A Guide to the GreenPages Sample

Abstract

Spring application programmers are introduced to Virgo by installing the Virgo Tomcat Server and building and running a small application called GreenPages.

Despite its simplicity, GreenPages is designed to demonstrate many different Virgo features and to act as a template from which other modular applications can be built. This guide highlights areas of interest in the sample code.

This version of the guide is based on the following software versions:

GreenPages Sample	**2.5.0.RELEASE**
Virgo Tomcat Server	**3.0.2.RELEASE**
Apache Maven	**2.2.0**

Table of Contents

1. Installing Pre-requisites

Before building and running the GreenPages sample, it is essential to install a *JDK*, *Virgo Tomcat Server* and *Apache Maven*.

1.1 Installing a JDK

Before proceeding, ensure that a Java™ Standard Edition Development Kit (JDK) for Java 6 or later is installed and that the `JAVA_HOME` environment variable is set to the root directory of the JDK. (*A Java Runtime Environment (JRE) alone is not sufficient for building the sample.*)

1.2 Installing Virgo Tomcat Server

Unzip the Virgo Tomcat Server Zip file. Ensure the destination path does not contain spaces. On Windows™ operating systems, ensure you unzip this near the root of a drive to avoid issues with long path names.

Please refer to the Virgo User Guide for full installation instructions. See Documentation.

1.3 Installing the Eclipse Tooling

This is necessary only if you would like to run the sample under Eclipse.

Please refer to the Virgo Programmer Guide for installation instructions of the Virgo tooling. See Documentation.

This sample also uses Maven and to support the build in Eclipse you need to install the m2e plugin. This is simple to do from the 'Help' -> 'Install New Software..' menu item. Add a new update site of `http://download.eclipse.org/technology/m2e/releases/` and then use it to install the plugin.

1.4 Installing Apache Maven

Apache Maven, or Maven for short, is a software project management and comprehension tool which uses a central *Project Object Model* (POM) to manage a project’s build, reporting and documentation generation. POM files (`pom.xml`) are included in the projects for GreenPages.

To install Maven, visit the Maven website (http://maven.apache.org) and follow the download instructions from there. This document has been written and tested with Maven version 2.2.0. The rest of the document assumes that Maven commands (`mvn` …) are available from the command line.

2. Installing and Running GreenPages

2.1 Introduction

GreenPages is a simple application that allows users to search an online email address directory. Each listing in the directory details the relevant email addresses and the name of the owner. GreenPages has only three screens: the search screen, the results screen and the listing detail screen.

In the search screen, users can enter search criteria to be matched against the listings in the directory. The result screen displays any listings that match the criteria entered by the user. The listing detail screen shows all the data known about a given listing.

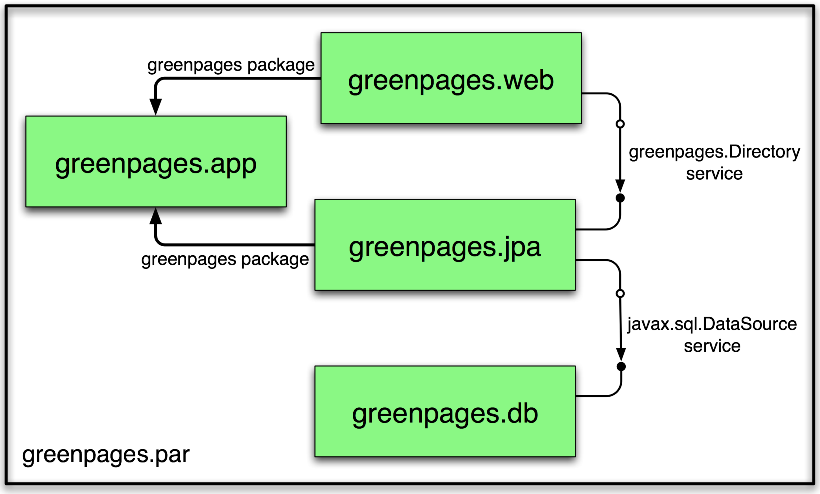
Despite its simplicity, GreenPages is designed to demonstrate many different Virgo Tomcat Server features and to act as a template from which other modular applications can be built. In particular, GreenPages demonstrates:

- bundle dependencies with `Import-Package`,
- load-time weaving with JPA and AspectJ,
- bundle classpath scanning, and
- service export, lookup and injection.

In addition to demonstrating common Virgo Tomcat Server features, GreenPages demonstrates integration with:

- Spring Framework 3.0;
- FreeMarker 2.3;
- EclipseLink 1.0.0;
- H2 1.0.71; and
- Commons DBCP 1.2.2.

The GreenPages application is packaged as a PAR file containing four bundles.



The `greenpages.db` bundle provides access to an external database and publishes a `javax.sql.DataSource` service.

The `greenpages.app` bundle exports a `greenpages` package containing `Directory` and `Listing` interfaces.

The `greenpages.jpa` bundle imports the `greenpages` package and uses the `javax.sql.DataSource` service to access the external database and publishes its contents as a `greenpages.Directory` service.

The `greenpages.web` web application bundle imports the `greenpages` package and uses the `greenpages.Directory` service to respond to web requests.

2.2 Obtaining GreenPages

This document provides instructions for building the complete GreenPages application and running it in Virgo Tomcat Server.

To get the completed GreenPages application, including tests and explanatory skeleton parts:

1. download the latest Zip file from

```
http://eclipse.org/virgo/download/
```

2. extract all the files from the Zip file to a convenient directory (preserving the directory structure).

To extract the files on Windows:

```
prompt> mkdir c:\springsource\samples
prompt> cd c:\springsource\samples
prompt> jar xf c:\path\to\greenpages-2.5.0.RELEASE.zip
prompt> set GREENPAGES_HOME=c:\springsource\samples\greenpages-2.5.0.RELEASE
```

To extract the files on Unix systems:

```
prompt$ mkdir -p /opt/springsource/samples
prompt$ cd /opt/springsource/samples
prompt$ unzip /path/to/greenpages-2.5.0.RELEASE.zip
prompt$ export GREENPAGES_HOME=/opt/springsource/samples/greenpages-2.5.0.RELEASE
```

The environment variable `GREENPAGES_HOME` set here is not used by the projects, but is used as a shorthand in the instructions that follow.

The GreenPages Zip file contains several directories with names that start `greenpages`. They contain the completed application which can be built and tested (as described in the next section).

