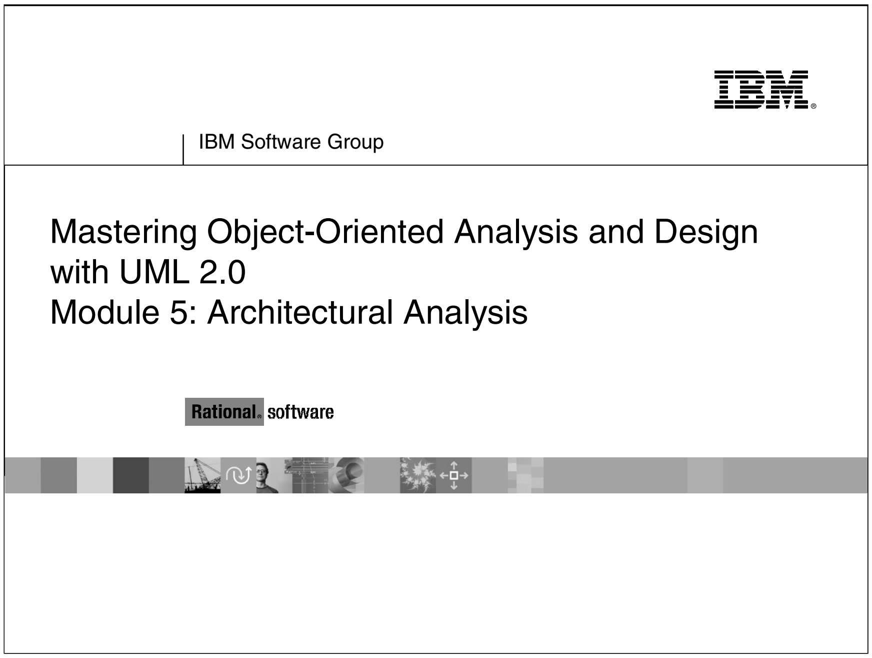
Instructor Notes:



IBM Software Group

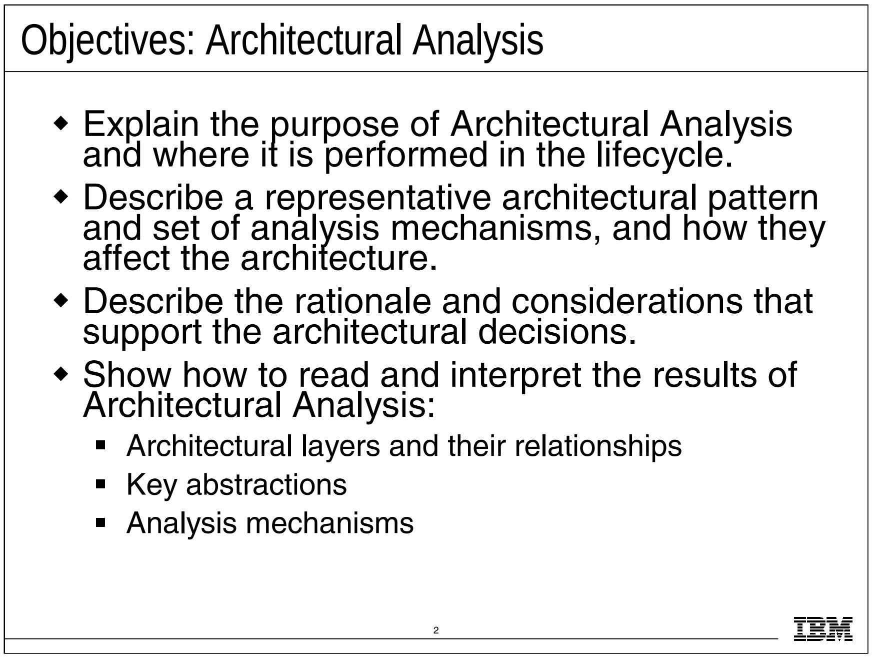
Mastering Object-Oriented Analysis and Design with UML 2.0
Module 5: Architectural Analysis

Rational. software

Instructor Notes:

Component-Based Development (CBD) seems to be the latest buzzword. If your students are interested in this topic, you can get their attention by stressing the following:

Component-Based Development is a best practice, and developing a component-based architecture is critical to successful CBD, as components are not divorced from architecture. Components require an architecture in which to run.



Objectives: Architectural Analysis

- Explain the purpose of Architectural Analysis and where it is performed in the lifecycle.
- Describe a representative architectural pattern and set of analysis mechanisms, and how they affect the architecture.
- Describe the rationale and considerations that support the architectural decisions.
- Show how to read and interpret the results of Architectural Analysis:
  - Architectural layers and their relationships
  - Key abstractions
  - Analysis mechanisms

2

A focus on software architecture allows you to articulate the structure of the software system (the packages/components), and the ways in which they integrate (the fundamental mechanisms and patterns by which they interact).

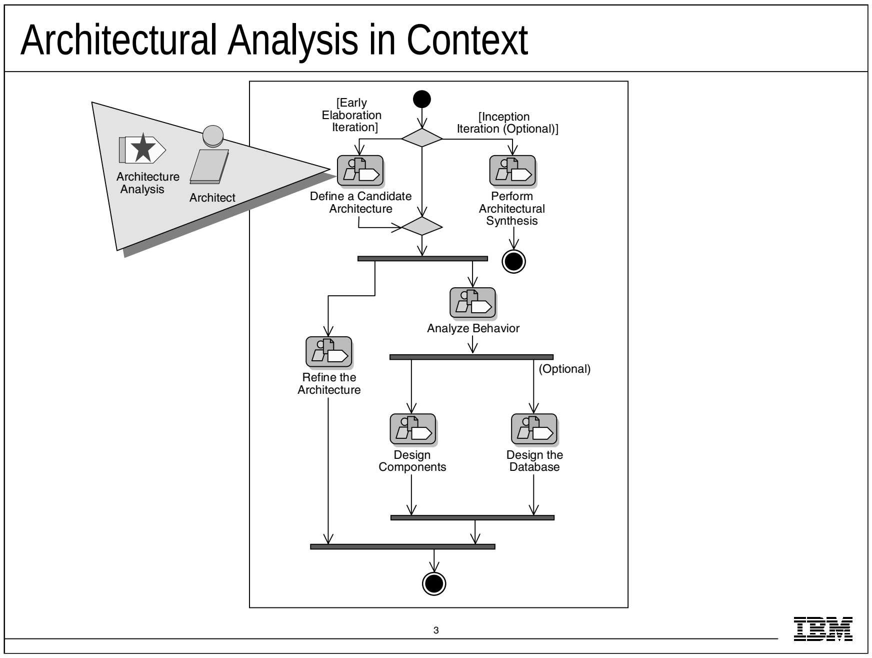
Architectural Analysis is where we make an initial attempt at defining the pieces/parts of the system and their relationships, organizing these pieces/parts into well-defined layers with explicit dependencies, concentrating on the upper layers of the system. This will be refined, and the lower layers will be defined during Incorporate Existing Design Elements.

Instructor Notes:

The architecture produced during Architectural Analysis is the “on the back of a paper napkin” architecture. It is the definition of the conceptual architecture.

Architectural Analysis can be performed during Inception, but it is definitely done in early Elaboration.

Starting with Architectural Analysis may make the course look like it is using a top-down approach. Explain to the students that this is not the case, but that a good architecture supporting all requirements is key for good software development.



Architectural Analysis in Context

Architecture Analysis
Architect
[Early Elaboration Iteration]
[Inception Iteration (Optional)]
Define a Candidate Architecture
Perform Architectural Synthesis
Analyze Behavior
Refine the Architecture
(Optional)
Design Components
Design the Database
3

As you may recall, the above diagram illustrates the workflow that we are using in this course. It is a tailored version of the Analysis and Design core workflow of the Rational Unified Process. **Architectural Analysis** is an activity in the Define a Candidate Architecture workflow detail.

Architectural Analysis is how the project team (or the architect) decides to define the project’s high-level architecture. It is focused mostly on bounding the analysis effort in terms of agreed-upon architectural patterns and idioms, so that the “analysis” work is not working so much from “first principles.” **Architectural Analysis** is very much a configuring of Use-Case Analysis.

During **Architectural Analysis,** we concentrate on the upper layers of the system, making an initial attempt at defining the pieces/parts of the system and their relationships and organizing these pieces/parts into well-defined layers with explicit dependencies.

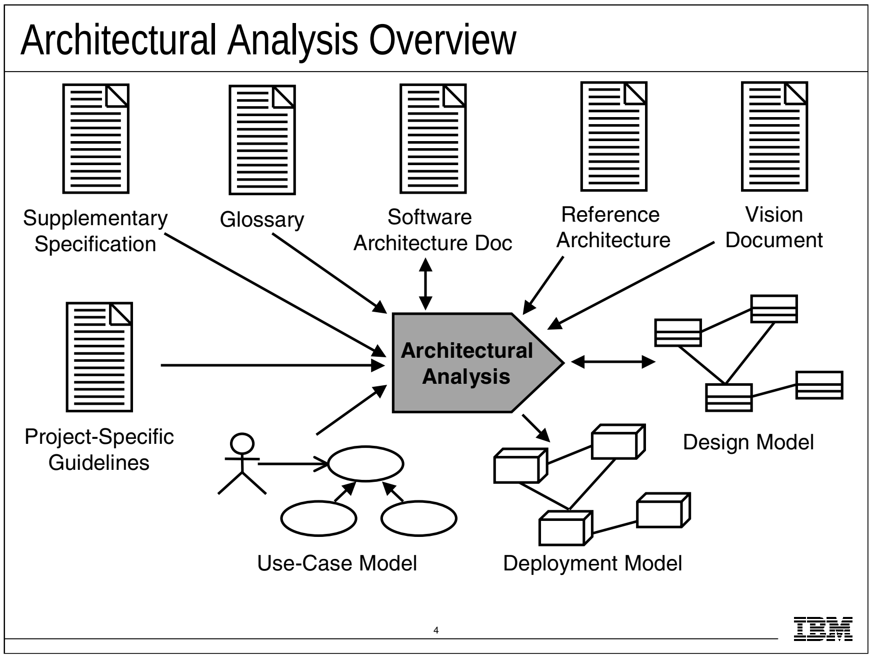
In Use-Case Analysis, we will expand on this architecture by identifying analysis classes from the requirements. Then, in Incorporate Existing Design Elements, the initial architecture is refined, and the lower architecture layers are defined, taking into account the implementation environment and any other implementation constraints.

Architectural Analysis is usually done once per project, early in the Elaboration phase. The activity is performed by the software architect or architecture team.

This activity can be skipped if the architectural risk is low.

Instructor Notes:

In Architectural Analysis — prior to the use-case realizations, you define what flow of events (and therefore what use-case realizations), you are going to work on during the current iteration. The iteration planning is part of the Project Management discipline, performed by the project manager, but Architectural Analysis is where the actual use-case realization gets created.



Architectural Analysis Overview

Supplementary Specification

Glossary

Software Architecture Doc

Reference Architecture

Vision Document

Project-Specific Guidelines

Architectural Analysis

Design Model

Use-Case Model

Deployment Model

4

Purpose:

- To define a candidate architecture for the system based on experience gained from similar systems or in similar problem domains.
- To define the architectural patterns, key mechanisms, and modeling conventions for the system.
- To define the reuse strategy.
- To provide input to the planning process.

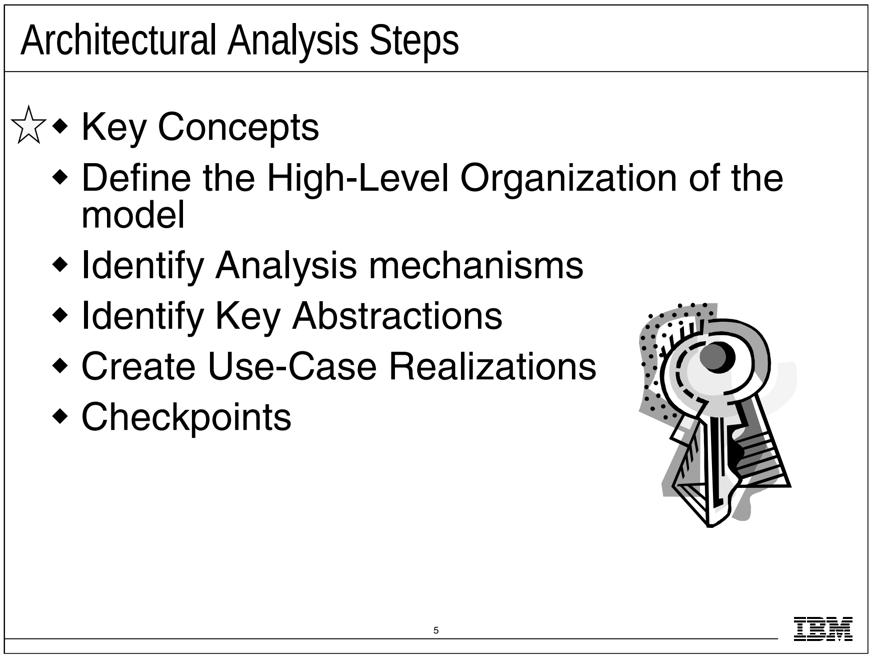
Input Artifacts:

- Use-Case Model
- Supplementary Specifications
- Glossary
- Design Model
- Reference Architecture
- Vision Document
- Project Specific Guidelines
- Software Architecture Document

Resulting Artifacts:

- Software Architecture Document
- Design Model
- Deployment Model

Instructor Notes:



Architectural Analysis Steps

- ☆ Key Concepts
- Define the High-Level Organization of the model
- Identify Analysis mechanisms
- Identify Key Abstractions
- Create Use-Case Realizations
- Checkpoints

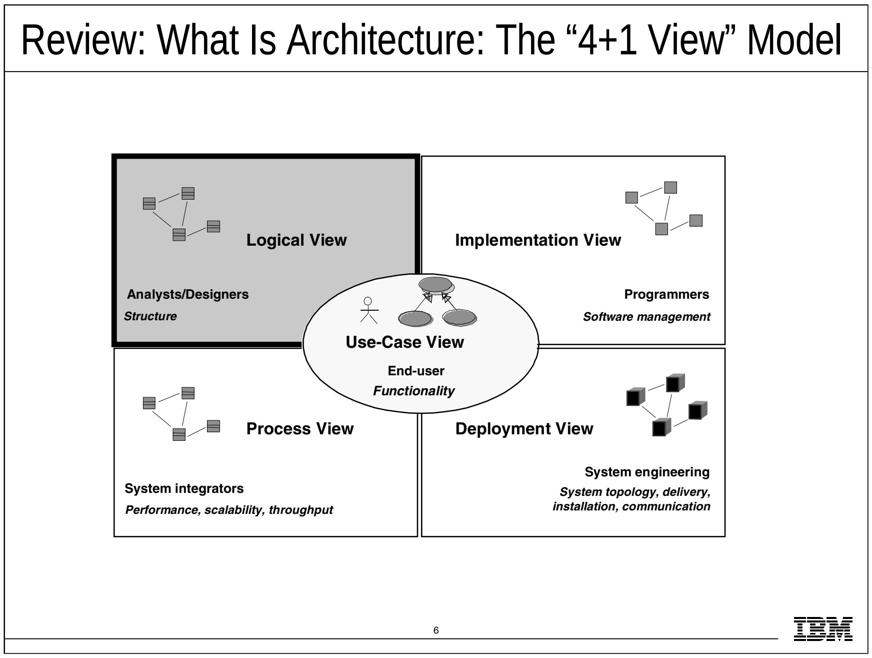
5 IBM

The above are the topics we will be discussing within the **Architectural Analysis** module. Unlike the designer activity modules, you will not be discussing each step of the activity, as the objective of this module is to understand the important **Architectural Analysis** concepts, not to learn HOW to create an architecture.

Before you discuss **Architectural Analysis** in any detail, it is important to review/define some key concepts.

Instructor Notes:

This should be a review of the 4+1 views. They were initially described in the Analysis and Design Overview module.



