace context.

## Leveraging the Metadata API and Tooling APIs from Ant

The Migration Toolkit actually wraps the Metadata API with some handy Ant tasks that we have been using in the preceding Ant scripts. The toolkit itself is written in Java and complies with the necessary interfaces and base classes that the Ant framework requires, to allow XML elements representing the tasks to be injected into the build scripts such as the `sf:retrieve` and `sf:deploy` tasks.

While you can apply the same approach as Salesforce to develop your own Ant tasks for more custom tasks relating to your application and/or automation of common tasks during setup or deployment, you will need to be a Java programmer to do so. As an alternative and with the addition of a few supporting Ant tasks (those copied into your `/lib` folder), you can actually call these APIs directly from the Ant scripting language.

In a previous chapter, we saw how Ant macros can be written to call the Metadata API's package install and uninstall capabilities, this was achieved without Java code. This capability from Ant can be quite useful if you are developing an application that extends another package, as you can easily automate installation/upgrade of the package(s) ahead of the deployment by extending the `deploy` script we ran earlier.

The open source `exec_anon.xml` file from FinancialForce.com imported earlier into the `build.xml` file actually contains within it an Ant macro that leverages the Tooling API's ability to call the Apex code anonymously, much like the Force.com IDE and developer console tools offer.

In previous chapters, we leveraged the `SeasonService.createTestSeason` method to create test record data in the application's Custom Objects. Using the Ant `executeApex` task, this can now be called from the Ant script in order to autorecreate some useful data in a developer org. This approach will help developers, testers, or business analysts to easily try out or demonstrate the new features from the latest builds with the manual data setup as follows:

```
<target name="deploy" depends="undeploy">

    <sf:deploy
        username="${sf.username}"
        password="${sf.password}"
        serverurl="${sf.server}"
        deployRoot="${basedir}/src"/>

    <executeApex
        username="${sf.username}"
        password="${sf.password}">
        SeasonService.createTestSeason();
    </executeApex>

</target>
```

## Updating your Source Control repository

Once the application is deployed to a developer org, you have a number of options and tools to choose from as you then proceed in developing on Force.com. Your choices impact the way in which your changes find their way back into your Source Control repository. Making sure that everyone in the development team is crystal clear on this aspect of the development workflow is not only important to their efficiency, but also helps prevent work being lost or rogue files finding their way into Source Control.

Browser-based tools such as the **Setup** menu and **Schema Builder** provide an easier way of editing **Custom Objects**, **Fields**, **Layouts**, and **Permission Sets** than their XML-based formats. However, for other aspects of development the browser-based developer console is not to everyone's liking when it comes to editing Apex and Visualforce code. I personally prefer a desktop tool such as Force.com IDE to edit these types of files.

You can either the browser- or desktop-based approaches exclusively or in combination. It is important to keep in mind which approach is automatically keeping your local repository files in sync with the org and which is not.

- **Browser-based development:** Any changes that you make via the browser-based tools (including developer console) will remain in the developer org and will not automatically find their way to your local repository folder, thus, they are not visible to the Git tools for you to commit to Source Control.
- **Desktop-based development:** If you're using a desktop tool such as Force.com IDE, mapped to your repository local folder location, edits you make here will automatically sync between your local repository folder and your developer org by such tools.
- **Browser and desktop-based development:** This option allows the developer to make the best use of the tools at their disposal, albeit at the cost of some complexity and additional consideration when it comes to gathering all the changes to commit to Source Control.

## Browser-based development and Source Control

To download the changes that you have made using the browser-based development tools to your local repository folder, an Ant script and the Migration Toolkit can once again be used by applying a similar approach to that used when initially downloading the contents of the package from the packaging org using the `sf:retrieve` Ant task earlier.

