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Cloud Native Java

DESIGNING RESILIENT SYSTEMS WITH SPRING BOOT, SPRING CLOUD, AND CLOUD FOUNDRY

Josh Long & Kenny Bastani

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Cloud Native Java

Designing Resilient Systems with Spring Boot, Spring Cloud, and Cloud Foundry

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Josh Long & Kenny Bastani

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CHAPTER 1

Bootcamp: Introducing Spring Boot and Cloud Foundry

From the project website, "Spring Boot makes it easy to create stand-alone, production-grade Spring based Applications that you can "just run". We take an opinionated view of the Spring platform and third-party libraries so you can get started with minimum fuss. Most Spring Boot applications need very little Spring configuration."

This pretty much says it all! Spring builds upon the Spring ecosystem and interesting third-party libraries, adding in opinions and establishing conventions to streamline the realization of production-worthy applications. This last aspect is arguably the most important aspect of Spring Boot. Any framework these days can be used to standup a simple REST endpoint, but a simple REST endpoint does not a production-worthy service make. When we say that an application is **cloud native**, it means that it is designed to thrive in a cloud-based production environment.

This chapter will introduce you to building Spring Boot applications and deploying them to production with Cloud Foundry. The rest of the book will talk about what it means to build applications that **thrive** in such an environment.

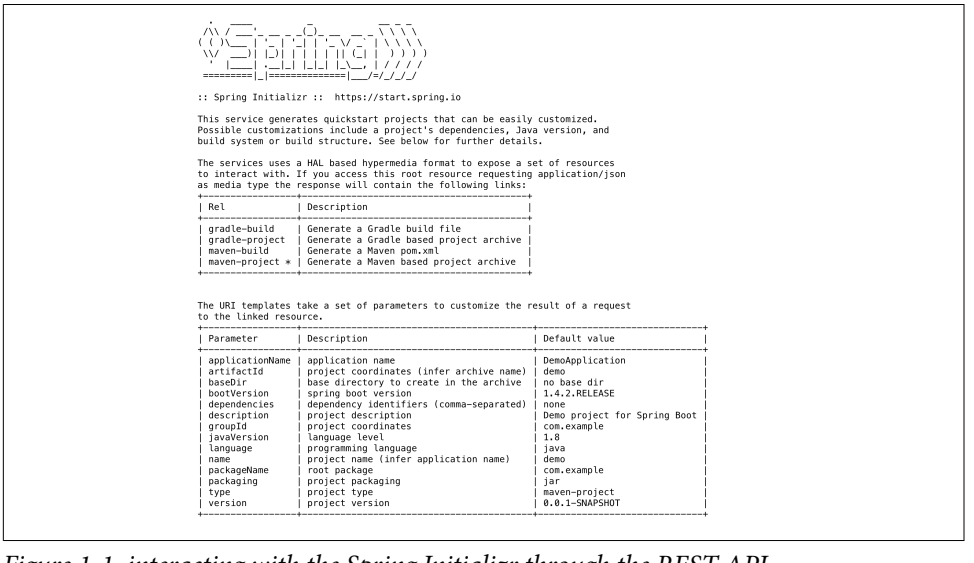
Getting Started with the Spring Initializr

The *Spring Initializr* is an open source project and tool in the Spring ecosystem that helps you quickly generate new Spring Boot applications. Pivotal runs an instance of the Spring Initializr hosted on Pivotal Web Services at *http://start.spring.io*. It generates Maven and Gradle projects with any specified dependencies, a skeletal entry point Java class and a skeletal unit test.

In the world of monolithic applications, this cost may be prohibitive, but it's easy to amortize the cost of that initialization across the lifetime of the project. When you move to the cloud native architecture, you'll end up with lots of small microservices. The first requirement, then, is to reduce the cost of creating a new service. The Spring Initializr helps reduce that upfront cost. The Spring Initializr application is both a web application that you can consume from your web browser, and as a REST API, that will generate new projects for you. You could generate a default project using `curl`:

```
curl http://start.spring.io
```

The results will look something like this:



```
  .   ____          _            __ _ _
 /\\ / ___'_ __ _ _(_)_ __  __ _ \ \ \ \
( ( )\___ | '_ | '_| | '_ \/ _` | \ \ \ \
 \\/  ___)| |_)| | | | | || (_| |  ) ) ) )
  '  |____| .__|_| |_|_| |_\__, | / / / /
 =========|_|==============|___/=/_/_/_/

:: Spring Initializr ::  https://start.spring.io

This service generates quickstart projects that can be easily customized.
Possible customizations include a project's dependencies, Java version, and
build system or build structure. See below for further details.

The services uses a HAL based hypermedia format to expose a set of resources
to interact with. If you access this root resource requesting application/json
as media type the response will contain the following links:
+-----------------+-----------------------------------------+
| Rel             | Description                             |
+-----------------+-----------------------------------------+
| gradle-build    | Generate a Gradle build file            |
| gradle-project  | Generate a Gradle based project archive |
| maven-build     | Generate a Maven pom.xml                |
| maven-project * | Generate a Maven based project archive  |
+-----------------+-----------------------------------------+


The URI templates take a set of parameters to customize the result of a request
to the linked resource.
+-----------------+-----------------------------------------+-------------------------------+
| Parameter       | Description                             | Default value                 |
+-----------------+-----------------------------------------+-------------------------------+
| applicationName | application name                        | DemoApplication               |
| artifactId      | project coordinates (infer archive name) | demo                          |
| baseDir         | base directory to create in the archive | no base dir                   |
| bootVersion     | spring boot version                     | 1.4.2.RELEASE                 |
| dependencies    | dependency identifiers (comma-separated) | none                          |
| description     | project description                     | Demo project for Spring Boot  |
| groupId         | project coordinates                     | com.example                   |
| javaVersion     | language level                          | 1.8                           |
| language        | programming language                    | java                          |
| name            | project name (infer application name)   | demo                          |
| packageName     | root package                            | com.example                   |
| packaging       | project packaging                       | jar                           |
| type            | project type                            | maven-project                 |
| version         | project version                         | 0.0.1-SNAPSHOT                |
+-----------------+-----------------------------------------+-------------------------------+
```

Figure 1-1. interacting with the Spring Initializr through the REST API

Alternatively, you can use the Spring Initializr from the browser as in shown here.

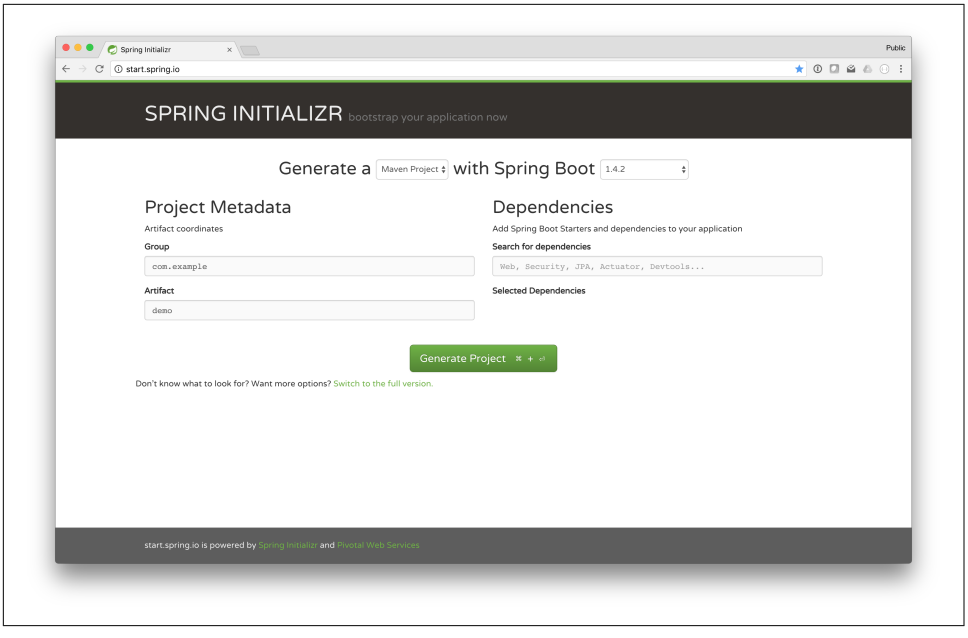


Figure 1-2. The Spring Initializr website

Let's suppose we want to build a simple REST service that talks to a SQL database (H2). We'll need different libraries from the Spring eocsystem, including Spring MVC, Spring Data JPA and Spring Data REST. We'll look at what these libraries do, later.

Search for *Dependencies* in the search box or click *Switch to the full version* and manually selecting checkboxes for the desired dependencies. Most of these are *starter* dependencies.

In Spring Boot, a *starter* dependency is an opinionated dependency. It is a Maven `pom.xml` that is published as a `.jar` that brings in other Maven dependencies, but has no Spring Boot code in of itself. The interesting Java code from Spring Boot lives in only a couple of `.jar` libraries. The Spring Boot *starter* depdencies transitively import these core libraries.

If we were to build a Spring Boot application from scratch, we would have to weather the web of dependency version conflicts. We might encounter a version conflict if our application used dependency `A` and dependency `B` and they shared a common, but conflicting, dependency on `C`. Spring Boot solves this for you in Maven and Gradle builds, allowing you to focus on what you want on your CLASSPATH, not how to resolve conflicts from having it.

Table 1-1. Some example Spring Boot Starters for a typical Spring Boot application

Spring Project	Starter Projects	Maven `artifactId`
Spring Data JPA	JPA	`spring-boot-starter-data-jpa`
Spring Data REST	REST Repositories	`spring-boot-starter-data-rest`
Spring Framework (MVC)	Web	`spring-boot-starter-web`
Spring Security	Security	`spring-boot-starter-security`
H2 Embedded SQL DB	H2	`h2`

Make your selections and include just `Web`, `H2`, `REST Repositories`, and `JPA`. We'll leave everything else as default. Click **Generate Project** and an archive, `demo.zip`, will begin downloading. Decompress the archive and you'll have a skeletal project ready to import into an IDE of your choice.

Example 1-1. the contents of the generated Spring Boot application archive once decompressed

```
.
├── mvnw
├── mvnw.cmd
├── pom.xml
└── src
    ├── main
    │   ├── java
    │   │   └── com
    │   │       └── example
    │   │           └── DemoServiceApplication.java
    │   └── resources
    │       ├── application.properties
    │       ├── static
    │       └── templates
    └── test
        └── java
            └── com
                └── example
                    └── DemoServiceApplicationTests.java
```

In the listing of our application's directory structure we can see the directory structure of our generated application. The Spring Initializr provides a wrapper script - either the Gradle wrapper (`gradlew`) or a Maven wrapper (from the Maven wrapper project) `mvnw` - as a part of the contents of the generated project. You can use this wrapper to build and run the project. The wrapper downloads a configured version of the build tool on its first run. The version of Maven or Gradle are version controlled. This means that all subsequent users will have a reproducible build. There's no risk that someone will try to build your code with an incompatible version of Maven or

Gradle. This also greatly simplifies continuous delivery: the build used for development is the exact same one used in the continuous integration environment.

The following command will run a clean installation of the Maven project, downloading and caching the dependencies specified in the `pom.xml` and installing the built `.jar` artifact into the local Maven repository (typically `$HOME/.m2/repository/*`).

```
$ ./mvnw clean install
```

To run the Spring Boot application from the command line, use the provided Spring Boot Maven plugin, configured automatically in the generated `pom.xml`:

```
$ ./mvnw spring-boot:run
```

The web application should be up and running and available at *http://localhost:8080*. Don't worry, nothing particularly interesting has happened, *yet*.

Open the project's `pom.xml` file in a text editor of your choice. `emacs`, `vi`, TextMate, Sublime, Atom, Notepad.exe, etc., are all valid choices.

Example 1-2. The `demo-service` project's `pom.xml` file's dependencies section.

```
<dependencies>

        ❶
        <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-data-jpa</artifactId>
        </dependency>

        ❷
        <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-data-rest</artifactId>
        </dependency>

        ❸
        <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-web</artifactId>
        </dependency>

        ❹
        <dependency>
                <groupId>com.h2database</groupId>
                <artifactId>h2</artifactId>
                <scope>runtime</scope>
        </dependency>

        ❺
```

```
        <dependency>
                <groupId>org.springframework.boot</groupId>
                <artifactId>spring-boot-starter-test</artifactId>
                <scope>test</scope>
        </dependency>
</dependencies>
```

❶ `spring-boot-starter-data-jpa` brings in everything needed to persist Java objects using the Java ORM (Object Relational Mapping) specification, JPA (the Java Persistence API), and be productive out of the gate. This includes the JPA specification types, basic SQL Java database connectivity (JDBC) and JPA support for Spring, Hibernate as an implementation, Spring Data JPA and Spring Data REST.

❷ `spring-boot-starter-data-rest` makes it trivial to export hypermedia-aware REST services from a Spring Data repository definition.

❸ `spring-boot-starter-web` brings in everything needed to build REST applications with Spring. It brings in JSON and XML marshalling support, file upload support, an embedded web container (the default is the latest version of Apache Tomcat), validation support, the Servlet API, and so much more. This is a redundant dependency as `spring-boot-starter-data-rest` will automatically bring it in for us. It's highlighted here for clarity.

❹ `h2` is an in-memory, embedded SQL database. If Spring Boot detects an embedded database like H2, Derby or HSQL on the classpath and it detects that you haven't otherwise configured a `javax.sql.DataSource` somewhere, it'll configure one for you. The embedded `DataSource` will spin up when the application spins up and it'll destroy itself (and all of its contents!) when the application shuts down.

❺ `spring-boot-starter-test` brings in all the default types needed to write effective mock and integration tests, including the Spring MVC test framework. It's assumed that testing support is needed, and this dependency is added by default.

The parent build specifies all the versions for these dependencies. In a typical Spring Boot project the only version explicitly specified is the one for Spring Boot itself. When one day a new version of Spring Boot is available, point your build to the new version and all the corresponding libraries and integrations get updated with it.

Next, open up the application's entry point class, `demo/src/main/java/com/example/DemoApplication.java` in your favorite text editor and replace it with the following code:

Example 1-3.

```
package com.example;

import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.data.jpa.repository.JpaRepository;
import org.springframework.data.rest.core.annotation.RepositoryRestResource;

import javax.persistence.Entity;
import javax.persistence.GeneratedValue;
import javax.persistence.Id;

❹
@RepositoryRestResource
interface CatRepository extends JpaRepository<Cat, Long> {
}

@SpringBootApplication
❶
public class DemoApplication {

        public static void main(String[] args) {
                SpringApplication.run(DemoApplication.class, args); ❷
        }
}

❸
@Entity
class Cat {

        @Id
        @GeneratedValue
        private Long id;
        private String name;

        Cat() {
        }

        public Cat(String name) {
                this.name = name;
        }

        @Override
        public String toString() {
                return "Cat{" + "id=" + id + ", name='" + name + '\'' + '}';
        }

        public Long getId() {
                return id;
        }
```

```
        public String getName() {
                return name;
        }
}
```

❶ annotates a class as a Spring Boot application.

❷ starts the Spring Boot application

❸ a plain JPA entity to model a `Cat` entity

❹ a Spring Data JPA repository (which handles all common create-read-update-and-delete operations) that has been exported as a REST API

This code *should* work, but we can't be sure unless we have a test! If we have tests, we can establish a baseline working state for our software and then make measured improvements to that baseline quality. So, open up the test class, `demo/src/test/java/com/example/DemoApplicationTests.java`, and replace it with the following code:

Example 1-4.

```
package com.example;

import org.junit.Before;
import org.junit.Test;
import org.junit.runner.RunWith;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.boot.test.autoconfigure.web.servlet.AutoConfigureMockMvc;
import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.http.MediaType;
import org.springframework.test.context.junit4.SpringRunner;
import org.springframework.test.web.servlet.MockMvc;

import java.util.stream.Stream;

import static org.junit.Assert.assertTrue;
import static org.springframework.test.web.servlet.request.MockMvcRequestBuild
ers.get;
import static org.springframework.test.web.servlet.result.MockMvcResultMatchers.con
tent;
import static org.springframework.test.web.servlet.result.MockMvcResultMatchers.sta
tus;

❶
@RunWith(SpringRunner.class)
@SpringBootTest(webEnvironment = SpringBootTest.WebEnvironment.MOCK)
@AutoConfigureMockMvc
public class DemoApplicationTests {
```

```
        ❷
        @Autowired
        private MockMvc mvc;

        ❸
        @Autowired
        private CatRepository catRepository;

        ❹
        @Before
        public void before() throws Exception {
                Stream.of("Felix", "Garfield", "Whiskers").forEach(
                                n -> catRepository.save(new Cat(n)));
        }

        ❺
        @Test
        public void catsReflectedInRead() throws Exception {
                MediaType halJson = MediaType.parseMediaType("application/hal
+json;charset=UTF-8");
                this.mvc
                                .perform(get("/cats"))
                                .andExpect(status().isOk())
                                .andExpect(content().contentType(halJson))
                                .andExpect(
                                                mvcResult -> {
                                                        String contentAsString =
mvcResult.getResponse().getContentAsString();
                                                        assertTrue(contentAs
String.split("totalElements")[1].split(":")[1].trim()
                                                                        .split(",")
[0].equals("3"));
                                                });
        }
}
```

❶ this is a unit test that leverages the Spring framework test runner. We configure it to also interact nicely with the Spring Boot testing apparata, standing up a mock web application.

❷ inject a Spring MVC test `MockMvc` client with which we make calls to the REST endpoints

❸ we can reference any other beans in our Spring application context, including `CatRepository`

❹ install some sample data in the database

❺ invoke the HTTP `GET` endpoint for the `/cats` resource.

We'll learn more about testing in our discussion on testing. Start the application and manipulate the database through the HAL-encoded hypermedia REST API on `http://locahost:8080/cats`. We'll learn more about data manipulation in Spring in ??? and we'll learn more about processing data in ???. We'll learn more about REST and web applications in the ??? chapter. If you run the test, it should be green! We'll learn more about testing in the chapter on ???.

Thus far we've done everything using a text editor, but most developers today use an IDE. There are many fine choices out there and Spring Boot works well with any of them. If you don't already have a Java IDE, you might consider the Spring Tool Suite (STS). The Spring Tool Suite is an Eclipse-based IDE that packages up common ecosystem tooling to deliver a smoother Eclipse experience than what you'd get out of the box if you were to download the base Eclipse platform from Eclipse. STS is freely-available under the terms of the Eclipse Public License.

STS provides an in-IDE experience for the Spring Initializr. Indeed, the functionality in Spring Tool Suite, IntelliJ Ultimate edition, NetBeans and the Spring Initializr web application itself all delegate to the Spring Initializr's REST API, so you get a common result no matter where you start.

Let's build a new project in the Spring Tool Suite.

Getting Started with the Spring Tool Suite

You do *not need* to use any particular IDE to develop Spring or Spring Boot applications. The authors have built Spring applications in emacs, plain Eclipse, Apache Netbeans (with and without the excellent Spring Boot plugin support that engineers from no less than Oracle have contributed) and IntelliJ IDEA Community edition and IntelliJ IDEA Ultimate edition with no problems. Spring Boot 1.x, in particular, needs Java 6 or better and support for editing plain `.properties` files as well as support for working with Maven or Gradle-based builds. Any IDE from 2010 or later will do a good job here.

If you use Eclipse, the Spring Tool Suite has a lot of nice features that make working with Spring Boot-based projects even nicer:

- you can access all of the Spring guides in the STS IDE
- you can generate new projects with the Spring Initializr in the IDE.
- If you attempt to access a type that doesn't exist on the CLASSPATH, but can be discovered within one of Spring Boot's `-starter` dependencies, then STS will automatically add that type for you.
- The **Boot Dashboard** makes it seamless to edit local Spring Boot applications and have them synchronized with a Cloud Foundry deployment. You can further debug and live-reload deployed Cloud Foundry applications, all within the IDE.

- STS makes editing Spring Boot `.properties` or `.yml` files effortless, offering autocompleion out of the box.
- The Spring Tool Suite is a stable, integrated edition of Eclipse that's released shortly after the mainline Eclipse release.

Installing Spring Tool Suite (STS)

Download and install the Spring Tool Suite (STS), available from *http://www.spring.io:*

- Go to *https://spring.io/tools/sts*
- Choose **Download STS**
- Download, extract, and run STS.

After you have downloaded, extracted, and have run the STS program, you will be prompted to choose a workspace location. Select your desired workspace location and click **OK**. If you plan to use the same workspace location each time you run STS, click on the option "*Use this as the default and do not ask again*". After you have provided a workspace location and clicked **OK**, the STS IDE will load for the first time.

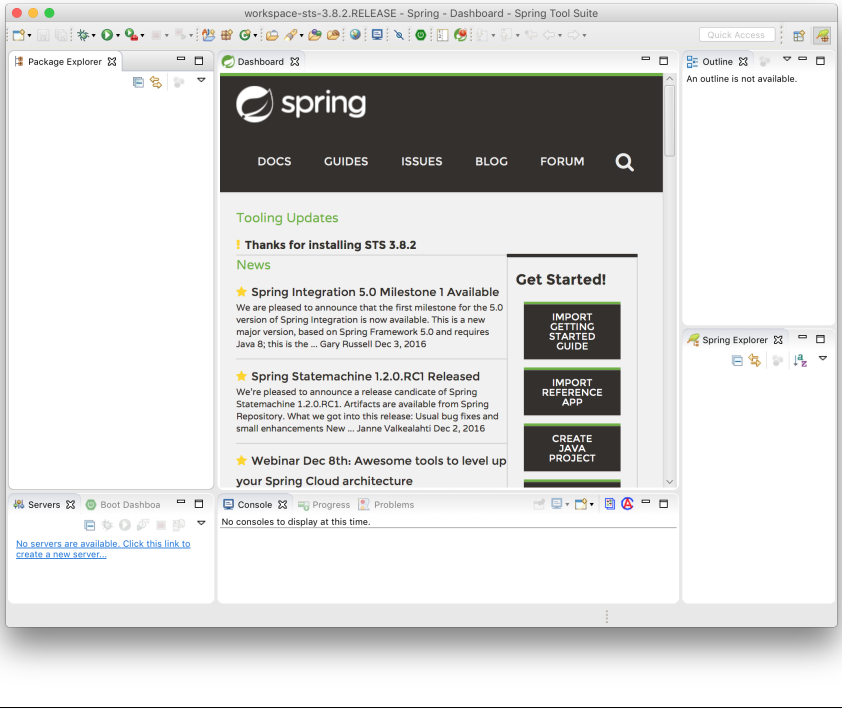


Figure 1-3. The STS dashboard

There are also packages available for numerous operating systems, as well. For example, if you use Homebrew Cask on OS X or macOS Sierra, you can use the Pivotal tap and then say `brew cask install sts`.

Creating a new Project with the Spring Initializr

We could import the example that we just created from the Spring Initializr, directly, by going to `File` > `Import` > `Maven` and then pointing the import to the `pom.xml` at the root of our existing `demo` project, but let's instead use STS to create our first Spring Boot application. We're going to create a simple "Hello World" web service using the Spring Boot starter project for web applications. To create a new Spring Boot application using a Spring Boot Starter project, choose from the menu `File` > `New` > `Spring Starter Project`.

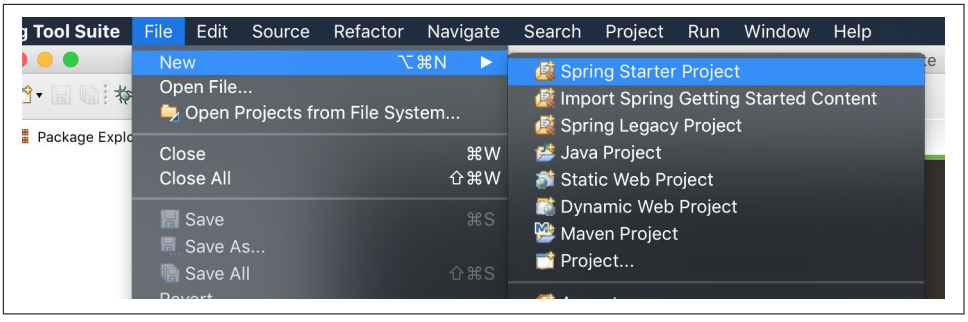


Figure 1-4. Create a new Spring Boot Starter Project

After choosing to create a new Spring Boot Starter Project, you will be presented with a dialog to configure your new Spring Boot application.

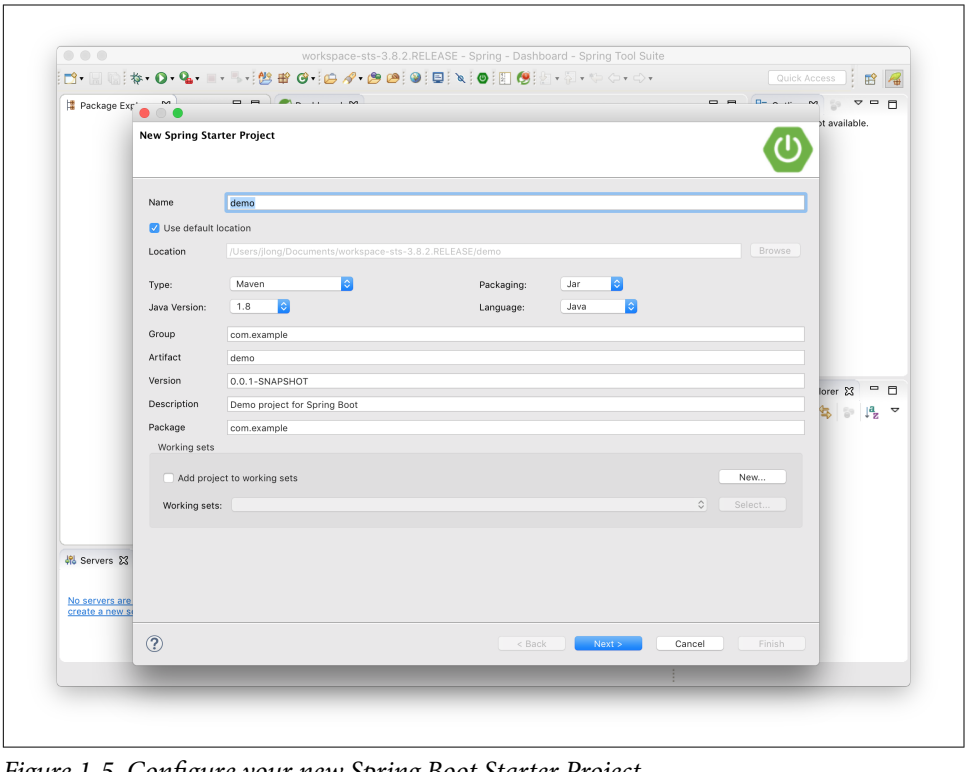


Figure 1-5. Configure your new Spring Boot Starter Project

You can configure your options, but for the purposes of this simple walkthrough, let's use the defaults and click **Next**. After clicking **Next**, you will be provided with a set of Spring Boot Starter projects that you can choose for your new Spring Boot application. For our first application we're going to select the **Web** support.