Review: What Is Architecture: The “4+1 View” Model

Logical View

Analysts/Designers

Structure

Implementation View

Programmers

Software management

Use-Case View

End-user

Functionality

Process View

System integrators

Performance, scalability, throughput

Deployment View

System engineering

System topology, delivery, installation, communication

6

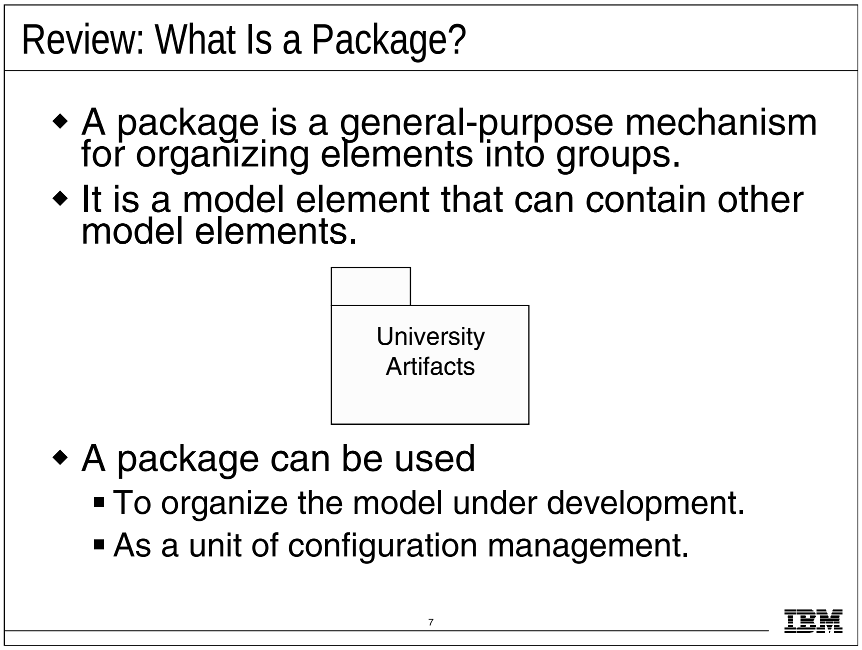
The above diagram describes the model Rational uses to describe the software architecture. This is the recommended way to represent a software architecture. There may be other “precursor” architectures that are not in this format. The goal is to mature those architectural representations into the 4+1 view representation.

In **Architectural Analysis,** you will concentrate on the Logical View. The other views will be addressed in later architecture modules:

- The Logical View will be refined in the Identify Design Mechanisms, Identify Design modules.
- The Process View will be discussed in the Describe Run-time Architecture module.
- The Deployment View will be discussed in the Describe Distribution module.
- The Implementation View is developed during Implementation and is thus considered out of scope for this Analysis and Design course.

Instructor Notes:

Before discussing how to define the upper-level layers, let's review some key concepts that we depend on in this step.



Review: What Is a Package?

- A package is a general-purpose mechanism for organizing elements into groups.
- It is a model element that can contain other model elements.

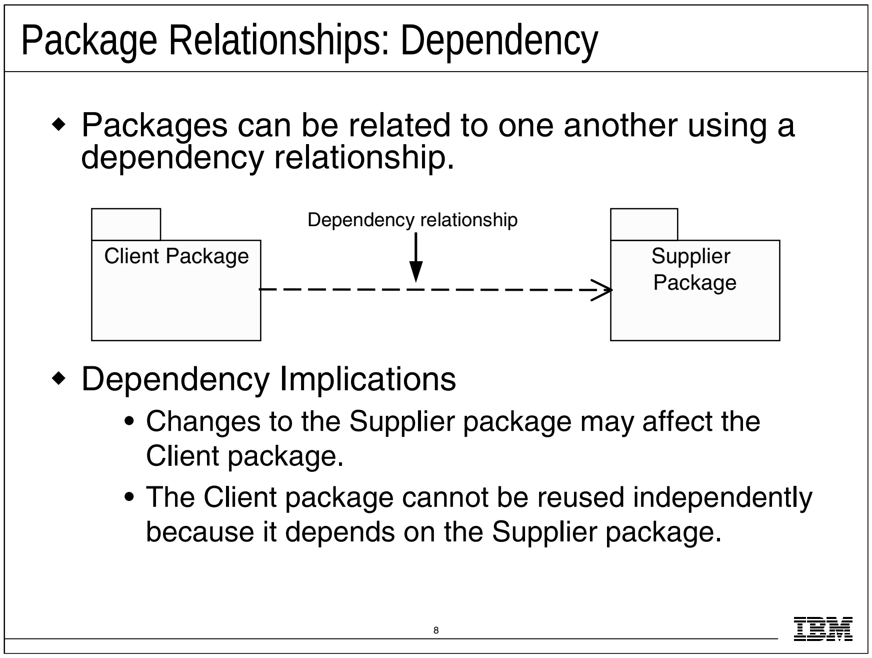
- A package can be used
  - To organize the model under development.
  - As a unit of configuration management.

Packages were first introduced in the *Essentials of Visual Modeling* course: Concepts of Object Orientation.The slide is repeated here for review purposes.

Packages can be used to group any model elements. However, in this module, we will be concentrating on how they are used within the Design Model.

Instructor Notes:

Generalization relationships are permitted between packages. Refinement relationships are also permitted for packages.



Package Relationships: Dependency

- Packages can be related to one another using a dependency relationship.

Dependency relationship
Client Package
Supplier Package

- Dependency Implications
  - Changes to the Supplier package may affect the Client package.
  - The Client package cannot be reused independently because it depends on the Supplier package.

8
IBM

Elements in one package can import elements from another package. In the UML, this is represented as a dependency relationship.

The relationships of the packages reflect the allowable relationships between the contained classes. A dependency relationship between packages indicates that the contents of the supplier packages may be referenced by the client. In the above example, if a dependency relationship exists between the Client package and the Supplier package, then classes in the Client package may access classes in the Supplier package.

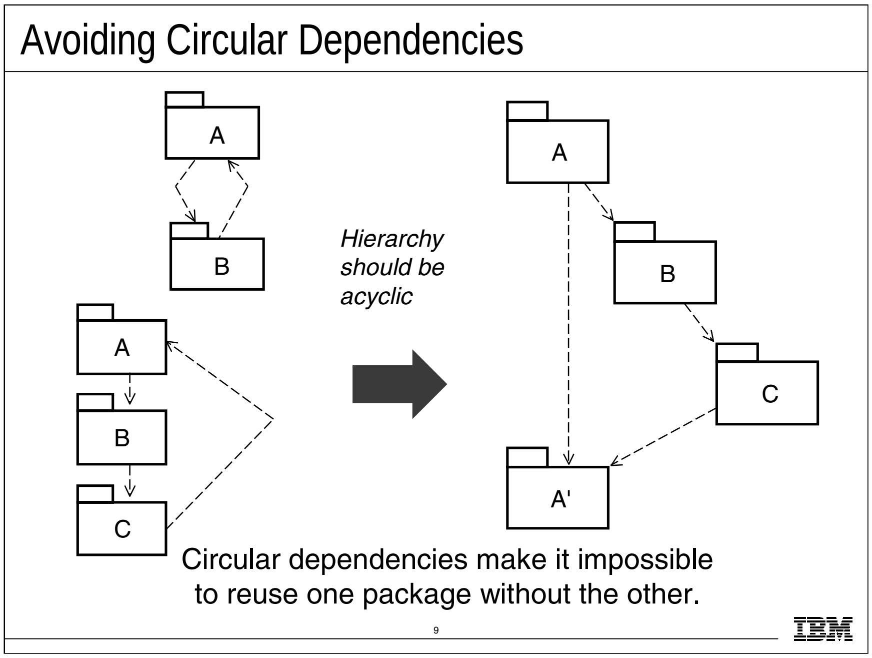
Some of the implications of package dependency are:

- Whenever a change is made to the Supplier package, the Client package potentially needs to be recompiled and re-tested.
- The Client package cannot be reused independently because it depends on the Supplier package.

The grouping of classes into logical sets and the modeling of their relationships can occur anywhere in the process when a set of cohesive classes is identified.

Instructor Notes:

In Architectural Analysis, it is important to recognize that cycles are bad and should be avoided when possible. However, resolving circular dependencies should really be focussed on in Incorporate Existing Design Elements.



Avoiding Circular Dependencies

Hierarchy should be acyclic

Circular dependencies make it impossible to reuse one package without the other.

9

It is desirable that the package hierarchy be acyclic. This means that the following situation should be avoided (if possible):

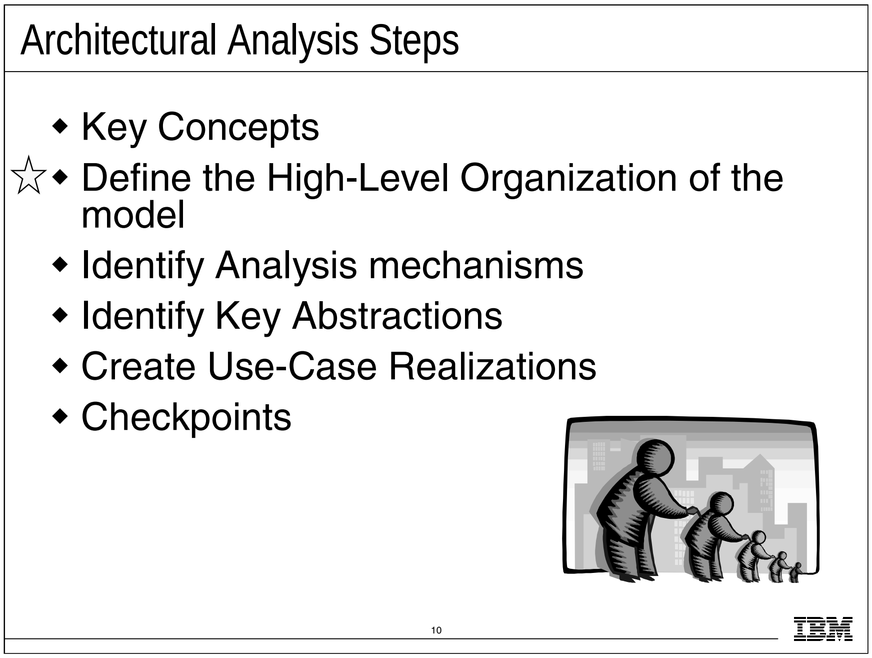
- Package A uses package B, which uses package A.

If a circular dependency exists between Package A and Package B, if you change Package A it might cause a change in Package B, which might cause a change in Package A, etc. A circular dependency between packages A and B means that they will effectively have to be treated as a single package.

Circles wider than two packages must also be avoided. For example, package A uses package B, which uses package C, which uses package A.

Circular dependencies may be able to be broken by splitting one of the packages into two smaller ones. In the above example, the elements in package A that were needed by the other packages were factored out into their own package, A’, and the appropriate dependencies were added.

Instructor Notes:



Architectural Analysis Steps

- Key Concepts
- ☆ Define the High-Level Organization of the model
- Identify Analysis mechanisms
- Identify Key Abstractions
- Create Use-Case Realizations
- Checkpoints

10

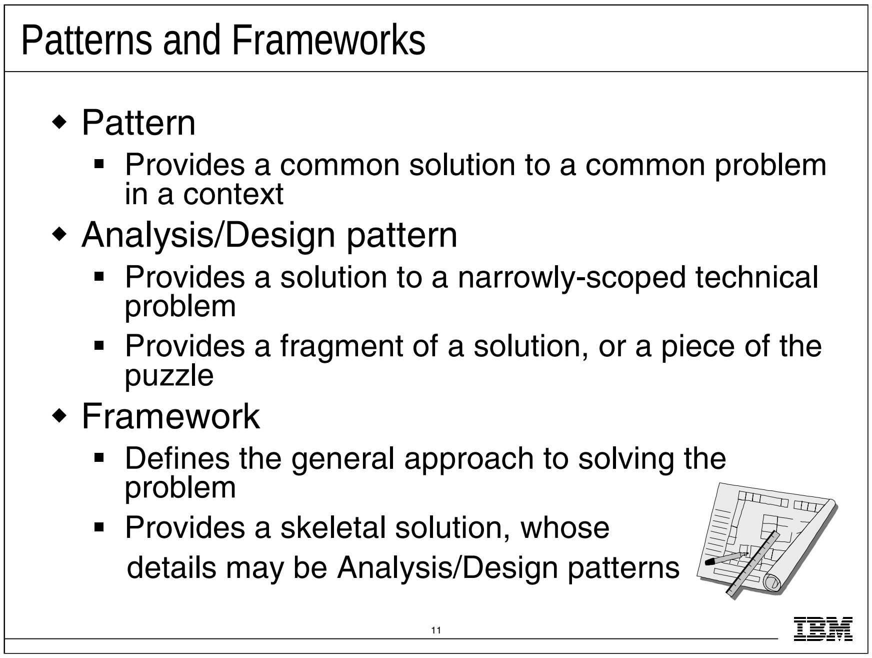
Early in the software development lifecycle, it is important to define the modeling conventions that everyone on the project should use. The modeling conventions ensure that the representation of the architecture and design are consistent across teams and iterations.

Instructor Notes:

Frameworks enable scalability of development: the ability to develop and deliver systems as quickly as the market requires by using a leveraged solution.

An analogy in bridge building may help clarify this. Examples of frameworks are suspension bridge, piling-and-trestle bridge, and cantilever bridge. Examples of design patterns are rivet fastener, bolt, and weld. In building a bridge, each is substitutable in some cases, and each is uniquely superior in other cases. (Both a weld and a bolt can be used to join two materials; the weld can be stronger if done correctly, but cannot be undone, or repaired, or replaced as the bolt can.)

Taking the analogy a bit further, a suspension bridge can be a footbridge or the Golden Gate bridge. Both represent the same basic design approach and principles, so that one could readily say "that is a suspension bridge," but the extensions and localizations cause the end result to be quite different.



Patterns and Frameworks

- Pattern
  - Provides a common solution to a common problem in a context
- Analysis/Design pattern
  - Provides a solution to a narrowly-scoped technical problem
  - Provides a fragment of a solution, or a piece of the puzzle
- Framework
  - Defines the general approach to solving the problem
  - Provides a skeletal solution, whose details may be Analysis/Design patterns

11

IBM

The selection of the upper-level layers may be affected by the choice of an architectural pattern or framework. Thus, it is important to define what these terms mean.

A **pattern** codifies specific knowledge collected from experience. Patterns provide examples of how good modeling solves real problems, whether you come up with the pattern yourself or you reuse someone else's. Design patterns are discussed in more detail on the next slide.

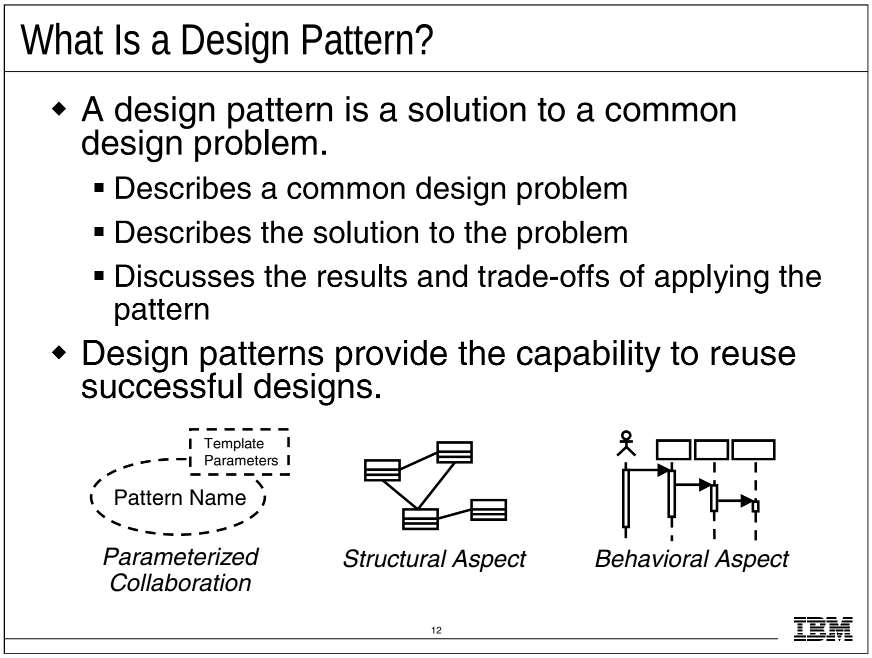
Frameworks differ from Analysis and Design patterns in their scale and scope. Frameworks describe a skeletal solution to a particular problem that may lack many of the details, and that may be filled in by applying various Analysis and Design patterns.