The following Ant script will refresh the contents of the `/src` folder based on the component types listed in the `package.xml` file (again you might need to add new component types to this file from time to time as you make use of new platform features):

```
<target name="retrieve">
  <sf:retrieve
    username="${sf.username}"
    password="${sf.password}"
    serverurl="${sf.server}"
    retrieveTarget="${basedir}/src"
    unpackaged="${basedir}/src/package.xml"/>
</target>
```

To run the preceding target, use the following command (all on one command line):

```
ant retrieve
-Dsf.username=yourdevusername
-Dsf.password=yourdevpasswordyourdevtoken
```

Once this command completes, you can use the Git tools to review changed files, accepting, ignoring, or discarding (reverting back to the last committed version) accordingly. These are some use cases you might encounter with this approach and ways to handle them:

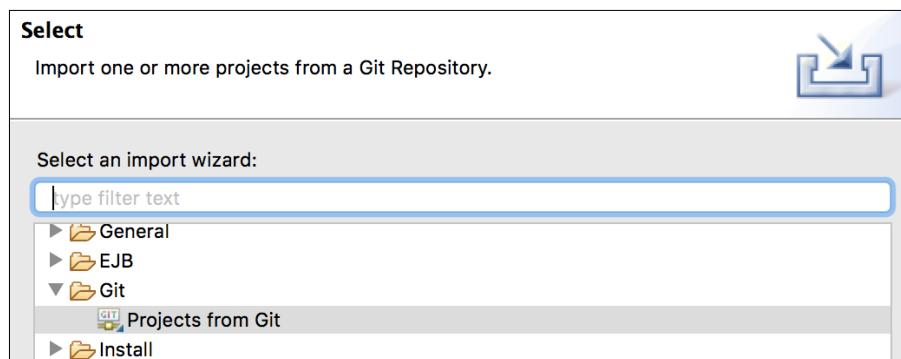
- **Additional files downloaded:** Wildcards are used in the `package.xml` file, as described earlier, to make it easier to add and remove files. The downside is that for some components such as **application** and **layout**, you might find that some of the standard files for these get created in your repository folders as well. One solution is to drop using wildcards for these metadata types and the other is to leverage the `.gitignore` file to prevent these files from being candidates for commits. With the GitHub UI tool, you can right-click on these files and select **Ignore**. This will create a `.gitignore` file if one does not already exist and add the appropriate file to it. As this file is also committed into the repository, you only have to do this once.

- **Differences in file content order or additional elements:** Sometimes file changes are flagged up by the Git tools when you have not directly made modifications to the corresponding component in the browser tools. This can be the case after a platform upgrade when new features arise or an org-wide configuration change is made (such as switching on the Multi-Currency support), or on occasions when the order of the XML elements have changed, but the overall effect on the object is the same. If you experience these changes often and they result in a change that you're happy to accept, it can be tempting to initially accept them, such that less false differences appear in the future. However, don't let such browser-based development differences go unexplained, the root cause could be quite important! Use of different org types or org templates between developers can also result in this type of issue. Ensure that all developers are sourcing their developer orgs from the same sign-up page and are of the same org type.

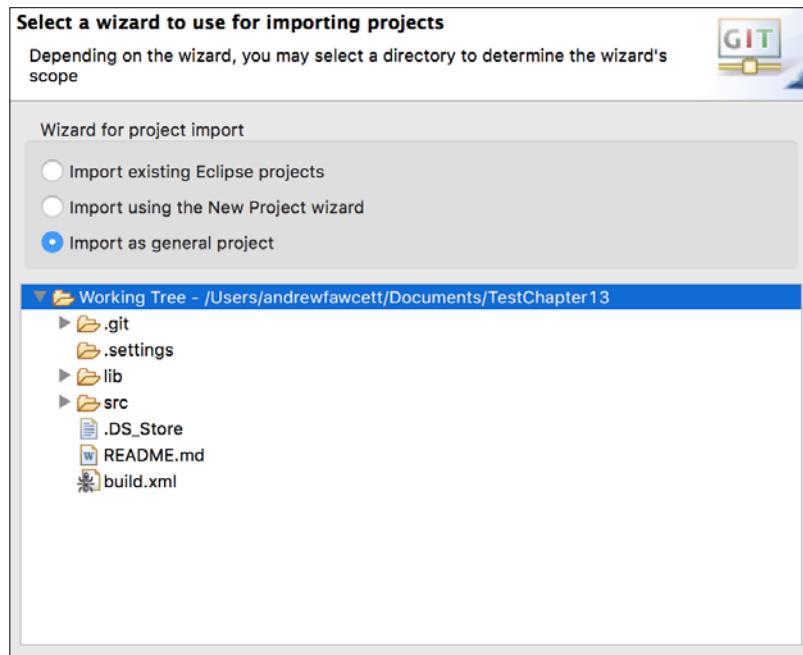
## Desktop-based development and Source Control