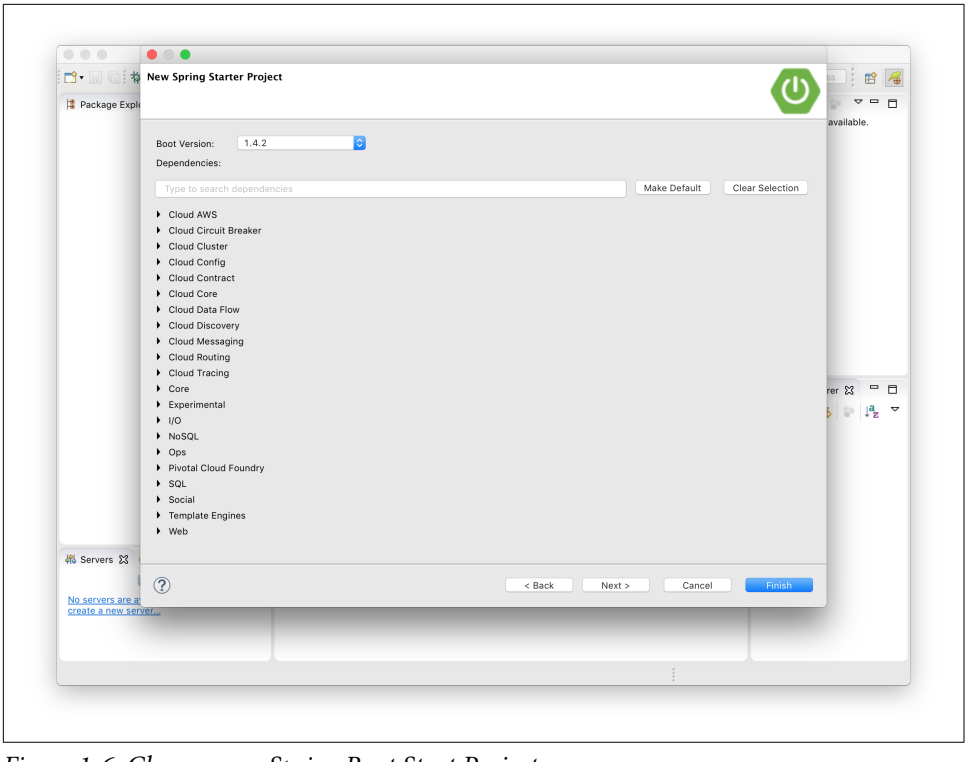


Figure 1-6. Choose your Spring Boot Start Project

Once you've made your selections, click **Finish**. After you click **Finish**, your Spring Boot application will be created and imported into the IDE workspace for you and visible in the package explorer.

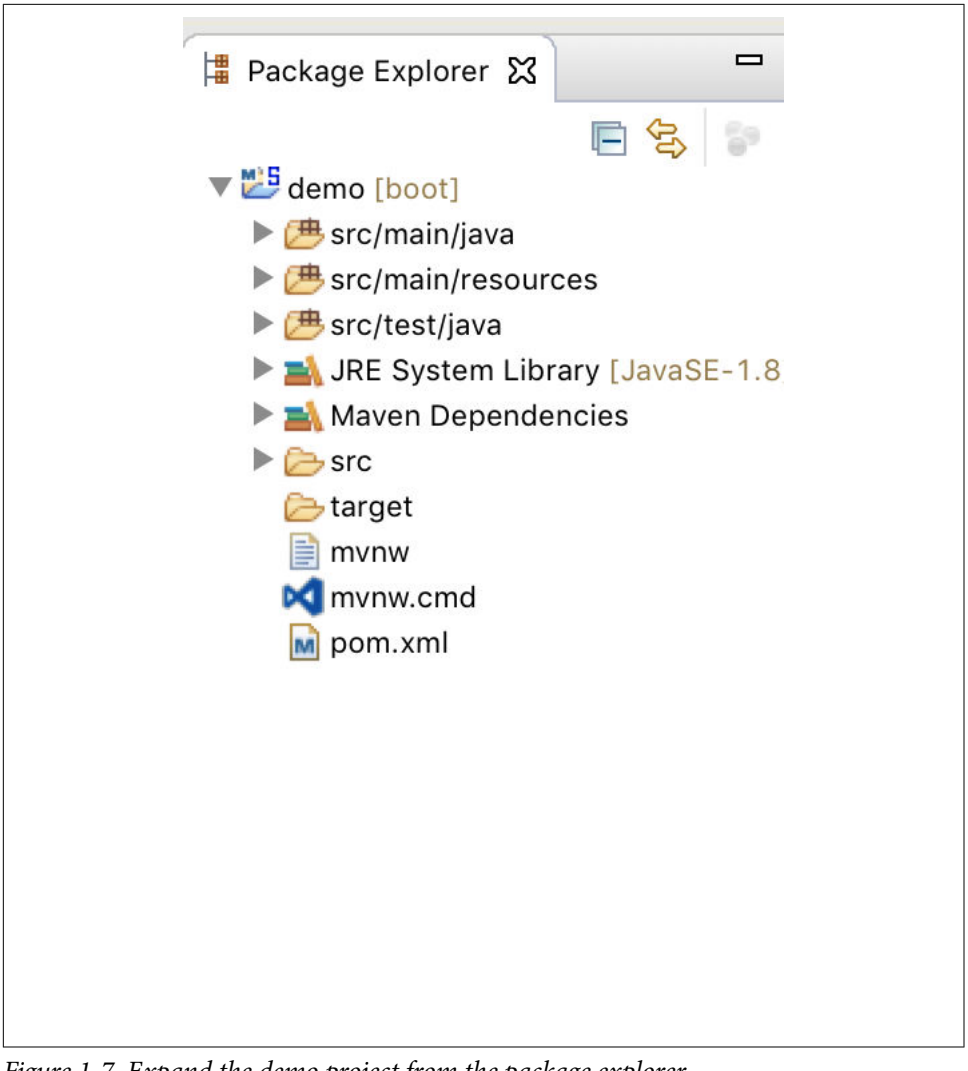


Figure 1-7. Expand the demo project from the package explorer

If you haven't already, expand the ***demo [boot]*** node in the Package Explorer and view the project contents as shown in the screenshot above. From the expanded project files, navigate to `src/main/java/com/example/DemoApplication.java`. Let's go ahead and run the application. Run the application from the **Run** > **Run** menu.

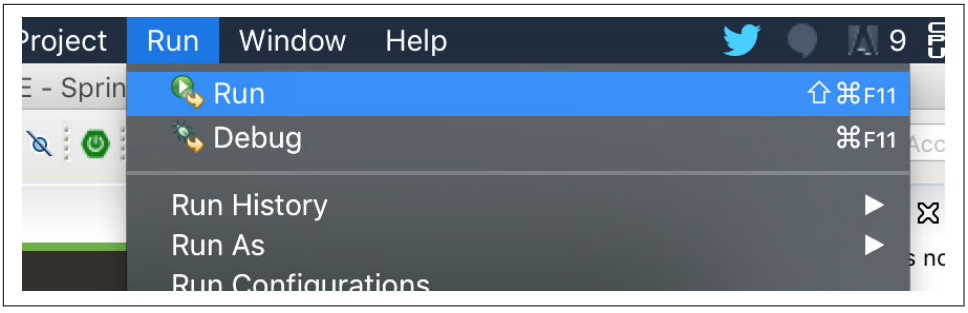


Figure 1-8. Run the Spring Boot application

After choosing the **Run** option from the menu, you'll be presented with a *Run As* dialog. Choose **Spring Boot App** and then click **OK**.

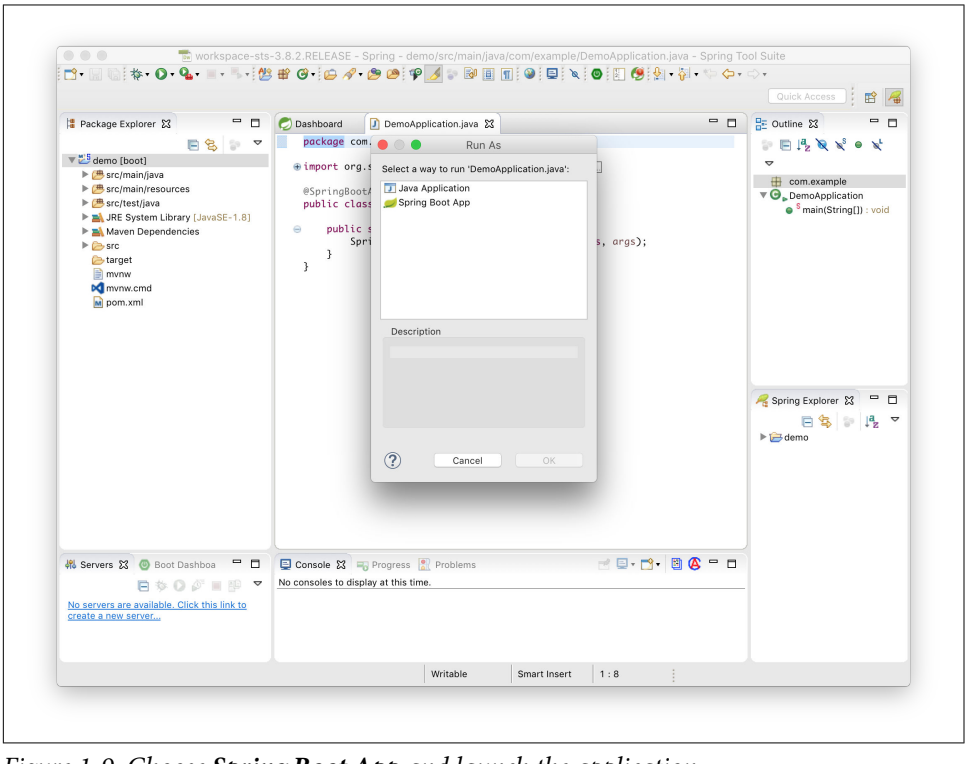


*Figure 1-9. Choose **Spring Boot App** and launch the application*

Your Spring Boot application will now start up. If you look at your STS console, you should see the iconic Spring Boot ASCII art and the version of Spring Boot as it starts up. The log output of the Spring Boot application can be seen here. You'll see that an

embedded Tomcat server is being started up and launched on the default port of *8080*. You can access your Spring Boot web service from ***http://localhost:8080***.

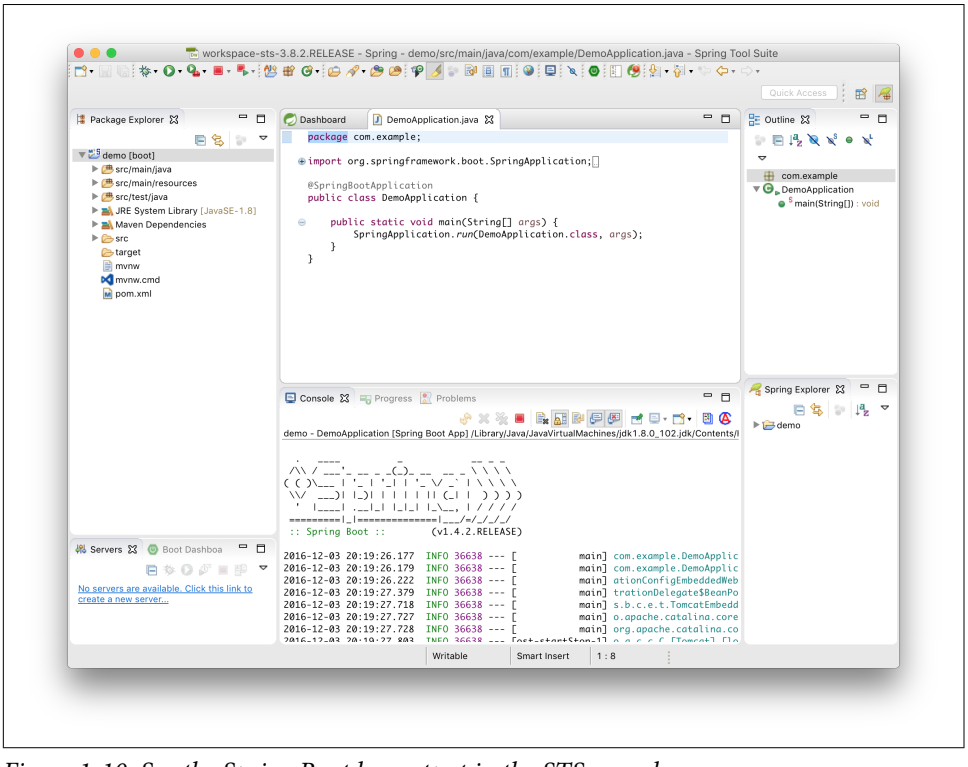


Figure 1-10. See the Spring Boot log output in the STS console

Congratulations! You've just created your first Spring Boot application with the Spring Tool Suite!

The Spring Guides

The Spring Guides are a set of small, focused introductions to all manner of different topics in terms of Spring projects. There are many guides, most of which were written by experts on the Spring team, though some of them were contributed from ecosystem partners. Each Spring guide takes the same approach to providing a comprehensive yet consumable guide that you should be able to get through within 15-30 minutes. These guides are one of the most useful resources (in addition to this book, of course!) when getting started with Spring Boot. To get started with the *Spring Guides*, head over to *https://spring.io/guides*.

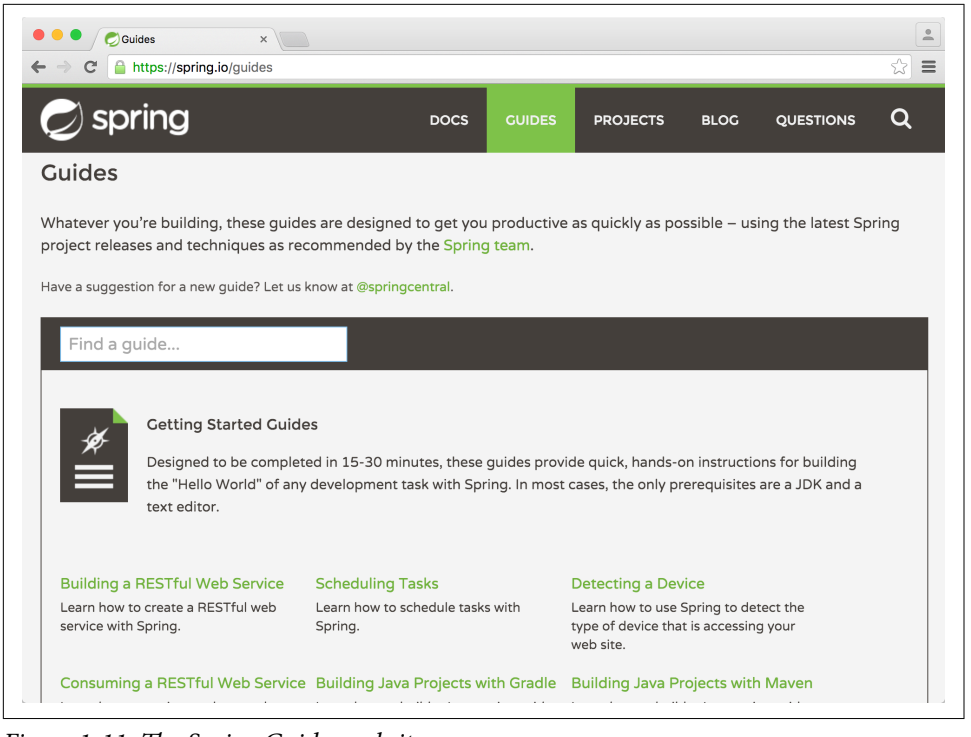


Figure 1-11. The Spring Guides website

As we can see from Figure 1-11, the *Spring Guides* website provides a collection of maintained examples that target a specific use case.

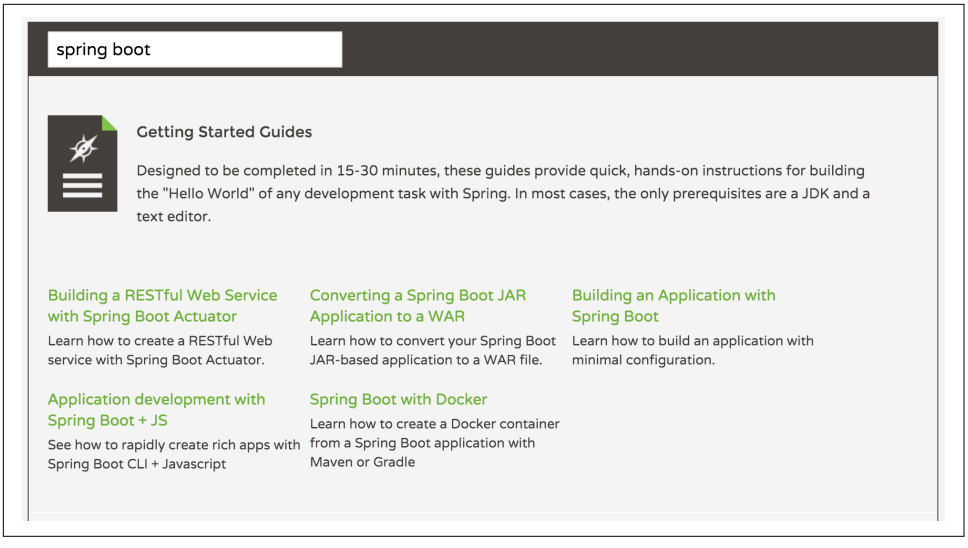


Figure 1-12. Exploring the Spring Guides

In Figure 1-12 I've entered the search term *spring boot*, which will narrow down the list of guides to those that focus on Spring Boot.

As a part of each *Spring Guide*, we'll find the following familiar features.

- Getting started
- Table of contents
- What you'll build
- What you'll need
- How to complete this guide
- Walkthrough
- Summary
- Get the code
- Link to GitHub repository

Let's now choose one of the basic Spring Boot guides: Building an Application with Spring Boot.

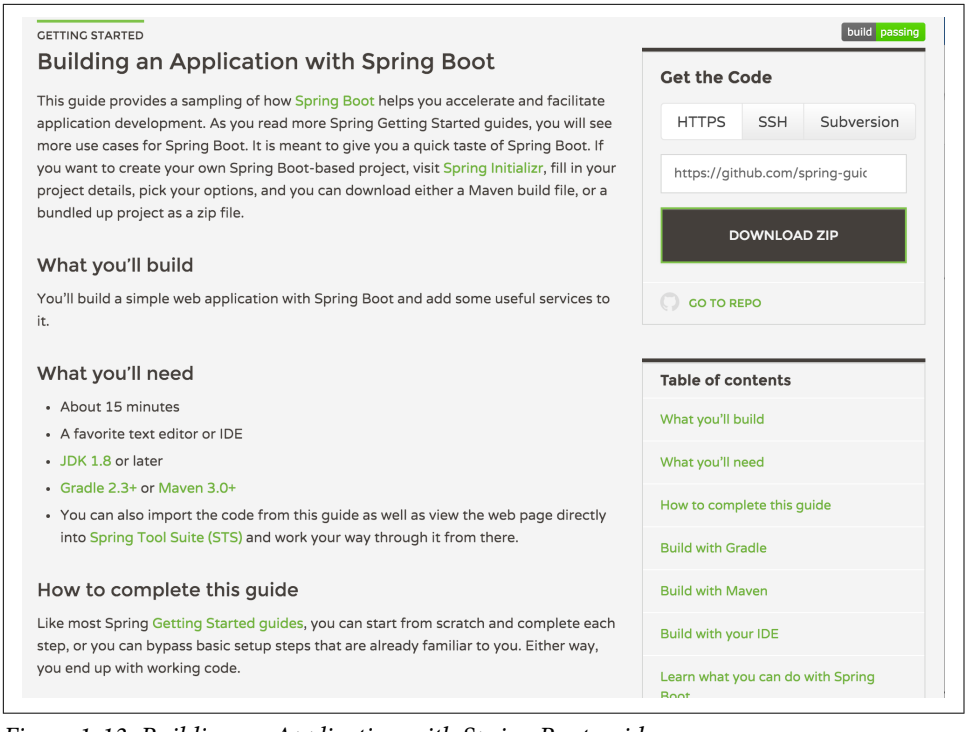


Figure 1-13. Building an Application with Spring Boot guide

In Figure 1-13 we see the basic anatomy of a Spring Guide. Each guide is structured in a familiar way to help you move through the content as effectively as possible. Each guide features a GitHub repository that contains three folders: `complete`, `initial`, and `test`. The `complete` folder contains the final working example so that you can check your work. The `initial` folder contains a skeletal, almost empty file system that you can use to push past the boilerplate and focus on that which is unique to the guide. The `test` folder has whatever's required to confirm that the `complete` project works.

Throughout this book you'll find situations or scenarios that you may need an expanded companion guide to help you get a better understanding of the content. It's recommended in this case that you take a look at the *Spring Guides* and find a guide that best suits your needs.

Following the Guides in STS

If you're using the Spring Tool Suite, you can follow along with the guides from within the IDE. Choose **File** > **New** > **Import Spring Getting Started Content**.

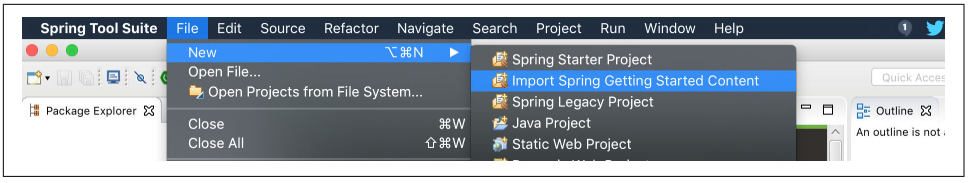


Figure 1-14. Import Spring Getting Started Content

You'll be given the same catalog of guides as you would at spring.io/guides.

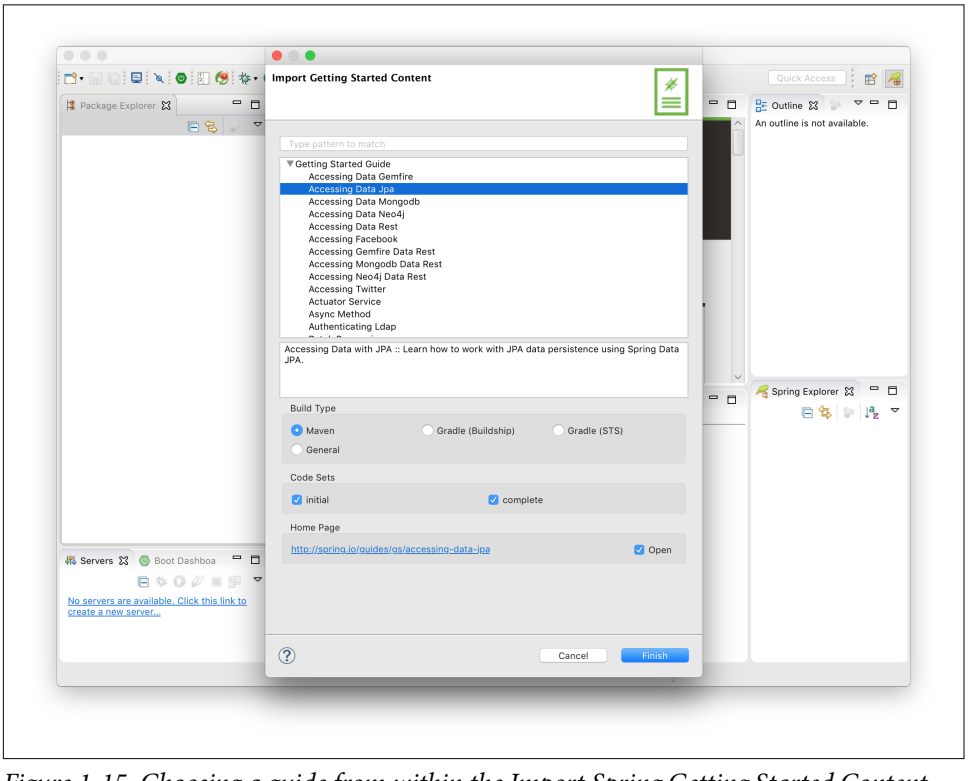


Figure 1-15. Choosing a guide from within the Import Spring Getting Started Content dialog

Select a guide and it'll be displayed within your IDE and the associated code will be shown.

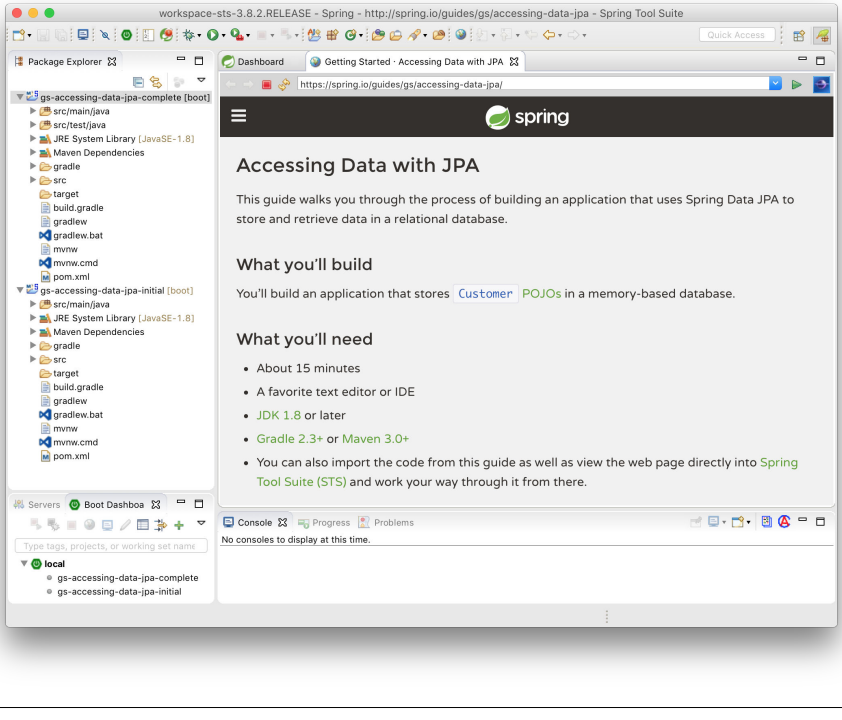


Figure 1-16. The IDE loads the guide and the relevant Git projects

Configuration

At the end of the day, a Spring application is a collection of objects. Spring manages those objects and their relationships for you, providing services to those objects as necessary. In order for Spring to support your objects - *beans* - it needs to be made aware of them. Spring provides a few different (complimentary) ways to describe your beans.

Let's suppose we have a typical layered service, with a service object in turn talking to a `javax.sql.DataSource` to talk to a (in this case) embedded database, H2. We'll need to define a service. That service will need a datasource. We could instantiate that data source in-place, where it's needed, but then we'd have to duplicate that logic whenever we wish to reuse the data source. In other objects. The resource accquisition and initialization is happening at the call site, which means that we can't reuse that logic elsewhere.

Example 1-5.

```
package com.example.raai;

import com.example.Customer;
import org.springframework.core.io.ClassPathResource;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseBuilder;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseType;
import org.springframework.jdbc.datasource.init.DataSourceInitializer;
import org.springframework.jdbc.datasource.init.ResourceDatabasePopulator;
import org.springframework.util.Assert;

import javax.sql.DataSource;
import java.sql.Connection;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;
import java.util.ArrayList;
import java.util.Collection;
import java.util.List;

public class CustomerService {

        private final DataSource dataSource = new EmbeddedDatabaseBuilder()
                        .setName("customers").setType(EmbeddedDatabase
Type.H2).build();

        public static void main(String argsp[]) throws Throwable {
                CustomerService customerService = new CustomerService();

                ❶
                DataSource dataSource = customerService.dataSource;
                DataSourceInitializer init = new DataSourceInitializer();
                init.setDataSource(dataSource);
                ResourceDatabasePopulator populator = new ResourceDatabasePopula
tor();
                populator.setScripts(new ClassPathResource("schema.sql"), new Class
PathResource(
                                "data.sql"));
                init.setDatabasePopulator(populator);
                init.afterPropertiesSet();

                ❷
                int size = customerService.findAll().size();
                Assert.isTrue(size == 2);

        }

        public Collection<Customer> findAll() {
                List<Customer> customerList = new ArrayList<>();
                try {
                        try (Connection c = dataSource.getConnection()) {
```

```
                                Statement statement = c.createStatement();
                                try (ResultSet rs = statement.executeQuery("select
* from CUSTOMERS")) {
                                        while (rs.next()) {
                                                customerList.add(new Customer(rs.get
Long("ID"), rs.getString("EMAIL")));
                                        }
                                }
                        }
                }
                catch (SQLException e) {
                        throw new RuntimeException(e);
                }
                return customerList;
        }
}
```

❶ it's hard to stage the datasource as the only reference to it is buried in a `private final` field in the `CustomerService` class itself. The only way to get access to that variable is by taking advantage of Java's *friend* access, where instances of a given object are able to see other instances private variables.