A framework is a micro-architecture that provides an incomplete template for applications within a specific domain. Architectural frameworks provide the context in which the components run. They provide the infrastructure (plumbing, if you will) that allows the components to co-exist and perform in predictable ways. These frameworks may provide communication mechanisms, distribution mechanisms, error processing capabilities, transaction support, and so forth.

Frameworks may range in scope from persistence frameworks that describe the workings of a fairly complex but fragmentary part of an application to domain-specific frameworks that are intended to be customized (such as Peoplesoft, SanFransisco, Infinity, and SAP). For example, SAP is a framework for manufacturing and finance.

Instructor Notes:

OOAD is not intended to be a patterns course, but will use/introduce patterns to solve particular problems.



What Is a Design Pattern?

- A design pattern is a solution to a common design problem.
  - Describes a common design problem
  - Describes the solution to the problem
  - Discusses the results and trade-offs of applying the pattern
- Design patterns provide the capability to reuse successful designs.

Template
Parameters
Pattern Name

Parameterized Collaboration

Structural Aspect

Behavioral Aspect

12
IBM

We will look at a number of design patterns throughout this course. Thus, it is important to define what a design pattern is up front.

Design patterns are being collected and cataloged in a number of publications and mediums.You can use design patterns to solve issues in your design without "reinventing the wheel." You can also use design patterns to validate and verify your current approaches.

Using design patterns can lead to more maintainable systems and increased productivity.They provide excellent examples of good design heuristics and design vocabulary. In order to use design patterns effectively, you should become familiar with some common design patterns and the issues that they mitigate.

A design pattern is modeled in the UML as a parameterized collaboration.Thus it has a structural aspect and a behavioral aspect. The structural part is the classes whose instances implement the pattern, and their relationships (the static view).The behavioral aspect describes how the instance collaborate — usually by sending messages to each other — to implement the pattern (the dynamic view).

A parameterized collaboration is a template for a collaboration.The Template Parameters are used to adapt the collaboration for a specific usage.These parameters may be bound to different sets of abstractions, depending on how they are applied in the design.

Instructor Notes:

The chosen architectural pattern may change, in some significant ways, the approach taken to solving a problem (that is, choosing another pattern would require too much "tweaking" in design). Thus, you want to account for this in analysis; however, be careful not to make the analysis approach too vendor–specific.

Some examples:

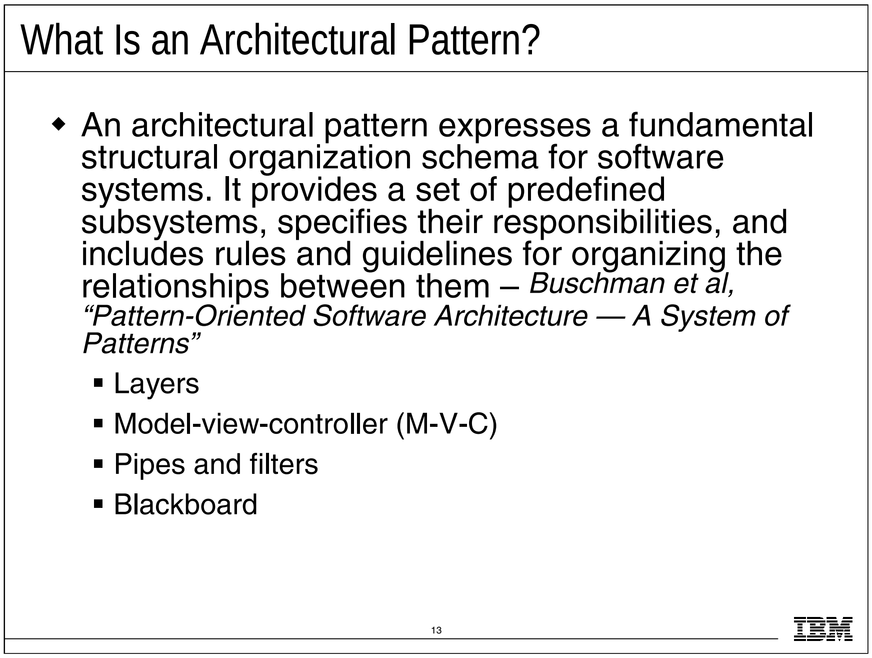
•Layers: The Course Registration and Payroll architecture; The OSI 7 layer model. (This will be discussed shortly.)

•MVC: Visual Modeling Tools, GUI, Image Processing Tools

•Pipes and Filters: Telecom Billing (processing of incoming calls).

Remind the students that this is not an architecture course. Thus, for scope reasons, our discussions will be limited to the layers pattern.

Note: Client/Server and 2/3/n-tier have sometimes been called an analysis pattern, but in this course it will be treated as a distribution pattern and will be discussed in the Describe Distribution module.



What Is an Architectural Pattern?

- An architectural pattern expresses a fundamental structural organization schema for software systems. It provides a set of predefined subsystems, specifies their responsibilities, and includes rules and guidelines for organizing the relationships between them – *Buschman et al, "Pattern-Oriented Software Architecture — A System of Patterns"*
  - Layers
  - Model-view-controller (M-V-C)
  - Pipes and filters
  - Blackboard

13

Architectural Analysis is where you consider architectural patterns, as this choice affects the high-level organization of your object model.

Layers: The layers pattern is where an application is decomposed into different levels of abstraction. The layers range from application-specific layers at the top to implementation/technology-specific layers on the bottom.

Model-View-Controller: The MVC pattern is where an application is divided into three partitions: The Model, which is the business rules and underlying data, the View, which is how information is displayed to the user, and the Controllers, which process the user input.

Pipes and Filters: In the Pipes and Filters pattern, data is processed in streams that flow through pipes from filter to filter. Each filter is a processing step.

Blackboard: The Blackboard pattern is where independent, specialized applications collaborate to derive a solution, working on a common data structure.

Architectural patterns can work together. (That is, more than one architectural pattern can be present in any one software architecture.)

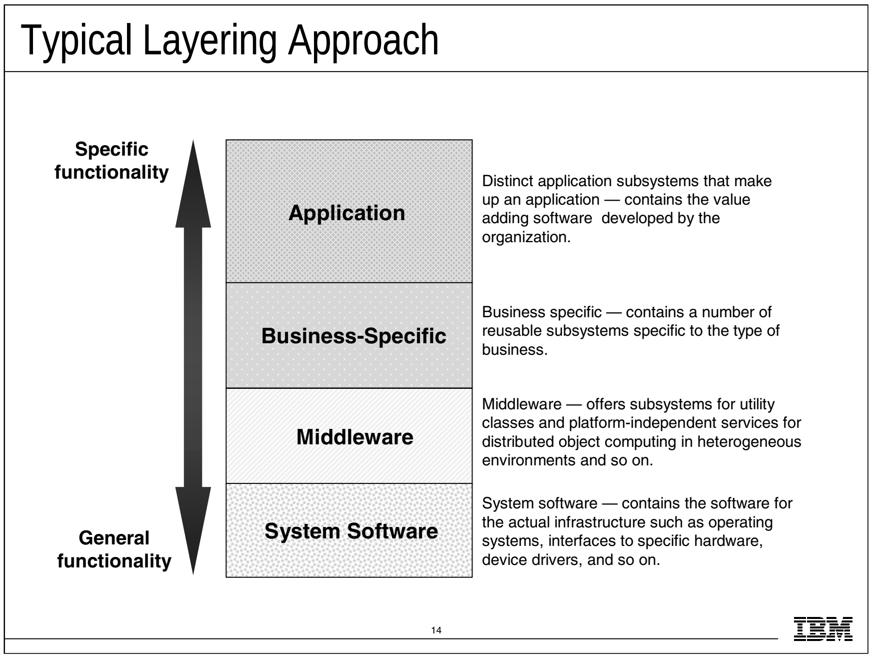
The architectural patterns listed above imply certain system characteristics, performance characteristics, and process and distribution architectures. Each solves certain problems but also poses unique challenges. For this course, you will concentrate on the Layers architectural pattern.

Instructor Notes:

Remind the students that during Architectural Analysis, the focus is normally on the high-level layers — the application and business-specific layers. The other lower-level layers are focused on during Incorporate Existing Design Elements.

Layering is a fundamental separation of concerns.

Note: Most of the GUI and persistence frameworks cut across layers in a somewhat transparent way, so instead of visualizing layers in only two dimensions, think of a framework as layering in a third dimension that cuts across the normal layering dimensions (or "plugs into" the side of the layering diagram, cutting across layers). This is part of what makes frameworks so hard to explain — they don't behave like "service providers" (classes and subsystems), but instead act more like skeletal architectures and proto-services that both extend and are extended by the project-specific stuff. The "GUI layer" is really not so much a layer as a framework that extends across a number of layers.



Typical Layering Approach

Distinct application subsystems that make up an application — contains the value adding software developed by the organization.

Business specific — contains a number of reusable subsystems specific to the type of business.

Middleware — offers subsystems for utility classes and platform-independent services for distributed object computing in heterogeneous environments and so on.

System software — contains the software for the actual infrastructure such as operating systems, interfaces to specific hardware, device drivers, and so on.

14

Layering represents an ordered grouping of functionality, with the application-specific functions located in the upper layers, functionality that spans application domains in the middle layers, and functionality specific to the deployment environment at the lower layers.

The number and composition of layers is dependent upon the complexity of both the problem domain and the solution space:

- There is generally only a single application-specific layer.
- In domains with existing systems, or that have large systems composed of inter-operating smaller systems, the Business-Specific layer is likely to partially exist and may be structured into several layers for clarity.
- Solution spaces, which are well-supported by middleware products and in which complex system software plays a greater role, have well-developed lower layers, with perhaps several layers of middleware and system software.

This slide shows a sample architecture with four layers:

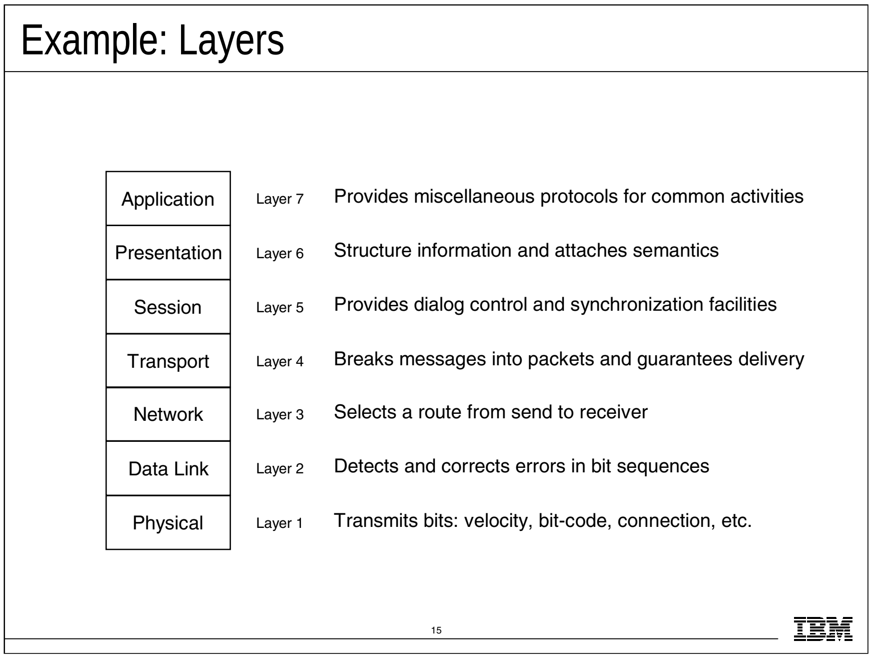
- The top layer, **Application layer**, contains the application-specific services.
- The next layer, **Business-Specific layer**, contains business-specific components used in several applications.
- The **Middleware layer** contains components such as GUI-builders, interfaces to database management systems, platform-independent operating system services, and OLE-components such as spreadsheets and diagram editors.
- The bottom layer, **System Software layer**, contains components such as operating systems, databases, interfaces to specific hardware, and so on.

Instructor Notes:

This course will make use of the Layers architectural pattern. Take a few moments to explain the context, problem, and solution that this pattern addresses.

While this is not an architectural course, architecture does drive everything that occurs in design, so it is important for the designer to understand the architectural pattern that is being employed.

A layer represents a horizontal slice through an architecture whereas a partition represents a vertical slice.



Example: Layers

Application	Layer 7	Provides miscellaneous protocols for common activities
Presentation	Layer 6	Structure information and attaches semantics
Session	Layer 5	Provides dialog control and synchronization facilities
Transport	Layer 4	Breaks messages into packets and guarantees delivery
Network	Layer 3	Selects a route from send to receiver
Data Link	Layer 2	Detects and corrects errors in bit sequences
Physical	Layer 1	Transmits bits: velocity, bit-code, connection, etc.

15

Context

A large system that requires decomposition.

Problem

A system that must handle issues at different levels of abstraction; for example: hardware control issues, common services issues, and domain-specific issues. It would be extremely undesirable to write vertical components that handle issues at all levels. The same issue would have to be handled (possibly inconsistently) multiple times in different components.

Forces

- Parts of the system should be replaceable.
- Changes in components should not ripple.
- Similar responsibilities should be grouped together.
- Size of components — complex components may have to be decomposed.

Solution

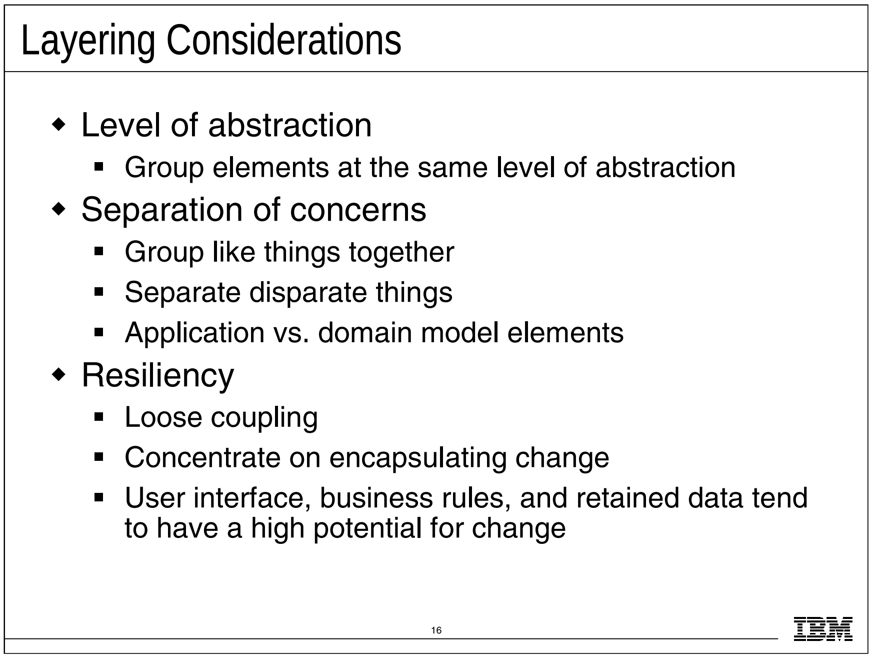
Structure the systems into groups of components that form layers on top of each other. Make upper layers use services of the layers below only (never above). Try not to use services other than those of the layer directly below. (Do not skip layers unless intermediate layers would only add pass-through components.)