The key benefit with desktop-based tools and Source Control is that they allow you to edit Force.com source files while synchronizing with both Source Control and an attached Salesforce Developer Edition org. In Force.com IDE the default is to not to automatically upload to the attached developer org each time a file is saved, right click the project node in the **Package Explorer** and under the **Force.com** sub menu, select **Work Online**. So long as these tools are editing files from the local repository folder location, file edits are automatically seen by the Source Control system, which in our case is Git.

1. Force.com IDE provides a means to easily associate Git repository folders with projects. Simply open Force.com IDE and select **Import...** from the **File** menu. Select **Projects from Git** from the import wizard list presented and click **Next**.



Select **Existing local repository**, if your repository is not shown, click **Add** and navigate to the folder used previously to download the GitHub repository. Finally click **Import** using the **New project wizard** and click **Finish**:



Give your project a suitable name and click **Finish**. This project is now connected to your local Git repository. The Eclipse IDE has built-in support for Git if you have **eGIT** plugin installed, so you can choose to either use the GitHub desktop tool or continue within Eclipse.

In order to connect the project with Salesforce you need to add the **Force.com IDE** features to the project. Right-click on the project in the **Package Explorer**, then from under the **Force.com** sub-menu, select the **Add Force.com Nature** option. You will see a prompt to remind you that need to provide connection details to complete the connection:



Once again right-click on the project in the **Package Explorer**, then from under the **Force.com** sub menu, select the **Project Properties** option. Complete the login details using the developer edition org you deployed to earlier in this chapter then click **Apply**.



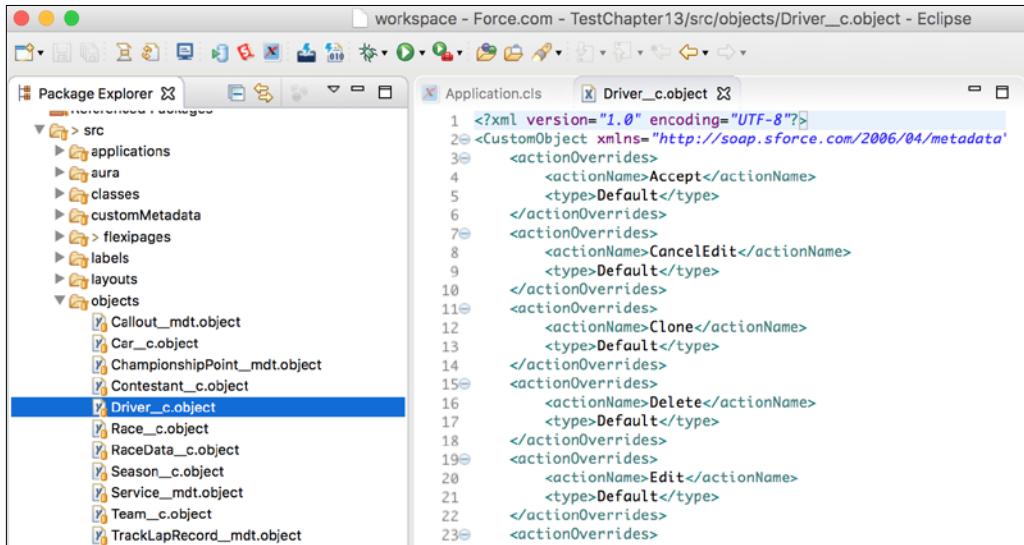
Once you click **Apply** you may be asked whether you want to re-fetch and overwrite the projects all Force.com components in the project. Select **No**. This is because the project folder already has source code contained within it and the org your using was populated from the same folder contents, there is no need for the wizard to download.