❷ here we use types from Spring itself, not JUnit, since the JUnit library is `test` scoped, to "exercise" the component. The Spring framework `Assert` class supports design-by-contract behavior, not unit testing!

As we can't plugin a mock datasource, and we can't stage the datasource any other way, we're forced to embed the *test* code in the component itself. This *won't* be easy to test in a proper fashion and it means we need `test`-time dependencies on the CLASSPATH for our main code.

We're using an embedded datasource and so the datasource would be the same in both development and production, but in a realistic example, the configuration of environment-specific details like usernames and hostnames would be parameterizable, otherwise any attempt to exercise the code might execute against a production datasource!

It would be cleaner to centralize the bean definition, outside of the call sites where it's used. How does our component code get access to that centralized reference? We could store them in static variables, but how do we test it since we have static references littered throughout our code? How do we *mock* the reference out? We could also store the references in some sort of shared context, like JNDI (Java Naming and Directory Interface), but we end up with the same problem: it's hard to test this arrangement without mocking out all of JNDI!

Instead of burying resource initialization and accquisition logic code in all the consumers of those resources, we could create the objects and establish their wiring in

one place, in a single class. This principle is called *inversion of control*. The wiring of objects is seprate from the components themselves. In teasing these things apart, we're able to build component code that is dependant on base-types and interfaces, not coupled to a particular implementation. This is called *dependency injection*. A component that is ignorant of how and where a pariticular dependency was created won't care if that dependency is a fake (*mock*) object during a unit test.

Instead, let's move the wiring of the objects - the configuration - into a separate class, a *configuration* class. Let's look at how this is supported with Spring's Java configuration.

What about XML? Spring debuted with support for XML-based configuration. XML configuration offers a lot of the same benefits of Java configuration: it's a centralized artifact separate from the components being wired. It's still supported, but it's not the best fit for a Spring Boot application which relies on Java configuration. In this book, we won't use XML-based configuration.

Example 1-6.

```
package com.example.javaconfig;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseBuilder;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseType;

import javax.sql.DataSource;

❶
@Configuration
public class ApplicationConfiguration {

        ❷
        @Bean(destroyMethod = "shutdown")
        DataSource dataSource() {
                return new EmbeddedDatabaseBuilder().setType(EmbeddedDatabase
Type.H2)
                                .setName("customers").build();
        }

        ❸
        @Bean
        CustomerService customerService(DataSource dataSource) {
                return new CustomerService(dataSource);
        }
}
```

❶ this class is a Spring `@Configuration` class, which tells Spring that it can expect to find definitions of objects and how they wire together in this class.

❷ we'll extract the definition of the `DataSource` into a bean definition. Any other Spring component can see, and work with, this single instance of the `DataSource`. If ten Spring components *depend* on the `DataSource`, then they will *all* have access to the same instance in memory, by default. This has to do with Spring's notion of scope. By default, a Spring bean is *singleton scoped*.

❸ register the `CustomerService` instance with Spring and tell Spring to satisfy the `DataSource` by sifting through the other registered beans in the application context and finding the one whose type matches the bean provider parameter.

Revisit the `CustomerService` and remove the explicit `DataSource` creation logic.

Example 1-7.

```
package com.example.javaconfig;

import com.example.Customer;

import javax.sql.DataSource;
import java.sql.Connection;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.sql.Statement;
import java.util.ArrayList;
import java.util.Collection;
import java.util.List;

public class CustomerService {

        private final DataSource dataSource;

        ❶
        public CustomerService(DataSource dataSource) {
                this.dataSource = dataSource;
        }

        public Collection<Customer> findAll() {
                List<Customer> customerList = new ArrayList<>();
                try {
                        try (Connection c = dataSource.getConnection()) {
                                Statement statement = c.createStatement();
                                try (ResultSet rs = statement.executeQuery("select
* from CUSTOMERS")) {
                                        while (rs.next()) {
                                                customerList.add(new Customer(rs.get
```

```
Long("ID"), rs.getString("EMAIL")));
                                        }
                                    }
                                }
                        }
                        catch (SQLException e) {
                                throw new RuntimeException(e);
                        }
                        return customerList;
                }
}
```

❶ the definition of the `CustomerService` type is markedly simpler, since it now merely depends on a `DataSource`. We've limited its responsibilities, arguably, to things more in scope for this type: interacting with the `dataSource`, not defining the `dataSource` itself.

The configuration is explicit, but also a bit redundant. Spring could do some of the construction for us, if we let it! After all, why should *we* do all of the heavy lifting? We could use Spring's stereotype annotations to mark our own components and let spring instantiate those for us based on convention.

Let's revisit the `ApplicationConfiguration` class and let Spring discover our stereotyped components using *component scanning*. We no longer need to explicitly describe how to construct a `CustomerService` bean, so we'll remove that definition too. The `CustomerService` type is exactly the same as before, except that it has the `@Component` annotation applied to it.

Example 1-8.

```
package com.example.componentscan;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.ComponentScan;
import org.springframework.context.annotation.Configuration;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseBuilder;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseType;

import javax.sql.DataSource;

@Configuration
@ComponentScan
❶
public class ApplicationConfiguration {

        @Bean(destroyMethod = "shutdown")
        DataSource dataSource() {
                return new EmbeddedDatabaseBuilder().setType(EmbeddedDatabase
Type.H2)
```

```
                                .setName("customers").build();
        }

}
```

❶ this annotation tells Spring to discover other beans in the application context by scanning the current package (or below) and looking for all objects annotated with *stereotype* annotations like `@Component`. This annotation, and others besides that are themselves annotated with `@Component`, act as sorts of markers for Spring. Tags. Spring perceives them on components and creates a new instance of the object on which they're applied. It calls the no-argument constructor by default, or it'll call a constructor with parameters so long as all the parameters themselves are satisfyable with references to other objects in the application context. Spring provides a lot of services as *opt-in* annotations expected on `@Configuration` classes.

The code in our example uses a datasource directly and we're forced to write a lot of low-level boilerplate JDBC code to get a simple result. Dependency injection is a powerful tool, but it's the least interesting aspect of Spring. Let's use one of Spring's most compelling features: the portable service abstractions, to simplify our interaction with the datasource. We'll swap out our manual and verbose JDBC-code and use Spring framework's `JdbcTemplate` instead.

Example 1-9.

```
package com.example.psa;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.ComponentScan;
import org.springframework.context.annotation.Configuration;
import org.springframework.jdbc.core.JdbcTemplate;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseBuilder;
import org.springframework.jdbc.datasource.embedded.EmbeddedDatabaseType;

import javax.sql.DataSource;

@Configuration
@ComponentScan
public class ApplicationConfiguration {

        @Bean(destroyMethod = "shutdown")
        DataSource dataSource() {
                return new EmbeddedDatabaseBuilder().setType(EmbeddedDatabase
Type.H2)
                                .setName("customers").build();
        }

        ❶
```

```
        @Bean
        JdbcTemplate jdbcTemplate(DataSource dataSource) {
                return new JdbcTemplate(dataSource);
        }

}
```

❶ the `JdbcTemplate` is one of many implementations in the Spring ecosystem of the *template pattern*. It provides convenient utility methods that make working with JDBC a one-liner for common things. It handles resource initialization and acquisition, destruction, exception handling and so much more so that we can focus on the essence of the task at hand.

With the `JdbcTemplate` in place, our revised `CustomerService` is *much* cleaner.

Example 1-10.

```
package com.example.psa;

import com.example.Customer;
import org.springframework.jdbc.core.JdbcTemplate;
import org.springframework.jdbc.core.RowMapper;
import org.springframework.stereotype.Component;

import java.util.Collection;

@Component
public class CustomerService {

        private final JdbcTemplate jdbcTemplate;

        public CustomerService(JdbcTemplate jdbcTemplate) {
                this.jdbcTemplate = jdbcTemplate;
        }

        public Collection<Customer> findAll() {
                ❶
                RowMapper<Customer> rowMapper = (rs, i) -> new Customer(rs.get
Long("ID"),
                                rs.getString("EMAIL"));
                ❷
                return this.jdbcTemplate.query("select * from CUSTOMERS ", rowMap
per);
        }
}
```

❶ there are many overloaded variants of the `query` method, one of which expects a `RowMapper` implementation. It is a callback object that Spring will invoke for you on each returned result, allowing you to map objects returned from the database

to the domain object of your systemm. The `RowMapper` interface also lends itself nicely to Java 8 lambas!

❷ the query is a trivial one-liner. Much better!

As we control the wiring in a central place, in the bean configuration, we're able to *substitute* (or *inject*) implementations with different specializations or capabilites. If we wanted to, we could change all the injected implementations to support cross-cutting concerns without altering the consumers of the beans. Suppose we wanted to support logging the time it takes to invoke all methods. We could create a class that subclasses our existing `CustomerService` and then, in method overrides, insert logging functionality before and after we invoke the `super` implementation. The logging functionality is a cross-cutting concern, but in order to inject it into the behavior of our object hierarchy we'd have to override all methods.

Ideally, we wouldn't need to go through so many hoops to interpose trivial cross-cutting concerns over objects like this. Languages (like Java) that only support single-inheritance don't provide a clean way to address this use case for any arbitrary object. Spring suppports an alternative, *aspect-oriented programming* (AOP). AOP is a larger topic than Spring, but Spring provides a very approachable subset of AOP for Spring objects. Spring's AOP support centers around the notion of an *aspect* which codifies cross-cutting behavior. A *pointcut* describes the pattern that should be matched when applying an aspect. The pattern in a pointcut is part of a full-featured pointcut language that Spring supports. The pointcut language lets you describe method invocations for objects in a Spring application. Let's suppose we wanted to create an aspect that will match all method invocations, today and tomorrow, in our `CustomerService` example and interpose logging to capture timing.

Add `@EnableAspectJAutoProxy` to the `ApplicationConfiguration` `@Configuration` class to activate Spring's AOP functionality. Then, we need only extract our cross-cutting functionality into a separate type, an `@Aspect`-annotated object.

Example 1-11.

```
package com.example.aop;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.aspectj.lang.ProceedingJoinPoint;
import org.aspectj.lang.annotation.Around;
import org.aspectj.lang.annotation.Aspect;
import org.springframework.stereotype.Component;

import java.time.LocalDateTime;

@Component
```

```
@Aspect
❶
public class LoggingAroundAspect {

        private Log log = LogFactory.getLog(getClass());

        ❷
        @Around("execution(* com.example.aop.CustomerService.*(..))")
        public Object log(ProceedingJoinPoint joinPoint) throws Throwable {
                LocalDateTime start = LocalDateTime.now();

                Throwable toThrow = null;
                Object returnValue = null;

                ❸
                try {
                        returnValue = joinPoint.proceed();
                }
                catch (Throwable t) {
                        toThrow = t;
                }
                LocalDateTime stop = LocalDateTime.now();

                log.info("starting @ " + start.toString());
                log.info("finishing @ " + stop.toString() + " with duration "
                                + stop.minusNanos(start.getNano()).getNano());

                ❹
                if (null != toThrow)
                        throw toThrow;

                ❺
                return returnValue;
        }
}
```

❶ mark this bean as an aspect

❷ declare that this method is to be given a chance to execute *around* - before and afer - the execution of any method that matches the pointcut expression in the `@Around` annotation. There are numerous other annotations, but for now this one will give us a lot of power. For more, you might investigate Spring's support for AspectJ.

❸ when the method matching this pointcut is invoked, our aspect is invoked first, and passed a `ProceedingJoinPoint` which is a handle on the running method invocation. We can choose to interrogate the method execution, to proceed with it, to skip it, etc. This aspect logs before and after it proceeds with the method invocation.

❹ if an exception is thrown it is cached and rethrown later

❺ if a return value is recorded it is returned as well (assuming no exception's been thrown)

We can use AOP directly, if we need to, but many of the really important cross cutting concerns we're likely going to encounter in typical application development are already extracted out for us in Spring itself. An example is declarative transaction management. In our example, we have one method which is read-only. If we were to introduce another business service method - one that mutated the database multiple times in a single service call - then we'd need to need to ensure that those mutations all happened in a single unit-of-work; either every interaction with the stateful resource (the datasource) succeeds or none of them do. We don't want to leave the system in an inconsistent state. This is an ideal example of a cross-cutting concern: we might use AOP to begin a transactional block before every method invocation in a business service and commit (or rollback) that transaction upon the completion of the invocation. We *could*, but thankfully Spring's declarative transaction support does this for us already, we don't need to write lower-level AOP-centric code to make it work. Add `@EnableTransactionManagement` to a configuration class and then delineate transactional boundries on business services using the `@Transactional` annotation.

We have a service tier, a logical next step might be to build a web application. We could use Spring MVC to create a REST endpoint. We would need to configure Spring MVC itself, and then deploy it an Servlet-compatible application server, and then confgure the application server's interaction with Servlet API. It can be a lot of work before we can take that next step and realize a humble working web application and REST endpoint!

We've used straight JDBC here but we could've elected to use an ORM layer, instead. This would've invited even more complexity. None of it is too much, step by step, but taken together the cognitive load can be overwhelming.

This is where Spring Boot and and its auto-configuration kick in.

In our first example in this chapter, we created an application with an interface, a JPA entity, a few annotations and a `public static void main` entry-point class and.. that's it! Spring Boot started up, and *presto!*, there was a working REST API running on `http://localhost:8080/cats`. The application supported manipulating JPA entities using the Spring Data JPA-based repository. It did a lot of things for which there was, seemingly, no explicit code - *magic*!

If you know much about Spring then you'll no doubt recognize that we were using, among other things, Spring framework and its robust support for JPA, Spring Data JPA to configure a declarative, interface-based repository, Spring MVC and Spring

Data REST to serve an HTTP-based REST API, and even then you might be wondering about where the web server itself came from. If you know much about Spring then you'll appreciate that each of these modules requires *some* configuration. Not much, usually, but certainly more than what we did there! They require, if nothing else, an annotation to *opt-in* to certain default behavior.

Historically, Spring has opted to expose the configuration. It's a configuration plane - a chance to refine the behavior of the application. In Spring Boot, the priority is providing a sensible default and supporting easy overrides. It's a full throated embrace of convention-over-configuration. Ultimately, Spring Boot's auto-configuration is the same sort of configuration that you could write by hand, with the same annotations and the same beans you might register, along with common sense defaults.

Spring supports the notion of a service loader to support registering custom contributions to the application without changing Spring itself. A service loader is a mapping of types to Java configuration class names that are then evaluated and made available to the Spring application later on. The registration of custom contributions happens in the `META-INF/spring.factories` file. Spring Boot looks in the `spring.factories` file for, among other things, all classes under the `org.springframework.boot.autoconfigure.EnableAutoConfiguration` entry. In the `spring-boot-autoconfigure .jar` that ships with the Spring Boot framework itself there are *dozens* of different configuration classes here, and Spring Boot will try to evaluate them all! It'll try, but *fail*, to evaluate all of them, at least, thanks to various conditions - guards, if you like - that have been placed on the configuration classes and the `@Bean` definitions therein. This facility, to conditionally register Spring components, is from Spring framework itself, on which Spring Boot is built. These conditions are wide-ranging: they test for the availability of beans of a given type, the presence of environment properties, the availability of certain types on the CLASSPATH, and more.

Let's review our `CustomerService` example. We want to build a Spring Boot-version of the application that uses an embedded database, the Spring framework `JdbcTemplate` and then support building a web application. Spring Boot will do all of that for us. Revisit the `ApplicationConfiguration` and turn it into a Spring Boot application accordingly:

Example 1-12. `ApplicationConfiguration.java` class

```
package com.example.boot;

import org.springframework.boot.autoconfigure.SpringBootApplication;

@SpringBootApplication
public class ApplicationConfiguration {
        ❶
}
```

❶ Look ma, no configuration! Spring Boot will contribute all the things that we contributed ourselves, manually, and so much more.

Let's introduce a Spring MVC-based controller to expose a REST endpoint to respond to HTTP `GET` requests at `/customers`.

Example 1-13. `CustomerRestController.java` class

```
package com.example.boot;

import com.example.Customer;
import org.springframework.web.bind.annotation.GetMapping;
import org.springframework.web.bind.annotation.RestController;

import java.util.Collection;

@RestController
❶
public class CustomerRestController {

        private final CustomerService customerService;

        public CustomerRestController(CustomerService customerService) {
                this.customerService = customerService;
        }

        ❷
        @GetMapping("/customers")
        public Collection<Customer> readAll() {
                return this.customerService.findAll();
        }
}
```

❶ `@RestController` is another stereotype annotation, like `@Component`. It tells Spring that this component is to serve as a REST controller.

❷ We can use Spring MVC annotations that map to the domain of what we're trying to do, in this case, to handle HTTP `GET` requests to a certain endpoint with `@GetMapping`

You could create an entry point in the `ApplicationConfiguration` class and then run the application and visit `http://localhost:8080/customers` in your browser. Cognitively, it's much easier to reason about what's happening in our business logic *and* we've done more in less!

Example 1-14.

```
//...

public static void main(String [] args){
 SpringApplication.run (ApplicationConfiguration.class, args);
}

//...
```

We got more for less, but we know that somewhere something is doing the same configuration as we did explicitly, before. Where is the `JdbcTemplate` being created? It's created in an auto-configuration class called `JdbcTemplateAutoConfiguration`, whose definition is (roughly):

Example 1-15. `JdbcTemplateAutoConfiguration`

```
@Configuration ❶
@ConditionalOnClass({ DataSource.class, JdbcTemplate.class }) ❷
@ConditionalOnSingleCandidate(DataSource.class) ❸
@AutoConfigureAfter(DataSourceAutoConfiguration.class) ❹
public class JdbcTemplateAutoConfiguration {

        private final DataSource dataSource;

        public JdbcTemplateAutoConfiguration(DataSource dataSource) {
                this.dataSource = dataSource;
        }

        @Bean
        @Primary
        @ConditionalOnMissingBean(JdbcOperations.class) ❺
        public JdbcTemplate jdbcTemplate() {
                return new JdbcTemplate(this.dataSource);
        }

        @Bean
        @Primary
        @ConditionalOnMissingBean(NamedParameterJdbcOperations.class) ❻
        public NamedParameterJdbcTemplate namedParameterJdbcTemplate() {
                return new NamedParameterJdbcTemplate(this.dataSource);
        }

}
```

❶ this is a normal `@Configuration` class

❷ the configuration class should *only* be evaluated if the type `DataSource.class` and `JdbcTemplate.class` are somewhere on the classpath, otherwise this would no doubt fail with an error like `ClassNotFoundException`

❸ we only want this configuration class if, somewhere in the application context, a `DataSource` bean has been contributed.

❹ we know that `DataSourceAutoConfiguration` will contribute an embedded H2 datasource if we let it, so this annotation ensures that this configuration happens **after** that `DataSourceAutoConfiguration` has run. If a database is contributed, then this configuration class will evaluate.

❺ we want to contribute a `JdbcTemplate` but only so long as the user (that's to say, so long as you and I) haven't already defined a bean of the same type in our own configuration classes.

Spring Boot's auto-configuration greatly reduces the actual code count and the cognitive load associated with that code. It frees us to focus on the essence of the business logic, leaving the tedium to the framework. If we want to exert control over some aspect of the stack we're free to contribute beans of certain types and those will be plugged in to the framework for us. Spring Boot is an implementation of the open-closed principal: it's open for extension but closed for modification. You don't *need* to recompile Spring or Spring Boot in order to override parts of the machine. You may see your Spring Boot application exhibit some odd behavior that you want to override or customize. It's important to know how to customise the application and how to debug it. Specify the `--Ddebug=true` flag when the application starts up and Spring Boot will print out the Debug Report, showing you all the conditions that have been evaluated and whether they're a positive or negative match. From there, it's easy to examine what's happening in the relevant auto-configuration class to ascertain its behavior.

Cloud Foundry

Spring Boot lets us focus on the essence of the application itself, but what good would all that newfound productivity be if we then lost it all struggling to move the application to production? Operationalizing an application is a daunting task, but one that must not be ignored. Our goal is to continuously deploy our application into a production-like environment, to validate in integration and acceptance tests, that things will work when they're deployed to production. It's important to get to production as early and often as possible for that is the only place where the customer, the party most invested in the outcome of a team's deliverable, can validate that it works. If moving to production is arduous, inevitably, a software team will come to fear the

process and hesitate, increasing the delta between development and production pushes. This increases the backlog of work that hasn't been moved to production, which means that each push becomes more risky because there's more business value in each release. In order to de-risk the move to production, reduce the batch of work and increase the frequency of deployment. If there's a mistake in production, it should be as cheap as possible to fix it and deploy that fix.

The trick is to automate away everything that can be automated in the value chain from product management to production that doesn't add value to the process. Deployment is not a business differentiating activity; it adds no value to the process. It should be completely automated. You get velocity through automation.

Cloud Foundry is a cloud platform that wants to help. It's a Platform-as-a-service (PaaS). Cloud Foundry focuses not on hard disks, RAM, CPU, Linux installations and security patches as you would with an Infrastructure-as-a-service (IaaS) offering, or on containers as you might in a container-as-a-service offering, but instead on applications and their services. Operators focus on applications and their services, nothing else. We'll see Cloud Foundry throughout this book, so far now let's focus on deploying the Spring Boot application we iteratively developed when looking at Spring's configuration support.

There are multiple implementations of Cloud Foundry, all based on the open-source Cloud Foundry code. For this book we've run and deployed all applications on Pivotal Web Services. Pivotal Web Services offers a subset of the functionality of Pivotal's on-premise Pivotal Cloud Foundry offering. It's hosted on Amazon Web Services, in the AWS East region. If you want to take your first steps with Cloud Foundry, PWS is an affordable and approachable option that serves projects large and small every day and is maintained by the operations team at Pivotal who turns that know-how that gets driven back into the product.

Go to the main page. You'll find a place to sign in an existing account, or register new accounts.

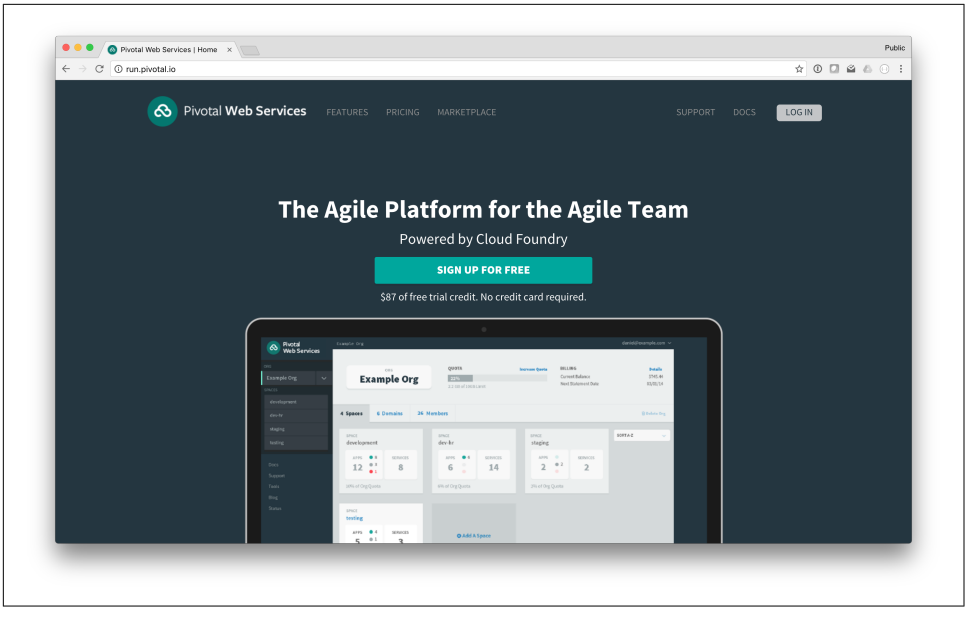


Figure 1-17. The PWS main page

Once logged in you can interact with your account and get information about deployed applications.

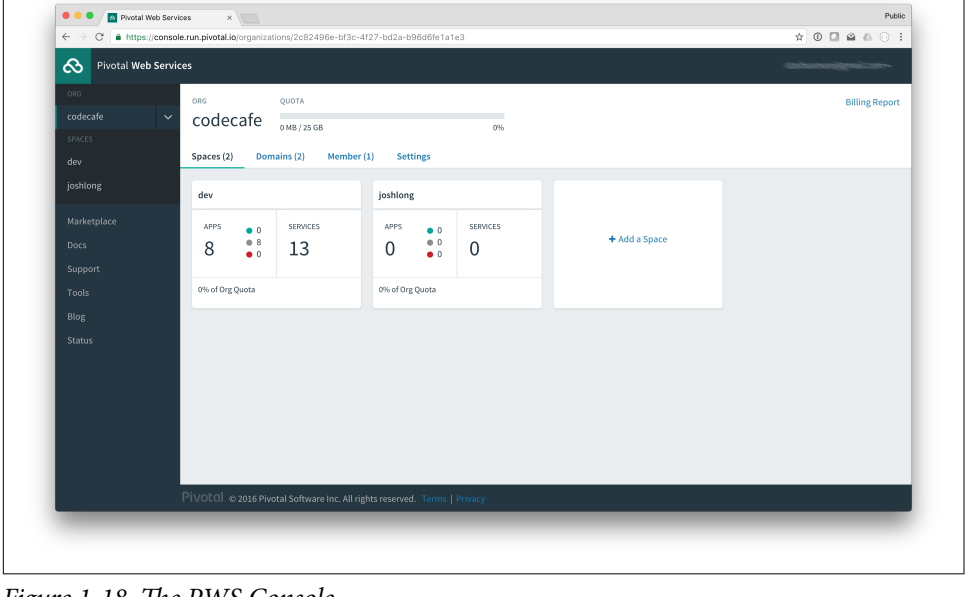


Figure 1-18. The PWS Console

Once you have an account, make sure you have the `cf` CLI. You'll need to login if you haven't before.

Target the appropriate Cloud Foundry instance using `cf target api.run.pivotal.io` and then login using `cf login`.

Example 1-16. authenticating and targeting a Cloud Foundry organization and a space

```
   cf login

API endpoint: https://api.run.pivotal.io

Email> email@gmail.com

Password>
Authenticating...
OK

Select an org (or press enter to skip):
1. marketing
2. sales
2. back-office

Org> 1
Targeted org back-office

Targeted space development

API endpoint:   https://api.run.pivotal.io (API version: 2.65.0)
User:           email@gmail.com
Org:            back-office     # 1
Space:          development    # 2
```

❶ in Cloud Foundry, there might be many organizations to which a given user has access.

❷ within that organization, there might be multiple environments (for example, `development`, `staging`, and `integration`).

Now that we have a valid account and are logged in, we can deploy our existing application, in `target/configuration.jar`. We'll need to provision a database using the `cf create-service` command.

Example 1-17. create a MySQL database, bind it to our application and then start the application

```
#!/usr/bin/env bash

cf create-service p-mysql 100mb bootcamp-customers-mysql           # 1
```

```
cf push -p target/configuration.jar bootcamp-customers \
 --random-route --no-start                                    # 2

cf bind-service bootcamp-customers bootcamp-customers-mysql   # 3

cf start bootcamp-customers                                   # 4
```

❶ first we need to provision a MySQL database from the MySQL service (called `p-mysql`) at the `100mb` plan. Here, we'll assign it a logical name, `bootcamp-customers-mysql`. Use `cf marketplace` to enumerate other services in a Cloud Foundry instance's service catalog.