A strict layered architecture states that design elements (classes, components, packages, and subsystems) only utilize the services of the layer below them. Services can include event-handling, error-handling, database access, and so forth. It contains more palpable mechanisms, as opposed to the raw operating system level calls documented in the bottom layer.

Instructor Notes:

Subsystems and packages within a particular layer should only depend upon subsystems within the same layer, and at the next lower layer. Failure to restrict dependencies in this way causes architectural degradation, and makes the system brittle and difficult to maintain.

Exceptions include cases where subsystems need direct access to lower layer services: A conscious decision should be made on how to handle primitive services needed throughout the system, such as printing and sending messages. There is little value in restricting messages to lower layers if the solution is to effectively implement call pass-throughs in the intermediate layers.



Layering Considerations

- Level of abstraction
  - Group elements at the same level of abstraction
- Separation of concerns
  - Group like things together
  - Separate disparate things
  - Application vs. domain model elements
- Resiliency
  - Loose coupling
  - Concentrate on encapsulating change
  - User interface, business rules, and retained data tend to have a high potential for change

16

Layers are used to encapsulate conceptual boundaries between different kinds of services and provide useful abstractions that make the design easier to understand.

When layering, concentrate on grouping things that are similar together, as well as encapsulating change.

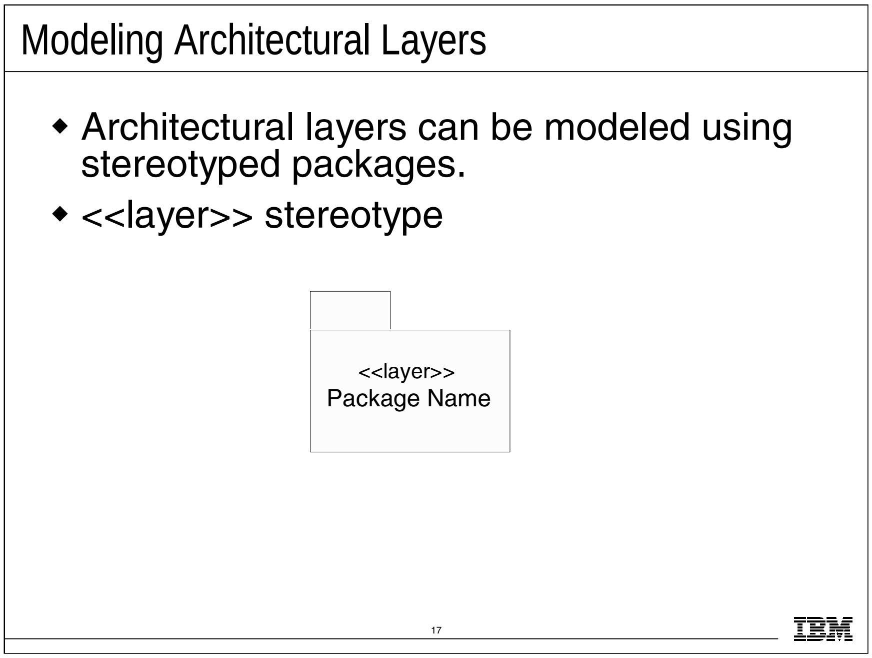
There is generally only a single application layer. On the other hand, the number of domain layers is dependent upon the complexity of both the problem and the solution spaces.

When a domain has existing systems, complex systems composed of inter-operating systems, and/or systems where there is a strong need to share information between design teams, the Business-Specific layer may be structured into several layers for clarity.

In **Architectural Analysis**, we are concentrating on the upper-level layers (the Application and Business-Specific layers). The lower level layers (infrastructure and vendor-specific layers) will be defined in Incorporate Existing Design Elements.

Instructor Notes:

Layer is not a standard UML 2 stereotype but a commonly used one.



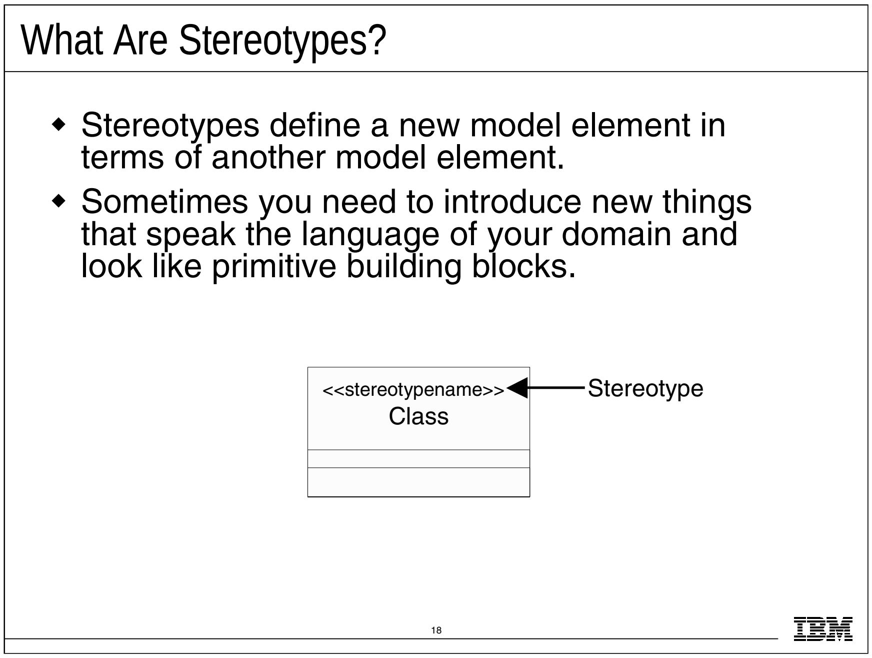
Modeling Architectural Layers

- Architectural layers can be modeled using stereotyped packages.
- <<layer>> stereotype

<<layer>>
Package Name

Layers can be represented as packages with the <<layer>> stereotype. The layer descriptions can be included in the documentation field of the specification of the package.

Instructor Notes:



What Are Stereotypes?

- Stereotypes define a new model element in terms of another model element.
- Sometimes you need to introduce new things that speak the language of your domain and look like primitive building blocks.

<<stereotypename>>
Class
Stereotype

18

A **stereotype** can be defined as:

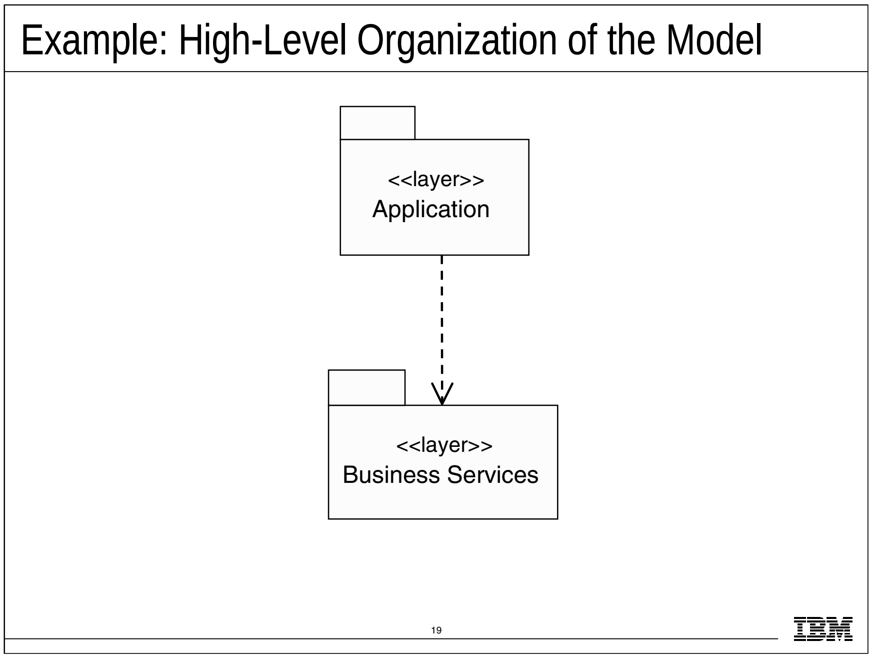
An extension of the basic UML notation that allows you to define a new modeling element based on an existing modeling element.

- The new element may contain additional semantics but still applies in all cases where the original element is used. In this way, the number of unique UML symbols is reduced, simplifying the overall notation.
- The name of a stereotype is shown in guillemets (<< >>).
- A unique icon may be defined for the stereotype, and the new element may be modeled using the defined icon or the original icon with the stereotype name displayed, or both.
- Stereotypes can be applied to all modeling elements, including classes, relationships, components, and so on.
- Each UML element can only have one stereotype.
- Stereotype uses include modifying code generation behavior and using a different or domain-specific icon or color where an extension is needed or helpful to make a model more clear or useful.

Instructor Notes:

Layers can be represented as packages with the <<layer>> stereotype. The layer descriptions can be included in the documentation field of the specification of the package.

This diagram could be included as the main diagram in the Analysis and/or Design Model package.



Example: High-Level Organization of the Model

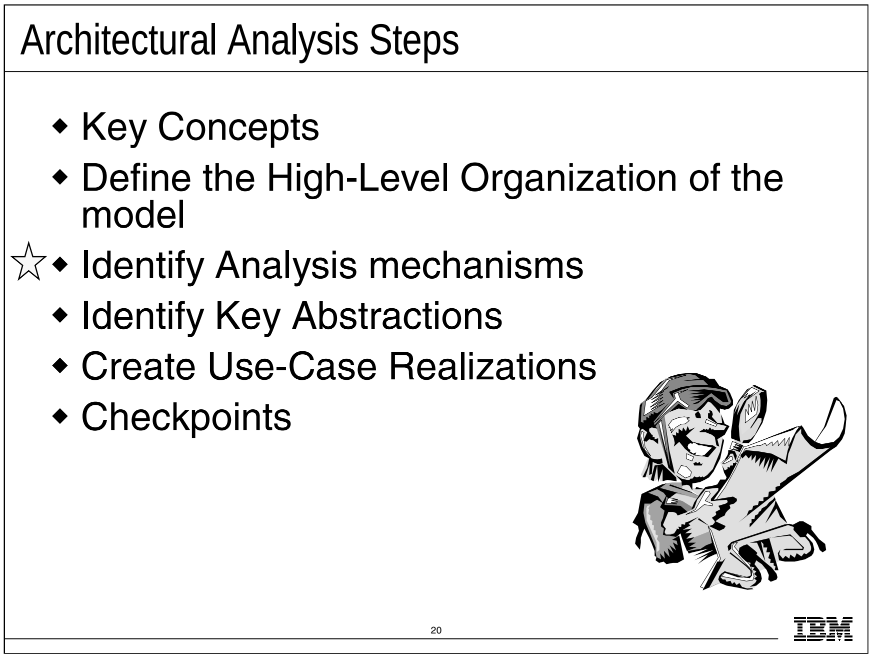
The above example includes the Application and Business-Specific layers for the Course Registration System.

The Application layer contains the design elements that are specific to the Course Registration application.

We expect that multiple applications will share some key abstractions and common services. These have been encapsulated in the Business Services layer, which is accessible to the Application layer. The Business Services layer contains business-specific elements that are used in several applications, not necessarily just this one.

Instructor Notes:

Emphasize that analysis mechanisms allow the designer to “build in” standard abstractions and conventions for the nonfunctional requirements right into the architecture. Analysis mechanisms can be considered a shorthand representation for complex behavior.



Architectural Analysis Steps

- Key Concepts
- Define the High-Level Organization of the model
- ☆ Identify Analysis mechanisms
- Identify Key Abstractions
- Create Use-Case Realizations
- Checkpoints

20

The architecture should be simple, but not simplistic. It should provide standard behavior through standard abstractions and mechanisms. Thus, a key aspect in designing a software architecture is the definition and the selection of the mechanisms that designers use to give "life" to their objects.

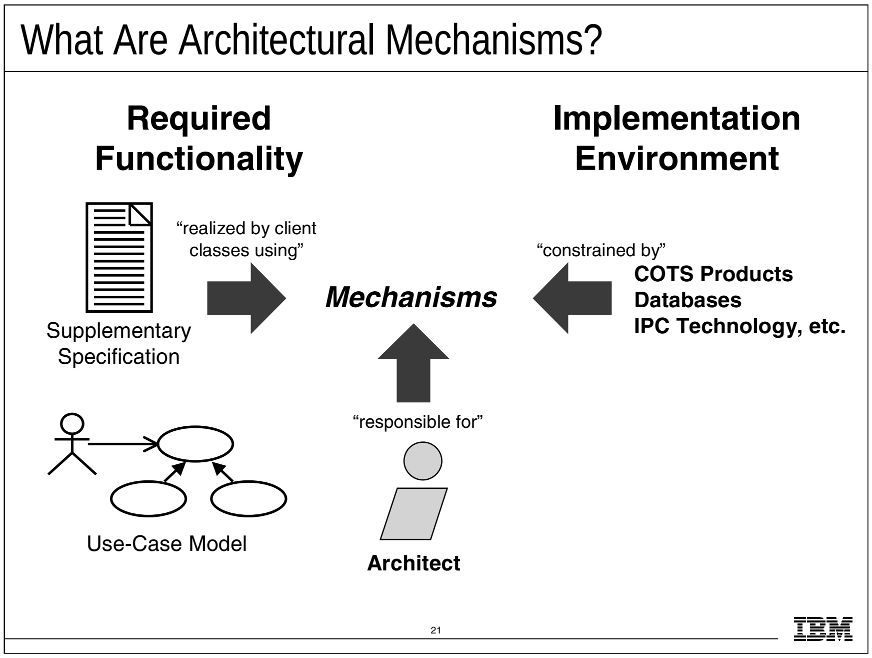
In **Architectural Analysis**, it is important to identify the analysis mechanisms for the software system being developed. Analysis mechanisms focus on and address the nonfunctional requirements of the system (that is, the need for persistence, reliability, and performance), and builds support for such non-functional requirements directly into the architecture.

Analysis mechanisms are used during analysis to reduce the complexity of analysis, and to improve its consistency by providing designers with a shorthand representation for complex behavior. Mechanisms allow the analysis effort to focus on translating the functional requirements into software abstractions without becoming bogged down in the specification of relatively complex behavior that is needed to support the functionality but which is not central to it.

Instructor Notes:

Good sources for more information on mechanisms are the various documents on CORBA and COM. COM is usually only an implementation mechanism, but the CORBA documentation tends to be a bit more general. So you can look at the definitions for the CORBA services and, with a little abstraction, define general mechanisms for such functions as messaging, transaction management, and persistence.

There are similar "standards" that can be gleaned for other kinds of mechanisms —things like workflow management, and other more application-specific things. Using standards as a starting point for mechanisms tends to make the build- versus-buy decisions easier.



What Are Architectural Mechanisms?

Required Functionality

Implementation Environment

"realized by client classes using"

Mechanisms

"constrained by"

COTS Products
Databases
IPC Technology, etc.

Supplementary Specification

"responsible for"

Use-Case Model

Architect

21

In order to better understand what an analysis mechanism is, we have to understand what an architectural mechanism is.

An architectural mechanism is a strategic decision regarding common standards, policies, and practices. It is the realization of topics that should be standardized on a project. Everyone on the project should utilize these concepts in the same way, and reuse the same mechanisms to perform the operations.