The Force.com IDE project wizard creates a `/ .settings` folder, `/Referenced Packages` and `.project` and `salesforce.schema` files in the repository's root folder. You can use the `.gitignore` facility to omit these from Source Control visibility unless everyone in your team is using Force.com IDE. This screenshot shows how the project looks after creation, allowing you to begin editing your Apex code immediately:

The screenshot shows the Eclipse IDE interface with the following details:

- Package Explorer:** Shows the project structure under `TestChapter13`:
  - `lib` (Referenced Packages)
  - `src` (contains `applications`, `aura`, and `classes`):
    - `Application.cls` (selected)
    - `Application.cls-meta.xml`
    - `ApplicationDomain.cls`
    - `ApplicationDomain.cls-meta.xml`
    - `ApplicationSelector.cls`
    - `ApplicationSelector.cls-meta.xml`
    - `CalloutsSelector.cls`
    - `CalloutsSelector.cls-meta.xml`
    - `Cars.cls`
    - `Cars.cls-meta.xml`
    - `CarsSelector.cls`
    - `CarsSelector.cls-meta.xml`
    - `ChampionshipPointsSelector.cls`
    - `ChampionshipPointsSelector.cls-meta.xml`
    - `ComplianceCheckerComponent.cls`
    - `ComplianceCheckerComponent.cls-meta.xml`
    - `ComplianceController.cls`
    - `ComplianceController.cls-meta.xml`
    - `ComplianceResource_v1_0.cls`
    - `ComplianceResource_v1_0.cls-meta.xml`
    - `ComplianceResource.cls`
    - `ComplianceResource.cls-meta.xml`
    - `ComplianceService.cls`
    - `ComplianceService.cls-meta.xml`
    - `ComplianceServiceTest.cls`
    - `ComplianceServiceTest.cls-meta.xml`
- Application.cls Editor:** Displays the Apex code for `Application.cls`. The code defines a global class `Application` with static final configurations for `UnitOfWorkFactory`, `ServiceFactory`, `SelectorFactory`, `DomainFactory`, and `CalloutFactory`, and a static final `SelectorFactory` for `TeamsSelector`.
- Outline View:** Shows the class structure with nodes for `UnitOfWork`, `Service`, `Selector`, `Domain`, `Callouts`, `ServiceFactory`, `CalloutFactory`, `ExceptionCode`, and `ApplicationException`.
- Bottom Bar:** Includes tabs for `Problems`, `Apex Test`, `Execute An`, `Synchronize`, `Search`, `Progress`, `Terminal`, and `Error Log`.

You are also able to edit files that represent Custom Objects and fields:



The screenshot shows the Eclipse IDE interface. The left side is the 'Package Explorer' view, which displays a project structure under 'src'. The 'objects' folder contains several custom objects: Callout\_mdt.object, Car\_c.object, ChampionshipPoint\_mdt.object, Contestant\_c.object, Driver\_c.object (which is selected and highlighted in blue), Race\_c.object, RaceData\_c.object, Season\_c.object, Service\_mdt.object, Team\_c.object, and TrackLapRecord\_mdt.object. The right side is a code editor window titled 'Driver\_c.object' showing the XML metadata for the custom object. The XML code includes definitions for action overrides like 'Accept', 'Delete', 'Edit', and 'Clone'.

```
1 <?xml version="1.0" encoding="UTF-8"?>
2 <CustomObject xmlns="http://soap.sforce.com/2006/04/metadata">
3     <actionOverrides>
4         <actionName>Accept</actionName>
5         <type>Default</type>
6     </actionOverrides>
7     <actionOverrides>
8         <actionName>CancelEdit</actionName>
9         <type>Default</type>
10    </actionOverrides>
11    <actionOverrides>
12        <actionName>Clone</actionName>
13        <type>Default</type>
14    </actionOverrides>
15    <actionOverrides>
16        <actionName>Delete</actionName>
17        <type>Default</type>
18    </actionOverrides>
19    <actionOverrides>
20        <actionName>Edit</actionName>
21        <type>Default</type>
22    </actionOverrides>
23    <actionOverrides>
```

If you choose to combine this development approach with the browser-based approach, the Force.com IDE offers a way to refresh the files from within the desktop tool. Simply right-click on the folder and select the appropriate option. This facility effectively performs a retrieve operation similar to that described in the earlier section via the `Ant build.xml` script. As such, watch out for similar side-effects in terms of additional files or file changes.