❷ then push the application's artifact, `target/configuration.jar`, to Cloud Foundry. We assign the application and a random route (a URL, in this case under the PWS `cfapps.io` domain), but we don't want to start it yet: it still needs a database!

❸ the database exists, but nobody can talk to it unless we bind it to an application. Ultimately, *binding* results in environment variables being exposed in the application with the relevant connection information in the environmental variables.

❹ now that the application is bound to a database, we can finally start it up!

When you push the application to Cloud Foundry, you're giving it an application binary, a `.jar`, not a virtual machine or a Linux container (though, you *could* give it a Linux container). When Cloud Foundry receives the `.jar` it will try to determine what the nature of the application is - is it a Java application? A Ruby application? A .NET application? It'll eventually arrive at a Java application. It will pass the `.jar` to the Java buildpack. A buildpack is a directory full of scripts invoked according to a well-known lifecycle. You can override the default buildpack used by specifying its URL, or you can let the default buildpack kick in. There are buildpacks for all manner of different languages and platforms including Java, .NET, Node.js, Go, Python, Ruby, and a slew more. The Java buildpack will realize that the application is an executable `main(String [] args)` method, and that it is self-contained. It will pull down the latest OpenJDK version, and specify that our application is to run. All of this configuration is packaged into a Linux container which Cloud Foundry's scheduler will then deploy across a cluster. Cloud Foundry can run hundreds of thousands of containers in a single environment.

In no time at all, the application will spin up and report a URL on the console at which the application has been exposed. *Congratulations*! Our application is now deployed to a Cloud Foundry instance.

In our application, we have one datasource bean and so Cloud Foundry re-mapped it automatically to the single, bound MySQL service, overwriting the default embedded H2 datasource definition with one that points to a MySQL datasource.

There are a lot of aspects to the deployed application that we may want to describe on each deployment. In our first run, we used various `cf` incantations to configure the application, but that could get tedious, quickly. Instead, let's capture our application's configuration in a Cloud Foundry manifest file, typically named `manifest.yml`. Here's a `manifest.yml` for our application that will work so long as we've already got a MySQL datasource provisioned with the same name as specified earlier.

Example 1-18. a Cloud Foundry manifest

```
---
applications:
- name: bootcamp-customers                                          # 1
  buildpack: https://github.com/cloudfoundry/java-buildpack.git     # 2
  instances: 1
  random-route: true
  path: target/configuration.jar                                    # 3
  services:
    - bootcamp-customers-mysql                                      # 4
  env:
    DEBUG: "true"
    SPRING_PROFILES_ACTIVE: cloud                                   # 5
```

❶ we provide a logical name for the application

❷ specify a buildpack

❸ specify which binary to use

❹ specify a dependency on provisioned Cloud Foundry services

❺ specify environment variables to override properties to which Spring Boot will respond. `--Ddebug=true` (or `DEBUG: true`) enumerates the conditions in the auto-configuration and `--Dspring.profiles.active=cloud` specifies which profiles, or logical groupings with arbitrary names, should be activated in a Spring application. This configuration says to start all Spring beans without any profile as well as those with the `cloud` profile.

Now, instead of writing all those `cf` incantations, just run `cf push -f manifest.yml`. Soon, your application will be up and running and ready for inspection.

Thus far we've seen that the Cloud Foundry experience is all about obtaining velocity through automation: the platform does as much of the undifferentiated heavy lifting

as possible, letting you focus on the business logic that should matter. We've worked within the opinionated approach offered by Cloud Foundry: if your application needs something, you can declare as much in a `cf` incantation or in a `manifest.yml` and the platform will support you. It is surprising therefore that, despite constraining inputs into the platform, Cloud Foundry is itself also easy to program. It provides a rich API that supports virtually everything you'd want to do. Taking things a step further, the Spring and Cloud Foundry teams have developed a Java Cloud Foundry client that supports all the major components in a Cloud Foundry implementation. The Cloud Foundry Java client *also* supports higher-level, more granular business operations that correspond to the things you might do using the `cf` CLI.

The Cloud Foundry Java client is built on the Pivotal Reactor 3.0 project. Reactor in turn underpins the reactive web runtime in Spring Framework 5. The Cloud Foundry Java client is *fast*, and as it's built on reactive principles, it's almost entirely non-blocking.

The Reactor project in turn is an implementation of the Reactive Streams initiative. The Reactive Streams initiative, according to the website, "is an initiative to provide a standard for asynchronous stream processing with non-blocking back pressure." It provides a language and APIs to describe a potentially unlimited stream of *live* data that arrives asynchronously. The Reactor API makes it easy to write code that benefits from parallelization without write coding to achieve parallelization. The goal is to avoid aggressive resources usage and isolate the blocking parts of cloud-based workloads in an efficient way. The Reactive Streams initiative defines *backpressure*; a subscriber can signal to the publisher that it does not wish to receive any more notifications. In essence, it's pushing back on the producer, throttling consumption until it can afford it.

The heart of this API is the `org.reactivestreams.Publisher` which may produce zero or more values, eventually. A `Subscriber` subscribes to notifications of new values from a `Publisher`. The Reactor project defines two useful specializations of the `Publisher`: `Mono` and `Flux`. A `Mono<T>` is a `Publisher<T>` that produces one value. A `Flux<T>` is a `Publisher<T>` that produces zero or more values.

Cardinality	Synchronous	Asynchronous
One	`T`	`Future<T>`
Many	`Collection<T>`	`org.reactivestreams.Publisher<T>`

We won't delve too deeply into reactive streams or the Reactor project, but know that it provides the foundations for the extraordinary efficiencies of the Cloud Foundry Java API. The Cloud Foundry Java API lends itself to parallelization of processing that is *very* difficult to achieve using the `cf` CLI. So, we've deployed the same application using the `cf` CLI, and a `manifest.yml` file. Let's look at doing so in Java code. It's

particularly handy to use the Cloud Foundry Java client in integration tests. In order to use the Cloud Foundry Java client, you'll need to configure some objects required to securely integrate with different subsystems in Cloud Foundry, including the log-aggregation subsystem, the Cloud Foundry REST APIs, and the Cloud Foundry authentication subsystem. We'll demonstrate the configuration of those components here, for posterity, but it's very likely that you won't need to configure this functionality in a not-too-distant release of Spring Boot.

Example 1-19. configure the Cloud Foundry Java client

```
package com.example;

import org.cloudfoundry.client.CloudFoundryClient;
import org.cloudfoundry.operations.DefaultCloudFoundryOperations;
import org.cloudfoundry.reactor.ConnectionContext;
import org.cloudfoundry.reactor.DefaultConnectionContext;
import org.cloudfoundry.reactor.TokenProvider;
import org.cloudfoundry.reactor.client.ReactorCloudFoundryClient;
import org.cloudfoundry.reactor.doppler.ReactorDopplerClient;
import org.cloudfoundry.reactor.tokenprovider.PasswordGrantTokenProvider;
import org.cloudfoundry.reactor.uaa.ReactorUaaClient;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.context.annotation.Bean;

@SpringBootApplication
public class CloudFoundryClientExample {

        public static void main(String[] args) {
                SpringApplication.run(CloudFoundryClientExample.class, args);
        }

        ❶
        @Bean
        ReactorCloudFoundryClient cloudFoundryClient(ConnectionContext connectionCon
text,
                        TokenProvider tokenProvider) {
                return ReactorCloudFoundryClient.builder().connectionContext(connec
tionContext)
                                .tokenProvider(tokenProvider).build();
        }

        ❷
        @Bean
        ReactorDopplerClient dopplerClient(ConnectionContext connectionContext,
                        TokenProvider tokenProvider) {
                return ReactorDopplerClient.builder().connectionContext(connection
Context)
                                .tokenProvider(tokenProvider).build();
```

```
        }

        ❸
        @Bean
        ReactorUaaClient uaaClient(ConnectionContext connectionContext,
                        TokenProvider tokenProvider) {
                return ReactorUaaClient.builder().connectionContext(connectionCon
text)
                                .tokenProvider(tokenProvider).build();
        }

        ❹
        @Bean
        DefaultCloudFoundryOperations cloudFoundryOperations(
                        CloudFoundryClient cloudFoundryClient, ReactorDopplerClient
dopplerClient,
                        ReactorUaaClient uaaClient, @Value("${cf.org}") String orga
nization,
                        @Value("${cf.space}") String space) {
                return DefaultCloudFoundryOperations.builder().cloudFoundry
Client(cloudFoundryClient)
                                .dopplerClient(dopplerClient).uaaClient(uaa
Client).organization(organization)
                                .space(space).build();
        }

        ❺
        @Bean
        DefaultConnectionContext connectionContext(@Value("${cf.api}") String api
Host) {
                if (apiHost.contains("://")) {
                        apiHost = apiHost.split("://")[1];
                }
                return DefaultConnectionContext.builder().apiHost(apiHost).build();
        }

        ❻
        @Bean
        PasswordGrantTokenProvider tokenProvider(@Value("${cf.user}") String user
name,
                        @Value("${cf.password}") String password) {
                return PasswordGrantTokenProvider.builder().password(password).user
name(username)
                                .build();
        }
}
```

❶ the `ReactorCloudFoundryClient` is the client for the Cloud Foundry REST API.

❷ the `ReactorDopplerClient` is the client for Cloud Foundry's websocket-based log-aggregation subsystem, Doppler

❸ the `ReactorUaaClient` is the client for UAA, the authorization and authentication subsystem in Cloud Foundry

❹ the `DefaultCloudFoundryOperations` instance provides coarser-grained operations that compose the lower-level subsystem clients. **Start here**.

❺ the `ConnectionContext` describes the Cloud Foundry instance that we wish to target

❻ the `PasswordGrantTokenProvider` describes our authentication

❼ all this ado about nothing! The *client* spins up and prints out the registered applications in a given user's account.

It's trivial to get a simple proof-of-concept with this in place. Here is a simple example that will enumerate all the deployed applications in a particular Cloud Foundry space and organization.

Example 1-20. configure the Cloud Foundry Java client

```
package com.example;

import org.cloudfoundry.operations.CloudFoundryOperations;
import org.springframework.boot.CommandLineRunner;
import org.springframework.stereotype.Component;

@Component
class ApplicationListingCommandLineRunner implements CommandLineRunner {

        private final CloudFoundryOperations cf; ❶

        ApplicationListingCommandLineRunner(CloudFoundryOperations cf) {
                this.cf = cf;
        }

        @Override
        public void run(String... args) throws Exception {
                cf.applications().list().subscribe(System.out::println); ❷
        }
}
```

❶ inject the configured `CloudFoundryOperations`

❷ .. and use it to enumerate all the deployed applications in this particular Cloud Foundry space and organization.

For a more real-world example, let's deploy our `bootcamp-customers` application using the Java client. Here's a simple integration-test that provisions a MySQL service, pushes the application to Cloud Foundry (but doesn't start it), binds environment variables, binds the MySQL service and then, *finally*, starts the application. First, let's look at the skeletal code where we identify the deployable `.jar`, name our application and the service. We'll delegate to two components, `ApplicationDeployer` and `ServicesDeployer`.

Example 1-21. the skeleton of an integration-test that provisions an application

```
package bootcamp;

import org.cloudfoundry.operations.CloudFoundryOperations;
import org.junit.Test;
import org.junit.runner.RunWith;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.boot.test.context.SpringBootTest;
import org.springframework.context.annotation.Bean;
import org.springframework.test.context.junit4.SpringJUnit4ClassRunner;
import reactor.core.publisher.Mono;

import java.io.File;

@RunWith(SpringJUnit4ClassRunner.class)
@SpringBootTest(classes = SpringConfigurationIT.Config.class)
public class SpringConfigurationIT {

        @Autowired
        private ApplicationDeployer applicationDeployer;
        @Autowired
        private ServicesDeployer servicesDeployer;

        @Test
        public void deploy() throws Throwable {
                File projectFolder = new File(new File("."), "../spring-
configuration");
                File jar = new File(projectFolder, "target/spring-
configuration.jar");
                String applicationName = "bootcamp-customers";
                String mysqlServiceName = "bootcamp-customers-mysql";

                ❶
                Mono<Void> service = servicesDeployer.deployService(
                                applicationName, mysqlServiceName);

                ❷
                Mono<Void> apps = applicationDeployer.deployApplication(
                                jar, applicationName, mysqlServiceName);
```

```
                ❸
                service.then(apps).block();
        }

        @SpringBootApplication
        public static class Config {

                @Bean
                ApplicationDeployer applications(CloudFoundryOperations cloudFoun
dryOperations) {
                        return new ApplicationDeployer(cloudFoundryOperations);
                }

                @Bean
                ServicesDeployer services(CloudFoundryOperations cloudFoundryOpera
tions) {
                        return new ServicesDeployer(cloudFoundryOperations);
                }
        }

}
```

❶ first deploy our services..

❷ ..then the application

❸ ..then chain the flows together, one after the other, using the `.next`

This example composes two `Publisher` instances, one describing the processing required to provision a service, and another describing the processing required to provision the application. The final call in the chain, `.block()`, triggers processing; it is a terminal method that activates the entire flow.

The `ServicesDeployer` takes the required parameters and provisions our MySQL instance. It also unbinds and deletes the instance if it should already exist.

Example 1-22. `ServicesDeployer`

```
package bootcamp;

import org.cloudfoundry.operations.CloudFoundryOperations;
import org.cloudfoundry.operations.services.CreateServiceInstanceRequest;
import org.cloudfoundry.operations.services.DeleteServiceInstanceRequest;
import org.cloudfoundry.operations.services.UnbindServiceInstanceRequest;
import reactor.core.publisher.Mono;


class ServicesDeployer {

        private final CloudFoundryOperations cf;
```

```
        ServicesDeployer(CloudFoundryOperations cf) {
                this.cf = cf;
        }

        Mono<Void> deployService(String applicationName, String mysqlServiceName) {
                return cf.services()
                                .listInstances()
                                .filter(si -> si.getName().equalsIgnoreCase(mysqlSer
viceName)) ❶
                                .singleOrEmpty()
                                .then(serviceInstance ->
                                                cf.services()
                                                                .unbind(UnbindServi
ceInstanceRequest.builder() ❷
                                                                                .app
licationName(applicationName)
                                                                                .ser
viceInstanceName(mysqlServiceName)
                                                                                .bui
ld())
                                                                .then(cf.services()
                                                                                .del
eteInstance(DeleteServiceInstanceRequest.builder() ❸

.name(serviceInstance.getName())

.build())))
                                .then(cf.services()
                                                .createInstance(CreateServiceInstan
ceRequest.builder() ❹
                                                                .serviceName("p-
mysql")
                                                                .planName("100mb")
                                                                .serviceInstance
Name(mysqlServiceName)
                                                                .build()));
        }
}
```

❶ In keeping with the ideas of immutable infrastructure, let's ensure that if the service has already been provisioned, that we..

❷ ..unbind it and then..

❸ ..delete it.

❹ Finally, we need to create the instance.

The `ApplicationDeployer` then provisions the application itself. It binds to the service that will have already been provisioned in the earlier `ServicesDeployer` flow.

Example 1-23. `ApplicationDeployer`

```
package bootcamp;

import org.cloudfoundry.operations.CloudFoundryOperations;
import org.cloudfoundry.operations.applications.PushApplicationRequest;
import org.cloudfoundry.operations.applications.SetEnvironmentVariableApplicationRe
quest;
import org.cloudfoundry.operations.applications.StartApplicationRequest;
import org.cloudfoundry.operations.services.BindServiceInstanceRequest;
import reactor.core.publisher.Flux;
import reactor.core.publisher.Mono;

import java.io.File;
import java.time.Duration;
import java.util.stream.Stream;

class ApplicationDeployer {

        private final CloudFoundryOperations cf;

        ApplicationDeployer(CloudFoundryOperations cf) {
                this.cf = cf;
        }

        Mono<Void> deployApplication(
                        File jar,
                        String applicationName,
                        String... svcs) {

                return cf.applications()
                                .push(PushApplicationRequest.builder() ❶
                                                .name(applicationName)
                                                .noStart(true)
                                                .randomRoute(true)
                                                .buildpack("https://github.com/cloud
foundry/java-buildpack.git")
                                                .application(jar.toPath())
                                                .instances(1)
                                                .build())
                                .thenMany(Flux.merge(Flux.from
Stream(Stream.of(svcs) ❷
                                                .map(svc ->
                                                                cf.services()
                                                                                .bin
d(BindServiceInstanceRequest.builder()

.applicationName(applicationName)
```

```
.serviceInstanceName(svc)

.build())))))
                                .then()
                                .then(cf.applications()
                                                .setEnvironmentVariable(SetEnviron
mentVariableApplicationRequest.builder() ❸
                                                                .name(application
Name)
                                                                .variable
Name("SPRING_PROFILES_ACTIVE")
                                                                .variable
Value("cloud")
                                                                .build()))
                                .then(cf.applications()
                                                .start(StartApplicationRe
quest.builder() ❹
                                                                .name(application
Name)
                                                                .stagingTimeout(Dura
tion.ofMinutes(5))
                                                                .startupTimeout(Dura
tion.ofMinutes(5))
                                                                .build()));
        }
}
```

❶ first, we push the application binary (the `path`), specifying a buildpack, memory, and deployment properties like instance count. Importantly, we do *not* start the application yet. We'll do that *after* the environment variables and services are bound. This step is automatically handled for you when you use Cloud Foundry manifests.

❷ then let's visit each service isntance name ensure that its bound to the the application

❸ then let's specify an environment variable

❹ and, finally, let's *start* the application.

Run the whole thing and it'll take a pittance of time, and even less once you tune it by specifying that certain branches of the flow should be run on different threads. The Cloud Foundry Java client is very powerful and one of the authors favorite ways to describe complex systems. It's also very handy when the deployment requires more than a trivial amount of of shell scripting.

Next Steps

In this chapter we looked every so briefly at getting started with Spring Boot and supporting tools like the Spring Tool Suite, creating Java configuration, and then moving that application to a cloud environment. We've automated the deployment of the code to a production environment, and it wouldn't be hard to standup a continuous integration flow using Jenkins or Bamboo. In the next chapters, we'll look more heavily at all things Spring Boot and Cloud Foundry.

CHAPTER 2

The Cloud Native Application

The patterns for how we develop software, both in teams and as individuals, are always evolving. The open source software movement has provided the software industry with somewhat of a Cambrian explosion of tools, frameworks, platforms, and operating systems—all with an increasing focus on flexibility and automation. A majority of today's most popular open source tools focus on features that give software teams the ability to continuously deliver software faster than ever before possible, at every level, from development to operations.

Amazon's Story

In the span of two decades, starting in the early 90s, an online bookstore headquartered in Seattle, called Amazon.com, grew into the world's largest online retailer. Known today simply as *Amazon*, the company now sells far more than just books. In 2015, Amazon surpassed Walmart as the most valuable retailer in the United States. The most interesting part of Amazon's story of unparalleled growth can be summarized in one simple question: How did a website that started out as a simple online bookstore transform into one of the largest retailers in the world—doing so without ever opening a single retail location?

It's not hard to see how the world of commerce has been shifted and reshaped around digital connectivity, catalyzed by ever increasing access to the internet from every corner of the globe. As personal computers became smaller, morphing into the ubiquitous smart phone, tablets and watches we use today, we've experienced an exponential increase in accessibility to distribution channels that are transforming the way the world does commerce.

Amazon's CTO, Werner Vogels, oversaw the technical evolution of Amazon from a hugely successful online bookstore into one of the world's most valuable technology

companies and product retailers. In June 2006, Vogels was interviewed in a piece for the computer magazine *ACM Queue* on the rapid evolution of the technology choices that powered the growth of the online retailer. In the interview Vogels talks about the core driver behind the company's continued growth.

> A large part of Amazon.com's technology evolution has been driven to enable this continuing growth, **to be ultra-scalable while maintaining availability and performance**.
>
> —Werner Vogels, *ACM Queue, Volume 4 Issue 4, A Conversation with Werner Vogels*

Vogels goes on to state that in order for Amazon to achieve ultra-scalability it needed to move towards a different pattern of software architecture. Vogels mentions in the interview that Amazon.com started as a monolithic application. Over time, as more and more teams operated on the same application, the boundries of ownership of the codebase began to blur. "There was no isolation and, as a result, no clear ownership." said Vogels.

Vogels went on to pinpoint that shared resources, such as databases, were making it difficult to scale-out the overall business. The greater the number of shared resources, whether it be application servers or databases, the less control teams would have when delivering features into production.

> You build it, you run it.
>
> —Werner Vogels, *CTO, Amazon*

Vogels touched on a common theme that cloud native applications share: the idea that teams own what they are building. He goes on to say that "the traditional model is that you take your software to the wall that separates development and operations, and throw it over and then forget about it. Not at Amazon. *You build it, you run it*."

In what has been one of the most reused quotes by prominent keynote speakers at some of the world's premier software conferences, the words "*you build it, you run it*" would later become a slogan of a popular movement we know today simply as *DevOps*.

Many of the practices that Vogels spoke about in 2006 were seeds for popular software movements that are thriving today. Practices such as *DevOps* and *microservices* can be tied back to the ideas that Vogels introduced over a decade ago. While ideas like these were being developed at large internet companies similar to Amazon, the tooling around these ideas would take years to develop and mature into a service offering.

In 2006 Amazon launched a new product named Amazon Web Services (AWS). The idea behind AWS was to provide a platform, the same platform that Amazon used internally, and release it as a service to the public. Amazon was keen to see the oppor-

tunity to commodotize the ideas and tooling behind the Amazon.com platform. Many of the ideas that Vogels introduced were already built into the Amazon.com platform. By releasing the platform as a service to the public, Amazon would enter into a new market called the *public cloud*.

The ideas behind the public cloud were sound. Virtual resources could be provisioned on-demand without needing to worry about the underlying infrastructure. One could simply rent a virtual machine to house their applications without needing to purchase or manage the infrastructure. This approach was a low-risk self-service option that would help to grow the appeal of the public cloud, with AWS leading the way in terms of adoption.

It would take years before AWS would mature into a set of services and patterns for building and running applications that are designed to be operated on a public cloud. While many developers flocked to these services for building new applications, many companies with existing applications still had concerns with migrations. Existing applications were not designed for portability. Also, many applications were still dependent on legacy workloads that were not compatible with the public cloud.

In order for most large companies to take advantage of the public cloud, they would need to make changes in the way they developed their applications.

The Promise of a Platform

Platform is an overused word today.

When we talk about platforms in computing, we are generally talking about a set of capabilities that help us to either build or run applications. Platforms are best summarized by the nature in which they impose constraints on how developers build applications.

Platforms are able to automate the tasks that are not essential to supporting the business requirements of an application. This makes development teams more agile in the way they are able to support only the features that help to differentiate value for the business.

Any team that has written shell scripts or stamped containers or virtual machines to automate deployment has built a platform, of sorts. The question is: what promises can that platform keep? How much work would it take to support the majority (or even all) requirements for continuously delivering new software?

When we build platforms, we are creating a tool that automates a set of repeatable practices. Practices are formulated from a set of constraints that translate valuable ideas into a plan.

- **Ideas** What are our core ideas of the platform and why are they valuable?

- **Constraints** What are the constraints necessary to transform our ideas into practices?
- **Practices** How do we automate constraints into a set of repeatable practices?

At the core of every platform are simple ideas that, when realized, increase differentiated business value through the use of an automated tool.

Let's take for example the Amazon.com platform. Werner Vogels stated that by increasing isolation between software components, teams would have more control over features they delivered into production.

Ideas:

- *By increasing isolation between software components, we are able to deliver parts of the system both rapidly and independently.*

By using this idea as the platform's foundation, we are able to fashion it into a set of constraints. Constraints take the form of an opinion about how a core ideal will create value when automated into a practice. The following statements are opinionated constraints about how isolation of components can be increased.

Constraints:

- *Software components are to be built as independently deployable services.*
- *All business logic in a service is encapsulated with the data it operates on.*
- *There is no direct access to a database from outside of a service.*
- *Services are to publish a web interface that allows access to its business logic from other services.*

With these constraints, we have taken an opinionated view on how isolation of software components will be increased in practice. The promises of these constraints, when automated into practices, will provide teams with more control over how features are delivered to production. The next step is to describe how these constraints can be captured into a set of repeatable practices.

Practices that are derived from these constraints should be stated as a collection of promises. By stating practices as promises we maintain an expectation with the users of the platform on how they will build and operate their applications.

Practices:

- *A self-service interface is provided to teams that allows for the provisioning of infrastructure required to operate applications.*
- *Applications are packaged as a bundled artifact and deployed to an environment using the self-service interface.*

- *Databases are provided to applications in the form of a service, and are to be provisioned using the self-service interface.*
- *An application is provided with credentials to a database as environment variables, only after declaring an explicit relationship to the database as a service binding.*
- *Each application is provided with a service registry that is used as a manifest of where to locate external service dependencies.*

Each of the practices listed above takes on the form of a promise to the user. In this way, the intent of the ideas at the core of the platform are realized as constraints imposed on applications.

Cloud native applications are built on a set of constraints that reduce the time spent doing undifferentiated heavy lifting.

When AWS was first released to the public, Amazon did not force its users to adhere to the same constraints that they used internally for Amazon.com. Staying true to the name, *Amazon Web Services*, AWS is not itself a cloud *platform*, but rather it is a collection of independent infrastructure services that can be composed into automated tooling resembling a platform of promises. Years after the first release of AWS, Amazon would begin to offer a collection of managed platform services, with use cases ranging from IoT (Internet of Things) to machine learning.

If every company needs to build their own platform from scratch, the amount of time delivering value in applications is delayed until the platform is fully assembled. Companies who were early adopters of AWS would have needed to assemble together some form of automation resembling a platform. Each company would have had to bake-in a set of promises that captured the core ideas of how to develop and deliver software into production.

More recently, the software industry has converged on the idea that there are a basic set of common promises that every cloud platform should make. These promises will be explored throughout this book using the open source *Platform-as-a-Service* (PaaS), named Cloud Foundry. The core idea behind Cloud Foundry is to provide a platform that encapsulates a set of common promises for quickly building and operating. Cloud Foundry makes these promises while still providing portability between multiple different cloud infrastructure providers.

The subject of much of this book is how to build cloud native Java applications. We'll focus largely on tools and frameworks that help to reduce undifferentiated heavy lifting, by taking advantage of the benefits and promises of a cloud native platform.

The Patterns

New patterns for how we develop software are enabling us to think more about the behavior of our applications in production. Both developers and operators, together, are placing more emphasis on understanding how their applications will behave in production, with fewer assurances of how complexity will unravel in the event of a failure.

As was the case with Amazon.com, software architectures are beginning to move away from large monolithic applications. Architectures are now focused on achieving ultra-scalability without sacrificing performance and availability. By breaking apart components of a monolith, engineering organizations are taking efforts to decentralize change management, providing teams with more control over how features make their way to production. By increasing isolation between components, software teams are starting to enter into the world of distributed systems development, with a focus of building smaller more singularly focused services with independent release cycles.

Cloud native applications take advantage of a set of patterns that make teams more agile in the way they deliver features to production. As applications become more distributed, a result of increasing isolation necessary to provide more control to the teams that own applications, the chance of failure in the way application components communicate becomes an important concern. As software applications turn into complex distributed systems, operational failures become an inevitable result.

Cloud native application architectures provide the benefit of ultra-scalability while still maintaining guarantees about overall availability and performance of applications. While companies like Amazon reaped the benefits of ultra-scalability in the cloud, widely available tooling for building cloud-native applications had yet to surface. The tooling and platform would eventually surface as a collection of open source projects maintained by an early pioneer of the public cloud, a company named Netflix.

Scalability

To develop software faster, we are required to think about scale at all levels. Scale, in a most general sense, is a function of cost that produces value. The level of unpredictability that reduces that value is called risk. We are forced to frame scale in this context because building software is fraught with risks. The risks that are being created by software developers are not always known to operators. By demanding that developers deliver features to production at a faster pace, we are adding to the risks of its operation without having a sense of empathy for its operators.