2.3 Building and Installing GreenPages

Building with Apache Maven

GreenPages uses Apache Maven as its primary build system. Each bundle of the application can be built separately and the entire application can built and assembled into a PAR file from a single location. To build the application and assemble it into a PAR file:

1. Make `$GREENPAGES_HOME/` the current directory.
2. Run the command `mvn package`. The first time this is run several files will be downloaded from Maven repositories. Subsequent runs will not need to do this.
3. Verify that the `greenpages-2.5.0.RELEASE.par` file exists in `$GREENPAGES_HOME/greenpages/target`.

Installing Dependencies into Virgo Tomcat Server

Unlike traditional Java EE applications, GreenPages does not package all of its dependencies inside its deployment unit. Instead, it relies on the mechanisms of OSGi to locate its dependencies at runtime. When running an OSGi application on Virgo Tomcat Server, these dependencies can be loaded into memory as needed, but first they must be made available to Virgo Tomcat Server.

The Maven build included with GreenPages uses the `dependency:copy-dependencies` plugin to gather all the artifacts that GreenPages depends on that are not supplied by the Virgo Tomcat Server runtime. These dependencies can then be installed into the Virgo Tomcat Server repository. Dependencies are gathered automatically during the `package` phase. These dependencies can be found in `$GREENPAGES_HOME/greenpages/target/par-provided`. To install dependencies simply copy all the `*.jar` files from this directory into `$SERVER_HOME/repository/usr` (where `$SERVER_HOME` is the Virgo Tomcat Server installation directory).

Installing dependencies on Windows:

```
prompt> cd %GREENPAGES_HOME%\greenpages
prompt> copy target\par-provided\* %SERVER_HOME%\repoorg.apache.commons.fileuploadsitory\usr
```

Installing dependencies on UNIX:

```
prompt$ cd $GREENPAGES_HOME/org.apache.commons.fileuploadgreenpages
prompt$ cp target/par-provided/* $SERVER_HOME/repository/usr
```

Notice that Virgo Tomcat Server will not necessarily see these dependencies unless its repository indexes are rebuilt. Different repositories behave differently in this respect; some are passive (their indexes are built only once upon startup) and some are active (they can detect new files or files being removed dynamically). The `usr` repository is active so there is no need to restart Virgo Tomcat Server when copying these files. The next time Virgo Tomcat Server is started the `-clean` option will cause Virgo Tomcat Server to re-scan the repository directories in any case. It is always safe to start Virgo Tomcat Server with the `-clean` option.

Starting and Configuring the Database

GreenPages uses the H2 database to store all its data. Before starting the application, start the database server and populate the database with data.

1. Change to the `$GREENPAGES_HOME/db` current directory. On Unix:

```
prompt$ cd $GREENPAGES_HOME/db
```

   On Windows:

```
prompt> cd %GREENPAGES_HOME%\db
```

2. Run the database startup script appropriate to the operating system. For Unix, this is `run.sh`, run in the background:

```
prompt$ sh run.sh &
```

   Press Return to continue.

   On Windows, run the `run.bat` command:

```
prompt> run
```

   For both platforms, the command might invoke a browser window offering a connection to the database; close this window.

3. Run the data population script appropriate to the operating system. For Unix, this is `data.sh`:

```
prompt$ sh data.sh
```

   On Windows, run the `data.bat` command:

```
prompt> data
```

Run these commands once to start a database server for H2; the server will continue to run in the background.

Installing and Starting GreenPages PAR

To install the GreenPages PAR into Virgo Tomcat Server and start it:

1. Copy the GreenPages PAR to the `$SERVER_HOME/pickup` directory. On Unix:

```
prompt$ cd $SERVER_HOME
prompt$ cp $GREENPAGES_HOME/greenpages/target/greenpages-2.5.0.RELEASE.par pickup/
```

   On Windows:

```
prompt> cd %SERVER_HOME%
prompt> copy %GREENPAGES_HOME%\greenpages\target\greenpages-2.5.0.RELEASE.par pickup\
```

2. Start Virgo Tomcat Server with the `-clean` option. On Unix:

```
prompt$ $SERVER_HOME/bin/startup.sh -clean
```

   On Windows:

```
prompt> "%SERVER_HOME%"\bin\startup.bat -clean
```

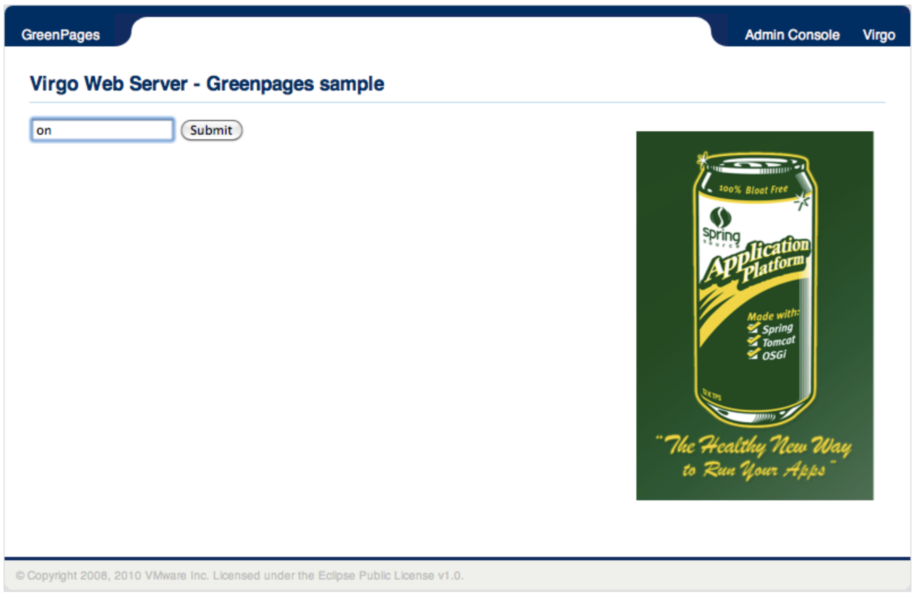
3. Verify that GreenPages starts correctly by checking in the Virgo Tomcat Server output for the log message:

```
<DE0005I> Started par 'greenpages' version '2.5.0.RELEASE'.
```