## Hooking up Continuous Integration

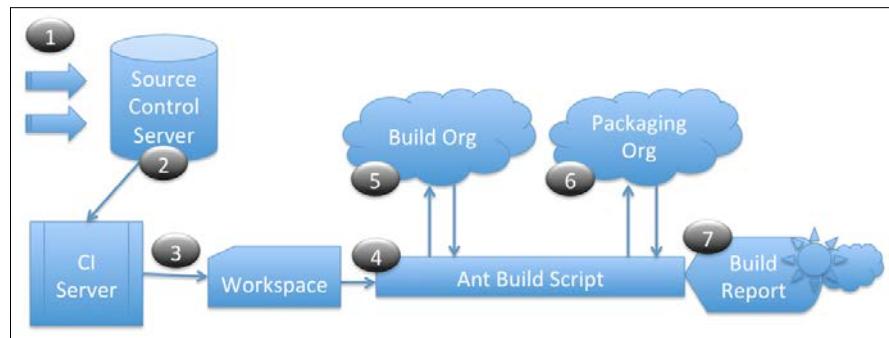
So far we have been depending on the developer to ensure that the changes they push up to the GitHub remote repository do not cause regressions elsewhere in the application, by running Apex tests before making their commits. This is always a good practice!

However, this is not always a fully reliable means of determining the quality of the code, as the main code base will likely have moved on due to other developers also pushing their changes. When integrated together, they might cause tests or even code to fail to compile. Continuous Integration monitors changes to the Source Control repository and automatically starts its own build over the fully integrated source code base. Failures are reported back to the developers who last pushed code to the repository.

In this part of the chapter, we are going to explore this process using the popular Jenkins Continuous Integration server that uses the Ant script to perform the build step. Before we get into setting this up, let's take a moment to review the CI process that we are going to use.

## The Continuous Integration process

The following diagram shows the CI process that we will be setting up over the course of the next few sections. Once you have a basic CI setup like this, you can start to add other features such as code documentation generation, static code analysis, security code scanner, and automated regression testing (something we will discuss briefly later on).



The following is the CI process:

1. Developers make multiple contributions to Source Control, just as we did earlier in this chapter via the GitHub UI desktop client.
2. The CI server is able to poll (configurable) the Source Control server (in our case, the GitHub remote repository) for changes.
3. Once changes are detected, it downloads the latest source code into a local workspace folder.
4. A part of the configuration of the CI server is to inform it of the location of the Ant build.xml script to execute after the workspace is set up.
5. A build org is simply a designated developer org set aside solely for the use of the CI process. We will create one of these shortly for this purpose, though, with Salesforce DX a scratch org can be created and deleted dynamically. As with the deploy process, the same Ant script is used to deploy the code to the build org (thus confirming code compilation) and run Apex tests.

6. As described earlier, developer orgs are used to develop the changes that are unmanaged environments as opposed to managed. Some of the constraints, such as the ability to change a previously released global Apex class, that would normally apply are not enforced. In this step, a verification check-only deployment is performed against the packaging org to confirm that the code would, when needed, still deploy to the packaging org for release. This step can also help validate that code and tests continue to execute in a managed namespace context. This deployment is only a check, no changes are made to the packaging org regardless of the outcome.
7. Finally, the CI server will record the log and results of the build for analysis and the number of success versus failed builds and provide reports and notifications on the overall health of the source code in Source Control. If there are failures, there are options to e-mail certain team members as well as specific targets (those who made the most recent changes). Making sure a team stops what they are doing and attends to a broken build is very important. The longer the broken builds exist, the harder they are to solve, especially when further changes occur.

## Updating the Ant build script for CI

Before we can set up our CI server, we need to ensure that our Ant script has an appropriate entry point for it. This is similar to that used by the developer in the steps described earlier. The following is a new target designed as an entry point for a CI server. More complex scripts might involve some reuse between developer usage and CI usage.