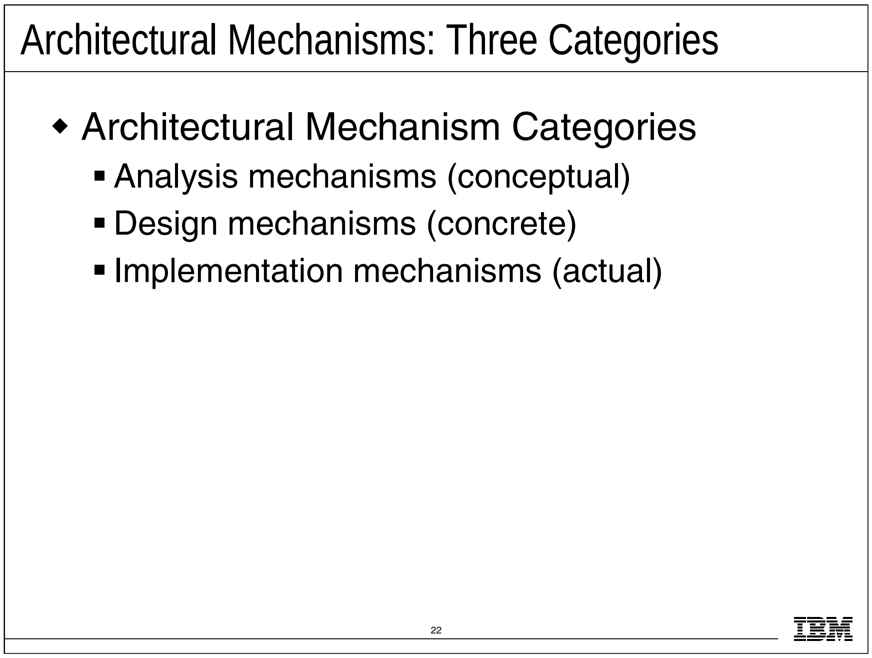
An architectural mechanism represents a common solution to a frequently encountered problem. It may be patterns of structure, patterns of behavior, or both. Architectural mechanisms are an important part of the "glue" between the required functionality of the system and how this functionality is realized, given the constraints of the implementation environment.

Support for architectural mechanisms needs to be built in to the architecture. Architectural mechanisms are coordinated by the architect. The architect chooses the mechanisms, validates them by building or integrating them, verifies that they do the job, and then consistently imposes them upon the rest of the design of the system.

Instructor Notes:

Note that in this section, we will be concentrating on Analysis mechanisms. Design and Implementation mechanisms will be discussed in the Identify Design mechanisms module.

In analysis, we just care that a mechanism must be provided; we don't care how it is provided. That's decided during design.
When doing use-case analysis and finding classes, you're really finding things in the upper two layers of the system — boundary and control classes which are application-specific; and boundary, entity, and control classes that are domain specific. Everything else at a lower layer is represented at this point using analysis mechanisms. The value of analysis mechanisms is that they prevent you from diving too deep too early.



Architectural Mechanisms: Three Categories

- Architectural Mechanism Categories
  - Analysis mechanisms (conceptual)
  - Design mechanisms (concrete)
  - Implementation mechanisms (actual)

22

There are three categories of architectural mechanisms. The only difference between them is one of refinement.

Analysis mechanisms capture the key aspects of a solution in a way that is implementation-independent. They either provide specific behaviors to a domain-related class or component, or correspond to the implementation of cooperation between classes and/or components. They may be implemented as a framework. Examples include mechanisms to handle persistence, inter-process communication, error or fault handling, notification, and messaging, to name a few.

Design mechanisms are more concrete. They assume some details of the implementation environment, but are not tied to a specific implementation (as is an implementation mechanism).

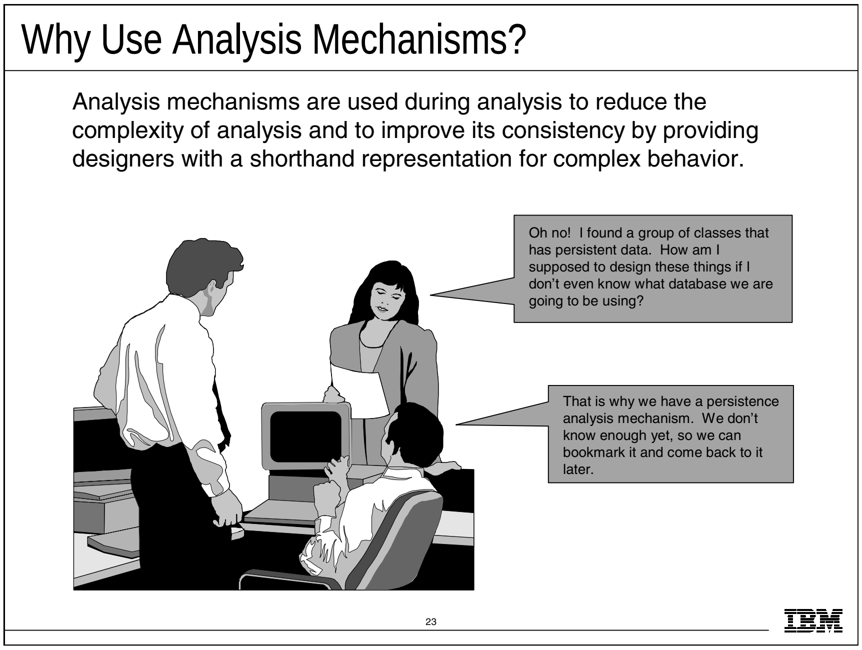
Implementation mechanisms specify the exact implementation of the mechanism. Implementation mechanisms are are bound to a certain technology, implementation language, vendor, or other factor.

In a design mechanism, some specific technology is chosen (for example, RDBMS vs. ODBMS), whereas in an implementation mechanism, a VERY specific technology is chosen (for example, Oracle vs. SYBASE).

The overall strategy for the implementation of analysis mechanisms must be built into the architecture. This will be discussed in more detail in Identify Design mechanisms, when design and implementation mechanisms are discussed.

Instructor Notes:

Analysis mechanisms are used during analysis to reduce the complexity of the analysis, and to improve its consistency. They do this by providing designers with a short hand representation for complex behavior.



Why Use Analysis Mechanisms?

Analysis mechanisms are used during analysis to reduce the complexity of analysis and to improve its consistency by providing designers with a shorthand representation for complex behavior.

Oh no! I found a group of classes that has persistent data. How am I supposed to design these things if I don't even know what database we are going to be using?

That is why we have a persistence analysis mechanism. We don't know enough yet, so we can bookmark it and come back to it later.

23

An analysis mechanism represents a pattern that constitutes a common solution to a common problem. These mechanisms may show patterns of structure, patterns of behavior, or both. They are used during analysis to reduce the complexity of the analysis, and to improve its consistency by providing designers with a shorthand representation for complex behavior. Analysis mechanisms are primarily used as "placeholders" for complex technology in the middle and lower layers of the architecture. When mechanisms are used as "placeholders" in the architecture, the architecting effort is less likely to become distracted by the details of mechanism behavior.

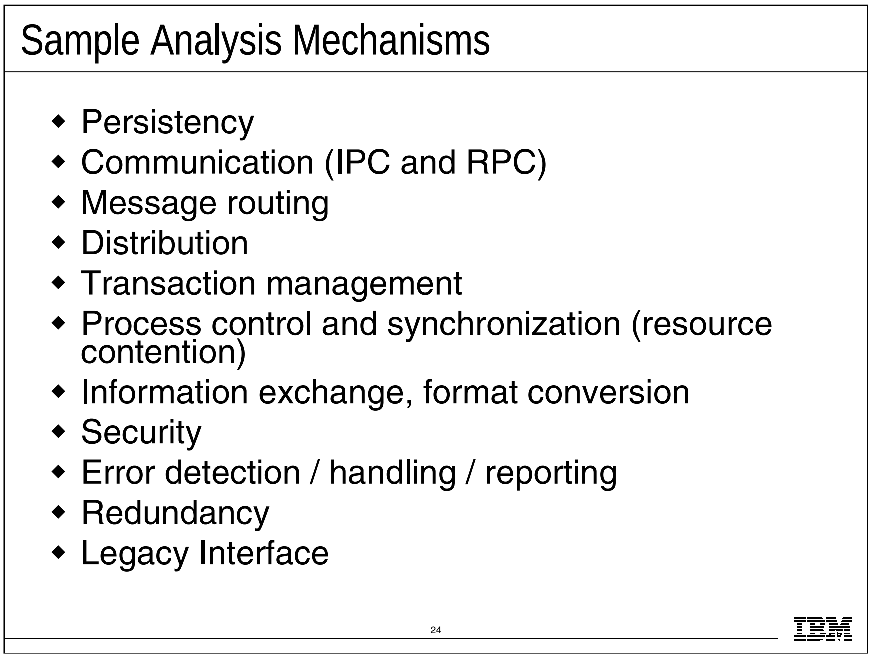
Mechanisms allow the analysis effort to focus on translating the functional requirements into software concepts without bogging down in the specification of relatively complex behavior needed to support the functionality but which is not central to it. Analysis mechanisms often result from the instantiation of one or more architectural or analysis patterns**.**

Persistence provides an example of analysis mechanisms. A persistent object is one that logically exists beyond the scope of the program that created it. The need to have object lifetimes that span use cases, process lifetimes, or system shutdown and startup, defines the need for object persistence. Persistence is a particularly complex mechanism. During analysis we do not want to be distracted by the details of how we are going to achieve persistence. This gives rise to a "persistence" analysis mechanism that allows us to speak of persistent objects and capture the requirements we will have on the persistence mechanism without worrying about what exactly the persistence mechanism will do or how it will work.

Analysis mechanisms are typically, but not necessarily, unrelated to the problem domain, but instead are "computer science" concepts. As a result, they typically occupy the middle and lower layers of the architecture. They provide specific behaviors to a domain-related class or component, or correspond to the implementation of cooperation between classes and/or components.

Instructor Notes:

The “mechanisms” are, in a sense, shorthand for ‘complex stuff’ that we don’t want to explain right now.



Sample Analysis Mechanisms

- Persistency
- Communication (IPC and RPC)
- Message routing
- Distribution
- Transaction management
- Process control and synchronization (resource contention)
- Information exchange, format conversion
- Security
- Error detection / handling / reporting
- Redundancy
- Legacy Interface

24

Analysis mechanisms either provide specific behaviors to a domain-related class or component, or they correspond to the implementation of cooperation between classes and/or components.

Some examples of analysis mechanisms are listed on this slide. This list is not meant to be exhaustive.

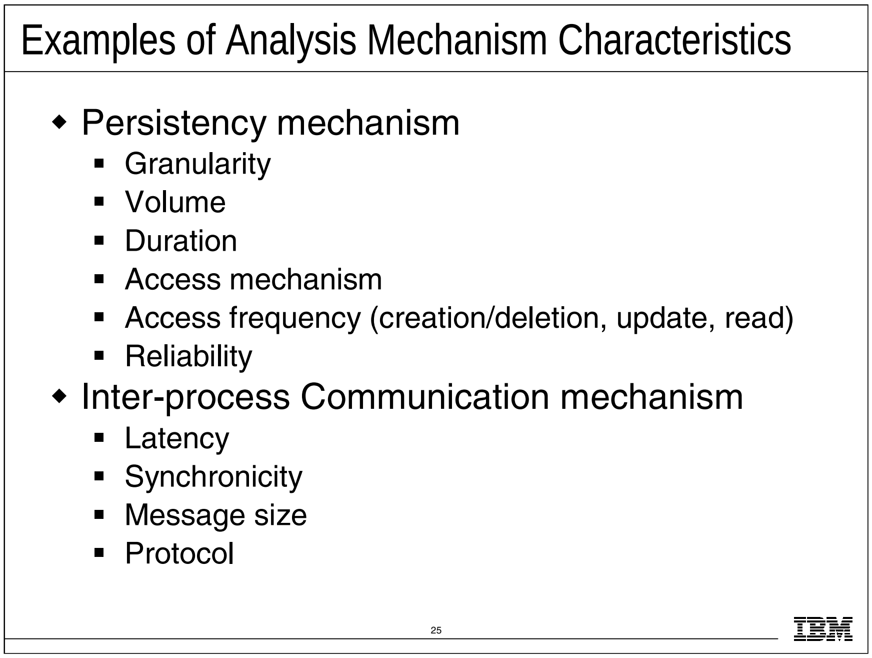
Examples of communication mechanisms include inter-process communication (IPC) and inter-node communication (a.k.a. remote process communication or RPC). RPC has both a communication and a distribution aspect.

Mechanisms are perhaps easier to discuss when one talks about them as “patterns” that are applied to the problem. So the inter-process communication pattern (that is, “the application is partitioned into a number of communicating processes”) interacts with the distribution pattern (that is, “the application is distributed across a number of nodes”) to produce the RPC pattern (that is, “the application is partitioned into a number of processes, which are distributed across a number of nodes”). This process provides us a way to implement remote IPC.

Instructor Notes:

It is important for the students to note that analysis mechanisms can have characteristics and to understand what they look like. However, we will not be emphasizing them in this class.

These are just some sample characteristics for some analysis mechanisms. The list is not meant to be exhaustive. A more complete list is provided in the Rational Unified Process.



Examples of Analysis Mechanism Characteristics

- Persistency mechanism
  - Granularity
  - Volume
  - Duration
  - Access mechanism
  - Access frequency (creation/deletion, update, read)
  - Reliability
- Inter-process Communication mechanism
  - Latency
  - Synchronicity
  - Message size
  - Protocol

25

Analysis mechanism characteristics capture some nonfunctional requirements of the system.

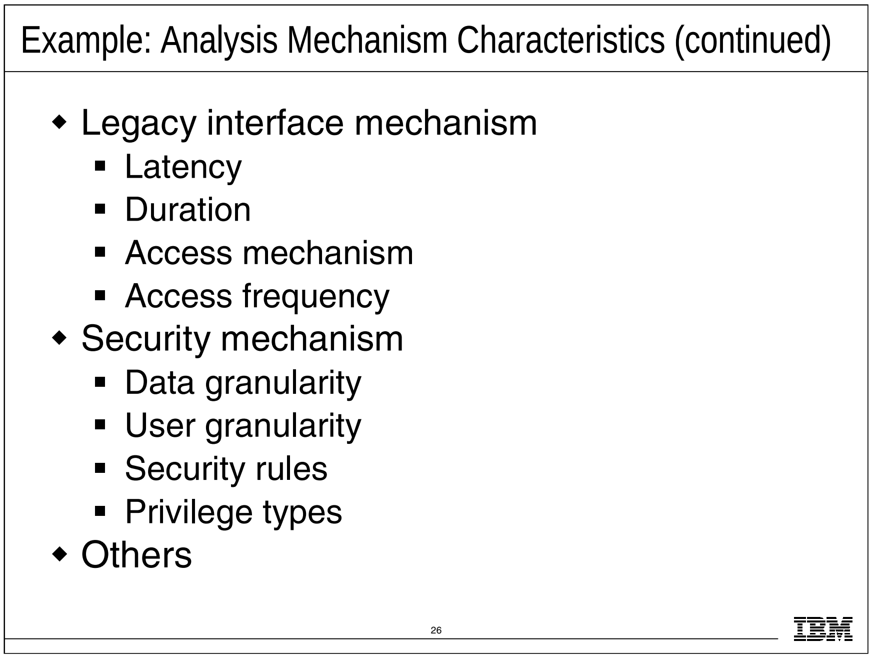
Persistency: For all classes whose instances may become persistent, we need to identify:

- **Granularity**: Range of size of the persistent objects
- **Volume**: Number of objects to keep persistent
- **Duration**: How long to keep persistent objects
- **Access mechanism**: How is a given object uniquely identified and retrieved?
- **Access frequency**: Are the objects more or less constant; are they permanently updated?
- **Reliability**: Shall the objects survive a crash of the process, the processor; the whole system?

Inter-process Communication: For all model elements that need to communicate with objects, components, or services executing in other processes or threads, we need to identify:

- **Latency**: How fast must processes communicate with another?
- **Synchronicity**: Asynchronous communication
- **Size of message**: A spectrum might be more appropriate than a single number.
- **Protocol**, flow control, buffering, and so on.