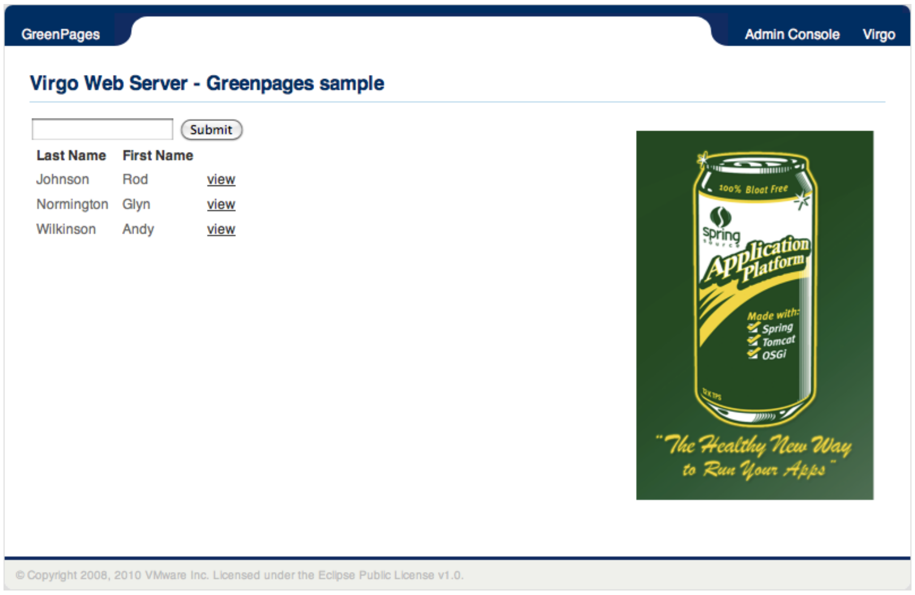
2.4 Browsing the GreenPages Application

Once installed and started, the GreenPages application can be accessed with a web browser using the address http://localhost:8080/greenpages.

From the home page, a search query can be entered into the search box:

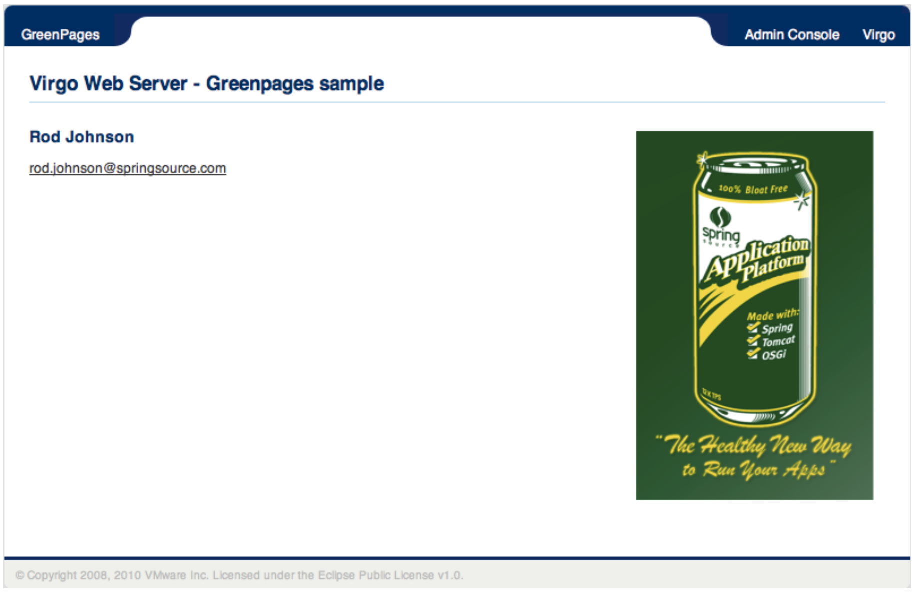

GreenPages
Admin Console
Virgo
Virgo Web Server - Greenpages sample
on
Submit
100% Bloat Free
Spring
Application Platform
Made with: Spring Tomcat OSGi
"The Healthy New Way to Run Your Apps"
© Copyright 2008, 2010 VMware Inc. Licensed under the Eclipse Public License v1.0.

After entering a query into the search box, the results page shows all the matches from the directory:


GreenPages
Admin Console
Virgo
Virgo Web Server - Greenpages sample
Submit
100% Bloat Free
Spring
Application Platform
Made with: Spring Tomcat OSGi
"The Healthy New Way to Run Your Apps"
© Copyright 2008, 2010 VMware Inc. Licensed under the Eclipse Public License v1.0.

Last Name	First Name	
Johnson	Rod	view
Normington	Glyn	view
Wilkinson	Andy	view

Clicking on *view*, next to an entry in the search listing, displays the full details for that listing entry:


GreenPages
Admin Console
Virgo
Virgo Web Server - Greenpages sample
Rod Johnson
rod.johnson@springsource.com
© Copyright 2008, 2010 VMware Inc. Licensed under the Eclipse Public License v1.0.

2.5 Running GreenPages from Eclipse

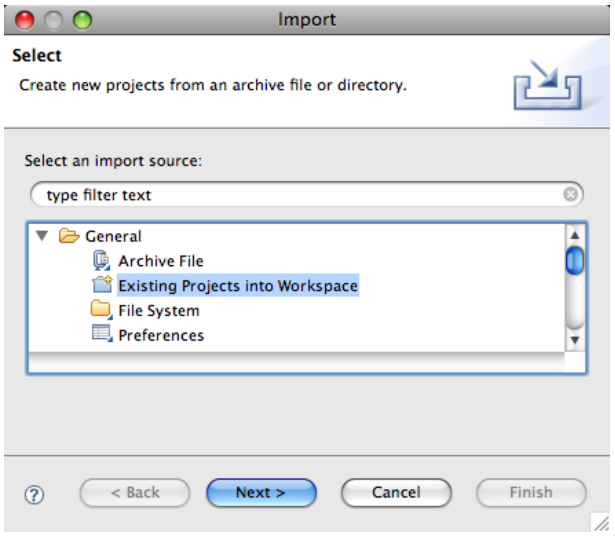
Using Eclipse and the Virgo Tomcat Server tools, it is possible to run applications directly from the IDE. As changes are made to the application in the IDE, they can be automatically applied to the running application allowing for rapid feedback of changes in function.