The result of this is that operators grow distrustful of the software that developers produce. The lack of trust between developers and operators creates a blame culture

that tends to confuse the causes of failures that impact the creation of value for the business.

To alleviate the strain that is being put on traditional structures of an IT organization, we need to rethink how software delivery and operations teams communicate. Communication between operations and developers can affect our ability to scale, as the goals of each party tends to become misaligned over time. To succeed at this requires a shift towards a more reliable kind of software development, one that puts emphasis on the experience of an operations team inside the software development process; one that fosters shared learning and improvement.

Reliability

The expectations that are created between teams, be it operations, development, or user experience design, we can think of these expectations as contracts. The contracts that are created between teams imply some level of service is provided or consumed. By looking at how teams provide services to one another in the process of developing software, we can better understand how failures in communication can introduce risk that lead to failures down the road.

Service agreements between teams are created in order to reduce the risk of unexpected behavior in the overall functions of scale that produce value for a business. A service agreement between teams is made explicit in order to guarantee that behaviors are consistent with the expected cost of operations. In this way, services enable units of a business to maximize its total output. The goal here for a software business is to reliably predict the creation of value through cost. The result of this goal is what we call *reliability*.

The service model for a business is the same model that we use when we build software. This is how we guarantee the reliability of a system, whether it be in the software that we produce to automate a business function or in the people that we train to perform a manual operation.

Agility

We are beginning to find that there is no longer only one way to develop and operate software. Driven by the adoption of agile methodologies and a move towards *Software as a Service* business models, the enterprise application stack is becoming increasingly distributed. Developing distributed systems is a complex undertaking. The move towards a more distributed application architecture for companies is being fueled by the need to deliver software faster and with less risk of failure.

The modern day software-defined business is seeking to restructure their development processes to enable faster delivery of software projects and continuous deploy-

ment of applications into production. Not only are companies wanting to increase the rate in which they develop software applications, but they also want to increase the number of software applications that are created and operated to serve the various business units of an organization.

Software is increasingly becoming a competitive advantage for companies. Better and better tools are enabling business experts to open up new sources of revenue, or to optimize business functions in ways that lead to rapid innovation.

At the heart of this movement is *the cloud*. When we talk about the cloud, we are talking about a very specific set of technologies that enable developers and operators to take advantage of web services that exist to provision and manage virtualized computing infrastructure.

Companies are starting to move out of the data center and into public clouds. One such company is the popular subscription-based streaming media company, named Netflix.

Netflix's Story

Today, Netflix is one of the world's largest on-demand streaming media services, operating their online services in the cloud. Netflix was founded in 1997 in Scotts Valley, California by Reed Hastings and Marc Randolph. Originally, Netflix provided an online DVD rental service that would allow customers to pay a flat-fee subscription each month for unlimited movie rentals without late fees. Customers would be shipped DVDs by mail after selecting from a list of movie titles and placing them into a queue using the Netflix website.

In 2008, Netflix had experienced a major database corruption that prevented the company from shipping any DVDs to its customers. At the time, Netflix was just starting to deploy its streaming video services to customers. The streaming team at Netflix realized that a similar kind of outage in streaming would be devastating to the future of its business. Netflix made a critical decision as a result of the database corruption, that they would move to a different way of developing and operating their software, one that ensured that their services would always be available to their customers.

As a part of Netflix's decision to prevent failures in their online services, they decided that they must move away from vertically scaled infrastructure and single points of failure. The realization stemmed from a result of the database corruption, which was a result of using a vertically scaled relational database. Netflix would eventually migrate their customer data to a distributed NoSQL database, an open source database project named Apache Cassandra. This was the beginning of the move to become a "cloud native" company, a decision to run all of their software applications as highly distributed and resilient services in the cloud. They settled on increasing the

robustness of their online services by adding redundancy to their applications and databases in a scale out infrastructure model.

As a part of Netflix's decision to move to the cloud, they would need to migrate their large application deployments to highly reliable distributed systems. They faced a major challenge. The teams at Netflix would have to re-architect their applications while moving away from an on-premise data center to a public cloud. In 2009, Netflix would begin its move to Amazon Web Services (AWS), and they focused on three main goals: scalability, performance, and availability.

By the start of 2009, the subscriptions to Netflix's streaming services had increased by nearly 100 times. Yuri Izrailevsky, VP Cloud Platform at Netflix, gave a presentation in 2013 at the AWS reinvent conference. "We would not be able to scale our services using an on-premise solution," said Izrailevsky.

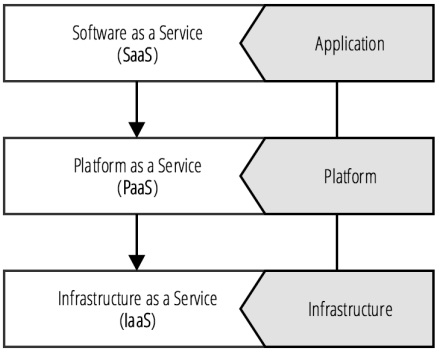
Furthermore, Izrailevsky stated that the benefits of scalability in the cloud became more evident when looking at its rapid global expansion. "In order to give our European customers a better low-latency experience, we launched a second cloud region in Ireland. Spinning up a new data center in a different territory would take many months and millions of dollars. It would be a huge investment." said Izrailevsky.

As Netflix began its move to hosting their applications on Amazon Web Services, employees of the company would chronicle their learnings on Netflix's company blog. Many of Netflix's employees were advocating a move to a new kind of architecture that focused on horizontal scalability at all layers of the software stack.

John Ciancutti, who was then the Vice President of Personalization Technologies at Netflix, said on the company's blog in late 2010 that, "cloud environments are ideal for horizontally scaling architectures. We don't have to guess months ahead what our hardware, storage, and networking needs are going to be. We can programmatically access more of these resources from shared pools within Amazon Web Services almost instantly."

What Ciancutti meant by being able to "programmatically access" resources, was that developers and operators could programmatically access certain management APIs that are exposed by Amazon Web Services in order to give customers a controller for provisioning their virtualized computing infrastructure. The interface for these APIs are in the form of RESTful web services, and they give developers a way to build applications that manage and provision virtual infrastructure for their applications.

Providing management services to control virtualized computing infrastructure is one of the primary concepts of cloud computing, called *Infrastructure as a Service*, commonly referred to as IaaS.



Ciancutti admitted in the same blog post that Netflix was not very good at predicting customer growth or device engagement. This is a central theme behind cloud native companies. Cloud native is a mindset that admits to not being able to reliably predict when and where capacity will be needed.

In Yuri Izrailevsky's presentation at the 2013 AWS reinvent conference, he said that "in the cloud, we can spin up capacity in just a few days as traffic eventually increases. We could go with a tiny footprint in the beginning and gradually spin it up as our traffic increases."

Izrailevsky goes on to say "As we become a global company, we have the benefit of relying on multiple Amazon Web Services regions throughout the world to give our customers a great interactive experience no matter where they are."

The economies of scale that benefited Amazon Web Services's international expansion also benefited Netflix. With AWS expanding availability zones to regions outside of the United States, Netflix expanded its services globally using only the management APIs provided by AWS.

Izrailevsky quoted a general argument of cloud adoption by enterprise IT, "Sure, the cloud is great, but it's too expensive for us." His response to this argument is that "as a result of Netflix's move to the cloud, the cost of operations has decreased by 87%. We're paying 1/8th of what we used to pay in the data center."

Izrailevsky explained further why the cloud provided such large cost savings to Netflix. "It's really helpful to be able to grow without worrying about capacity buffers. We can scale to demand as we grow."

Splitting the Monolith

There are two cited major benefits by Netflix of moving to a distributed systems architecture in the cloud from a monolith: agility and reliability.

Netflix's architecture before going cloud native comprised of a single monolithic JVM application. While there were multiple advantages of having one large application deployment, the major drawback was that development teams were slowed down due to needing to coordinate their changes.

When building and operating software, increased centralization decreases the risk of a failure at an increased cost of needing to coordinate. Coordination takes time. The more centralized a software architecture is, the more time it will take to coordinate changes to any one piece of it.

Monoliths also tend not to be very reliable. When components share resources on the same virtual machine, a failure in one component can spread to others, causing downtime for users. The risk of making a breaking change in a monolith increases with the amount of effort by teams needing to coordinate their changes. The more changes that occur during a single release cycle also increase the risk of a breaking change that will cause downtime. By splitting up a monolith into smaller more singularly focused services, deployments can be made with smaller batch sizes on a team's independent release cycle.

Netflix not only needed to transform the way they build and operate their software, they needed to transform the culture of their organization. Netflix moved to a new operational model, called DevOps. In this new operational model each team would become a product group, moving away from the traditional project group structure. In a product group, teams were composed vertically, embedding operations and product management into each team. Product teams would have everything they needed to build and operate their software.

Netflix OSS

As Netflix transitioned to become a cloud native company, they also started to participate actively in open source. In late 2010, Kevin McEntee, then the VP of Systems & Ecommerce Engineering at Netflix, announced in a blog post about the company's future role in open source.

McEntee stated that "the great thing about a good open source project that solves a shared challenge is that it develops its own momentum and it is sustained for a long time by a virtuous cycle of continuous improvement."

In the years that followed this announcement, Netflix open sourced over 50 of their internal projects, each of which would become a part of the *Netflix OSS* brand.

Key employees at Netflix would later clarify on the company's aspirations to open source many of their internal tools. In July 2012, Ruslan Meshenberg, Netflix's Director of Cloud Platform Engineering, published a post on the company's technology blog. The blog post, titled *Open Source at Netflix*, explained why Netflix was taking such a bold move to open source so much of its internal tooling.

Meshenberg wrote in the blog post, on the reasoning behind its open source aspirations, that "Netflix was an early cloud adopter, moving all of our streaming services to run on top of AWS infrastructure. We paid the pioneer tax – by encountering and working through many issues, corner cases and limitations."

The cultural motivations at Netflix to contribute back to the open source community and technology ecosystem are seen to be strongly tied to the principles behind the microeconomics concept known as *Economies of Scale*. Meshenberg then continues, stating that "We've captured the patterns that work in our platform components and automation tools. We benefit from the scale effects of other AWS users adopting similar patterns, and will continue working with the community to develop the ecosystem."

In the advent of what has been referred to as the *era of the cloud*, we have seen that its pioneers are not technology companies such as IBM or Microsoft, but rather they are companies that were born on the back of the internet. Netflix and Amazon are both businesses who started in the late 90s as dot-com companies. Both companies started out by offering online services that aimed to compete with their *brick and mortar* counterparts.

Both Netflix and Amazon would in time surpass the valuation of their *brick and mortar* counterparts. As Amazon had entered itself into the cloud computing market, it did so by turning its collective experience and internal tooling into a set of services. Netflix would then do the same on the back of the services of Amazon. Along the way, Netflix open sourced both its experiences and tooling, transforming themselves into a cloud native company built on virtualized infrastructure services provided by AWS by Amazon. This is how the economies of scale are powering forward a revolution in the cloud computing industry.

In early 2015, on reports of Netflix's first quarterly earnings, the company was reported to be valued at $32.9 billion. As a result of this new valuation for Netflix, the company's value had surpassed the value of the CBS network for the first time.

Cloud Native Java

Netflix has provided the software industry with a wealth of knowledge as a result of their move to become a cloud native company. This book is going to focus taking the learnings and open source projects by Netflix and apply them as a set of patterns with two central themes:

- Building resilient distributed systems using Spring and Netflix OSS
- Using continuous delivery to operate cloud native applications with Cloud Foundry

The first stop on our journey will be to understand a set of terms and concepts that we will use throughout this book to describe building and operating cloud native applications.

The Twelve Factors

The twelve-factor methodology is a popular set of application development principles compiled by the creators of the Heroku cloud platform. The *Twelve Factor App* is a website that was originally created by Adam Wiggins, a co-founder of Heroku, as a manifesto that describes *Software-as-a-Service* applications that are designed to take advantage of the common practices of modern cloud platforms.

On the website, which is located at *http://12factor.net*, the methodology starts out by describing a set of core foundational ideas for building applications.

Example 2-1. Core ideas of the 12-factor application

- Use **declarative** formats for setup automation, to minimize time and cost for new developers joining the project;
- Have a clean contract with the underlying operating system, offering **maximum portability** between execution environments;
- Are suitable for **deployment** on modern **cloud platforms**, obviating the need for servers and systems administration;
- **Minimize divergence** between development and production, enabling **continuous deployment** for maximum agility;
- And can **scale up** without significant changes to tooling, architecture, or development practices.

Earlier on in the chapter we talked about the promises that platforms make to its users who are building applications. In Example 2-1 we have a set of ideas that explicitly state the value proposition of building applications that follow the twelve-factor methodology. These ideas break down further into a set of constraints—the twelve individual factors that distill these core ideas into a collection of opinions for how applications should be built.

Example 2-2. The practices of a twelve-factor application

- **Codebase** — One codebase tracked in revision control, many deploys
- **Dependencies** — Explicitly declare and isolate dependencies
- **Config** — Store config in the environment

- **Backing services** — Treat backing services as attached resources
- **Build, release, run** — Strictly separate build and run stages
- **Processes** — Execute the app as one or more stateless processes
- **Port binding** — Export services via port binding
- **Concurrency** — Scale out via the process model
- **Disposability** — Maximize robustness with fast startup and graceful shutdown
- **Dev/prod parity** — Keep development, staging, and production as similar as possible
- **Logs** — Treat logs as event streams
- **Admin processes** — Run admin/management tasks as one-off processes

The twelve factors, each listed in Example 2-2, describe constraints that help to build applications that take advantage of the ideas in Example 2-1. The twelve factors are a basic set of constraints that can be used to build cloud native applications. Since the factors cover a wide range of concerns that are common practices in all modern cloud platforms, building 12-factor apps are a common starting point in cloud native application development.

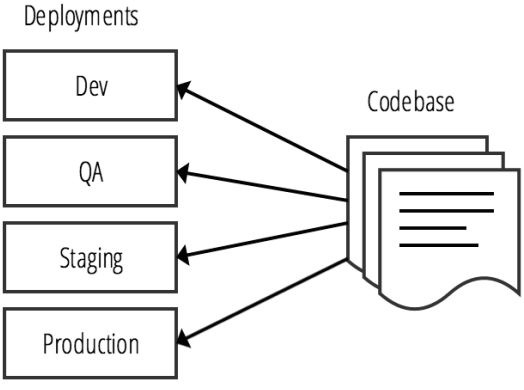
Outside of the 12-factor website—which covers each of the twelve factors in detail—there are full books that have been written that expand even greater details on each constraint. The twelve-factor methodology is now used in some application frameworks to help developers comply with some, or even all, of the twelve factors out-of-the-box.

We'll be using the twelve-factor methodology throughout this book to describe how certain features of Spring projects were implemented to satisfy this style of application development. For this reason, it's important that we summarize each of the factors here.

Codebase

One codebase tracked in revision control, many deploys

Source code repositories for an application should contain a single application with a manifest to its application dependencies.



Dependencies

Explicitly declare and isolate dependencies

Application dependencies should be explicitly declared and any and all dependencies should be available from an artifact repository that can be downloaded using a dependency manager, such as Apache Maven.

Twelve-factor applications never rely on the existence of implicit system-wide packages required as a dependency to run the application. All dependencies of an application are declared explicitly in a manifest file that cleanly declares the detail of each reference.

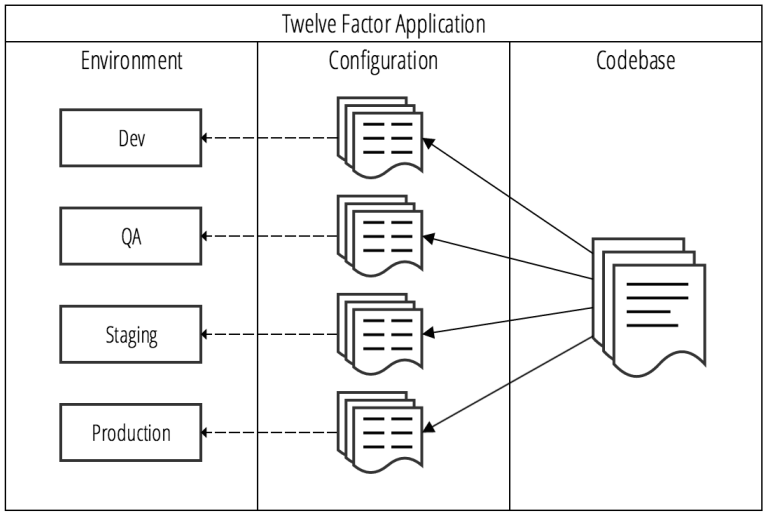
Config

Store config in the environment

Application code should be strictly separated from configuration. The configuration of the application should be driven by the environment.

Application settings such as connection strings, credentials, or host names of dependent web services, should be stored as environment variables, making them easy to change without deploying configuration files.

Any divergence in your application from environment to environment is considered an environment configuration, and should be stored in the environment and not with the application.



Backing services

Treat backing services as attached resources

A backing service is any service that the twelve-factor application consumes as a part of its normal operation. Examples of backing services are databases, API-driven RESTful web services, SMTP server, or FTP server.

Backing services are considered to be *resources* of the application. These *resources* are attached to the application for the duration of operation. A deployment of a twelve-factor application should be able to swap out an embedded SQL database in a testing environment with an external MySQL database hosted in a staging environment without making changes to the application's code.

Build, release, run

Strictly separate build and run stages

The twelve-factor application strictly separates the build, release, and run stages.

- *Build stage* — The build stage takes the source code for an application and either compiles or bundles it into a package. The package that is created is referred to as a *build*.
- *Release stage* — The release stage takes a build and combines it with its config. The release that is created for the deploy is then ready to be operated in an execution environment. Each release should have a unique identifier, either using

semantic versioning or a timestamp. Each release should be added to a directory that can be used by the release management tool to rollback to a previous release.

- *Run stage* — The run stage, commonly referred to as the *runtime*, runs the application in the execution environment for a selected release.

By separating each of these stages into separate processes, it becomes impossible to change an application's code at runtime. The only way to change the application's code is to initiate the build stage to create a new release, or to initiate a rollback to deploy a previous release.

Processes

Execute the app as one or more stateless processes

Twelve-factor applications are created to be stateless in a *share-nothing architecture*. The only persistence that an application may depend on is through a backing service. Examples of a backing service that provide persistence include a database or an object store. All resources to the application are attached as a backing service at runtime. A litmus test for testing whether or not an application is stateless is that the application's execution environment can be torn down and recreated without any loss of data.

Twelve-factor applications do not store state on a local file system in the execution environment.

Port bindings

Export services via port binding

Twelve-factor applications are completely self-contained, which means that they do not require a webserver to be injected into the execution environment at runtime in order to create a web-facing service. Each application will expose access to itself over an HTTP port that is bound to the application in the execution environment. During deployment, a routing layer will handle incoming requests from a public hostname by routing to the application's execution environment and the bound HTTP port.

Josh Long, one of the co-authors of this book, is attributed with popularizing the phrase "*Make JAR not WAR*" in the Java community. Josh uses this phrase to explain how newer Spring applications are able to embed a Java application server, such as Tomcat, in a build's JAR file.

Concurrency

Scale out via the process model

Applications should be able to scale out processes or threads for parallel execution of work in an on-demand basis. JVM applications are able to handle in-process concurrency automatically using multiple threads.

Applications should distribute work concurrently depending on the type of work that is used. Most application frameworks for the JVM today have this built in. Some scenarios that require data processing jobs that are executed as long-running tasks should utilize executors that are able to asynchronously dispatch concurrent work to an available pool of threads.

The twelve-factor application must also be able to scale out horizontally and handle requests load-balanced to multiple identical running instances of an application. By ensuring applications are designed to be stateless, it becomes possible to handle heavier workloads by scaling applications horizontally across multiple nodes.

Disposability

Maximize robustness with fast startup and graceful shutdown

The processes of a twelve-factor application are designed to be disposable. An application can be stopped at any time during process execution and gracefully handle the disposal of processes.

Processes of an application should minimize startup time as much as possible. Applications should start within seconds and begin to process incoming requests. Short startups reduce the time it takes to scale out application instances to respond to increased load.

If an application's processes take too long to start, there may be reduced availability during a high-volume traffic spike that is capable of overloading all available healthy application instances. By decreasing the startup time of applications to just seconds, newly scheduled instances are able to more quickly respond to unpredicted spikes in traffic without decreasing availability or performance.

Dev/prod parity

Keep development, staging, and production as similar as possible

The twelve-factor application should prevent divergence between development and production environments. There are three types of gaps to be mindful of.

- Time gap — Developers should expect development changes to be quickly deployed into production
- Personnel gap — Developers who make a code change are closely involved with its deployment into production, and closely monitor the behavior of an application after making changes

- Tools gap — Each environment should mirror technology and framework choices in order to limit unexpected behavior due to small inconsistencies

Logs

Treat logs as event streams

Twelve-factor apps write logs as an ordered event stream to `stout`. Applications should not attempt to manage the storage of their own log files. The collection and archival of log output for an application should instead be handled by the *execution environment*.

Admin processes

Run admin/management tasks as one-off processes

It sometimes becomes the case that developers of an application need to run one-off administrative tasks. These kinds of tasks could include database migrations or running one-time scripts that have been checked into the application's source code repository. These kinds of tasks are considered to be admin processes. Admin processes should be run in the execution environment of an application, with scripts checked into the repository to maintain consistency between environments.

CHAPTER 3
Messaging

Messaging supports connecting publishing application events to services across processes and networks. The idea is simple enough: email for distributed processes. Messaging has a lot of applications, many of which Martin Fowler captures in this blog post, *What do you mean by "Event-Driven"?*:

- **event notifications**: one system sends event messages to notify other systems of a change in the domain. There is no expectation that the recipient of the message produce a reply. The source system doesn't expect it, and doesn't use it. The event notification doesn't contain any state, so the recipients will need to know how to re-source the state from the source system or map the event to its internal state.
- **event-carried state transfer**: a system produces a message which contains a self-contained message, including everything the recipient will need to process. In this scenario, the recipient won't need to call the sender for more information. This is convenient if the source system goes down.
- **event-sourcing**: in this setup, an event message is produced to notify all interested consumer systems of a state change (as with an event notification), and that event is *also* recorded and persisted for replay later on. In this way, the state of the system is functionally the ultimate state of the system after all the recorded messages have been replayed. If any of the consumers should lose their data, the events may be replayed to reproduce the original state.

Martin also includes CQRS in his discussion, though it isn't strictly to do with messaging, so we'll leave it off of this list.

Message brokers - like Apache Kafka, RabbitMQ, ActiveMQ, or MQSeries - act as the repository and hub for messages. Producers and consumers connect to a message broker, not to each other. Traditional brokers are fairly static, but offerings like RabbitMQ and Apache Kafka can scale as needed. Messaging systems decouple producer

from consumer. A producer or a consumer does not need to share the same location, exist in the same place or process, or even be available at the same time. These qualities are even *more* important in a cloud environment where services are fluid and ephemeral. Cloud platforms support elasticity - they can grow and shrink as demand requires. Messaging systems are an ideal way to throttle load when systems are down and to load-balance when scale requires.

Event Driven Architectures with Spring Integration

We've looked thus far at processing that we initiate, on our schedule. The world doesn't run on our schedule. We are surrounded by events that drive everything we do. The logical windowing of data is valuable, but some data just can't be treated in terms of windows. Some data is continuous and connected to events in the real world. In this section we'll look at how to work with data driven by events.

When we think of events, most of us probably think of messaging technologies. Messaging technologies, like JMS, RabbitMQ, Apache Kafka, Tibco Rendezvous and IBM MQSeries. These technologies let us connect different autonomous clients through messages sent to centralized middleware, in much the same way that e-mail lets humans connect to each other. The message broker stores delivered messages until such time as the client can consume and respond to it (in much the same way as an e-mail inbox does).

Most of these technologies have an API, and a usable client that we can use. Spring has always had good low-level support for messaging technologies; you'll find sophisticated low-level support for the JMS API, AMQP (and brokers like RabbitMQ), Redis and Apache Geode.

There are many types of events int he world, of course. receiving an email is one. Receiving a tweet another. A new file in a directory? That's an event too. An XMPP-powered chat message? Also an event. Your MQTT-powered microwave sending a status update? That's also an event.

It's all a bit overwhelming! If you're looking at the landscape of different event sources out there then you're (hopefully) seeing a lot of opportunity *and* of complexity. Some of the complexity comes from the act of integration itself. How do you build a system that depends on events from these various systems? One might address integration int erms of point-to-point connections between the various event sources. This will result eventually in *spaghetti architecture*, and it's a mathematically poor idea, too, as every integration point needs a connection with every other one. It's a binomial coefficient: `n(n-1) / 2`. Thus, for six services you'd need 15 different point-to-point connections!

Instead, let's take a more structured approach to integration with Spring Integration. At the heart of Spring Integration are the Spring framework `MessageChannel` and `Mes`

sage<T> types. A Message<T> object has a payload and a set of headers that provide metadata about the message payload itself. A MessageChannel is like a java.util.Queue. Message<T> objects flow through MessageChannel instances.

Spring Integration supports the integration of services and data across multiple otherwise incompatible systems. Conceptually, composing an integration flow is similar to composing a pipes-and-filters flow on a UNIX OS with stdin and stdout:

Example 3-1. an example of using the pipes-and-filters model to connect otherwise singly focused command line utilities

```
cat input.txt |  grep ERROR | wc -l > output.txt
```

Here, we take data from a source (the file input.txt), pipe it to the grep command to filter the results and keep only the lines that contain the token ERROR. Then we pipe it to the wc utility to count how many lines there are. Finally, the final count is written to an output file, output.txt. These components - cat, grep, and wc - know nothing of each other. They were not designed with each other in mind. Instead, they know only how to read from stdin and write to stdout. This normalization of data makes it very easy to compose complex solutions from simple atoms. In the example, the cat command turns the file data into data that any process aware of stdin can read. It *adapts* the inbound data into the normalized format, lines of strings on stdout. At the end, the redirect (>) operator turns the normalized data, lines of strings, into data on the file system. It *adapts* it. The pipe (|) character is used to signal that the output of one component should flow to the input of another.

A Spring Integration flow works the same way: data is normalized into Message<T> instances. Each Message<T> has a payload and headers - metadata about the payload in a Map<K,V> - that are the input and output of different messaging components. These messaging components are typically provided by Spring Integration, but it's easy to write and use your own. There are all manner of messaging components supporting all of the [the Enterprise Application Integration patterns](*http://www.enterpriseintegrationpatterns.com/*) (filters, routers, transformers, adapters, gateways, etc.). The Spring framework MessageChannel is a named conduit through which Message<T>`s flow between messaging components. They're pipes and, by default, they work sort of like a `java.util.Queue. Data in, data out.

Messaging Endpoints

These MessageChannel objects are connected through messaging endpoints, Java objects that do different things with the messages. Spring Integration will do the right thing when you give it a Message<T> or just a T for the various components. Spring Integration provides a component model that you might use, or a Java DSL. Each

messaging endpoint in a Spring Integraton flow may produce an output value which is then sent to whatever is downstream, or `null`, which terminates processing.

Inbound gateways take incoming requests from external systems, process them as `Message<T>`s, and send a reply. Outbound gateways take `Message<T>`s, forward them to an external system, and await the response from that system. They support request and reply interactions.

An **inbound adapter** is a component that takes messages from the outside world and then turns them into a Spring `Message<T>`. An **outbound adapter** does the same thing, in reverse; it takes a Spring `Message<T>` and delivers it as the message type expected by the downstream system. Spring Integration ships with a proliferation of different adapters for technologies and protocols including MQTT, Twitter, email, (S)FTP(S), XMPP, TCP/UDP, etc.