Instructor Notes:



Example: Analysis Mechanism Characteristics (continued)

- Legacy interface mechanism
  - Latency
  - Duration
  - Access mechanism
  - Access frequency
- Security mechanism
  - Data granularity
  - User granularity
  - Security rules
  - Privilege types
- Others

26

IBM

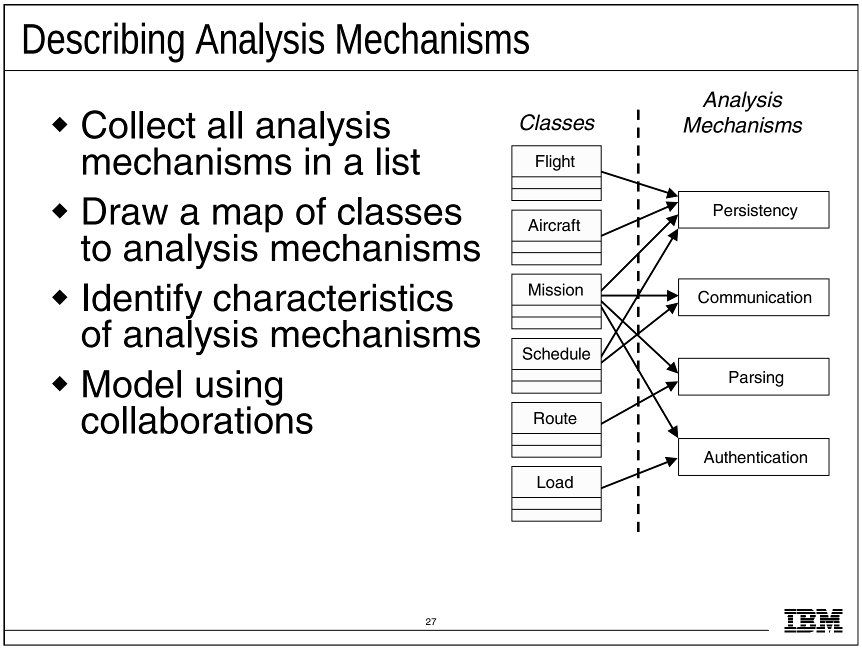
Security:

- **Data granularity**: Package-level, class-level, attribute level
- **User granularity**: Single users, roles/groups
- **Security Rules**: Based on value of data, on algorithm based on data, and on algorithm based on user and data
- **Privilege Types**: Read, write, create, delete, perform some other operation

Instructor Notes:

The architect is responsible for describing each analysis mechanism, but the designer is responsible for understanding how to interpret and properly use the analysis mechanisms. The idea of this slide is not to instruct the student how to create the mechanism, but to help the student understand how to use a mechanism properly.

Note: This is not a UML diagram. You will need to create this chart with some other tool.



Describing Analysis Mechanisms

- Collect all analysis mechanisms in a list
- Draw a map of classes to analysis mechanisms
- Identify characteristics of analysis mechanisms
- Model using collaborations

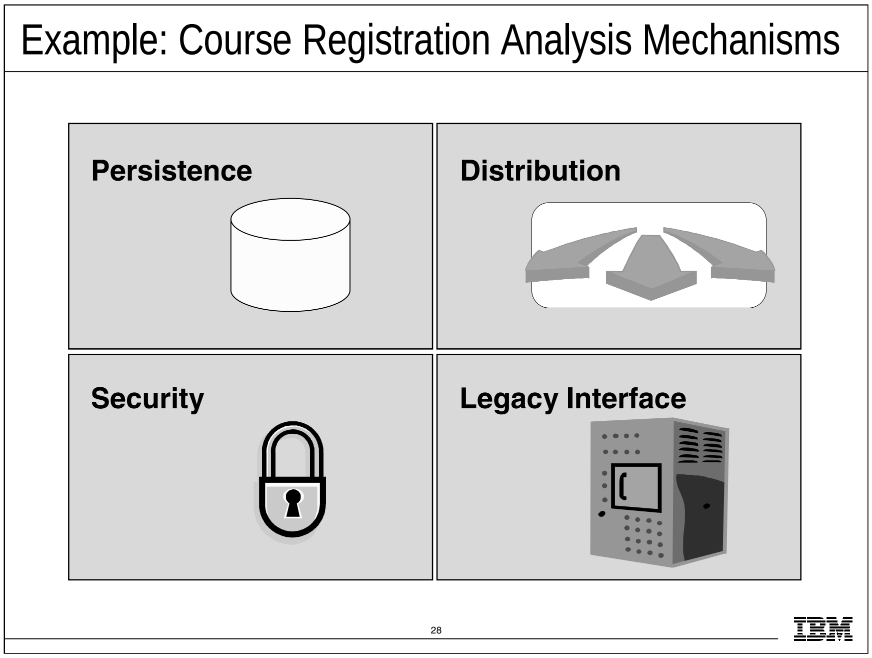
Classes
Analysis Mechanisms
Flight
Aircraft
Mission
Schedule
Route
Load
Persistency
Communication
Parsing
Authentication
27
IBM

The process for describing analysis mechanisms is:

1. **Collect all analysis mechanisms in a list.** The same analysis mechanism may appear under several different names across different use-case realizations, or across different designers. For example, **storage**, **persistency**, **database**, and **repository** might all refer to a persistency mechanism. **Inter-process communication**, **message passing**, or **remote invocation** might all refer to an inter-process communication mechanism.
2. **Draw a map of the client classes to the analysis mechanisms** (see graphic on slide).
3. **Identify Characteristics of the analysis mechanisms.** To discriminate across a range of potential designs, identify the key characteristics used to qualify each analysis mechanism. These characteristics are part functionality, part size, and performance.
4. **Model Using Collaborations.** Once all of the analysis mechanisms are identified and named, they should be modeled through the collaboration of a "society of classes." Some of these classes do not directly deliver application functionality, but exist only to support it. Very often, these "support classes" are located in the middle or lower layers of a layered architecture, thus providing a common support service to all application-level classes.

Instructor Notes:

Anytime, anyone has issues with the included mechanisms (that is, persistence, security, and so forth), emphasize that these are just one set of choices. On your project, your architect may pick others. If he does, your design will be different.



Example: Course Registration Analysis Mechanisms

Persistence

Distribution

Security

Legacy Interface

28

The above are the selected analysis mechanisms for the Course Registration System.

Persistency: A means to make an element persistent (that is, exist after the application that created it ceases to exist).

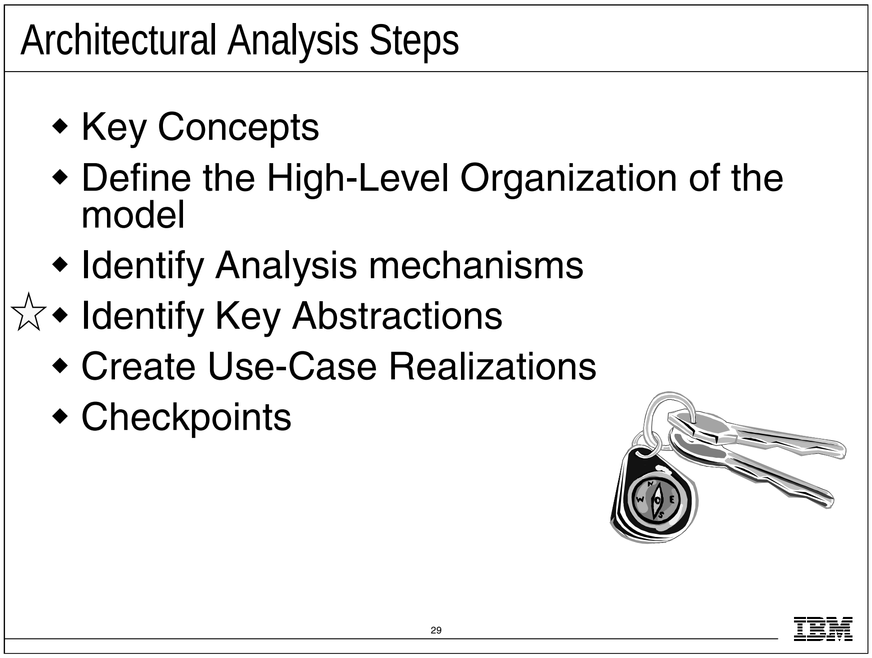
Distribution: A means to distribute an element across existing nodes of the system.

Security: A means to control access to an element.

Legacy Interface: A means to access a legacy system with an existing interface.

These are also documented in the *Payroll Architecture Handbook*, Architectural Mechanisms section.

Instructor Notes:



Architectural Analysis Steps

- Key Concepts
- Define the High-Level Organization of the model
- Identify Analysis mechanisms
- ☆ Identify Key Abstractions
- Create Use-Case Realizations
- Checkpoints

29

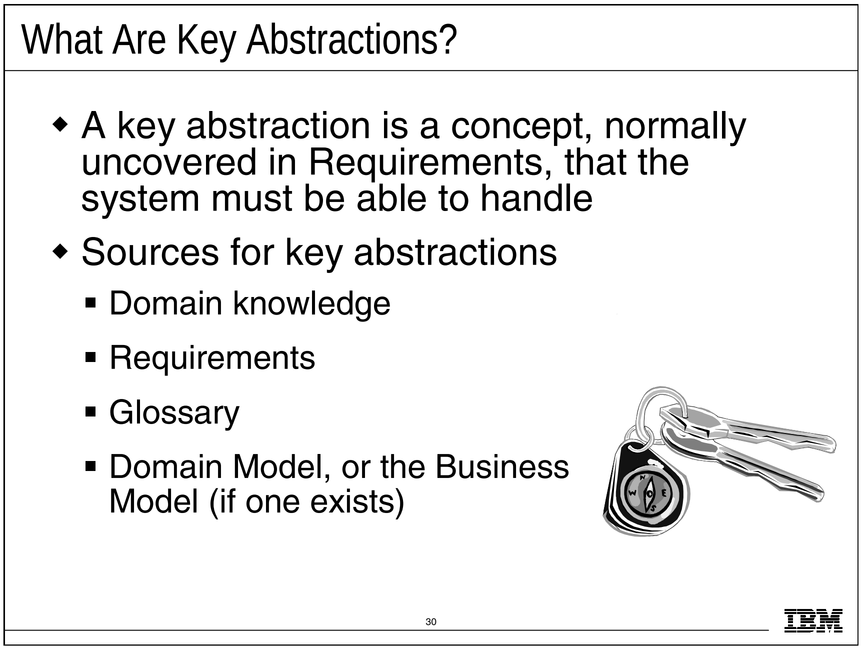
This is where the key abstractions for the problem domain are defined. Furthermore, this is where the “vocabulary” of the software system is established.

The purpose of this step is to "prime the pump" for analysis by identifying and defining the key abstractions that the system must handle. These may have been initially identified during business modeling and requirement activities. However, during those activities, the focus was on the problem domain. During analysis and design, our focus is more on the solution domain.

Instructor Notes:

These key abstractions are the "essence of the system," and identifying them now is meant to provide a starting point for Use-Case Analysis. By identifying and modeling these key abstractions before Use-Case Analysis, you improve the consistency across the Use-Case Analysis activities for the different use cases. You reduce the possibility that different terms will model the same abstractions when the classes are being identified for the different use cases. This is especially important if separate use-case teams will be working on the use cases, as it gives everyone a common starting point.

You need more than just the Glossary, because the Glossary should not document things purely in the solution space (for example, mechanisms, key abstractions related to the solution space, and architectural patterns being used.) The Glossary is primarily a "user-oriented" document.



What Are Key Abstractions?

- A key abstraction is a concept, normally uncovered in Requirements, that the system must be able to handle
- Sources for key abstractions
  - Domain knowledge
  - Requirements
  - Glossary
  - Domain Model, or the Business Model (if one exists)

30

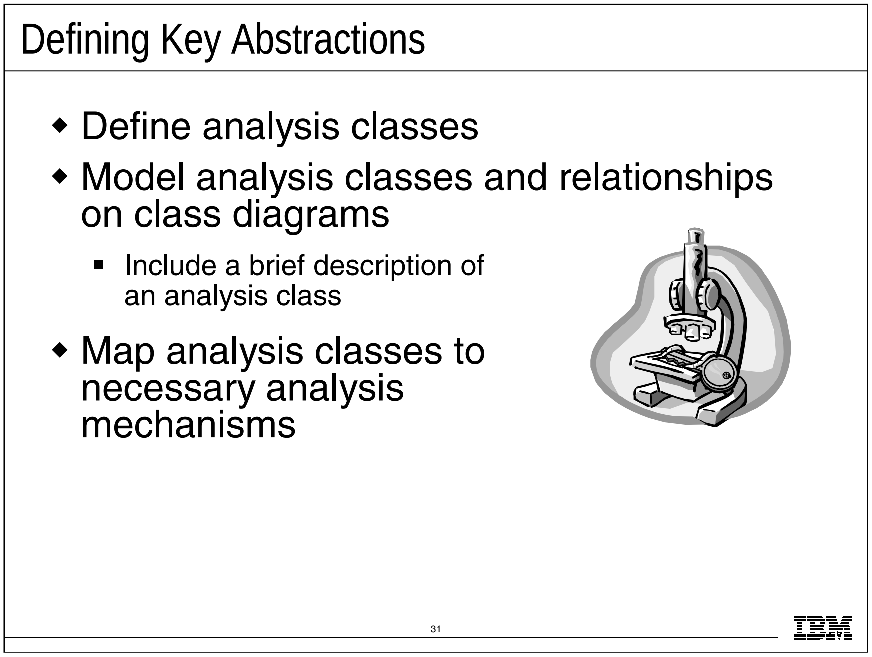
IBM

Requirements and Business Modeling activities usually uncover key concepts that the system must be able to handle. These concepts manifest themselves as key design abstractions. Because of the work already done, there is no need to repeat the identification work again during Use-Case Analysis. To take advantage of existing knowledge, we identify preliminary entity analysis classes to represent these key abstractions on the basis of general knowledge of the system. Sources include the **Requirements**, the **Glossary**, and in particular, the **Domain Model**, or the **Business Object Model**, if you have one.

Instructor Notes:

Relationships example: For a particular bank system, the relationship between a customer abstraction and an account abstraction is an important semantic relationship, since a customer has been defined as someone who has an account (or would like to open an account) at the bank.

Enter the brief descriptions in the class specification documentation field.



Defining Key Abstractions

- Define analysis classes
- Model analysis classes and relationships on class diagrams
    - Include a brief description of an analysis class
- Map analysis classes to necessary analysis mechanisms

31

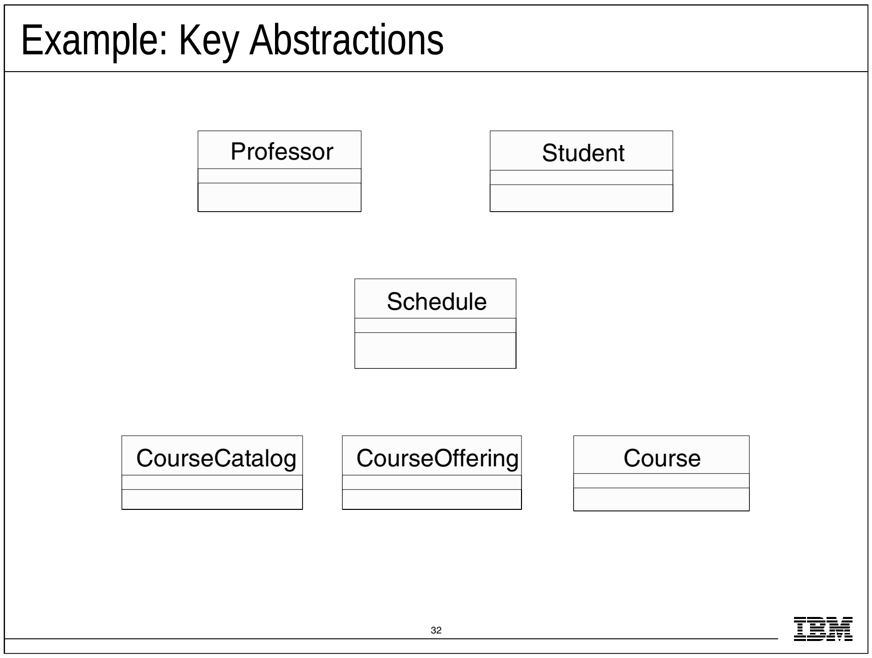
While defining the initial analysis classes, you can also define any relationships that exist between them. The relationships are those that support the basic definitions of the abstractions. It is not the objective to develop a complete class model at this point, but just to define some key abstractions and basic relationships to “kick off” the analysis effort. This will help to reduce any duplicate effort that may result when different teams analyze the individual use cases.