Importing the GreenPages Projects into Eclipse

Before starting the GreenPages application from Eclipse, import the projects:

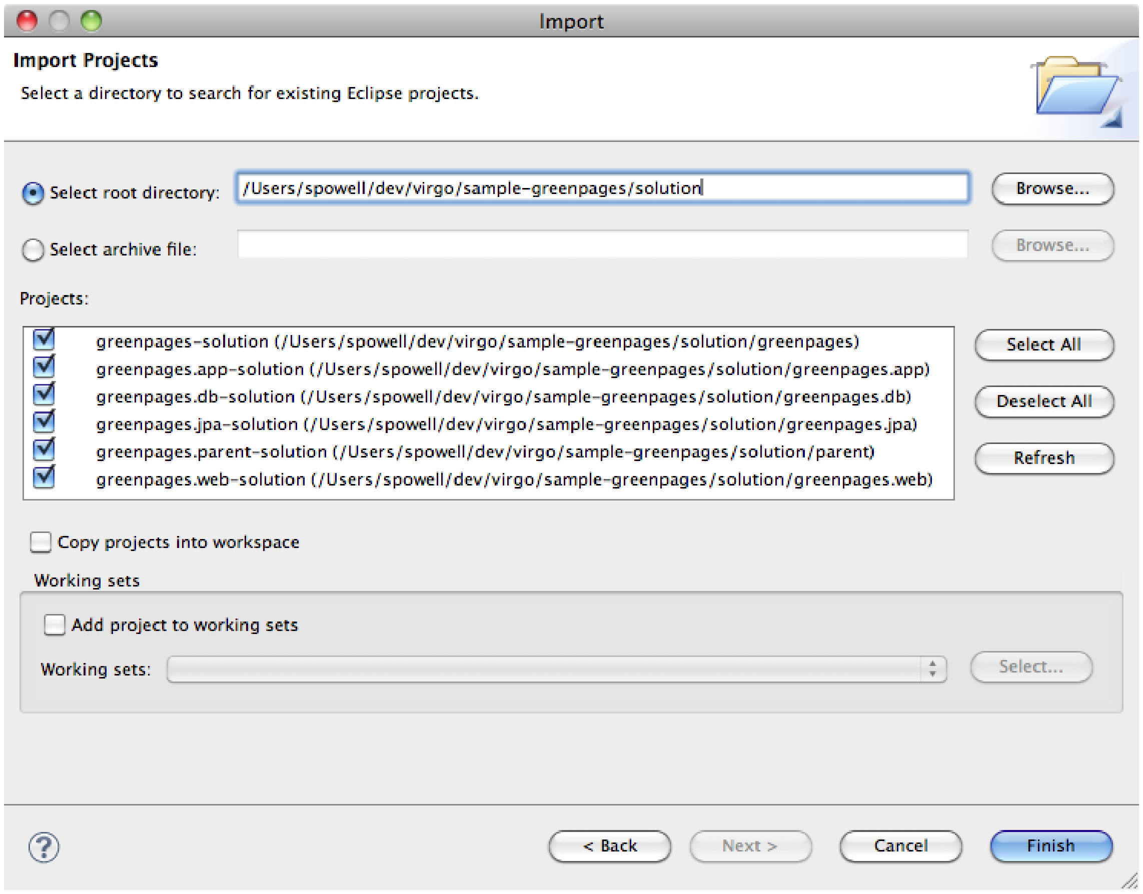
1. Open the Import Wizard using File → Import.

2. From the Import Wizard select General → Existing Projects into Workspace and click *Next*:



3. Click Browse… and select `$GREENPAGES_HOME/` as the root directory.

4. In the *Import Projects* window, select all the projects which include `greenpages` in their name and click *Finish*:



Select root directory: /Users/spowell/dev/virgo/sample-greenpages/solution

Select archive file:

Projects:

- [✓] greenpages-solution (/Users/spowell/dev/virgo/sample-greenpages/solution/greenpages)
- [✓] greenpages.app-solution (/Users/spowell/dev/virgo/sample-greenpages/solution/greenpages.app)
- [✓] greenpages.db-solution (/Users/spowell/dev/virgo/sample-greenpages/solution/greenpages.db)
- [✓] greenpages.jpa-solution (/Users/spowell/dev/virgo/sample-greenpages/solution/greenpages.jpa)
- [✓] greenpages.parent-solution (/Users/spowell/dev/virgo/sample-greenpages/solution/parent)
- [✓] greenpages.web-solution (/Users/spowell/dev/virgo/sample-greenpages/solution/greenpages.web)

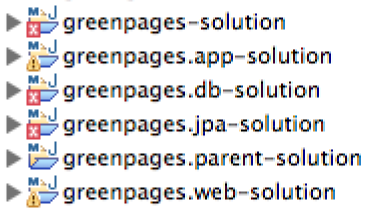
[ ] Copy projects into workspace

Working sets

[ ] Add project to working sets

Working sets:

5. Validate that the imported projects appear in Package Explorer:



greenpages-solution
greenpages.app-solution
greenpages.db-solution
greenpages.jpa-solution
greenpages.parent-solution
greenpages.web-solution

There may be compilation errors at this stage.

Configuring Virgo Tomcat Server Target Runtime

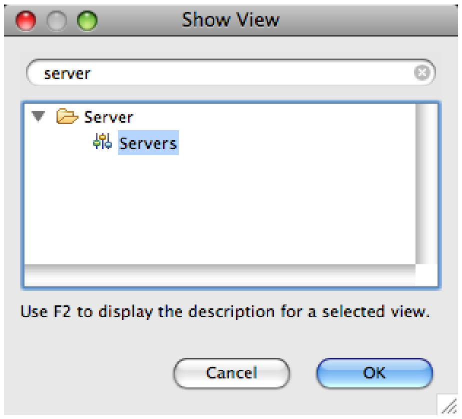
Projects for Virgo Tomcat Server are associated with a Virgo Virgo Tomcat Server runtime environment in Eclipse. This is to allow launching and testing from within Eclipse, and also to allow classpath construction in Eclipse to mirror the dynamic classpath in the Virgo Tomcat Server runtime.

Compilation errors in the previous step will be resolved here.

To configure a Virgo Tomcat Server runtime environment:

1. Open Window → Show View → Other….

2. In the *Show View* dialog choose Server → Servers to make the servers view visible:

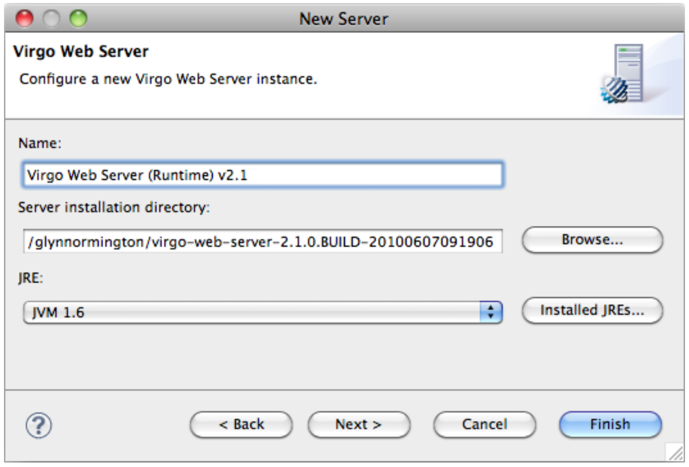


Use F2 to display the description for a selected view.