The following target will clean the build org (by virtue of the dependency on the `undeploy` target) and then deploy to it. It will then perform a second deploy to perform a check-only deployment to the packaging org. If you are following along, commit the changes to the `build.xml` file so that the Jenkins server can see the new target when it downloads the latest source code from GitHub.

```
<target name="deploy.jenkins" depends="undeploy">
  <sf:deploy
    username="${sf.username}"
    password="${sf.password}"
    serverurl="${sf.server}"
    runAllTests="true"
    deployRoot="${basedir}/src"/>
  <sf:deploy
    username="${sf.package.username}"
    password="${sf.package.password}"
    serverurl="${sf.server}"
```

```

checkOnly="true"
runAllTests="true"
deployRoot="${basedir}/src"/>
</target>

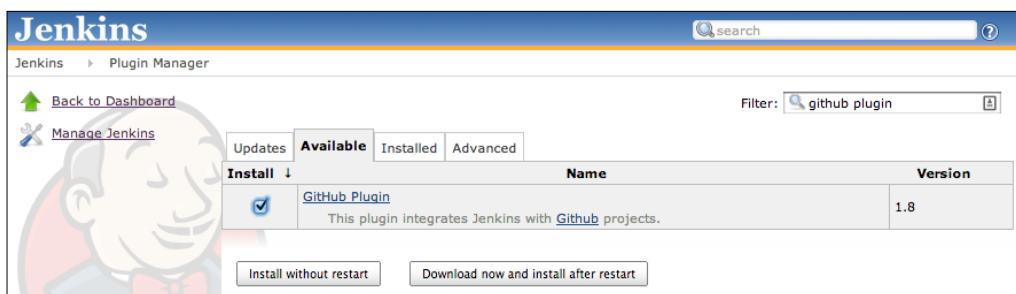
```

## Installing, configuring, and testing the Jenkins CI server

Setting up a Jenkins server is a broad topic beyond the scope of this chapter. A good way, however, to get started is to go to <http://jenkins-ci.org/> and download one of the prebuilt installations for your operating system. In this case I used the Mac pkg file download. After installation, I was able to navigate to <http://localhost:8080> to find Jenkins waiting for me!



Jenkins has a plugin system that permits many custom extensions to its base functionality, by clicking on **Manage Jenkins** and then **Manage Plugins** to locate a **GitHub Plugin**:

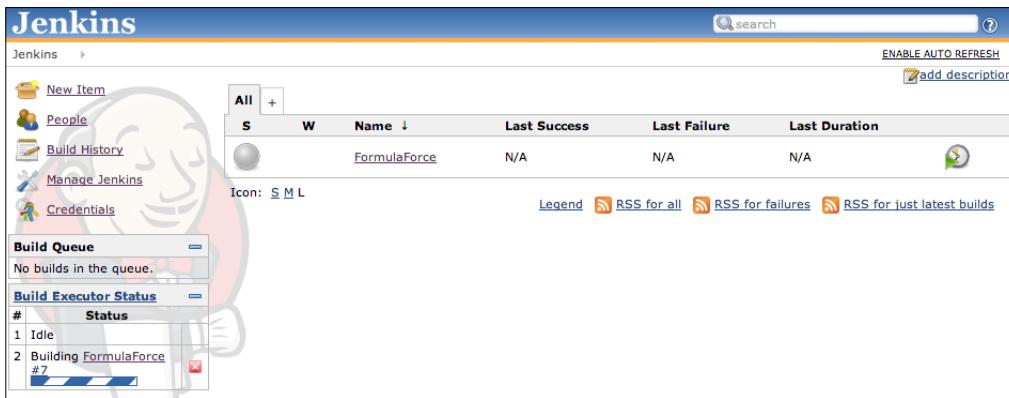


Once this plugin is installed, you can create a Jenkins job that points to your GitHub repository and Ant script to execute the `deploy.jenkins` target defined earlier. On the Jenkins main page, click on **New Item** and select the **Build a free-style software project** option. Complete the following steps to create a build project:

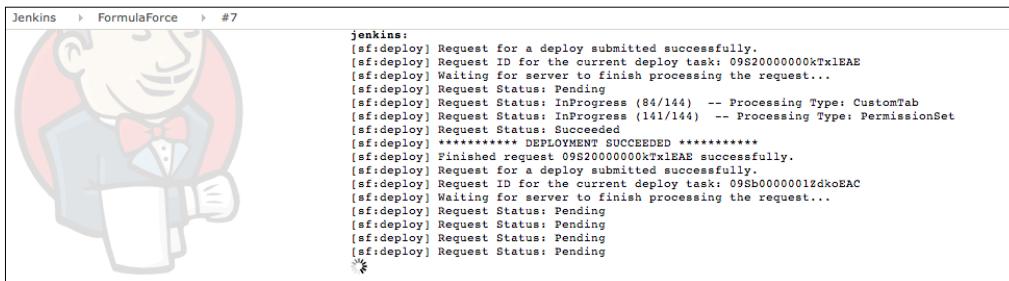
1. Complete the **Project Name** field with an appropriate name, such as `FormulaForce Build`.
2. In the **GitHub project** field, enter the full URL to your GitHub repository, for example `https://github.com/afawcett/formulaforce-chapter13`.
3. Under the **Source Control Management** section, select **Git**.
4. In the **Repository URL** field, enter your GitHub repository URL, which is different from the preceding URL and takes the format of `https://github.com:githubuser/repositoryname.git`, for example, `https://github.com:afawcett/formulaforce-chapter13.git`.
5. If your repository is private and not public, you will need to ensure that you have exchanged deployment keys between Jenkins and your GitHub account. This involves generating a key and copying and pasting it to the **Deploy keys** section in your GitHub repository settings. For the purposes of this book, it is recommended that you use a public GitHub repository.
6. Although not recommended for a production Jenkins server, let's set it to poll every minute for changes to the repository. In the **Build Triggers** section, select **Poll SCM** and enter `*/1 * * * *` in the **Schedule** field.
7. Scroll further down the project setup page to the **Build** section, and from the **Add build** step drop-down select **Invoke Ant**.
8. In the **Targets** field, enter `deploy.jenkins` (as per the name of the Ant target created in the `build.xml` file).
9. Click on the **Advanced** button, then click on the black down arrow icon to the right of the **Properties** field to expand it so that you are able to enter multiple properties. The `deploy.jenkins` Ant target that we created earlier requires the `username` and `password` parameters to deploy to the build org and perform the check deploy to the packaging org. Enter the property name-value pairs on separate lines as follows:

```
sf.username=buildorgusername
sf.password=buildorgpasswordbuildorgtoken
sf.package.username=packagingorgusername
sf.package.password=packagingorgpasswordpackagingorgtoken
```
10. Click on the **Save** button at the bottom of the page.

After a minute, Jenkins realizes that there has not been a build yet and starts one. However, you can also click on the project and click on the **Build Now** button if you cannot wait!



If you click on the hyperlink to the build itself (shown in the sidebar), you can monitor in real time the Ant script log just as if you had run it manually:



After this build completes, Jenkins will resume monitoring the GitHub repository for changes and automatically start a new build when it detects one.

## Exploring Jenkins and CI further

This section has barely scratched the surface of what is possible with Jenkins and Ant scripts. You can either extend your Ant scripts to perform additional checks as described earlier and/or even custom logic to write back statistics to your own Salesforce production environment. Continue to explore this process a bit further by making some minor and some major changes to the repository to see the effects.

For example, try changing the method name of one of the global Apex methods (for example, `ComplianceService.report` to `ComplianceService.reportX`) as well as the methods in `ComplianceResource` and `ComplianceResource_1_0` calling it. While this compiles in the developer and build orgs, it eventually results in the following error from the Jenkins build, as the check deployment to the packaging org failed because published global methods cannot be removed or renamed. In this case, the following build failure will be reported by Jenkins:

```
classes/ComplianceService.cls -- Error: Global/WebService identifiers  
cannot be removed from managed application: Method: LIST<fforce.  
ComplianceService.VerifyResult> report(SET<Id>) (line 1, column 8)
```

The dashboard on Jenkins shows the project with a dark cloud as one out of the last two builds have now failed. It is time to fix the build:

All	+	S	W	Name ↓	Last Success	Last Failure
Icon: <a href="#">S</a> <a href="#">M</a> <a href="#">L</a>		W	Description	% Build stability: 1 out of the last 2 builds failed. 50		

Once a new build completes successfully, Jenkins rewards you with some sunshine:

All	+	S	W	Name ↓	Last Success	Last Failure
Icon: <a href="#">S</a> <a href="#">M</a> <a href="#">L</a>		W	Description	% Build stability: 1 out of the last 3 builds failed. 66		

## Releasing from Source Control

When you're ready to release a beta or release version of the package for your application, you will transfer the source code from Source Control into your packaging org. Thankfully, this can also be achieved with the help of the following Ant script target. Note that unlike the `deploy` Ant target, this does not attempt to clean the target org!

```
<target name="deploy.package">
  <sf:deploy
    username="${sf.username}"
    password="${sf.password}"
    serverurl="${sf.server}"
    runAllTests="true"
    deployRoot="${basedir}/src"/>
</target>
```

The process of updating the packaging org can only be partially automated by running the preceding Ant target, as you still need to log in to the packaging org to add brand new components that are not automatically added through a relationship with components already in the package.

The following is a list of recommended steps to update and confirm that the content of your packaging org matches the content of Source Control:

1. Run the following command (all on one command line):

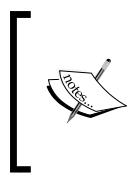
```
ant deploy.package
-Dsf.username=packagingusername
-Dsf.password=packagingpasswordpackagingtken
```

2. Log in to the packaging org and review the contents of the package. You can utilize the **Add Component** page to determine whether components now reside in the packaging org that are not presently included in the package.
3. Rename the `/src` folder to `/src.fromsc` and create a new `/src` folder. Then, run the `retrieve.package` Ant target as per the command line you used to download files from the packaging org at the beginning of this chapter.
4. Compare the `/src` and `/src.fromsc` folders using your favorite file comparison tool. Review differences to determine whether changes exist either in the packaging org or in the Source Control system that do not belong to the application being packaged!

5. As per best practice, confirm that your package dependencies are still as expected. Then, perform an upload in the usual way as discussed in the previous chapters.

## Automated regression testing

While Apex tests are very much a key tool in monitoring regressions in your application, the limitations and scope of functionality they can test is small, particularly to perform volume or user interface testing (clients using JavaScript for example).



You might wonder why the Ant script used by Jenkins deploys twice, as the check deploy to the packaging org will confirm whether the Apex code compiles and that all Apex tests complete successfully. The reason is that having the build org deployed with the latest build allows for it to go on to be used for other purposes, such as executing further regression testing steps.



Here are some considerations to implement further testing approaches:

- It is possible to execute the Apex code from the Ant scripts using the approach described earlier in this chapter, when we populated the developer org with sample data by calling the `SeasonService.createTestSeason` method. You can extend this approach by using loop constructs within Ant to create volume data or start more Batch Apex jobs (Apex tests only permit a single chunk of 200 records to be processed), pause for completion, and assert the results.
- The Salesforce data loader tool is actually a Java program with a command-line interface. Thus, you could consider using it to load data into a build org to test against different datasets, used in combination with the preceding Apex code executed to clean records between tests.
- Once you have the data loaded into the build org, you can execute tests using a number of Salesforce testing tools. For example, the **Selenium WebDriver** tool is an excellent choice, as it provides a headless mode (no need for a physical screen) and can be run on multiple operating systems. This tool allows you to test Visualforce pages with large amounts of JavaScript (<http://docs.seleniumhq.org/projects/webdriver/>).

## Summary

In this final chapter of the book, we have seen how to scale developer resources to the development of your enterprise application using industry strength Source Control tools, development processes, and servers such as Jenkins.

Some of the steps described in this chapter might initially seem excessive and overly complex compared to developing within a single packaging org or using other manual approaches to export and merge changes between developer orgs. Ultimately, more time is lost in resolving conflicts manually and not to mention the increased risk of losing changes.

Certainly, if your business is aiming to be audited for its development processes, adopting a more controlled approach with tighter controls over who has access to not only the source code but also your mechanism to release it (your packaging org) is a must.

Opening up your Force.com development process to tools such as Git for example allows for a much better developer interaction for aspects such as code reviews and carefully staging features in development to release. Such tools also give a greater insight into statistics around your development process that allow you optimize your development standards and productivity further over time.



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