Relationships defined at this point reflect the semantic connections between the defined abstractions, not the relationships necessary to support the implementation or the required communication among abstractions.

The analysis classes identified at this point will probably change and evolve during the course of the project. The purpose of this step is not to identify a set of classes that will survive throughout design, but to identify the key abstractions the system must handle. Do not spend much time describing analysis classes in detail at this initial stage, because there is a risk that you might identify classes and relationships that are not actually needed by the use cases. Remember that you will find more analysis classes and relationships when looking at the use cases.

Instructor Notes:

Note: Some of these abstractions map one-to-one with actors in the Use-Case Model. This is acceptable, as it is reasonable that you might need to maintain some information concerning the actors within the system. These abstractions, which correspond to external entities (that is, actors), have been called "surrogates or proxies."



Example: Key Abstractions

Professor: A person teaching classes at the university.

Student: A person enrolled in classes at the university.

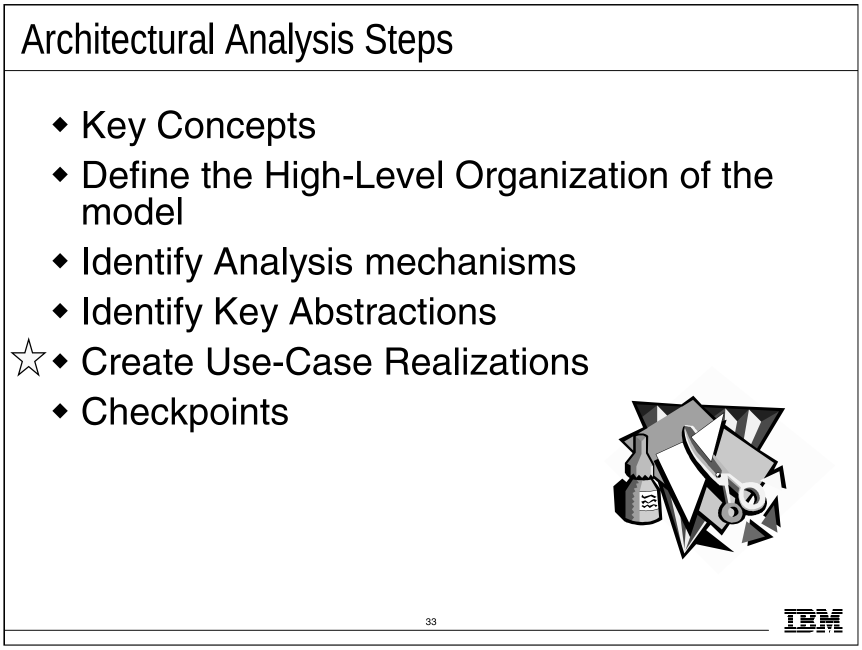
Schedule: The courses a student has enrolled in for a semester.

CourseCatalog: Unabridged catalog of all courses offered by the university.

CourseOffering: A specific offering for a course, including days of the week and times.

Course: A class offered by the university.

Instructor Notes:



Architectural Analysis Steps

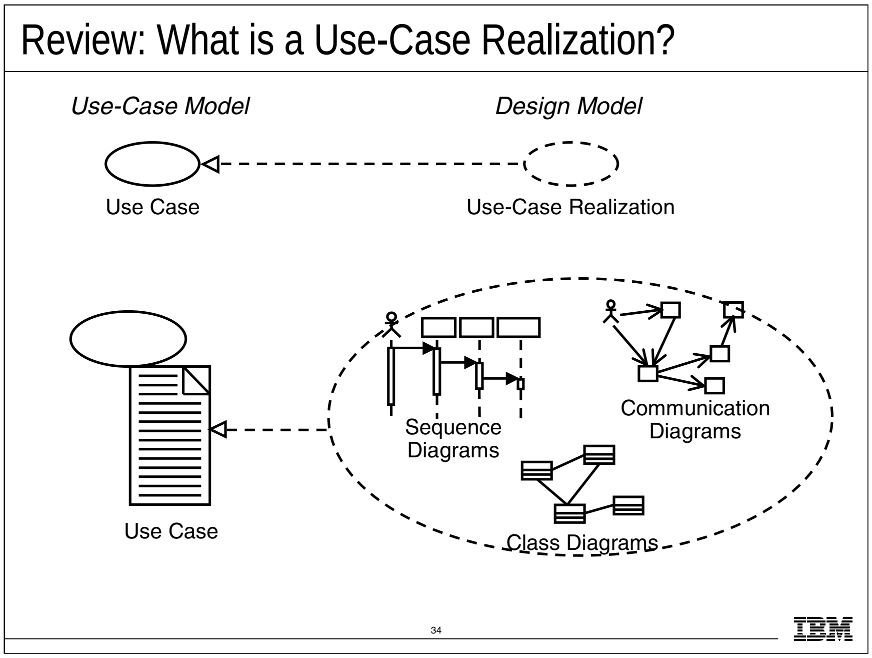
- Key Concepts
- Define the High-Level Organization of the model
- Identify Analysis mechanisms
- Identify Key Abstractions
- ☆ Create Use-Case Realizations
- Checkpoints

33

A use-case realization represents the design perspective of a use case. It is an organization model element used to group a number of artifacts related to the use-case design. Use cases are separate from use-case realizations, so you can manage each individually and change the design of the use case without affecting the baseline use case. For each use case in the Use-Case Model, there is a use-case realization in the design model with a realization relationship to the use case.

Instructor Notes:

Be sure to tell the students that the architect is the one who decides what use cases are realized in which iteration.



Review: What is a Use-Case Realization?

A use-case realization is the expression of a particular use case within the Design Model. It describes the use case in terms of collaborating objects. A use-case realization ties together the use cases from the Use-Case Model with the classes and relationships of the Design Model. A use-case realization specifies what classes must be built to implement each use case.

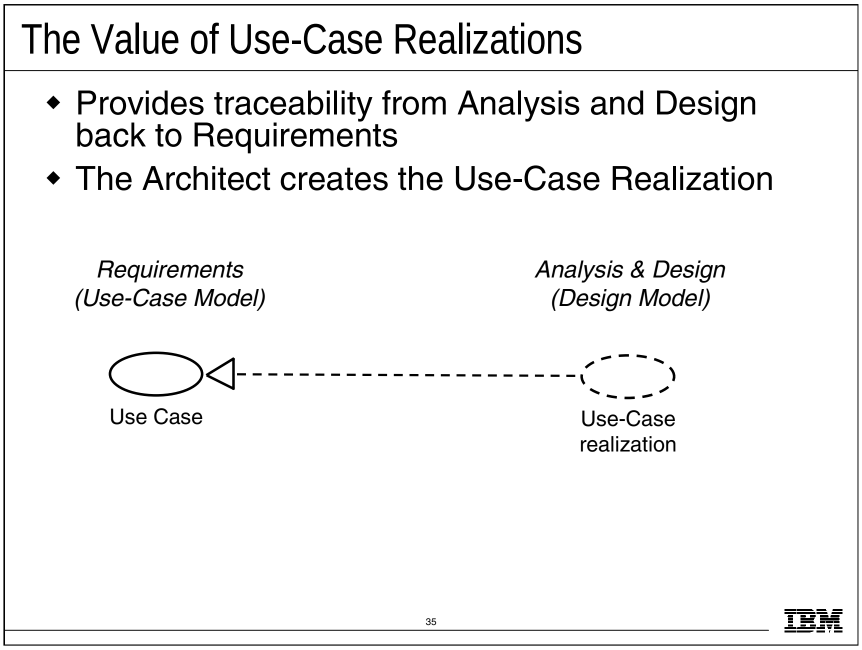
In the UML, use-case realizations are stereotyped collaborations. The symbol for a collaboration is an oval containing the name of the collaboration. The symbol for a use-case realization is a “dotted line” version of the collaboration symbol.

A use-case realization in the Design Model can be traced to a use case in the Use-Case Model. A realization relationship is drawn from the use-case realization to the use case it realizes.

Within the UML, a use-case realization can be represented using a set of diagrams that model the context of the collaboration (the classes/objects that implement the use case and their relationships — class diagrams), and the interactions of the collaborations (how these classes/objects interact to perform the use cases — collaboration and sequence diagrams).

The number and types of the diagrams that are used depend on what is needed to provide a complete picture of the collaboration and the guidelines developed for the project under development.

Instructor Notes:



The Value of Use-Case Realizations

- Provides traceability from Analysis and Design back to Requirements
- The Architect creates the Use-Case Realization

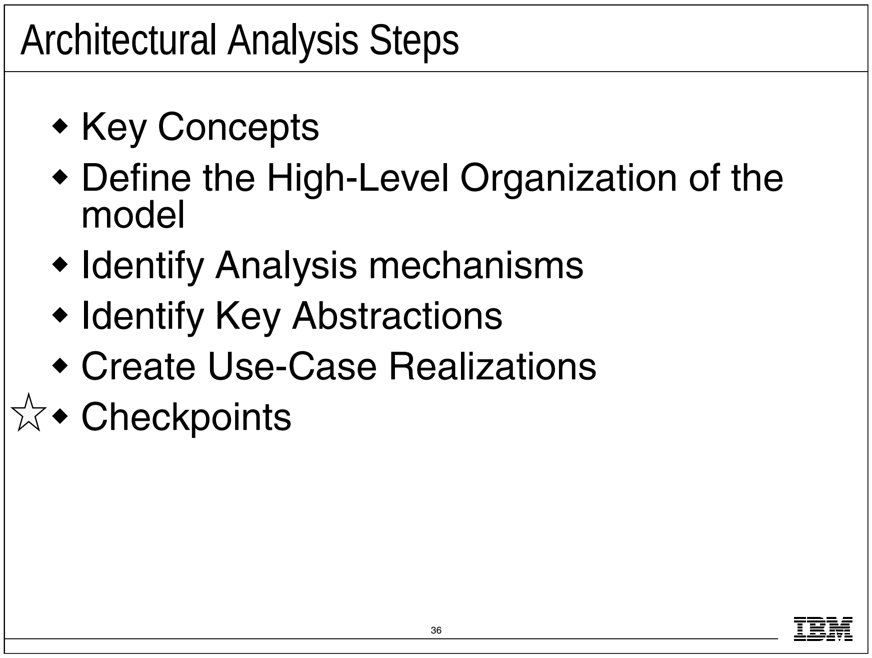
Requirements (Use-Case Model)

Analysis & Design (Design Model)

Use cases form the central focus of most of the early analysis and design work. To enable the transition between requirements-centric activities and design-centric activities, the use-case realization serves as a bridge, providing a way to trace behavior in the Design Model back to the Use-Case Model, as well as organizing collaborations in the Design Model around the use-case concept.

For each Use Case in the Use-Case Model, create a use-case realization in the Design Model.The name for the use-case realization should be the same as the associated use case, and a realize relationship should be established from the use-case realization to its associated use case.

Instructor Notes:



Architectural Analysis Steps

- Key Concepts
- Define the High-Level Organization of the model
- Identify Analysis mechanisms
- Identify Key Abstractions
- Create Use-Case Realizations
- ☆ Checkpoints

36

This is where the quality of the architecture modeled up to this point is assessed against some very specific criteria.

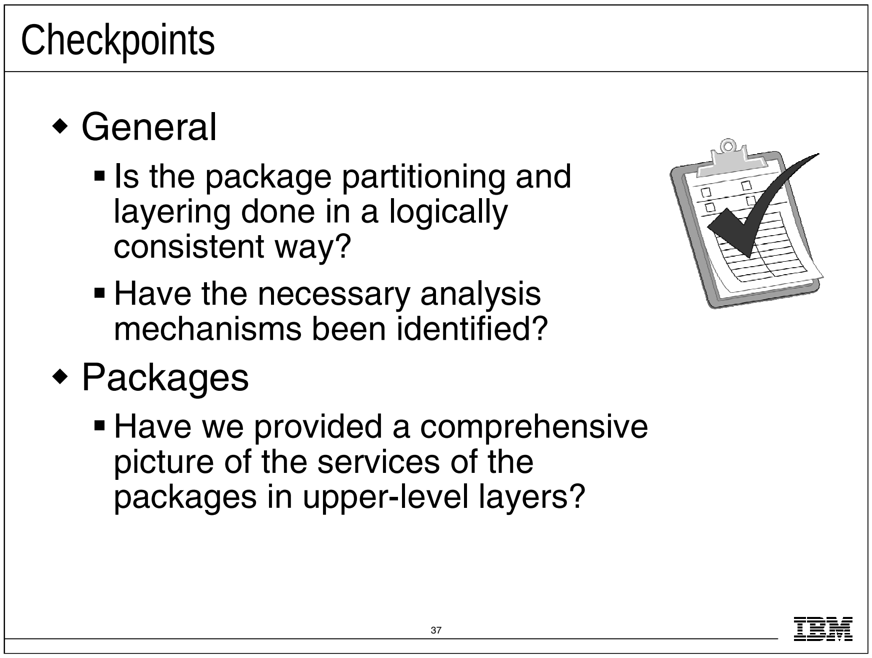
In this module, we will concentrate on those checkpoints that the designer is most concerned with (that is, looks for). The architect should do a much more detailed review of the **Architectural Analysis** results and correct any problems before the project moves on to the next activity. We will not cover those checkpoints, as they are out of scope of this course. (Remember, this is not an architecture course.)

Instructor Notes:

You do not need to read each bullet to the students. Just discuss a few of the key checkpoints.

The checklist shown on the next few slides represents an adaptation of the Design Model Checklist given in the Rational Unified Process, as only a subset of the Design Model review criteria really applies at Architectural Analysis.
Also, we have only listed those checkpoints that a designer would care about. The architect has a much more detailed list of checkpoints.

The complete checklist is provided in the Rational Unified Process.



Checkpoints

- General
  - Is the package partitioning and layering done in a logically consistent way?
  - Have the necessary analysis mechanisms been identified?
- Packages
  - Have we provided a comprehensive picture of the services of the packages in upper-level layers?

37

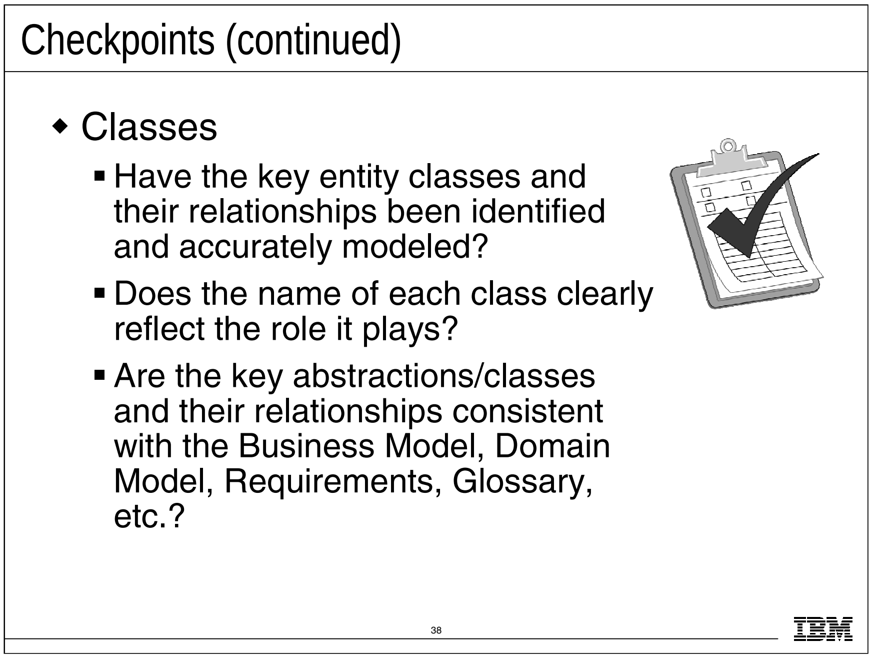
The next few slides contains the key things a designer would look for when assessing the results of **Architectural Analysis**. An architect would have a more detailed list.

A well-structured architecture encompasses a set of classes, typically organized into multiple hierarchies

Note: At this point, some of the packages/layers may not contain any classes, and that is okay. More classes will be identified over time, starting in the next activity, Use-Case Analysis.