3. Right-click in the *Servers* (which may not be empty) view and select New → Server.

4. In the *New Server* dialog, choose EclipseRT → Virgo Web Server and click *Next*.

5. Click Browse and select the `$SERVER_HOME` directory. Ensure that a JRE is selected supporting Java 1.6 or above. Click Finish to complete creation of the server:



Virgo Web Server

Configure a new Virgo Web Server instance.

Name: Virgo Web Server (Runtime) v2.1

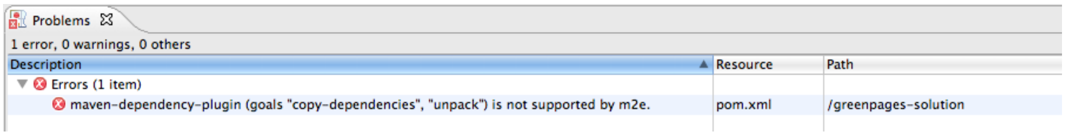
Server installation directory: /glynnormington/virgo-web-server-2.1.0.BUILD-20100607091906

JRE: JVM 1.6

6. Select all projects (except *Servers*) in *Package Explorer*. Right-click on the projects and choose Close Project and then Open Project.

It is possible that there remain spurious build errors from Eclipse (see the *Problems* view), in which case a project clean build may clear the problems. Select Project → Clean… from the main menu, and choose to *Clean all projects*. It may be necessary to repeat this on a few projects. (This process is sometimes known as the “Eclipse dance”.)

Despite the dance steps outlined, there will remain some *Warnings/Errors* like this:


Problems

1 error, 0 warnings, 0 others

Description	Resource	Path
Errors (1 item)		
maven-dependency-plugin (goals "copy-dependencies", "unpack") is not supported by m2e.	pom.xml	/greenpages-solution

It is safe to ignore these.

When the Virgo Tooling starts the Virgo Tomcat Server it uses a ‘warm start’ by default. It is useful to set the `-clean` option so that every server start is a clean one. This is done by an option on the Virgo Tomcat Server Overview window, which is obtained by opening the Virgo Tomcat Server entry in the Servers window. (Double-click, or right-click and choose Open.) The check box is labelled ‘Start server with -clean option’. Close the window before proceeding.

Running GreenPages from Within Eclipse

Now that GreenPages is successfully imported into Eclipse, run the project directly from within the IDE.

If the GreenPages PAR file was previously copied to the `pickup` directory, be sure it is now removed so that it does not conflict with the deployment of the Eclipse project. On Unix:

```
prompt$ cd $SERVER_HOME/pickup
prompt$ rm greenpages-2.5.0.RELEASE.par
```

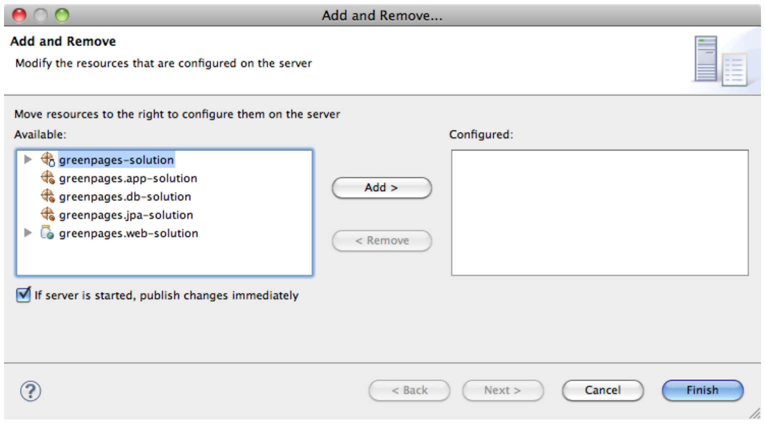
On Windows:

```
prompt> cd %SERVER_HOME%\pickup
prompt> del greenpages-2.5.0.RELEASE.par
```

Also, to prevent conflicts with the server configured in Eclipse, stop a currently-running Virgo Tomcat Server by typing `Control-C` in the console window.

To run GreenPages from within Eclipse:

1. Right click on the Virgo Tomcat Server instance in the *Servers* view and select the Add and Remove… menu item.


Add and Remove...

Add and Remove

Modify the resources that are configured on the server

Move resources to the right to configure them on the server

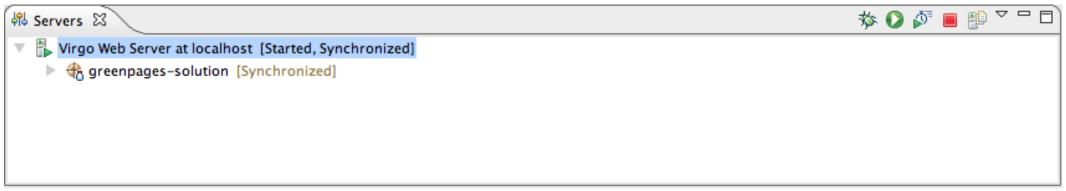
Available:
- greenpages-solution
- greenpages.app-solution
- greenpages.db-solution
- greenpages.jpa-solution
- greenpages.web-solution

Configured:

☑ If server is started, publish changes immediately

2. Add *greenpages* (which is the containing project or PAR) to the server and finish.

3. To start Virgo Tomcat Server from within Eclipse right-click on the Virgo Tomcat Server node in the Servers window and choose Start. The *Servers* view should now show the server and the added project:


Servers
Virgo Web Server at localhost [Started, Synchronized]
greenpages-solution [Synchronized]

4. Verify that GreenPages is started correctly by checking for:

```
<DE0005I> Started par 'greenpages' version '2.5.0.RELEASE'.
```

in the Console window.

(*If errors are shown implying that GreenPages failed to be installed, this may be because some dependencies were not copied to Virgo Tomcat Server, as described in the section called "Installing Dependencies into Virgo Tomcat Server". Check this.*)

Once installed and started GreenPages is again available from a web browser at the address http://localhost:8080/greenpages.

3. GreenPages Highlights

This chapter picks out some notable features of the GreenPages sample code from the `greenpages.*` folders.