There are two types of inbound adapters: either a polling adapter or an event drive adapter. The inbound polling adapter is configured to automatically pull a certain interval or rate an upstream message source.

A **gateway** is a component that handles both requests and replies. For example, an inbound gateway would take a message from the outside world, deliver it to Spring Integration, and then deliver a reply message back to the outside world. A typical HTTP flow might look like this. An outbound gateway would take a spring integration message and deliver it to the outside world, then take the reply and delivered back in the spring integration. You might see this when using the RabbitMQ broker and you've specified a reply destination.

A **filter** is a component that takes incoming messages and then applies some sort of condition to determine whether the message should proceed. Think of a filter like an `if (...)` test in Java.

A **router** takes an incoming message and applies a test (any test you want) to determine where to send that message downstream. Think of a router as a switch statement for messages.

A **transformer** takes a message and does something with it, optionally enriching or changing it, and then it sends the message out.

A **splitter** takes a message and then, based on some property of the message, divides it into multiple smaller messages that are then fowarded downstream. You might for example have an incoming message for an order and then forward a message for each line item in that order to some sort of fulfillment flow.

An **aggregator** takes multiple messages, correlated through some unique property and then synthesizes a message that is sent downstream.

The integration flow is aware of the system, but the involved components used in the integration don't need to be. This makes it easy to compose complex solutions from small, otherwise silo'd services. The act of building a Spring integration flow is rewarding in of itself. It forces a logical decomposition of services; they must be able to communicate in terms of messages that contain payloads. The schema of the payload is the contract. This property is very useful in a distributed system.

From Simple Components, Complex Systems

Spring Integration supports *event-driven architectures* because it can help detect and then respond to events in the external world. For example, you can use Spring Integration to poll a filesystem every 10 seconds and publish a `Message<T>` whenever a new file appears. You can use Spring Integration to act as a listener to messages delivered to a Apache Kafka topic. The adapter handles responding to the external event and frees you from worrying too much about originating the message and lets you focus on handling the message once it arrives. It's the integration equivalent of dependency injection!

Dependency injection leaves component code free of worries about resource initialization and acquisition and leaves it free to focus on writing code with those dependencies. Where did the `javax.sql.DataSource` field come from? Who cares! Spring wired it in, and it may have gotten it from a Mock in a test, from JNDI in a classic application server, or from a configured Spring Boot bean. Component code remains ignorant of those details. You can explain dependency injection with the "Hollywood principal:" "don't call me, I'll call you!" Dependant objects are provided to an object, instead of the object having to initialize or lookup the resource. This same principle applies to Spring Integration: code is written in such a way that its ignorant of where messages are coming from. It simplifies development considerably.

So, let's start with something simple. Let's look at a simple example that responds to new files appearing in a directory, logs the observed file, and then dynamically routes the payload to one of two possible flows based on a simple test, using a router.

We'll use the Spring Integration Java DSL. The Java DSL works very nicely with lambdas in Java 8. Each `IntegrationFlow` chains components together implicitly. We can make explicit this chaining by providing connecting `MessageChannel` references.

Example 3-2. an example of using the pipes-and-filters model to connect otherwise singly focused command line utilities

```
package eda;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
```

```
import org.springframework.context.annotation.Configuration;
import org.springframework.integration.dsl.IntegrationFlow;
import org.springframework.integration.dsl.IntegrationFlows;
import org.springframework.integration.dsl.channel.MessageChannels;
import org.springframework.integration.dsl.file.Files;
import org.springframework.messaging.MessageChannel;

import java.io.File;

@Configuration
public class IntegrationConfiguration {

        private final Log log = LogFactory.getLog(getClass());

        @Bean
        IntegrationFlow etlFlow(@Value("${input-directory:${HOME}/Desktop/in}")
File dir) {
                // @formatter:off
                return IntegrationFlows
                                (1)
                                .from(Files
                                                                        .inboundAdapter(dir)
                                                                        .autoCreateDirec
tory(true),
                                        consumer -> consumer.poller(
                                                spec -> spec.fixedRate(1000)))
                                (2)
                                .handle(File.class, (file, headers) -> {
                                        log.info("we noticed a new file, " + file);
                                        return file;
                                })
                                (3)
                                .routeToRecipients(
                                        spec -> spec
                                                .recipient(csv(),
                                                                        msg ->
hasExt(msg.getPayload(), ".csv"))
                                                .recipient(txt(),
                                                                        msg ->
hasExt(msg.getPayload(), ".txt")))
                                .get();
                // @formatter:on
        }

        private boolean hasExt(Object f, String ext) {
                File file = File.class.cast(f);
                return file.getName().toLowerCase().endsWith(ext.toLowerCase());
        }

        (4)
        @Bean
        MessageChannel txt() {
```

```
                return MessageChannels.direct().get();
        }

        ❺
        @Bean
        MessageChannel csv() {
                return MessageChannels.direct().get();
        }

        ❻
        @Bean
        IntegrationFlow txtFlow() {
                return IntegrationFlows.from(txt()).handle(File.class, (f, h) -> {
                        log.info("file is .txt!");
                        return null;
                }).get();
        }

        ❼
        @Bean
        IntegrationFlow csvFlow() {
                return IntegrationFlows.from(csv()).handle(File.class, (f, h) -> {
                        log.info("file is .csv!");
                        return null;
                }).get();
        }
}
```

❶ configure a Spring Integration inbound File adapter. We also want to configure how the adapter consumes incoming messages and at what millisecond rate the poller that sweeps the directory should scan.

❷ this method announces that we've received a file and then forward the payload onward

❸ route the request to one of two possible integration flows, derived from the extension of the file, through well-known `MessageChannel` instances

❹ the channel through which all files with the `.txt` extension will travel

❺ the channel through which all files with the `.csv` extension will travel

❻ the `IntegrationFlow` to handle files with `.txt`

❼ the `IntegrationFlow` to handle files with `.csv`

The channel is a logical decoupling; it doesn't matter what's on either the other end of the channel, so long as we have a pointer to the channel. Today the consumer that

comes from a channel might be a simple logging `MessageHandler<T>`, as in this example, but tomorrow it might instead be a component that writes a message to Apache Kafka. We can also begin a flow from the moment it arrives in a channel. How, exactly, it arrives in the channel is irrelevant. We could accept requests from a REST API, or adapt messages coming in from Apache Kafka, or monitor a directory. It doesn't matter so long as we somehow adapt the incoming message into a `java.io.File` and submit it to the right channel.

Let's suppose we have a batch process that works on files. Traditionally, such a job would run at a fixed time, on a scheduler like `cron`, perhaps. This introduces idle time between runs and that idle period delays the results we're looking for. We can use Spring Integration to kick off a batch job whenever a new `java.io.File` appears, instead. Spring Integration provides an inbound file adapter. We'll listen for messages coming from the inbound file adapter, transform it into a message whose payload is a `JobLaunchRequest`. The `JobLaunchRequest` describes which `Job` to launch and it describes the `JobParameters` for that job. Finally, the `JobLaunchRequest` is forwarded to a `JobLaunchingGateway` which then produces as its output a `JobExecution` object that we inspect to decide where to route execution. If a job completes normally, we'll move the input file to a directory of completed jobs. Otherwise, we'll move the file to an error directory.

We'll have one main flow that forwards execution to one of two branches, so two channels: `invalid` and `completed`.

Example 3-3. the two `MessageChannel` instances

```
package edabatch;

import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.integration.dsl.channel.MessageChannels;
import org.springframework.messaging.MessageChannel;

@Configuration
class BatchChannels {

        @Bean
        MessageChannel invalid() {
                return MessageChannels.direct().get();
        }

        @Bean
        MessageChannel completed() {
                return MessageChannels.direct().get();
        }

}
```

The main flow, called `etlFlow`, monitors a directory (`directory`) at a fixed rate and turns each event into a `JobLaunchRequest`.

Example 3-4. the two `EtlFlowConfiguration` instances

```
package edabatch;

import org.springframework.batch.core.*;
import org.springframework.batch.core.launch.JobLauncher;
import org.springframework.batch.integration.launch.JobLaunchRequest;
import org.springframework.batch.integration.launch.JobLaunchingGateway;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.integration.dsl.IntegrationFlow;
import org.springframework.integration.dsl.IntegrationFlows;
import org.springframework.integration.dsl.file.Files;
import org.springframework.integration.support.MessageBuilder;
import org.springframework.messaging.Message;

import java.io.File;

import static org.springframework.integration.file.FileHeaders.ORIGINAL_FILE;

@Configuration
class EtlFlowConfiguration {

        ❶
        @Bean
        IntegrationFlow etlFlow(@Value("${input-directory:${HOME}/Desktop/in}")
File directory,
                        BatchChannels c, JobLauncher launcher, Job job) {

                // @formatter:off
                return
                        IntegrationFlows
                                .from(
                                                Files.inboundAdapter(direc
tory).autoCreateDirectory(true),
                                                cs -> cs.poller(p -> p.fixe
dRate(1000)))
                                .handle(File.class, (file, headers) -> {

                                        String absolutePath = file.getAbsolute
Path();

                                        JobParameters params = new JobParameters
Builder()
                                                        .addString("file", absolute
Path)
                                                        .toJobParameters();
```

```
                                        return MessageBuilder
                                                .withPayload(new JobLaunchRe
quest(job, params))
                                                .setHeader(ORIGINAL_FILE, absolute
Path)
                                                .copyHeadersIfAbsent(headers)
                                                .build();
                                })
                                .handle(new JobLaunchingGateway(launcher))
                                .routeToRecipients(
                                        spec -> spec
                                                .recipient(c.invalid(), this::notFin
ished)
                                                .recipient(c.completed(), this::fin
ished))
                                .get();

                // @formatter:on
        }

        private boolean finished(Message<?> msg) {
                Object payload = msg.getPayload();
                return JobExecution.class.cast(payload).getExitStatus().equals(Exit
Status.COMPLETED);
        }

        private boolean notFinished(Message<?> msg) {
                return !this.finished(msg);
        }

}
```

❶ this `EtlFlowConfiguration` starts off the same as in the previous example

❷ setup some `JobParameters` for our Spring Batch job using the `JobParameters Builder`

❸ forward the job and associated parameters to a `JobLaunchingGateway`

❹ test to see if the job exited normally by examining the `JobExecution`

The last component in the Spring Integration flow is a router that examines the `Exit Status` from the `Job` and determines to which directory the input file should be moved. If the file was completed successfully, it will be routed to `completed` channel. If there was an error or the job terminated early, for some reason, it will be routed to the `invalid` channel.

The `FinishedFileFlowConfiguration` configuration listens for incoming messages on the `completed` channel, moves its incoming payload (a `java.io.File`) to a `completed` directory, and then queries the table to which the data was written.

Example 3-5. the `FinishedFileFlowConfiguration` instances

```
package edabatch;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.batch.core.JobExecution;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.integration.dsl.IntegrationFlow;
import org.springframework.integration.dsl.IntegrationFlows;
import org.springframework.integration.file.FileHeaders;
import org.springframework.jdbc.core.JdbcTemplate;

import java.io.File;
import java.util.List;

import static edabatch.Utils.mv;

@Configuration
class FinishedFileFlowConfiguration {

        private Log log = LogFactory.getLog(getClass());

        @Bean
        IntegrationFlow finishedJobsFlow(BatchChannels channels,
                        @Value("${completed-directory:${HOME}/Desktop/completed}")
File finished,
                        JdbcTemplate jdbcTemplate) {
                // @formatter:off
                return IntegrationFlows
                                .from(channels.completed())
                                .handle(JobExecution.class,
                                                (je, headers) -> {
                                                        String ogFileName =
String.class.cast(headers
                                                                        .get(File
Headers.ORIGINAL_FILE));
                                                        File file = new File(ogFile
Name);
                                                        mv(file, finished);
                                                        List<Contact> contacts =
jdbcTemplate.query(
                                                                        "select *
from CONTACT",
                                                                        (rs, i) ->
```

```
new Contact(

rs.getBoolean("valid_email"),

rs.getString("full_name"),

rs.getString("email"),

rs.getLong("id")));
                                                        contacts.forEach(log::info);
                                                        return null;
                                                }).get();
                // @formatter:on
        }

}
```

The `InvalidFileFlowConfiguration` configuration listens for incoming messages on the `invalid` channel, moves its incoming payload (a `java.io.File`) to an `errors` directory and then terminates the flow.

Example 3-6. the `InvalidFileFlowConfiguration` instances

```
package edabatch;

import org.springframework.batch.core.JobExecution;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.integration.dsl.IntegrationFlow;
import org.springframework.integration.dsl.IntegrationFlows;
import org.springframework.integration.file.FileHeaders;

import java.io.File;

import static edabatch.Utils.mv;

@Configuration
class InvalidFileFlowConfiguration {

        @Bean
        IntegrationFlow invalidFileFlow(BatchChannels channels,
                        @Value("${error-directory:${HOME}/Desktop/errors}") File
errors) {
                // @formatter:off
                return IntegrationFlows
                                .from(channels.invalid())
                                .handle(JobExecution.class,
                                                (je, headers) -> {
                                                        String ogFileName =
String.class.cast(headers
```

```
                                                        .get(File
Headers.ORIGINAL_FILE));
                                                File file = new File(ogFile
Name);

                                                mv(file, errors);
                                                return null;
                                            }).get();
                    // @formatter:on
            }

}
```

The `MessageChannel` definitions serve to decouple different integration flows. We're able to reuse common functionality and compose higher order systems using only a channel as a connection. The `MessageChannel` is the interface.

Message Brokers, Bridges, the Competing Consumer Pattern and Event-Sourcing

The last example was fairly straightforward. It's a simple flow that works in terms of messages (events). We're able to begin processing as soon as possible without overwhelming the system. As our integration is built in terms of channels, and every component could consume or produce messages with a channel, it would be trivial to introduce a message broker in between the inbound file adapter and the node that actually launches the Spring Batch job. This would help us scale out the work across a cluster, like one powered by Cloud Foundry.

That said, you're not likely going to be integrating file systems in a cloud-native architecture. You will, however, probably have other, non-transactional, event sources (message producers) and sinks (message consumers) with which you'll want to integrate.

We could use the saga pattern and design compensatory transactions for every service with which we integrate and the possible failure conditions, but we might be able to get away with something simpler if we use a message broker. Message brokers are conceptually very simple: as messages are delivered to the broker, they're stored and delivered to connected consumers. If there are no connected consumers, then the broker will store the messages and redeliver them upon connection of a consumer.

Message brokers typically offer two types of destinations (think of them as mailboxes): publish-subscribe and point-to-point. A public-subscribe destination delivers one message to all connected consumers. It's a bit like broadcasting a message over a megaphone to a full room.

Publish-subscribe messaging supports event-collaboration, wherein multiple systems keep their own view or perspective of the state of the world. As new events arrive

from different components in the system, with updates to state, each system updates its local view of the system state. Suppose you had a catalog of products. As new entries were added to the product-service, it might publish an event describing the delta. The search-engine service might consume the messages and update its internal Elasticsearch index. The inventory-service might update its own internal state in an RDBMS. The recommendation-service might update its internal state in a Neo4J service. These systems no longer need to *ask* the product-service for anything, the product-service *tells*. If you record every event in a log, you have the ability to do temporal queries, analyzing the state of the system at any time since in the past. If any service should fail, its internal state may be replayed entirely from the log. You can *cherry pick* parts of the state by replaying state up until a point and perhaps skipping over some anomolous event. Yes, this *is* how a version control system works! This approach is called *event-sourcing*, and it's very powerful. Message brokers like Apache Kafka have the ability to selectively consume messages given an offset. You could, of course, re-read *all* the messages which would give you, in effect, a poor man's event-source. There are also some purpose-built event-source technologies like Chris Richardson's Eventuate platform.

A point-to-point destination delivers one message to one consumer, even if there are multiple connected consumers. This is a bit like telling one person a secret. If you connect multiple consumers and they all work as fast as they can to drain messages from the point-to-point destination then you get a sort of load-balancing: work gets divided by the number of connected consumers. This approach, called the competing consumers pattern, simplifies load-balancing work across multiple consumers and makes it an ideal way to leverage the elasticity of a cloud computing environment like Cloud Foundry, where horizontal capacity is elastic and (virtually) infinite.

Message brokers also have their own, resource-local notion of a transaction. A producer may deliver a message and then, if necessary, withdraw it, effectively rolling the message back. A consumer may accept delivery of a message, attempt to do something with it, and then acknowledge the delivery or - if something should go wrong - return the message to the broker, effectively rolling back the delivery. *Eventually* both sides we'll agree upon the state. This is different than a distributed transaction in that the message broker introduces the variable of time, or temporal decoupling. In so doing it simplifies the integration between services. This property makes it easier to reason about state in a distributed system. You can ensure that two otherwise non-transactional resources will - *eventually* agree upon state. In this way, a message broker *bridges* the two otherwise non-transactional resources.

A message broker complicates the architecture by adding another moving part to the system. Message brokers have well-known recipes for disaster recovery, backups, and scale out. An organization will neeed to know how to do this and then they can reuse that across all services. The alternative is that *every* service be forced to re-invent or, less desirably, go without these qualities. If you're using a platform like Cloud Foun-

dry which already manages the message broker for you, then using a message broker should be a *very* easy decision for it.

Logically, message brokers make a lot of sense as a way by which we can connect different services. Spring Integration provides ample support here in the way of adapters that produce and consume messages from a diverse set of brokers.

Spring Cloud Stream

While Spring Integration is on solid footing to solve the problems of service-to-service communication with message brokers, it might seem a bit too clumsy in the large. We want to support messaging with the same ease as we think about REST-based interactions with Spring. We're not going to connect our services using Twitte, or e-mail. More likely, we'll use RabbitMQ or Apache Kafka or similar message brokers with known interaction modes. We could explicitly configure inbound and outbound RabbitMQ or Apache Kafka adapers, of course. Instead, let's move up the stack a little bit, to simplify our work and remove the congnitive dissonance of configuring inbound and outbound adapters every time we want to work with another service.

Spring integration does a great job of decoupling component in terms of `Message Channel` objects. A `MessageChannel` is a nice level of indirection. From the perspective of our application logic, a channel represents a logical conduit to some downstream service that will route through a message broker.

In this section, we'll look at Spring Cloud Stream. Spring Cloud Stream sits atop Spring Integration, with the channel at the heart of the inteaction model. It implies conventions and supports easy externalization of configuration. In exchange, it makes the common case of connecting services with a message broker much cleaner and more concise.

Let's have a look at a simple example. We'll build a producer and a consumer. The producer will expose a REST API endpoint that, when invoked, publishes a message into two channels. One for *broadcast*, or publish-subscribe-style messaging, and the other for point-to-point messaging. We'll then standup a consumer to accept these incoming messages.

Spring Cloud Stream makes it easy to define channels that are then connected to messaging technologies. We can use *binder* implementations to, by convention, connect to a broker. In this example, we'll use RabbitMQ, a popular message broker that speaks the AMQP specification. The binder for Spring Cloud Stream's RabbitMQ support is `org.springframework.cloud : spring-cloud-starter-stream-rabbit`. There are clients and bindings in dozens of languages, and this makes RabbitMQ (and the AMQP specification in general) a fine fit for integration across different languages and platforms. Spring Cloud Stream builds on Spring Integration (which provides the necessary inbound and outbound adapters) and Spring Integration in turn

builds on Spring AMQP (which provides the low-level `AmqpOperations`, `RabbitTemplate`, a RabbitMQ `ConnectionFactory` implementation, etc.). Spring Boot autoconfigures a `ConnectionFactory` based on defaults or properties. On a local machine with an unadulterated RabbitMQ instance, this application will work out of the box.

A Stream Producer

The centerpiece of Spring Cloud Stream is a *binding*. A binding defines logical references to other services through `MessageChannel` instances that we'll leave to Spring Cloud Stream to connect for us. From the perspective of our business logic, these downstream or upstream messaging-based services are unknowns on the other side of `MessageChannel` objects. We don't need to worry about how the connection is made, for the moment. Let's define two channels, one for broadcasting a greeting to all consumers and another for sending a greeting point-to-point, once, to whichever consumer happens to receive it first.

Example 3-7. a simple `MessageChannel`-centric greetings producer

```
package stream.producer;

import org.springframework.cloud.stream.annotation.Output;
import org.springframework.messaging.MessageChannel;

public interface ProducerChannels {

        ❶
        String DIRECT = "directGreetings";
        String BROADCAST = "broadcastGreetings";

        @Output(DIRECT)
        ❷
        MessageChannel directGreetings();

        @Output(BROADCAST)
        MessageChannel broadcastGreetings();
}
```

❶ by default the name of the stream, which we'll work with in other parts of the system, is based on the `MessageChannel` method itself. It's useful to provide a String constant in the interface so we can reference without any magic strings.

❷ Spring Cloud Stream provides two annotations, `@Output` and `@Input`. An `@Output` annotation tells Spring Cloud Stream that messages put into the channel will be sent out (usually, and ultimately, through an outbound channel adapter in Spring Integration).

We need to give Spring Cloud Stream an idea of what to do with data sent into these channels which we can do with some well-placed properties in the environment. Here's what our producer node's `application.properties` looks like.

Example 3-8. a simple `MessageChannel`-centric greetings producer

```
❶
spring.cloud.stream.bindings.broadcastGreetings.destination=greetings-pub-sub
spring.cloud.stream.bindings.directGreetings.destination=greetings-p2p
❷
spring.rabbitmq.addresses=localhost
```

❶ in these two lines the sections just after `spring.cloud.stream.bindings.` and just before `.destination` have to match the name of the Java `MessageChannel`. This is the application's local perspective on the service it's calling. The bit after the `=` sign is the agreed upon rendez-vous point for the producer and the consumer. Both sides need to specify the exact name here. This is the name of the destination in whatever broker we've configured.

❷ we're using Spring Boot's auto-configuration to create a RabbitMQ `ConnectionFactory` which Spring Cloud Stream will depend on.

Let's look now at a simple producer that stands up a REST API that then publishes messages to be observed in the consumer.

Example 3-9. a simple `MessageChannel`-centric greetings producer

```
package stream.producer.channels;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.cloud.stream.annotation.EnableBinding;
import org.springframework.http.ResponseEntity;
import org.springframework.messaging.MessageChannel;
import org.springframework.messaging.support.MessageBuilder;
import org.springframework.web.bind.annotation.PathVariable;
import org.springframework.web.bind.annotation.RequestMapping;
import org.springframework.web.bind.annotation.RestController;
import stream.producer.ProducerChannels;

@SpringBootApplication
@EnableBinding(ProducerChannels.class)
❶
public class StreamProducer {

        public static void main(String args[]) {
                SpringApplication.run(StreamProducer.class, args);
```

```
        }
}

@RestController
class GreetingProducer {

        private final MessageChannel broadcast, direct;

        ❷
        @Autowired
        GreetingProducer(ProducerChannels channels) {
                this.broadcast = channels.broadcastGreetings();
                this.direct = channels.directGreetings();
        }

        @RequestMapping("/hi/{name}")
        ResponseEntity<String> hi(@PathVariable String name) {
                String message = "Hello, " + name + "!";

                ❸
                this.direct.send(MessageBuilder.withPayload("Direct: " + mes
sage).build());

                this.broadcast.send(MessageBuilder.withPayload("Broadcast: " + mes
sage).build());
                return ResponseEntity.ok(message);
        }
}
```

❶ the `@EnableBinding` annotation activates Spring Cloud Stream

❷ we inject the hydrated `ProducerChannels` and then dereference the required channels in the constructor so that we can send messages whenever somebody makes an HTTP request at `/hi/{name}`.

❸ this is a regular Spring framework channel, so it's simple enough to use the `MessageBuilder` API to create a `Message<T>`.

Style matters, of course, so while we've reduced the cost of workign with our downstream services to an interface, a few lines of property declarations and a few lines of messaging-centric channel manipulation, we *could* do better if we used Spring Integration's messaging gateway support. A messaging gateway, as a design pattern, is meant to hide the client from the messaging logic behind a service. From the client perspective, a gateway may seem like a regular object. This can be very convenient. You might define an interface and synchronous service today and then extract it out as a messaging gateway based implementation tomorrow and nobody would be the wiser. Let's revisit our producer and, instead of sending messages directly with Spring Integration, let's send messages using a messaging gateway.

Example 3-10. a messaging gateway producer implementation.

```
package stream.producer.gateway;

import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.cloud.stream.annotation.EnableBinding;
import org.springframework.http.ResponseEntity;
import org.springframework.integration.annotation.Gateway;
import org.springframework.integration.annotation.IntegrationComponentScan;
import org.springframework.integration.annotation.MessagingGateway;
import org.springframework.web.bind.annotation.PathVariable;
import org.springframework.web.bind.annotation.RequestMapping;
import org.springframework.web.bind.annotation.RequestMethod;
import org.springframework.web.bind.annotation.RestController;
import stream.producer.ProducerChannels;

❸
@MessagingGateway
interface GreetingGateway {

        @Gateway(requestChannel = ProducerChannels.BROADCAST)
        void broadcastGreet(String msg);

        @Gateway(requestChannel = ProducerChannels.DIRECT)
        void directGreet(String msg);
}

@SpringBootApplication
@EnableBinding(ProducerChannels.class)
❶
@IntegrationComponentScan
❷
public class StreamProducer {

        public static void main(String args[]) {
                SpringApplication.run(StreamProducer.class, args);
        }
}

@RestController
class GreetingProducer {

        private final GreetingGateway gateway;

        ❹
        @Autowired
        GreetingProducer(GreetingGateway gateway) {
                this.gateway = gateway;
        }
```

```
        @RequestMapping(method = RequestMethod.GET, value = "/hi/{name}")
        ResponseEntity<?> hi(@PathVariable String name) {
                String message = "Hello, " + name + "!";
                this.gateway.directGreet("Direct: " + message);
                this.gateway.broadcastGreet("Broadcast: " + message);
                return ResponseEntity.ok(message);
        }
}
```

❶ the `@EnableBinding` annotation activates Spring Cloud Stream, as before

❷ many Spring frameworks register stereotype annotations for custom components, but Spring Integration can also turn interface definitions into beans, so we need a custom annotation to activate Spring Integration's component-scanning to find our declarative, interface-based messaging gateway

❸ the `@MessagingGateway` is one of the many messaging endpoints supported by Spring Integration (as an alternative to the Java DSL, which we've used thus far). Each method in the gateway is annotated with `@Gateway` where we specify on which message channel the arguments to the method should go. In this case, it'll be as though we sent the message onto a channel and called `.send(Message<String>)` with the argument as a payload.

❹ the `GreetingGateway` is just a regular bean, as far as the rest of our business logic is concerned.

A Stream Consumer

On the other side, we want to accept delivery of messages and log them out. We'll create channels using an interface. It's worth reiterating: these channel names *don't* have to line up with the names on the producer side; only the names of the destinations in the brokers do.

Example 3-11. the channels for incoming greetings

```
package stream.consumer;

import org.springframework.cloud.stream.annotation.Input;
import org.springframework.messaging.SubscribableChannel;

public interface ConsumerChannels {

        String DIRECTED = "directed";
        String BROADCASTS = "broadcasts";

        ❶
        @Input(DIRECTED)
```

```
        SubscribableChannel directed();

        @Input(BROADCASTS)
        SubscribableChannel broadcasts();

}
```

❶ the only thing worth noting here is that these channels are annotated with `@Input` (naturally!) and that they return a `MessageChannel` subtype that supports *subscribing* to incoming messages, `SubscribableChannel`.

Remember, all bindings in Spring Cloud Stream are publish-subscribe by default. We can achieve the effect of exclusivity and a direct connection with a consumer group. Given, say, ten instances of a consumer in a group named `foo`, only one instance would see a message delivered to it. In a sufficiently distributed system, we can't be assured that a service will always be running, so we'll take advantage of durable subscriptions to ensure that messages are redelivered as soon as a consumer connects to the broker.