Instructor Notes:

Again, the checklist shown on the slide represents an adaptation of the Design Model Checklist given in the Rational Unified Process, as only a subset of the Design Model review criteria really applies at this stage of the software lifecycle (initial Architectural Analysis).



Checkpoints (continued)

- Classes
  - Have the key entity classes and their relationships been identified and accurately modeled?
  - Does the name of each class clearly reflect the role it plays?
  - Are the key abstractions/classes and their relationships consistent with the Business Model, Domain Model, Requirements, Glossary, etc.?

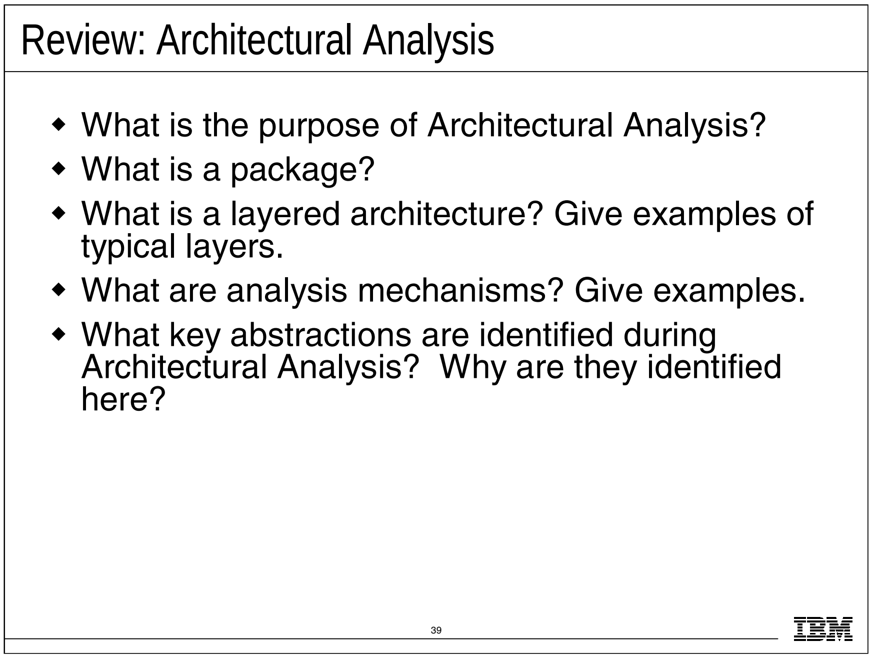
38

IBM

A well-structured class provides a crisp abstraction of something drawn from the vocabulary of the problem domain or the solution domain.

Instructor Notes:

1. The purpose of Architectural Analysis is to define a candidate architecture for the system based on experience gained from similar systems or in similar problem domains.
2. A **package** is a general-purpose mechanism for organizing elements into groups.
3. **Layers** are used to encapsulate conceptual boundaries between different kinds of services and provide useful abstractions that make the design easier to understand. Typical layers include: Application, Business-Specific, Middleware, and System Software.
4. **Analysis mechanisms** capture the key aspects of a solution in a way that is implementation-independent. Examples include mechanisms to handle persistence, inter-process communication, error or fault handling, notification, and messaging, to name a few.
5. Requirements and Business Modeling activities usually uncover key concepts that the system must be able to handle. These concepts manifest themselves as key design abstractions. Because of the work already done, there is no need to repeat the identification work again during Use-Case Analysis.



Review: Architectural Analysis

- What is the purpose of Architectural Analysis?
- What is a package?
- What is a layered architecture? Give examples of typical layers.
- What are analysis mechanisms? Give examples.
- What key abstractions are identified during Architectural Analysis? Why are they identified here?

Instructor Notes:

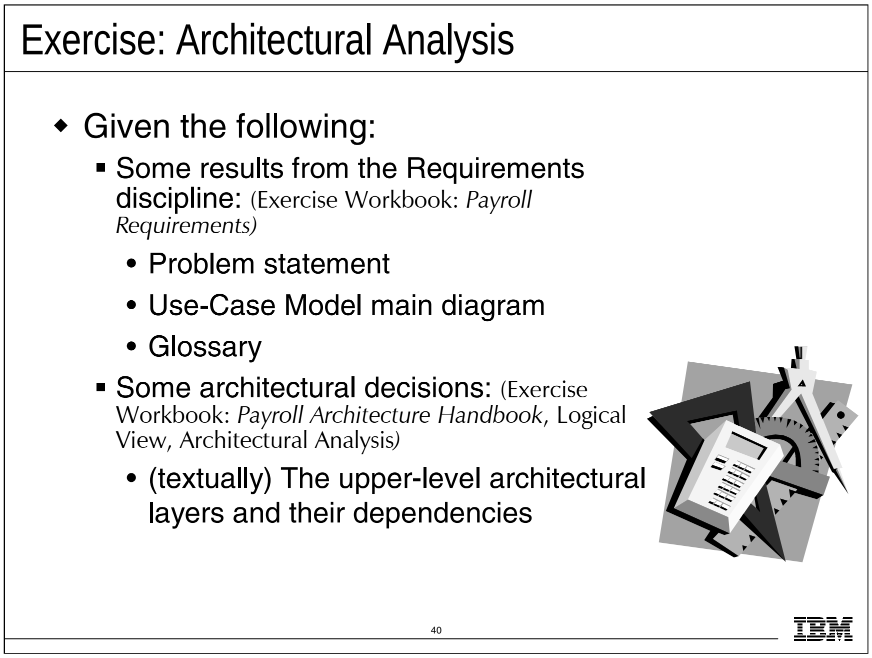
Have each student work individually on this exercise. Review and compare/contrast results.

If you are teaching to a very introductory audience, you may want try one of the following:

• Run this exercise as a group exercise, with the instructor facilitating, or

• Walk through the solution in the Payroll Exercise Solution book.

However, keep in mind that the whole idea behind an exercise is to give the students a chance to apply what they have learned. Thus, use your best judgment when choosing a delivery option for this exercise.



Exercise: Architectural Analysis

- Given the following:
  - Some results from the Requirements discipline: (Exercise Workbook: *Payroll Requirements)*
    - Problem statement
    - Use-Case Model main diagram
    - Glossary
  - Some architectural decisions: (Exercise Workbook: *Payroll Architecture Handbook*, Logical View, Architectural Analysis*)*
    - (textually) The upper-level architectural layers and their dependencies

40

IBM

The goal of this exercise is to jump-start analysis.

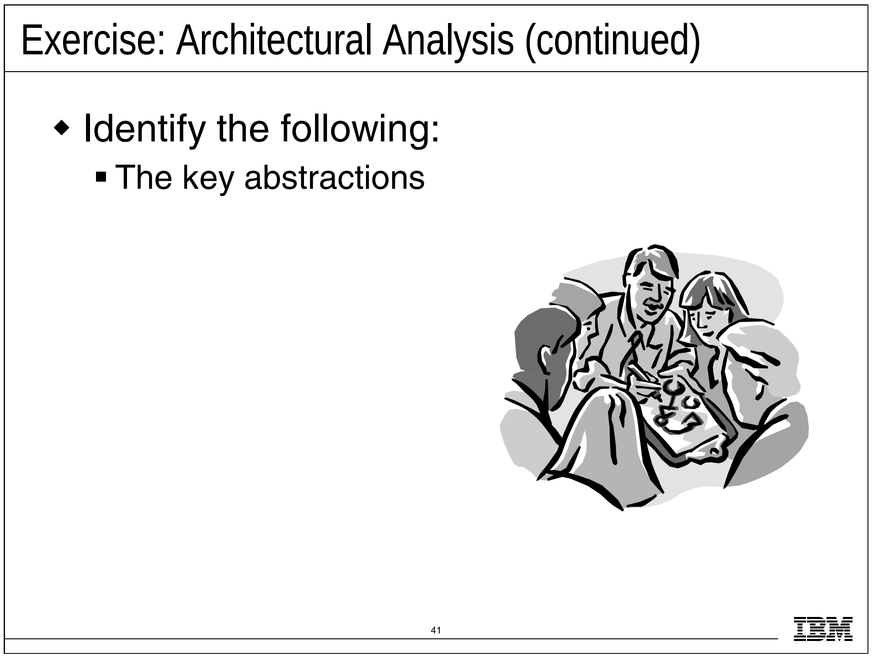
References to givens:

- **Requirements Results**: Exercise Workbook: *Payroll Requirements*
- **Architectural Decisions**: Exercise Workbook: *Payroll Architecture Handbook*, Logical View, Architectural Analysis section.

Note: This exercise has been tightly scoped to emphasize the Analysis and Design modeling concepts and reduce the emphasis on architectural issues. Thus, much of the architecture has been provided to you, rather than asking you to provide it as part of the exercise. Remember, this is not an architecture course.

Instructor Notes:

Review what is meant by a "key abstraction," as well as just how much modeling is done at this point.



Exercise: Architectural Analysis (continued)

- Identify the following:
  - The key abstractions

41

IBM

To identify the key abstractions, you can probably concentrate on the Problem Statement and the Glossary.

Create a class to represent each key abstraction. Be sure to include a brief description for each class. You do not need to allocate the classes to packages. That will occur in the next module. You do not need to define relationships between the classes at this point. We will concentrate on class relationships in later modules.

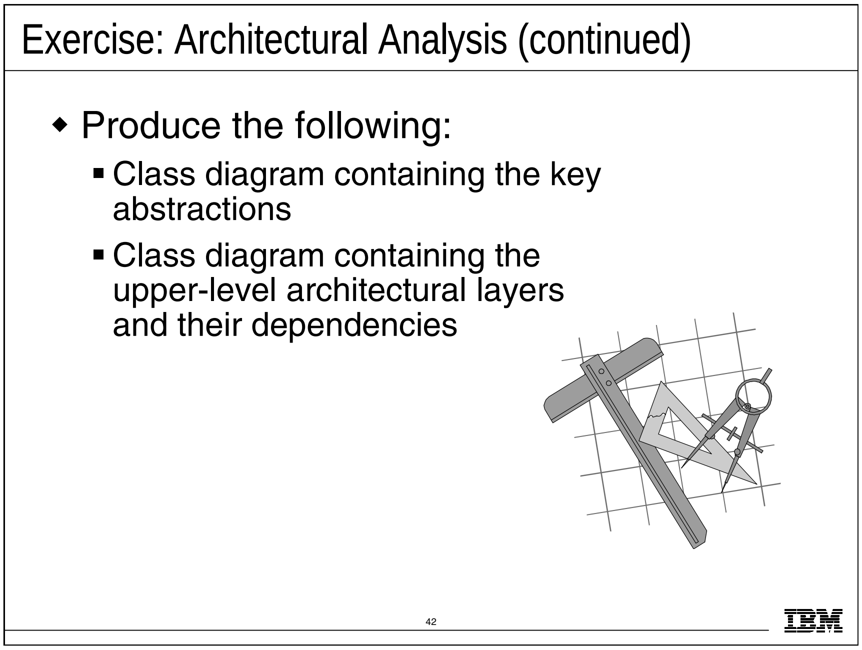
The class diagrams of the upper-level layers and their dependencies should be drawn using the given textual descriptions.

References to sample diagrams within the course that are similar to what should be produced are:

Refer to the following slides if needed;

- What Are Key Abstractions – p. 5-30
- Defining Key Abstractions – p. 5-31

Instructor Notes:



Exercise: Architectural Analysis (continued)

- Produce the following:
  - Class diagram containing the key abstractions
  - Class diagram containing the upper-level architectural layers and their dependencies

42

IBM

You will need to create two different class diagrams in this solution: one showing the key abstractions and one showing the architectural layers and their dependencies.

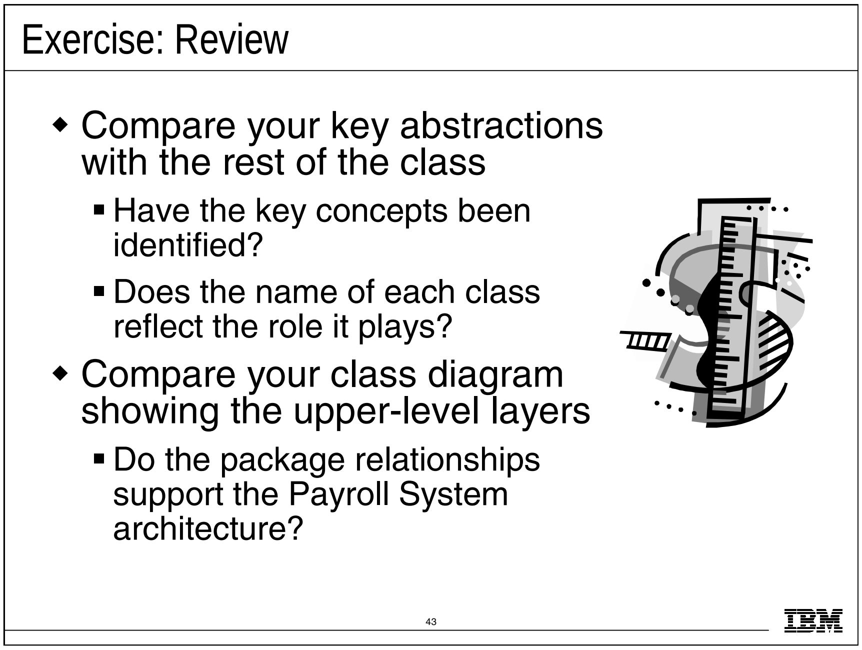
Refer to the following slides if needed;

- Package Relationships: Dependency – p. 5-8
- Example: Key Abstractions – p. 5-32
- Example: High-level Organization of the Model – p. 5-19

Instructor Notes:

Walk the students through the architectural layers. (They reviewed the requirements artifacts in the previous exercise.)

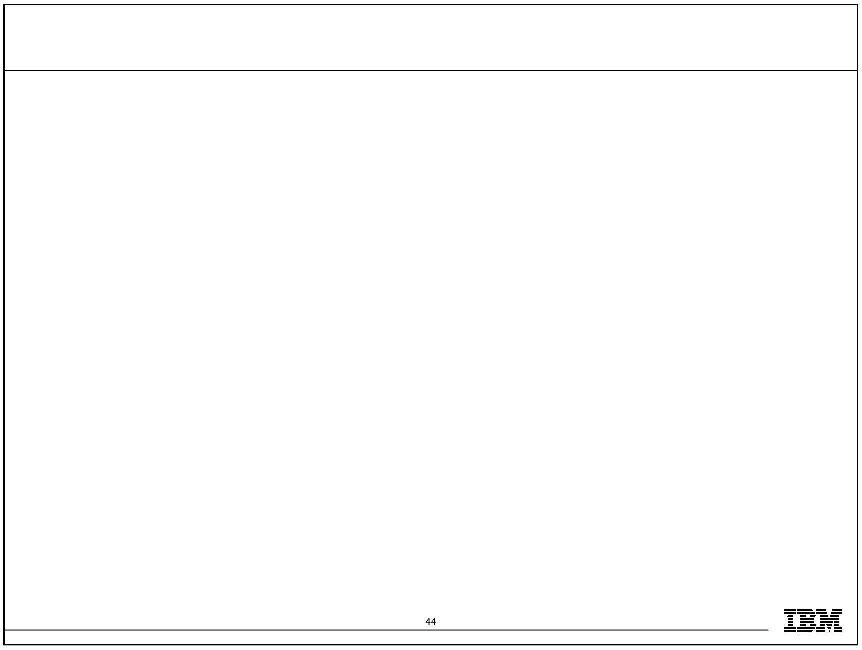
The exercise solution can be found in the Payroll Exercise Solution book, Exercise: Architectural Analysis section. See the table of contents for the specific page numbers. Discuss any questions that they might have.



Exercise: Review

- Compare your key abstractions with the rest of the class
  - Have the key concepts been identified?
  - Does the name of each class reflect the role it plays?
- Compare your class diagram showing the upper-level layers
  - Do the package relationships support the Payroll System architecture?

Instructor Notes:



44