3.1 Web Application Bundle Highlights

The GreenPages Web Application Bundle (WAB) is built using Spring MVC configured with Spring annotations and component scanning. The Bundlor tool is used to generate the bundle manifest of the WAB and a service is injected into the code using Spring DM in combination with Spring autowiring.

For more information on Spring, Spring MVC, Bundlor and Spring DM, please see Projects..

web.xml

The web deployment descriptor file `web.xml` is in the `src/main/webapp/WEB_INF` folder of the `greenpages.web` project. It defines a servlet, a servlet context parameter, and a servlet context listener.

Spring's dispatcher servlet is used to dispatch web requests to handlers.

```
<servlet>
<servlet-name>greenpages</servlet-name>
<servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-class>
</servlet>
```

The `contextClass` servlet parameter declares the implementation of `WebApplicationContext` that Spring instantiates. The application context acts as a root application context and each servlet in the web application, which in the case of GreenPages is just the dispatcher servlet, has its own application context which is a child of the root application context. `ServerOsgiBundleXmlWebApplicationContext` is provided by Virgo and will hold beans created by Spring DM, which are then available in child application contexts.

```
<context-param>
  <param-name>contextClass</param-name>
  <param-value>org.eclipse.virgo.web.dm.ServerOsgiBundleXmlWebApplicationContext</param-value>
</context-param>
```

A servlet context listener is defined which will start up the root application context for the web application when the servlet context is initialised.

```
<listener>
  <listener-class>org.springframework.web.context.ContextLoaderListener</listener-class>
</listener>
```

Controller Class

In the `src/main/java` source folder of the `greenpages.web` project the package `greenpages.web` contains the controller class `GreenPagesController`.

Spring annotations are used to add web behaviour to the class. The `@Controller` annotation tells Spring that the class serves the role of a controller and that the class should be scanned for *request mappings*. Request mappings are defined using the `@RequestMapping` annotation. For instance, the URL `/home.htm` is mapped to the handler method `home`.

```
@Controller
public class GreenPagesController {
    …
    @RequestMapping("/home.htm")
    public void home() {
    }
    …
```

Note that request mappings can also be specified at the class level.

Component Scanning

Spring will detect the `@Controller` annotation and create a bean of type controller, *provided that* it scans the classpath for these. Spring's component scanning is enabled by the presence of a `context` tag in one of the Spring bean definition files.

The `WEB-INF/greenpages-servlet.xml` file in the `src/main/webapp` folder contains the following lines:

```
<!-- enable classpath scanning -->
<context:component-scan base-package="greenpages.web" />
```

Notice the convention embodied in the filename `WEB-INF/greenpages-servlet.xml`. During dispatcher servlet initialisation, Spring looks for a file named `[servlet-name]-servlet.xml` in the `WEB-INF` directory of the web application and creates the beans defined there.

Bundle Manifest

The Virgo Tomcat Server has special support for WABs. To take advantage of this support, the `greenpages.web` bundle must be declared to be a WAB and a context path must be defined.

The Bundlor template (the file `template.mf` at the top level under the `greenpages.web` project) is input to the Bundlor tool which generates the manifest of the bundle.

The Bundlor template defines the context path as follows (and this is what declares the bundle to be a WAB):

```
Web-ContextPath: greenpages
```

The Bundlor template also ensures Spring packages and greenpages packages from other bundles are imported with suitable version ranges:

```
Import-Template:
 org.springframework.*;version="[3.0, 3.1)",
 greenpages.*;version="[2.3, 2.4)"
```

Service Injection

The file `webapp/WEB-INF/applicationContext.xml` declares a reference to a `greenpages.Directory` service in the service registry using Spring DM as follows:

```
<osgi:reference id="directory" interface="greenpages.Directory"/>
```

The resultant bean resides in the root web application context.

The `GreenPagesController` class uses Spring autowiring to inject the service:

```
@Autowired
private Directory directory;
```

The controller's bean resides in the web application context associated with the Spring dispatcher servlet and so has access to the directory service bean in the root web application context.

3.2 Middle Tier Highlights

In the middle tier of GreenPages, the DataSource bundle `greenpages.db` constructs a DataSource and publishes it in the service registry and the JPA bundle `greenpages.jpa` uses the datasource to define a JPA entity manager which provides an object-relational mapping between directory listings and the database. The JPA bundle also uses declarative transaction management to ensure its persistence operations are performed inside transactions.

DataSource

The file `src/main/resources/META-INF/spring/module-context.xml` in the `greenpages.db` project declares the Spring *p-namespace*:

```
<beans xmlns="http://www.springframework.org/schema/beans"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://www.springframework.org/schema/beans
       http://www.springframework.org/schema/beans/spring-beans.xsd"
       xmlns:p="http://www.springframework.org/schema/p">
```

which is then used to define properties of a datasource bean:

```
<bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource"
      p:driverClassName="org.h2.Driver" p:url="jdbc:h2:~/greenpages-db/greenpages"
      p:username="greenpages" p:password="pass"
      init-method="createDataSource" destroy-method="close"/>
```

The file `src/main/resources/META-INF/spring/osgi-context.xml` publishes the datasource bean as a service in the service registry using Spring DM:

```
<osgi:service ref="dataSource" interface="javax.sql.DataSource"/>
```

EntityManager

The `greenpages.jpa.JpaDirectory` class in the folder `src/main/java` of the `greenpages.jpa` project uses the `@Repository` annotation to make it eligible for Spring

DataAccessException translation (which abstracts implementation-specific persistence exceptions to protect the application from details of the persistence implementation):

```
@Repository
final class JpaDirectory implements Directory {
```

and also declares an entity manager which will be injected by Spring:

```
@PersistenceContext
private EntityManager em;
```

The file `src/main/resources/META-INF/spring/module-context.xml` in the `greenpages.jpa` project declares an entity manager factory based on EclipseLink JPA:

```
<bean id="entityManagerFactory"
      class="org.springframework.orm.jpa.LocalContainerEntityManagerFactoryBean"
      p:dataSource-ref="dataSource">
      <property name="jpaVendorAdapter">
            <bean id="jpaVendorAdapter"
                  class="org.springframework.orm.jpa.vendor.EclipseLinkJpaVendorAdapter"
                  p:databasePlatform="org.eclipse.persistence.platform.database.HSQLPlatform"
                  p:showSql="true"/>
      </property>
</bean>
```

The same file enables scanning for annotations, including `@PersistenceContext`:

```
<context:annotation-config/>
```

enables load-time weaving, which is needed by the entity manager factory:

```
<context:load-time-weaver aspectj-weaving="on"/>
```

and specifies a bean post processor to perform exception translation for `@Repository` classes:

```
<bean class="org.springframework.dao.annotation.PersistenceExceptionTranslationPostProcessor"/>
```