Example 3-12. the `application.properties` for our consumer

```
❶
spring.cloud.stream.bindings.broadcasts.destination=greetings-pub-sub
❷
spring.cloud.stream.bindings.directed.destination=greetings-p2p
spring.cloud.stream.bindings.directed.group=greetings-p2p-group
spring.cloud.stream.bindings.directed.durableSubscription=true
server.port=0
spring.rabbitmq.addresses=localhost
```

❶ this should look fairly familiar given what we just covered in the producer

❷ here we configure a destination, as before, but we *also* give our directed consumer an exclusive consumer group. Only one node among all the active consumers in the group `greetings-p2p-group` will see an incoming message. We ensure that the broker will store and redeliver failed messages as soon as a consumer is connected by specifying that the binding has a durableSubscription.

Finally, let's look at the Spring Integration Java DSL based consumer. This should look very familiar.

Example 3-13. a consumer driven by the Spring Integration Java DSL

❶ as before, we see `@EnableBinding` activates the consumer channels.

❷ This `@Configuration` class defines two `IntegrationFlow` flows that do basically the same thing take the incoming message, transform it by capitalizing it, and then logging it. One flow listens for the broadcasted greetings and the other for the direct, point-to-point greetings. We stop processing by returning `null` in the final component in the chain.

You can try it all out easily. Run one instance of one of the producer nodes (whichever one) and run three instances of the consumer. Visit `http://localhost:8080/hi/World` and then observe in the logs of the three consumers that all three have the message sent to the broadcast channel and one (although there's no telling which, so check all of the consoles) will have the message sent to the direct channel. Raise the stakes by killing all of the consumer nodes, then visiting `http://localhost:8080/hi/Again`. All the consumers are down, but we specified that the point-to-point connection be durable, so as soon as you restart one of the consumers you'll see the direct message arrive and logged to the console.

Next Steps

Messaging provides a communications channel for complex distributed interactions. We'll see in later chapters that you can connect batch processing solutions, workflow engines, and services in terms of a messaging substrait.

CHAPTER 4

Batch Processes and Tasks

The cloud gives us unprecedented scale. It costs virtually nothing to spin up new application instances to accommodate demand and, once the dust has settled, it's easy to scale down. This means that, as long as the work at hand lends itself to parallelization, we improve our efficiency with scale. Many problems are *embarrassingly parallel* and require no coordination between nodes. Others may require some coordination. Both of these types of workloads are ideal for a cloud computing environment, while others are inherently serial. For work that is not particularly parallelized, a cloud computing environment is ideal for horizontally scaling compute to multiple nodes. In this chapter, we will look at a few different ways, both old and new, to ingest and process data using microservices.

Batch Workloads

Batch processing has a long history. Batch processing refers to the idea that a program processes *batches* of input data at the same time. Historically, batch processing is a more efficient way of utilizing computing resources. The approach amortizes the cost of a set of machines by prioritizing windows of interactive work — when operators are using the machines — and non-interactive work in the evening hours, when the machine would otherwise be idle. Today, in the era of the cloud with virtually infinite and ephemeral computing capacity, efficient utilization of a machine isn't a particularly compelling reason to adapt batch processing.

Batch processing is also attractive when working with large data sets. Sequential data - SQL data, `.csv` files, etc. - in particular, lends itself to being processed in batches. Expensive resources, like files, SQL table cursors, and transactions may be preserved over a chunk of data, allowing processing to continue more quickly.

Batch processing supports the logical notion of a *window* - an upper and lower bound that delimits one set of data from another. Perhaps the window is temporal: all records from the last 60 minutes, or all logs from the last 24 hours. Perhaps the window is logical; the first 1,000 records, or all the records with a certain property.

If the dataset being processed is too large to fit into memory, then it's possible to process it in smaller chunks. A chunk is an efficient, albeit resource-centric, division of a batch of data. Suppose you want to visit every record in a product sales database that spans over twenty-million rows. Without paging, executing `SELECT * FROM PRODUCT_SALES` may cause the entire dataset to be loaded into memory, which could quickly overwhelm the system. Paging through this large dataset is far more efficient, loading only a thousand (or ten thousand!) records at a time. Process chunks either sequentially or in parallel, moving forward until eventually visiting all records of a large query — doing so without having to load everything into memory at the same time.

Batch provides processing efficiencies, in the case that your system is able to tolerate stale data. Many systems fit into this category. For example, a weekly sales report won't need to calculate last week's sales until the end of the week.

Spring Batch

Spring Batch is a framework that's designed to support processing large volumes of records. Spring Batch includes logging/tracing, transaction management, job processing statistics, job restart, skip, and resource management. It has become widely used industry standard for batch processing on the JVM.

At the heart of Spring Batch is the notion of a `job` — which in turn might have multiple steps. Each step would then provide a context to an optional `ItemReader`, `ItemProcessor` and `ItemWriter`.

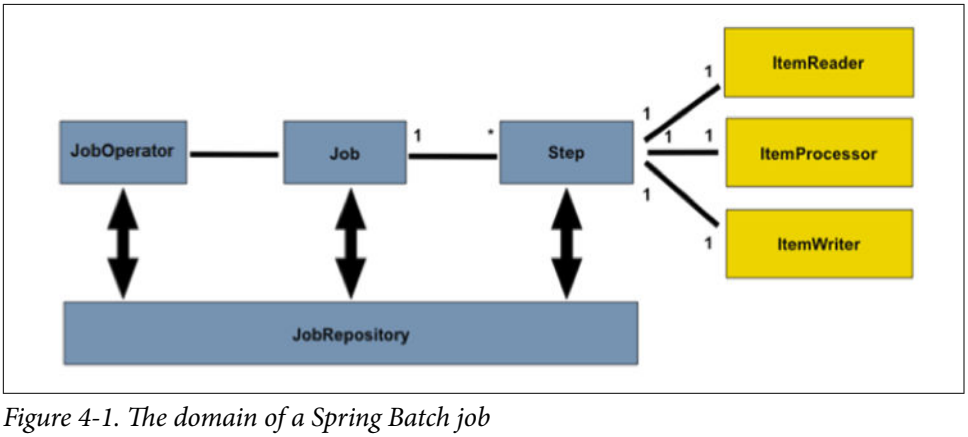


Figure 4-1. The domain of a Spring Batch job

Batch jobs have multiple steps. A step is meant to do some sort of preparation, or staging, of data before it's sent off to the next step. You may guide the flow of data from one step to another with routing logic - conditions, concurrence and basic looping. Steps might also define generic business functionality in a *tasklet*. In this case, you're using Spring Batch to orchestrate the *sequence* of an execution. Steps may extend `ItemReader`, `ItemProcessor` and `ItemWriter` implementations for more defined processing.

An `ItemReader` takes input from the outside world (`.csv` or XML documents, SQL databases, directories, etc.) and adapts it into something that we can work with logically in a job: an *item*. The item can be anything. An item could be a record from a database or a paragraph from a text file, a record from a `.csv` file, or a stanza of an XML document. Spring Batch provides useful out-of-the-box `ItemReader` implementations. `ItemReader` implementations read one item at a time, but accumulate the resulting items in a buffer that matches a specified *chunk* size.

If an `ItemProcessor` is specified, then it will be given each item from the `ItemReader`. An `ItemProcessor` is meant to handle processing and transformation. Data goes in, data goes out. An `ItemProcessor` is an ideal place for any staging or validation — or general purpose business logic not specifically concerned with input and output.

If an `ItemWriter` is specified, then it will be given the *accumulated* (not individual) items from the `ItemProcessor` (if so configured) or the `ItemReader`. Spring Batch provides useful out-of-the-box `ItemWriter` implementations. The `ItemWriter` writes the accumulated chunk of items to a resource like a database or a file. The `ItemWriter` writes as many as it can, up to the specified chunk size, per write.

This is what we mean when we talk about *batch* processing. Writing batches of items is more efficient for most types of I/O. It becomes more efficient to write batches of lines in a buffer, and much more efficient to batch the writes to a database.

Our First Batch Job

Let's look first at a high level `Job` and the flow of the configured `Step` instances.

Example 4-1. a trivial `Job` with three `Step`

```
package processing;

import org.springframework.batch.core.Job;
import org.springframework.batch.core.Step;
import org.springframework.batch.core.configuration.annotation.JobBuilderFactory;
import org.springframework.batch.core.configuration.annotation.StepBuilderFactory;
import org.springframework.batch.core.launch.support.RunIdIncrementer;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
```

```
import org.springframework.web.client.HttpStatusCodeException;
import processing.email.InvalidEmailException;

import java.util.Map;

@Configuration
class BatchConfiguration {

        (1)
        @Bean
        Job etl(JobBuilderFactory jbf, StepBuilderFactory sbf, Step1Configuration
step1, (2)
                        Step2Configuration step2, Step3Configuration step3) throws
Exception {

                Step setup = sbf.get("clean-contact-table").tasklet(step1.task
let(null)) (3)
                                .build();

                Step s2 = sbf.get("file-db").<Person, Person>chunk(1000)
                                (4)
                                .faultTolerant()
                                (5)
                                .skip(InvalidEmailException.class).retry(HttpStatus
CodeException.class)
                                .retryLimit(2).reader(step2.fileReader(null)) (6)
                                .processor(step2.emailValidatingProcessor(null)) (7)
                                .writer(step2.jdbcWriter(null)) (8)
                                .build();

                (9)
                Step s3 = sbf.get("db-file").<Map<Integer, Integer>, Map<Integer,
Integer>>chunk(100)
                                .reader(step3.jdbcReader(null)).writer(step3.file
Writer(null)).build();

                return jbf.get("etl").incrementer(new RunIdIncrementer()) (10)
                                
                                .start(setup)
                                
                                .next(s2).next(s3).build();
        }
}
```

(1) Define a Spring Batch `Job` using the `JobBuilderFactory` and `StepBuilderFactory`

(2) We also need beans for each step so those have been defined in configuration classes and injected to be easily dereferenced

❸ The first step will use a `Tasklet` which is a sort of free-form callback in which you can do anything. You describe when it's executed relative to the rest of the job by including it in a `Step`

❹ We want to write ten records a time to the configured `ItemWriter`

❺ We want to handle possible failures, so we configure the job's skip policy (on what exceptions an individual record should be skipped) and retry policy (on what exceptions should the step be retried for a given item and how many times). Spring Batch gives you a lot of knobs and levers here so that you don't have to abort the whole job just because of a single record with malformed data.

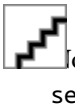
❻ Here we dereference the `FlatFileItemReader` from `Step1Configuration`. The `ItemReader` reads data from a `.csv` file and turns it into a `Person` POJO. The `@Bean` definition expects parameters, but Spring will provide those. It's fine to call the method with `null` arguments as the bean will have already been created (with the container-provided parameters) and the return value of the method will be the cached, pre-created instance.

❼ The `ItemProcessor` is an ideal place to insert a call to a web service to validate the email on the `Person` record is valid.

❽ Dereference an `ItemWriter` to write to a JDBC `DataSource`

❾ This step runs a query against the just persisted data from the first step and calculates how frequently records have a given age and then writes those calculations to an output `.csv`.

❿ A Spring Batch `Job` is parameterized. These parameters contribute to the *identity* of the job. This identity is maintained in the metadata tables for your database. In this example, the metadata tables are being persisted in MySQL. If we attempt to start the same `Job` with the same parameters twice, it'll refuse to run as it's already *seen* the job before, and recorded as much in the metadata tables. Here, we configure a `RunIdIncrementer` that derives a new key by incrementing an existing one (called the `run.id` parameter) if it already exists.

 ow we finally string together the flow of the steps in the job, starting with the `setup` step, and continuing to the `s1` step and the `s3` step.

 inally, build the `Job`

Let's say we run the job and something goes wrong - a read fails and the job aborts. Spring Batch will run through the configured retry and skip policies and attempt to carry on. If the job should fail, its progress will be recorded in the metadata tables and an operator can then decide to intervene and possibly restart (as opposed to start another, duplicate instance) the job. The job will need to resume where it left off. This is possible as some `ItemReader` implementations read stateful resources whose progress can be recorded, like a file.

This job is not particularly performant. As configured, it will read from the `ItemReader` in a single thread, serially. We could configure a `TaskExecutor` implementation for the `Job` and Spring Batch will read concurrently, effectively dividing the read time by however many threads the configured `TaskExecutor` supports.

you can retry failed jobs with recorded offsets *or* you can parallelize the reads with a `TaskExecutor` but *not* both! This is because the offset is stored in a thread local and so would end up corrupting the values observed in other threads.

Spring Batch is stateful; it keeps metadata tables for all of the jobs running in a database. The database records, among other things, how far along the job is, what its exit code is, whether it skipped certain rows (and whether that aborted the job or it was just skipped). Operators (or autonomous agents) may use this information to decide whether to re-run the job or to intervene manually.

It's dead simple to get everything running. When the Spring Boot auto-configuration for Spring Batch kicks in, it looks for a `DataSource` and attempts to create the appropriate metadata tables based on schema on the classpath, automatically.

Example 4-2. The Spring Batch metadata tables in MySQL

```
mysql> show tables;
+------------------------------+
| Tables_in_batch              |
+------------------------------+
| BATCH_JOB_EXECUTION          |
| BATCH_JOB_EXECUTION_CONTEXT  |
| BATCH_JOB_EXECUTION_PARAMS   |
| BATCH_JOB_EXECUTION_SEQ      |
| BATCH_JOB_INSTANCE           |
| BATCH_JOB_SEQ                |
| BATCH_STEP_EXECUTION         |
| BATCH_STEP_EXECUTION_CONTEXT |
| BATCH_STEP_EXECUTION_SEQ     |
+------------------------------+
9 rows in set (0.00 sec)
```

In the example, we configure two levels of fault tolerance: we configure that a certain step could be retried, two times, before it's considered an error. We use a third party web service which may or may not be available. You can simulate the service's availability by turning off your machine's internet connection. You'll observe that it'll fail to connect, throw an `HttpStatusCodeException` subclass, and then be retried. We also want to skip records that aren't validated, so we've configured a skip policy that, whenever an exception is thrown that can be assigned to the `InvalidEmailException` type, skips the processing on that row.

Let's inspect the configuration for the individual steps. First, the `setup` step, which couldn't be more straightforward.

Example 4-3. configure the first `Step` which has only a `Tasklet`

```
package processing;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.batch.core.step.tasklet.Tasklet;
import org.springframework.batch.repeat.RepeatStatus;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.jdbc.core.JdbcTemplate;

@Configuration
class Step1Configuration {

        @Bean
        Tasklet tasklet(JdbcTemplate jdbcTemplate) {

                Log log = LogFactory.getLog(getClass());

                return (contribution, chunkContext) -> { ❶
                        log.info("starting the ETL job.");
                        jdbcTemplate.update("delete from PEOPLE");
                        return RepeatStatus.FINISHED;
                };
        }
}
```

❶ the `Tasklet` is a general-purpose callback in which you can do anything. In this case, we stage the `PEOPLE` table by deleting any data.

The `Tasklet` stages the table for the second step, which reads data from an input file, validates the email, and then writes the results our freshly cleared database table. This step ingests data from a `.csv` file with three columns: the name, the age, and the email of a person.

Example 4-4. the contents of a `.csv` file to ingest

```
tam mie,30,tammie@email.com
srinivas,35,srinivas@email.com
lois,53,lois@email.com
bob,26,bob@email.com
jane,18,jane@email.com
jennifer,20,jennifer@email.com
luan,34,luan@email.com
toby,24,toby@email.com
toby,24,toby@email.com
...
```

This step demonstrates configuring a typical `ItemReader`, `ItemProcessor` and `ItemWriter`.

Example 4-5. read records from a `.csv` file and load them into a database table

```
package processing;

import org.springframework.batch.core.configuration.annotation.StepScope;
import org.springframework.batch.item.ItemProcessor;
import org.springframework.batch.item.database.JdbcBatchItemWriter;
import org.springframework.batch.item.database.builder.JdbcBatchItemWriterBuilder;
import org.springframework.batch.item.file.FlatFileItemReader;
import org.springframework.batch.item.file.builder.FlatFileItemReaderBuilder;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.core.io.Resource;
import processing.email.EmailValidationService;
import processing.email.InvalidEmailException;

import javax.sql.DataSource;

@Configuration
class Step2Configuration {

        @Bean
        @StepScope
        ❶
        FlatFileItemReader<Person> fileReader(
                        @Value("file://#{jobParameters['input']}") Resource in) ❷
                        throws Exception {

                ❸
                return new FlatFileItemReaderBuilder<Person>().name("file-
reader").resource(in)
                                .targetType(Person.class).delimited().delimiter(",")
                                .names(new String[] { "firstName", "age",
"email" }).build();
```

```
        }

        @Bean
        ItemProcessor<Person, Person> emailValidatingProcessor(
                        EmailValidationService emailValidator) { ❹
                return item -> {
                        String email = item.getEmail();
                        if (!emailValidator.isEmailValid(email)) {
                                throw new InvalidEmailException(email);
                        }
                        return item;
                };
        }

        @Bean
        JdbcBatchItemWriter<Person> jdbcWriter(DataSource ds) { ❺
                return new JdbcBatchItemWriterBuilder<Person>()
                                .dataSource(ds)
                                .sql(
                                                "insert into PEOPLE( AGE,
FIRST_NAME, EMAIL)"
                                                                + " values
(:age, :firstName, :email)").beanMapped().build();
        }
}
```

❶ Beans annotated with `@StepScope` are not singletons, they're created anew each time an instance of the job is run.

❷ The `@Value` uses the Spring Expression Language to obtain the `input` job parameter from the Spring Batch `jobParameters` context. This is a common practice in batch jobs: you might run the job today pointing to a file reflecting today's date, and run the same job tomorrow with a different file for a different date.

❸ Spring Batch's Java configuration DSL provides convenient builder APIs to configure common `ItemReader` and `ItemWriter` implementations. Here, we configure an `ItemReader` that reads a comma-separated line from the `in` file, maps the columns to names that in turn map to the fields on our `Person` POJO. The fields are then overlayed on an instance of the `Person` POJO and that `Person` is what's returned from the `ItemReader` to be accumulated.

❹ The custom `ItemProcessor` simply delegates to our `EmailValidationService` implementation which in turn calls a REST API.

❺ The `JdbcBatchItemWriter` takes the results of the `ItemProcessor<Person,Person>` and writes it to the underlying SQL datastore using a SQL statement that we provide. The named parameters for the SQL statement correspond to the Java-

Bean properties on the `Person` POJO instance being produced from the `ItemProcessor`.

The ingest is now complete. In the final step we'll analyze the results, identifying how common a given age is among the records ingested.

Example 4-6. Analyze the data and report the results to an output file

```
package processing;

import org.springframework.batch.core.configuration.annotation.StepScope;
import org.springframework.batch.item.database.JdbcCursorItemReader;
import org.springframework.batch.item.database.builder.JdbcCursorItemReaderBuilder;
import org.springframework.batch.item.file.FlatFileItemWriter;
import org.springframework.batch.item.file.builder.FlatFileItemWriterBuilder;
import org.springframework.batch.item.file.transform.DelimitedLineAggregator;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.core.io.Resource;

import javax.sql.DataSource;
import java.util.Collections;
import java.util.Map;

@Configuration
class Step3Configuration {

        ❶
        @Bean
        JdbcCursorItemReader<Map<Integer, Integer>> jdbcReader(DataSource data
Source) {
                return new JdbcCursorItemReaderBuilder<Map<Integer, Integer>>()
                                .dataSource(dataSource).name("jdbc-reader")
                                .sql("select COUNT(age) c, age a from PEOPLE group
by age")
                                .rowMapper((rs, i) -> Collections.singleton
Map(rs.getInt("a"), rs.getInt("c")))
                                .build();
        }

        ❷
        @Bean
        @StepScope
        FlatFileItemWriter<Map<Integer, Integer>> fileWriter(
                        @Value("file://#{jobParameters['output']}") Resource out) {

                DelimitedLineAggregator<Map<Integer, Integer>> aggregator = new
DelimitedLineAggregator<Map<Integer, Integer>>() {
                        {
                                ❸
```

```
                                setDelimiter(",");
                                setFieldExtractor(ageAndCount -> {
                                        Map.Entry<Integer, Integer> next = ageAnd
Count.entrySet().iterator().next();
                                        return new Object[] { next.getKey(),
next.getValue() };
                                });
                        }
                };

                return new FlatFileItemWriterBuilder<Map<Integer,
Integer>>().name("file-writer")
                                .resource(out).lineAggregator(aggregator).build();
        }
}
```

❶ The `JdbcCursorItemReader` executes a query and then visits every result in the result set and maps (using the same `RowMapper<T>` used by Spring Framework's `JdbcTemplate`) each row into an object that we want for the processor and/or writer: a single key `Map<Integer,Integer>` that reflects an age and a count of how frequent that age is in the result set.

❷ The writer is stateful, and needs to be recreated on every run of the `Job`, because each job writes the results to a differently named file. The `FlatFileItemWriter` needs a `LineAggregator` instance to figure out how to turn the incoming POJO (our `Map<Integer,Integer>`) and turn it into columns to be written to an output `.csv` file.

Now, all that's needed is to run it! Spring Boot's auto-configuration will run the job for us, on startup, by default. This job requires parameters (`input` and `output`) though, so we've disabled the default behavior and explicitly launched the job in a `CommandLineRunner` instance.

Example 4-7. The entry point into our batch application

```
package processing;

import org.springframework.batch.core.Job;
import org.springframework.batch.core.JobParametersBuilder;
import org.springframework.batch.core.configuration.annotation.EnableBatchProcess
ing;
import org.springframework.batch.core.launch.JobLauncher;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.boot.CommandLineRunner;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.context.annotation.Bean;
import org.springframework.jdbc.core.JdbcTemplate;
```

```
import org.springframework.web.client.RestTemplate;

import javax.sql.DataSource;
import java.io.File;

@EnableBatchProcessing
@SpringBootApplication
public class BatchApplication {

        public static void main(String[] args) {
                SpringApplication.run(BatchApplication.class, args);
        }

        @Bean
        RestTemplate restTemplate() {
                return new RestTemplate();
        }

        @Bean
        JdbcTemplate jdbcTemplate(DataSource dataSource) {
                return new JdbcTemplate(dataSource);
        }

        ❶
        @Bean
        CommandLineRunner run(JobLauncher launcher, Job job, @Value("${user.home}")
String home) {
                return args -> launcher.run(
                                job,
                                new JobParametersBuilder().addString("input",
path(home, "in.csv"))
                                                .addString("output", path(home,
"out.csv")).toJobParameters());
        }

        private String path(String home, String fileName) {
                return new File(home, fileName).getAbsolutePath();
        }
}
```

❶ The `CommandLineRunner` runs when the application starts up. In it, we just hard-code some path references pointing to the local filesystem and pass those in as `JobParameter` instances.

The `Job` will run synchronously by default. The `JobLauncher#run` method returns a `JobExecution` that you can use to interrogate the status of the job once it completes. If the configured `JobLauncher` has a `TaskExecutor` then you can run the job asynchronously.

Spring Batch is designed to safely handle large amounts of data though so far we've only looked at a single node. Later, we'll look at how to partition the processing of a Spring Batch `Job` with **remote partitioning**.

Spring Cloud Task is a generic abstraction that is designed to manage and make observable processes that run to completion and then terminate. We'll look at it later, but suffice it to say that it works with any Spring Boot-based service that defines an implementation of `CommandLineRunner` or `ApplicationRunner`, both of which are simple callback interfaces that, when perceived on a Spring bean, are given a callback with the application's `String [] args` array from the `main(String args[])` method. Spring Boot automatically configures a `CommandLineRunner` that runs any existing Spring Batch `Job` instances in the Spring application context. So, our Spring Batch jobs are *already* prime candidates to be run and managed as jobs with Spring Cloud Task! We'll look at this more when we discuss Spring Cloud Task.

Scheduling

One question that often comes up here is, "How do I schedule these jobs?" If your jobs are fat-`.jar`-based deployables that draw their configuration from ambient configuration sources like command-line parameters or environment variables, then it might be enough to just use good 'ol `cron` if you only have a single node. Maybe that's enough.

If you want finer-grained control over the way your jobs are scheduled, you could just use the `ScheduledExecutorService` in the JDK or even move up the abstraction a bit and leverage Spring's `@Scheduled` annotation, which in turn delegates to a `java.util.concurrent.Executor` instance. The main flaw with this approach is that there's no book keeping done on whether a job has been run or not; there's no builtin notion of a cluster. What happens if the node running a job should die? Will it get replaced and restarted on another node? What if the node that died should somehow be restored? How do you avoid the classic split-brain problem where two nodes, both operating under the assumption that it is the leader, end up running concurrently?

There are commercial schedulers like BMC, Flux Scheduler, or Autosys. These tools are powerful enough to schedule workloads, no matter what the job type, across a cluster. They work, although perhaps not as readily as you'd hope in a cloud environment. If you want more control over the scheduling and lifecycle of your jobs, you might checkout Spring's integration with the the Quartz Enterprise Job scheduler. Quartz runs well in a cluster and should have what you need to get the job done. It's also open-source and easy enough to get working in a cloud environment.

Another approach here might be to use leadership election to manage the promotion and demotion of leader nodes in a cluster. The leader node would need to be stateful, or risk running the same work twice. Spring integration has an abstraction to support

uses cases around leadership election and distributed locks, with implementations delegating to Apache Zookeeper, Hazelcast, and others. It makes it easy to transactionally rotate one node out of leadership and another one in. It provides implementations that work with Apache Zookeeper, Hazelcast and Redis. Such a leader node would farm work to other nodes in a cluster, on a schedule. The communication between nodes could be something as simple as messaging. We'll explore messaging a little later in this chapter.

There are many answers here, but it's worth underscoring that it's not a particularly interesting question as many workloads today are event-driven, not schedule-driven.

Remote Partitioning a Spring Batch Job with Messaging

Earlier, we saw that the `TaskExecutor` makes it easy to parallelize the reads in a Spring Batch `Job`. Spring Batch also supports parallelizing the writes through two mechanisms, **remote partitioning** and **remote chunking**.

Functionally, both remote partitioning and remote chunking forward control of a single step to another node in a cluster, typically connected through a messaging substrate (connected through Spring Framework `MessageChannel` instances).

Remote partitioning publishes a message to another node containing the range of records (e.g.: 0-100, 101-200, etc.) to be read. There, the actual `ItemReader`, `ItemProcessor` and / or `ItemWriter` are run. This approach requires that the worker node have full access to all the resources of the leader node. If the worker node is to read a range of records from a file, for example, then it would need access to that file. The statuses returned from the configured worker nodes are aggregated by the leader node. So, if your job is IO bound in the `ItemReader` and `ItemWriter`, prefer remote partitioning.

Remote chunking is similar to remote partitioning, except that data is read on the leader node and sent over the wire to the leader node for processing. The result's of the processing are then sent *back* to the leader node to be written. So, if your job is CPU bound in an `ItemProcessor`, prefer remote chunking.

Both remote chunking and remote partitioning lend themselves to the elasticity of a platform like Cloud Foundry. You can spin up as many nodes as you want to handle processing, let the job run, then spin down.

Spring Batch lead Michael Minella does a good job explaining all this in detail in this talk

Batch processing is almost always I/O bound and so we find more applications for remote partitioning than remote chunking, though your mileage may vary. Let's look at an example. In order for remote partitioning to work, both the leader and the worker node need access to the Spring Batch `JobRepository` which owns the state behind different instances of Spring Batch instances. The `JobRepository` in turn needs a few other components. So, any remote partitioning application will have code that lives only on the worker nodes, and code that lives only on the leader node, and code that lives in both. Thankfully, Spring provides a natural mechanism for enforcing this division within a single code-base: **profiles**! Profiles let us tag certain objects and conditionally, at runtime, toggle on or off the objects so tagged.