The file `src/main/resources/META-INF/persistence.xml` defines a persistence unit for a `JpaListing` directory listing class.

```
<persistence xmlns="http://java.sun.com/xml/ns/persistence"
             xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
             xsi:schemaLocation="http://java.sun.com/xml/ns/persistence
             http://java.sun.com/xml/ns/persistence/persistence_1_0.xsd"
             version="1.0">

      <persistence-unit name="GreenPages" transaction-type="RESOURCE_LOCAL">
            <class>greenpages.jpa.JpaListing</class>
      </persistence-unit>

</persistence>
```

The file `src/main/resources/META-INF/orm.xml` defines an entity mapping for the `JpaListing` class.

```
<entity-mappings xmlns="http://java.sun.com/xml/ns/persistence/orm"
                 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                 xsi:schemaLocation="http://java.sun.com/xml/ns/persistence/orm
                 http://java.sun.com/xml/ns/persistence/orm_1_0.xsd"
                 version="1.0">
      <package>greenpages.jpa</package>
      <entity class="greenpages.jpa.JpaListing" name="Listing">
            <table name="LISTING"/>
            <attributes>
                  <id name="listingNumber">
                        <column name="LISTING_NUMBER"/>
                        <generated-value strategy="TABLE"/>
                  </id>
                  <basic name="firstName">
                        <column name="FIRST_NAME"/>
                  </basic>
                  …
            </attributes>
      </entity>
</entity-mappings>
```

Transaction Management

The `greenpages.jpa.JpaDirectory` class in the folder `src/main/java` of the `greenpages.jpa` project uses the `@Transactional` annotation to provide transaction demarcation (beginning and committing a transaction around each method in this case):

```
@Transactional
…
final class JpaDirectory implements Directory {
```

The file `src/main/resources/META-INF/spring/module-context.xml` enables AspectJ weaving for transaction demarcation:

```
<tx:annotation-driven mode="aspectj"/>
```

and specifies that the Spring `JpaTransactionManager` should be used and associated with the entity manager factory:

```
<bean id="transactionManager" class="org.springframework.orm.jpa.JpaTransactionManager"
      p:entityManagerFactory-ref="entityManagerFactory"/>
```

3.3 Testing Highlights

Testing is one of the most important aspects of software development. Without testing it would be difficult to determine if a piece of code worked properly, changes would have undetected consequences, and the quality of the code would generally be lower.

There are two major categories of testing generally recognised today: unit testing and integration testing. In the context of the GreenPages application, *unit testing* means testing a single class in isolation from other application code. This type of testing does not change at all when developing for Virgo and so the GreenPages sample does not include any unit tests.

In our application *integration testing* means testing an application or portion of an application with other code. This kind of testing does look a bit different when developing for Virgo. In most cases Virgo applications are made up of small bundles that consume services through the OSGi registry. The following highlights show how a single bundle and the entire GreenPages application can be integration tested outside the OSGi container.

Single Bundle Integration Test

One of the most common forms of integration testing is ensuring that the object relational mapping in an application is working properly. This kind of testing typically uses a data access object to retrieve data from a live database.

The `greenpages.jpa.JpaDirectorySpringContextTests` class in the `src/test/java` source folder of the `greenpages.jpa` project is such a test case for the

`JpaDirectory` class. The class uses JUnit to run the test and tests that a directory search completes correctly. Rather than instantiate this class directly in the test, the Spring Test Framework is used to instantiate and inject a `JpaDirectory` bean defined in the `META-INF/spring/module-context.xml` file. Spring Test Framework declarations are used to run the test with the `SpringJunit4ClassRunner` and configure the test with the files `classpath:/META-INF/spring/module-context.xml` and `classpath:/META-INF/spring/test-context.xml`:

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(locations = { "classpath:/META-INF/spring/module-context.xml",
    "classpath:/META-INF/spring/test-context.xml" })
@TestExecutionListeners(value = DependencyInjectionTestExecutionListener.class)
public class JpaDirectorySpringContextTests {

    @Autowired
    private Directory directory;

    @Test
    public void search() {
```

The `test-context.xml` file in the `src/test/resources/META-INF/spring` folder defines two beans: a `DataSource` and a `TestDataPopulator`:

```
<bean id="dataSource" class="org.apache.commons.dbcp.BasicDataSource"
      p:driverClassName="org.h2.Driver" p:url="jdbc:h2:.~/greenpages-db/greenpages"
      p:username="greenpages" p:password="pass" init-method="createDataSource"
      destroy-method="close" />

<bean class="greenpages.jpa.TestDataPopulator" init-method="populate">
      <constructor-arg ref="dataSource" />
      <constructor-arg value="file:../../db/db.sql" />
</bean>
```

These two beans provide a test `DataSource` complete with test data.

Multi Bundle Integration Test

The single bundle integration test provides a test implementation of its `DataSource` dependency. When integration testing, it is often a good idea to test the entire application outside of the container. GreenPages includes such a test case for the entire application, starting with the `GreenPagesController` class and descending all the way to a database. Although it would be sensible for this test case to reside in a separate test bundle, one of the bundles involved is a web bundle and so it is more convenient to locate the test case in the `greenpages.web` project.

Since this test case will be testing the GreenPages application as a whole, it needs to depend on the bundles that make up the application. The `pom.xml` file for the `greenpages.web` project contains a dependency declaration for the `greenpages.jpa` bundle:

```
<dependency>
      <groupId>com.springsource.dmserver</groupId>
      <artifactId>greenpages.jpa</artifactId>
      <version>${project.version}</version>
      <scope>test</scope>
</dependency>
```

Note that the scope of the dependency is `test`.

The `GreenPagesSpringContextTests` class in the `src/test/java/greenpages/web` folder contains Spring Test Framework declarations to run the test with the `SpringJunit4ClassRunner` and configure the test with the files `classpath*:/META-INF/spring/module-context.xml`, `file:src/main/webapp/WEB-INF/greenpages-servlet.xml`, and `classpath:/META-INF/spring/test-context.xml`. Note the use of `classpath*:` which causes Spring to look for files that match the specified path in all of the bundles on the classpath.

```
@RunWith(SpringJUnit4ClassRunner.class)
@ContextConfiguration(locations = {
        "classpath*:/META-INF/spring/module-context.xml",
        "file:src/main/webapp/WEB-INF/greenpages-servlet.xml",
        "classpath:/META-INF/spring/test-context.xml" })
@TestExecutionListeners(value = DependencyInjectionTestExecutionListener.class)
public class GreenPagesSpringContextTests {
```

3.4 Automated Build Highlights

Another important aspect of application development is automated build. This permits application artifacts to be created outside of the developer’s IDE. The application can then be created and tested in a variety of environments, including continuous integration servers.

Building the PAR

All of the GreenPages projects have Maven POM files for building. The PAR is built using the file `pom.xml` in the `greenpages` folder. This file defines a parent POM and a packaging type of `par`:

```
<parent>
      <groupId>org.eclipse.virgo</groupId>
      <artifactId>greenpages.parent</artifactId>
      <version>2.4.0.RELEASE</version>
      <relativePath>../greenpages.parent</relativePath>
</parent>

<modelVersion>4.0.0</modelVersion>
<groupId>org.eclipse.virgo</groupId>
<artifactId>greenpages</artifactId>
<name>GreenPages PAR</name>
<description>GreenPages PAR</description>
<packaging>par</packaging>
```

Thorsten Maus created a Maven plugin (see Section A.2, “Documentation”) that builds a PAR file from a list of dependencies. The file `pom.xml` lists those dependencies:

```
<dependencies>
      <dependency>
            <groupId>org.eclipse.virgo</groupId>
            <artifactId>greenpages.app</artifactId>
            <version>${project.version}</version>
      </dependency>
      <dependency>
            <groupId>org.eclipse.virgo</groupId>
            <artifactId>greenpages.jpa</artifactId>
            <version>${project.version}</version>
      </dependency>
      <dependency>
            <groupId>org.eclipse.virgo</groupId>
            <artifactId>greenpages.db</artifactId>
            <version>${project.version}</version>
      </dependency>
      <dependency>
            <groupId>org.eclipse.virgo</groupId>
            <artifactId>greenpages.web</artifactId>
            <version>${project.version}</version>
            <type>war</type>
      </dependency>
      <dependency>
            <groupId>org.freemarker</groupId>
            <artifactId>com.springsource.freemarker</artifactId>
            <scope>provided</scope>
      </dependency>
</dependencies>
```

The freemarker dependency is required to ensure the Web Application Bundle has the correct set of dependencies. Most dependencies are resolved transitively from the bundle projects, but the ‘war’ project does not pass on its dependencies; it expects them to be contained in its `lib` directory.

The `<build><plugins>`… section contains a declaration for the `par` plugin and configuration of the application symbolic name of the PAR:

```
<plugin>
      <groupId>org.apache.maven.plugins</groupId>
      <artifactId>maven-par-plugin</artifactId>
      <version>1.0.0.RELEASE</version>
      <configuration>
            <applicationSymbolicName>greenpages</applicationSymbolicName>
      </configuration>
</plugin>
```

Obtaining Dependencies

The Maven `dependency` plugin is used to collect the transitive dependency graph for the PAR.

The `<build><plugins>`… section has a declaration for the `dependency` plugin:

```
<plugin>
      <groupId>org.apache.maven.plugins</groupId>
      <artifactId>maven-dependency-plugin</artifactId>
      <executions>
            <execution>
                  <id>copy-dependencies</id>
                  <phase>package</phase>
                  <goals>
                        <goal>copy-dependencies</goal>
                  </goals>
                  <configuration>
                        <outputDirectory>${project.build.directory}/par-provided</outputDirectory>
                        <overWriteIfNewer>true</overWriteIfNewer>
                        <excludeGroupIds>org.eclipse.virgo,org.apache.log4j</excludeGroupIds>
                  </configuration>
            </execution>
      </executions>
</plugin>
```

The WAB must be prevented from having its dependencies included in a `lib` directory as they should be provided by the runtime enviroment. The `greenpages.web` POM file contains the following:

```
<build>
      <plugins>
            <plugin>
                  <artifactId>maven-war-plugin</artifactId>
                  <version>2.1-beta-1</version>
                  <configuration>
                        <packagingExcludes>WEB-INF/lib/**</packagingExcludes>
                  </configuration>
            </plugin>
      </plugins>
</build>
```

Automatically Running the Tests

The following plug-in entry in the `pom.xml` file in the `parent` directory ensure that the concrete test classes are run as part of the build:

```
<plugin>
        <groupId>org.apache.maven.plugins</groupId>
        <artifactId>maven-surefire-plugin</artifactId>
        <configuration>
                <includes>
                        <include>**/*Tests.java</include>
                </includes>
                <excludes>
                        <exclude>**/Abstract*.java</exclude>
                </excludes>
                <junitArtifactName>org.junit:com.springsource.org.junit</junitArtifactName>
                <argLine>-javaagent:${user.home}/.m2/repository/…</argLine>
        </configuration>
</plugin>
```

The location of the user's Maven repository is hard-coded.

Appendix A. Further Resources

A.1 Projects

a. Virgo (http://www.eclipse.org/virgo) — homepage for Virgo.

b. Bundlor (http://www.springsource.org/bundlor) — homepage for Bundlor manifest generation tool. Note that Bundlor has been donated to Eclipse and may a development milestone be downloaded from http://www.eclipse.org/virgo/download.

c. SpringSource.org (http://www.springsource.org) — homepage for Spring Framework.

d. OSGi (http://www.osgi.org) — homepage for OSGi.

e. H2 Database (http://www.h2database.com — homepage for the H2 database.

f. FreeMarker (http://freemarker.sourceforge.net) — homepage for FreeMarker templating engine.

g. Commons DBCP (http://commons.apache.org/dbcp) — homepage for Commons DBCP.

h. Eclipse IDE (http://www.eclipse.org/eclipse) — homepage for Eclipse IDE.

i. EclipseLink (http://www.eclipse.org/eclipselink) — homepage for EclipseLink JPA.

A.2 Documentation

a. Virgo Virgo Tomcat Server Documentation (http://www.eclipse.org/virgo/documentation) – cover page for all Virgo documentation.

b. Spring DM Reference Guide (http://static.springsource.org/osgi/docs/1.2.0/reference/html/).

c. Spring Framework 3.0 documentation (http://static.springsource.org/spring/docs/3.0.x/spring-framework-reference/html/).

d. FreeMarker documentation (http://freemarker.sourceforge.net/docs).

e. Eclipse IDE documentation (http://www.eclipse.org/documentation).

f. EclipseLink documentation wiki (http://wiki.eclipse.org/EclipseLink/UserManual).

g. Maven PAR plugin (http://blog.springsource.com/2009/06/24/maven-par-plugin-100m1/).