Example 4-8. we've defined a set of profiles for this application

```
package partition;

public class Profiles {
        public static final String WORKER_PROFILE = "worker"; ❶
        public static final String LEADER_PROFILE = "!" + WORKER_PROFILE; ❷
}
```

❶ the profile for the worker nodes

❷ the profile that is active as long as the `worker` profile is *not* active

In a remote partitioning application, there are one or more worker nodes and a leader node. The leader node coordinates with the worker nodes using messaging. Specifically it communicates with worker nodes over `MessageChannel` instances which may be Spring Cloud Stream-powered `MessageChannel` instances connected to message brokers like RabbitMQ or Apache Kafka.

Let's look at a simple Spring Batch `Job` that reads all the records in one table (our `PEOPLE` table) and copies them to another empty table called `NEW_PEOPLE`. This is a simple example with one step so that we aren't distracted by the domain of the job and can focus on the components required to achieve the solution.

The entry point into the application is straightforward: it activates Spring Batch and Spring Integration and configures a `JdbcTemplate` and a default poller to to be used for Spring Integration components that periodically poll a downstream component.

Example 4-9. the entry point into the application

```
package partition;

import org.springframework.batch.core.configuration.annotation.EnableBatchProcess
ing;
import org.springframework.boot.SpringApplication;
```

```
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.context.annotation.Bean;
import org.springframework.integration.annotation.IntegrationComponentScan;
import org.springframework.integration.dsl.core.Pollers;
import org.springframework.integration.scheduling.PollerMetadata;
import org.springframework.jdbc.core.JdbcTemplate;

import javax.sql.DataSource;
import java.util.concurrent.TimeUnit;

@EnableBatchProcessing
❶
@IntegrationComponentScan
@SpringBootApplication
public class PartitionApplication {

        public static void main(String args[]) {
                SpringApplication.run(PartitionApplication.class, args);
        }

        ❷
        @Bean(name = PollerMetadata.DEFAULT_POLLER)
        PollerMetadata defaultPoller() {
                return Pollers.fixedRate(10, TimeUnit.SECONDS).get();
        }

        @Bean
        JdbcTemplate jdbcTemplate(DataSource dataSource) {
                return new JdbcTemplate(dataSource);
        }
}
```

❶ activate Spring Batch and Spring Integration

❷ specify a default, global poller for `MessageChannel` implenentations that require polling

The application has a single Spring Batch `Job` with two steps. The first step is a `Tasklet` step that stages the database by emptying it (`truncate` in MySQL). The second step is a partitioned step whose configuration we'll visit shortly.

Example 4-10. the partitioned `Step` configuration

```
package partition;

import org.springframework.batch.core.Job;
import org.springframework.batch.core.configuration.annotation.JobBuilderFactory;
import org.springframework.batch.core.launch.support.RunIdIncrementer;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
```

```
import org.springframework.context.annotation.Profile;

@Configuration
@Profile(Profiles.LEADER_PROFILE)
❶
class JobConfiguration {

        @Bean
        Job job(JobBuilderFactory jbf, LeaderStepConfiguration lsc) {
                return jbf.get("job").incrementer(new RunIdIncrementer())
                                .start(lsc.stagingStep(null, null)) ❷
                                .next(lsc.partitionStep(null, null, null, null)) ❸
                                .build();
        }
}
```

❶ the `Job` only exists in the leader node profile

❷ the `Tasklet` resets the `NEW_PEOPLE` table

❸ the partitioned `Step` farms the work out to other nodes.

Thw partitioned step doesn't do any work on the leader node. Instead, it acts as a sort of proxy node, dispatching work to worker nodes. The partitioned step needs to know how many worker nodes (the grid size) will be available. In this example, we've provided a hard-coded value through a property for the grid zie, but the size of the worker node pool could be dynamically resolved by looking up the service instances dynamically using the Spring Cloud `DiscoveryClient` abstraction, for instance, or by interrogating the underlying platform's API (e.g.: the Cloud Foundry API Client) and asking it for the size.

Example 4-11. the configuration for the partitioned step

```
package partition;

import org.springframework.batch.core.Step;
import org.springframework.batch.core.configuration.annotation.StepBuilderFactory;
import org.springframework.batch.core.explore.JobExplorer;
import org.springframework.batch.core.partition.PartitionHandler;
import org.springframework.batch.core.partition.support.Partitioner;
import org.springframework.batch.integration.partition.MessageChannelPartitionHan
dler;
import org.springframework.batch.repeat.RepeatStatus;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.integration.core.MessagingTemplate;
import org.springframework.jdbc.core.JdbcOperations;
import org.springframework.jdbc.core.JdbcTemplate;
```

```
@Configuration
class LeaderStepConfiguration {

        ❶
        @Bean
        Step stagingStep(StepBuilderFactory sbf, JdbcTemplate jdbc) {
                return sbf.get("staging").tasklet((contribution, chunkContext) -> {
                        jdbc.execute("truncate NEW_PEOPLE");
                        return RepeatStatus.FINISHED;
                }).build();
        }

        ❷
        @Bean
        Step partitionStep(StepBuilderFactory sbf, Partitioner p, PartitionHandler
ph,
                        WorkerStepConfiguration wsc) {
                Step workerStep = wsc.workerStep(null);
                return sbf.get("partitionStep").partitioner(workerStep.getName(), p)
                                .partitionHandler(ph).build();
        }

        ❸
        @Bean
        MessageChannelPartitionHandler partitionHandler(
                        @Value("${partition.grid-size:4}") int gridSize,
                        MessagingTemplate messagingTemplate, JobExplorer
jobExplorer) {
                MessageChannelPartitionHandler partitionHandler = new MessageChannel
PartitionHandler();
                partitionHandler.setMessagingOperations(messagingTemplate);
                partitionHandler.setJobExplorer(jobExplorer);
                partitionHandler.setStepName("workerStep");
                partitionHandler.setGridSize(gridSize);
                return partitionHandler;
        }

        ❹
        @Bean
        MessagingTemplate messagingTemplate(LeaderChannels channels) {
                return new MessagingTemplate(channels.leaderRequestsChannel());
        }

        ❺
        @Bean
        Partitioner partitioner(JdbcOperations jdbcTemplate,
                        @Value("${partition.table:PEOPLE}") String table,
                        @Value("${partition.column:ID}") String column) {
                return new IdRangePartitioner(jdbcTemplate, table, column);
        }
}
```

❶ the first `Step` in the `Job` on the leader node resets the database

❷ the next step, the partition step, needs to know which worker step to invoke on the remote nodes, a `Partitioner` and a `PartitionHandler`

❸ the `PartitionHandler` is responsible for taking the original `StepExecution` on the leader node and dividing it into a collection of `StepExecution` instances that it will farm out to worker nodes. The `PartitionHandler` wants to know how many worker nodes there will be so that it can divide the work accordingly. This particular `PartitionHandler` implementation coordinates with worker nodes using `MessageChannel` instances..

❹ .. and so requires a `MessagingOperations` implementation to send and/or receive messages conveniently

❺ the `Partitioner` is responsible for partitioning the workload. In this case, the partitioning is done with some basic division of the IDs of the records in the origin table, `PEOPLE`. In all the code we'll look at in this example, this is possibly the most tedious and it is typically specific to your business domain and application.

The worker nodes pick up the work from the broker, routes the requests to a `StepExecutionRequestHandler` which then uses a `StepLocator` resolve the actual step in the worker application context to run.

Example 4-12. the configuration for the partitioned step

```
package partition;

import org.springframework.batch.core.explore.JobExplorer;
import org.springframework.batch.core.step.StepLocator;
import org.springframework.batch.integration.partition.BeanFactoryStepLocator;
import org.springframework.batch.integration.partition.StepExecutionRequest;
import org.springframework.batch.integration.partition.StepExecutionRequestHandler;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.Profile;
import org.springframework.integration.dsl.IntegrationFlow;
import org.springframework.integration.dsl.IntegrationFlows;
import org.springframework.integration.dsl.support.GenericHandler;
import org.springframework.messaging.MessageChannel;

@Configuration
@Profile(Profiles.WORKER_PROFILE)
❶
class WorkerConfiguration {
```

```
        ❷
        @Bean
        StepLocator stepLocator() {
                return new BeanFactoryStepLocator();
        }

        ❸
        @Bean
        StepExecutionRequestHandler stepExecutionRequestHandler(JobExplorer
explorer,
                        StepLocator stepLocator) {
                StepExecutionRequestHandler handler = new StepExecutionRequestHan
dler();
                handler.setStepLocator(stepLocator);
                handler.setJobExplorer(explorer);
                return handler;
        }

        ❹
        @Bean
        IntegrationFlow stepExecutionRequestHandlerFlow(WorkerChannels channels,
                        StepExecutionRequestHandler handler) {

                MessageChannel channel = channels.workerRequestsChannels();
                GenericHandler<StepExecutionRequest> executionHandler = (payload,
headers) -> handler
                                .handle(payload);

                return IntegrationFlows.from(channel)
                                .handle(StepExecutionRequest.class, executionHan
dler)
                                .channel(channels.workerRepliesChannels()).get();
        }
}
```

❶ these objects should be present only in the `worker` node and under the `worker` profile.

❷ the `StepLocator` is responsible for locating a `Step` implementation by name. In this case, it'll resolve the `Step` by sifting through the beans in the containing `BeanFactory` implementation.

❸ the `StepExecutionRequestHandler` is the counterpart on the worker node to the `PartitionHandler` on the leader: it accepts incoming requests and turns them into executions of a given `Step`, the results of which are then sent in reply

❹ the `StepExecutionRequestHandler` is unaware of the `MessageChannel` instances on which incoming `StepExecutionRequests` will arrive, so we use Spring Integration to trigger the `StepExecutionRequestHandler` bean's `#handle(StepExecu`

`tionRequest)` method in response to messages, and to ensure that the return value is sent out as a messsage on a reply channel.

Finally, the actual step is activated along with information on which data to read. It is important that the reader have access to the same state (in this case, a JDBC `DataSource`) as the leader node.

Example 4-13. the configuration for the partitioned step

```
package partition;

import org.springframework.batch.core.Step;
import org.springframework.batch.core.configuration.annotation.StepBuilderFactory;
import org.springframework.batch.core.configuration.annotation.StepScope;
import org.springframework.batch.item.database.JdbcBatchItemWriter;
import org.springframework.batch.item.database.JdbcPagingItemReader;
import org.springframework.batch.item.database.Order;
import org.springframework.batch.item.database.builder.JdbcBatchItemWriterBuilder;
import org.springframework.batch.item.database.support.MySqlPagingQueryProvider;
import org.springframework.beans.factory.annotation.Value;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;

import javax.sql.DataSource;
import java.util.Collections;

@Configuration
class WorkerStepConfiguration {

        ❶
        @Value("${partition.chunk-size}")
        private int chunk;

        ❷
        @Bean
        @StepScope
        JdbcPagingItemReader<Person> reader(DataSource dataSource,
                        @Value("#{stepExecutionContext['minValue']}") Long min,
                        @Value("#{stepExecutionContext['maxValue']}") Long max) {

                MySqlPagingQueryProvider queryProvider = new MySqlPagingQueryPro
vider();
                queryProvider
                                .setSelectClause("id as id, email as email, age as
age, first_name as firstName");
                queryProvider.setFromClause("from PEOPLE");
                queryProvider.setWhereClause("where id >= " + min + " and id <= " +
max);
                queryProvider.setSortKeys(Collections.singletonMap("id",
Order.ASCENDING));
```

```
                JdbcPagingItemReader<Person> reader = new JdbcPagingItemReader<>();
                reader.setDataSource(dataSource);
                reader.setFetchSize(this.chunk);
                reader.setQueryProvider(queryProvider);
                reader.setRowMapper((rs, i) -> new Person(rs.getInt("id"),
rs.getInt("age"), rs
                                .getString("firstName"), rs.getString("email")));
                return reader;
        }

        ❸
        @Bean
        JdbcBatchItemWriter<Person> writer(DataSource ds) {
                return new JdbcBatchItemWriterBuilder<Person>()
                                .beanMapped()
                                .dataSource(ds)
                                .sql(
                                                "INSERT INTO NEW_PEO
PLE(age,first_name,email) VALUES(:age, :firstName, :email )")
                                .build();
        }

        ❹
        @Bean
        Step workerStep(StepBuilderFactory sbf) {
                return sbf.get("workerStep").<Person, Person>chunk(this.chunk)
                                .reader(reader(null, null,
null)).writer(writer(null)).build();
        }
}
```

❶ this is a Spring Batch job, at the end of the day, so the `JdbcPagingItemReader` implementation still cares about chunking through the records.

❷ Note that we're using a `JdbcPagingItemReader` and not an implementation like `JdbcCursorItemReader` as we don't have the ability to share a JDBC result cursor across all the worker nodes. Ultimately, both implementations let us divide a large JDBC `ResultSet` into smaller pieces, and it's useful to know when and where to apply which. The `ItemReader` will receive in the `ExecutionContext` sent from the `PartitionHandler` a map of keys and values providing useful information including, in this case, the bounds of the rows to be read. As these values are unique for every execution of the `Step`, the `ItemReader` has been given the `@Step Scope`.

❸ the `JdbcBatchItemWriter` is straightfoward, writing the fields of the `Person` POJO to the database by mapping the POJO properties to the named parameters in the SQL statement.

❹ finally, we build the worker `Step`. This should be very familiar at this point.

Finally, the application components are connected with `MessageChannel` implementations. Three of those definitions - `leaderRequests`, `workerRequests`, and `workerReplies` - are defined using Spring Cloud Stream and - in this example - RabbitMQ. One last `MessageChannel` - `leaderRepliesAggregatedChannel` - is used only to connect two components in-memory. We'll leave you to peruse the source code - `LeaderChannels`, `WorkerChannels`, and `application.properties` - to see those definitions as they're redundant given our earlier discussion of Spring Cloud Stream.

You'll need the `PEOPLE` table setup as well as a duplicate version of this table of identical configuration called `NEW_PEOPLE`. Launch a few instances of the worker nodes using the `worker` profile. Then, launch the leader node by not specifying a specific profile. Once those are all running, you can launch an instance of the job. This example does *not* run the `Job` on application launch, but you can trigger a run through a REST endpoint that's included in the source code: `curl -d{} http://localhost:8080/migrate`.

Task Management

Spring Boot knows what to do with our `Job`; when the application starts up Spring Boot runs all `CommandLineRunner` instances, including the one provided by Spring Boot's Spring Batch auto-configuration. From the outside looking in, however, there is no logical way to know how to *run* this job. We don't know, necessarily, that it describes a workload that will terminate and produce an exit status. We don't have common infrastructure that captures the start and end time for a task. There's no infrastructure to support us if an exception occurs. Spring Batch surfaces these concepts, but how do we deal with things that aren't Spring Batch `Job` instances, like `CommandLineRunner` or `ApplicationRunner` instances? Spring Cloud Task helps us here. Spring Cloud Task provides a way of identifying, executing and interrogating, well, *tasks*!

A *task* is something that starts and has an expected terminal state. Tasks are ideal abstractions for any ephemeral process or workload that may require an atypically long amount of time (longer than an ideal transaction in the main request and response flow of a service; this might imply seconds, hours or even days!). Tasks describe workloads that run once (in response to an event) or on a schedule. Common examples include:

- Somebody requests that the system generated and send *Reset Password* email
- A Spring Batch `Job` that runs whenever a new file arrives in a directory

- An application that periodically garbage collects stray files or audits inconsistent data or message queue logs
- Dynamic document (or report) generation
- Media transcoding

A key aspect of a task is that it provides a uniform interface for parameterization. Spring Cloud Task tasks accept parameters and Spring Boot configuration properties. If you specify parameters, Spring Cloud Task will perpetuate them `CommandLineRunner` or `ApplicationRunner` arguments or as Spring Batch `JobParameter` instances. Tasks may be configured using Spring Boot configuration properties. Indeed, as we'll see later, Spring Cloud Data Flow is even smart enough to let you interrogate the list of known properties for a given task and render a form for task-specific properties.

If you want your task to benefit from the smart integration with the Spring Cloud Data Flow, you'll need to include the Spring Boot configuration processor (`org.springframework.boot : spring-boot-configuration-processor`) and define a `@ConfigurationProperties` component.

Let's look at a simple example. Start a new Spring Boot project with nothing in it and then add `org.springframework.cloud : spring-cloud-task-starter`.

Example 4-14.

```
package task;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.boot.CommandLineRunner;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;
import org.springframework.cloud.task.configuration.EnableTask;
import org.springframework.cloud.task.repository.TaskExplorer;
import org.springframework.context.annotation.Bean;
import org.springframework.data.domain.PageRequest;

import java.util.stream.Stream;

@EnableTask
❶
@SpringBootApplication
public class HelloTask {

        private Log log = LogFactory.getLog(getClass());

        public static void main(String args[]) {
```

```
                SpringApplication.run(HelloTask.class, args);
        }

        @Bean
        CommandLineRunner runAndExplore(TaskExplorer taskExplorer) {
                return args -> {
                        Stream.of(args).forEach(log::info);

                        ❷
                        taskExplorer.findAll(new PageRequest(0, 1)).forEach(
                                        taskExecution -> log.info(taskExecu
tion.toString()));
                };
        }
}
```

❶ activate Spring Cloud Task

❷ inject the Spring Cloud Task `TaskExplorer` to inspect the current running task's execution

When you run the example, the `CommandLineRunner` runs just as we'd expect it would in a non-Task-based application. Helpfully, though, we can inject the `TaskExplorer` to dynamically interrogate the runtime about the status of the running task (or, indeed, any tasks). The `TaskExplorer` knows about the `CommandLineRunner`, `ApplicationRunner` and Spring Batch `Job` instances in our application context. You gain support for Spring Batch `Job` workloads with Spring Cloud Task's Batch integration (`org.springframework.cloud : spring-cloud-task-batch`).

We'll revisit Spring Cloud Task in our later discussion of Spring Cloud Data Flow, later.

Process-Centric Integration with Workflow

While Spring Batch gives us rudimentary workflow capabilities, its purpose is to support processing of large datasets, not to weave together autonomous agents and human agents in a comprehensive workflow. Workflow is the practice of explicitly modeling the progression of work through a system of autonomous (and human!) agents. Workflow systems define a state machine and constructs for modeling the progression of that state towards a goal. Workflow systems are designed to work closely with the business who may have their own designs on a given business process.

Workflow overlaps a lot with the ideas of business process management and business process modeling (both, confusingly, abbreviated as BPM). BPM refers to the technical capability to describe and run a workflow process, but also to the management discipline of automating business. Analysts use BPM to identify business processes, which they model and execute with a workflow engine like Activiti.

Workflow systems support ease of modeling processes. Typically, workflow systems provide design-time tools that facilitate visual modeling. The main goal of this is to arrive at an artifact that minimally specifies the process for both business and technologists. A process model is not directly executable code, but instead a series of steps. It is up to developers to provide appropriate behavior for the various states. Workflow systems typically provide a way to store and query the state of various processes. Like Spring Batch, workflow systems also provide a built-in mechanism to design compensatory behavior in the case of failures.

From a design perspective, workflow systems help keep your services and entities stateless and free of what would otherwise be irrelevant process state. We've seen many systems where an entity's progression through fleeting, one time processes was represented as booleans (`is_enrolled`, `is_fulfilled`, etc.) on the entity and in the database themselves. These flags muddy the design of the entity for very little gain.

Workflow systems map roles to sequences of steps. These roles correspond more or less to swimlines in UML. A workflow engine, like a swimlane, may describe *human* tasklists as well as autonomous activities.

Is workflow for everybody? Decidedly not. We've seen that workflow is most useful for organizations that have complex processes, or are constrained by regulation and policy and need a way to interrogate process state. It's optimal for collaborative processes where humans and services drive towards a larger business requirement; examples include loan approval, legal compliance, insurance reviews, document revision, and document publishing.

Workflow simplifies design to free your business logic from the strata of state required to support auditing and reporting of processes. We look at it in this section because it, like batch processing, provides a meaningful way to address failure in a complex, multi-agent and multi-node process. It is possible to model a saga execution coordinator on top of a workflow engine, although a workflow engine is not itself a saga execution coordinator. We get a lot of the implied benefits, though, if used correctly. We'll see later that workflows also lend themselves to horizontal scale on a cloud -environment through messaging infrastructure.

Let's walk through a simple exercise. Suppose you have a signup process for a new user. The business cares about the progression of new signups as a metric. Conceptu-

ally, the signup process is a simple affair: the user submits a new signup request through a form, which then must be validated and - if there are errors - fixed. Once the form is correct and accepted, a confirmation email must be sent. The user has to click on the confirmation email and trigger a well-known endpoint confirming the email is addressable. The user may do this in a minute or in two weeks.. or a year! The long-lived transaction is still valid. We could make the process even more sophisticated and specify timeouts and escalations within the definition of our workflow. For now, however, this is an interesting enough example that involves both autonomous and human work towards the goal of enrolling a new customer.

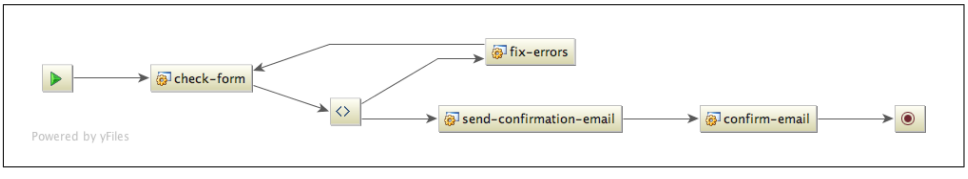


Figure 4-2. a signup process modeled using BPMN 2.0 as viewed from IntelliJ IDEA's yFiles-powered BPMN 2.0 preview.

Alfresco's Activiti project is a *business process engine*. It supports process definitions in an XML standard called BPMN 2.0. BPMN 2.0 enjoys robust support across multiple vendors' tooling and IDEs. The business process designer defines BPMN business processes using tools from, say, WebMethods or Activiti or IBM, and can then run the defined process in Activiti (or, in theory, in any other tool). Activiti also provides a modeling environment, is easy to deploy standalone or use in a cloud-based services, and is Apache 2 licensed. Conveniently for us, Activiti also offers a convenient Spring Boot auto-configuration.

as this book was being developed, the main developers on the Activiti project forked the project into a new Apache 2 licensed, completely backwards-compatible effort called Flowable. We would definitely watch that space if you like Activiti.

In Activiti, a `Process` defines an archetypical process definition. A `ProcessInstance` is a single execution of a given process. A process instance is uniquely defined by its process variables, which parameterize the process' execution. Think of them as command-line arguments, like `JobParameter` parameters for a Spring Batch `Job`.

The Activiti engine, like Spring Batch, keeps its execution state in a relational database. If you're using the Spring Boot auto-configuration, it'll automatically install the relevant tables for you provided you've a `DataSource` in your application context somewhere. Here are the relevant tables.

Example 4-15. the Activiti metadata tables in MySQL

```
mysql> show tables;
+------------------------------+
| Tables_in_activiti           |
+------------------------------+
| ACT_EVT_LOG                  |
| ACT_GE_BYTEARRAY             |
| ACT_GE_PROPERTY              |
| ACT_HI_ACTINST               |
| ACT_HI_ATTACHMENT            |
| ACT_HI_COMMENT               |
| ACT_HI_DETAIL                |
| ACT_HI_IDENTITYLINK          |
| ACT_HI_PROCINST              |
| ACT_HI_TASKINST              |
| ACT_HI_VARINST               |
| ACT_ID_GROUP                 |
| ACT_ID_INFO                  |
| ACT_ID_MEMBERSHIP            |
| ACT_ID_USER                  |
| ACT_PROCDEF_INFO             |
| ACT_RE_DEPLOYMENT            |
| ACT_RE_MODEL                 |
| ACT_RE_PROCDEF               |
| ACT_RU_EVENT_SUBSCR          |
| ACT_RU_EXECUTION             |
| ACT_RU_IDENTITYLINK          |
| ACT_RU_JOB                   |
| ACT_RU_TASK                  |
| ACT_RU_VARIABLE              |
+------------------------------+
24 rows in set (0.00 sec)
```

The Spring Boot auto-configuration expects any BPMN 2.0 documents to be in the `src/main/resources/processes` directory of an application, by default. Let's take a look at the definition of a BPMN 2.0 `signup` process.

Example 4-16. the `signup.bpmn20.xml` business process definition

```
<?xml version="1.0" encoding="UTF-8"?>
<definitions
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xmlns:activiti="http://activiti.org/bpmn"
        xmlns="http://www.omg.org/spec/BPMN/20100524/MODEL"
        typeLanguage="http://www.w3.org/2001/XMLSchema"
        expressionLanguage="http://www.w3.org/1999/XPath"
        targetNamespace="http://www.activiti.org/bpmn2.0">


    <process name="signup" id="signup">
```

```
        ❶
        <startEvent id="start"/>

        ❷
        <sequenceFlow sourceRef="start" targetRef="check-form"/>

        ❸
        <serviceTask id="check-form" name="check-form"
                     activiti:expression="#{checkForm.execute(execution)}"/>

        <sequenceFlow sourceRef="check-form" targetRef="form-completed-decision-
gateway"/>

        ❹
        <exclusiveGateway id="form-completed-decision-gateway"/>

        <sequenceFlow name="formOK" id="formOK" sourceRef="form-completed-decision-
gateway"
                      targetRef="send-confirmation-email">
            <conditionExpression xsi:type="tFormalExpression">${formOK == true}
            </conditionExpression>
        </sequenceFlow>

        <sequenceFlow id="formNotOK" name="formNotOK" sourceRef="form-completed-
decision-gateway"
                      targetRef="fix-errors">
            <conditionExpression xsi:type="tFormalExpression">${formOK == false}
            </conditionExpression>
        </sequenceFlow>

        ❺
        <userTask name="fix-errors" id="fix-errors">
            <humanPerformer>
                <resourceAssignmentExpression>
                    <formalExpression>customer</formalExpression>
                </resourceAssignmentExpression>
            </humanPerformer>
        </userTask>

        <sequenceFlow sourceRef="fix-errors" targetRef="check-form"/>

        ❻
        <serviceTask id="send-confirmation-email" name="send-confirmation-email"
                     activiti:expression="#{sendConfirmationEmail.execute(execu
tion)}"/>

        <sequenceFlow sourceRef="send-confirmation-email" targetRef="confirm-
email"/>

        ❼
        <userTask name="confirm-email" id="confirm-email">
            <humanPerformer>
```

```
            <resourceAssignmentExpression>
                <formalExpression>customer</formalExpression>
            </resourceAssignmentExpression>
        </humanPerformer>
    </userTask>

    <sequenceFlow sourceRef="confirm-email" targetRef="end"/>

    <endEvent id="end"/>
  </process>
</definitions>
```

❶ the first state is the `startEvent`. All processes have a defined `start` and `end`.

❷ the `sequenceFlow` elements serve as guidance to the engine about where to go next. They're logical, and are represented as lines in the workflow model itself.

❸ a `serviceTask` is a state in the process. Our BPMN 2.0 definition uses the Activiti-specific `activiti:expression` attribute to delegate handling to method, `execute(ActivityExecution)` on a Spring bean (called `checkForm`). Spring Boot's auto-configuration activates this behavior.

❹ After the form is submitted and checked, the `checkForm` method contributes a boolean *process variable* called `formOK`, whose value is used to drive a decision downstream. A process variable is context that's visible to participants in a given process. Process variables can be whatever you'd like, though we tend to keep them as trivial as possible to be used later to act as claim-checks for real resources elsewhere. This process expects one input process variable, `customerId`.

❺ if the form is invalid, then work flows to the `fix-errors` user task. The task is contributed to a worklist and assigned to a human. This tasklist is supported through a `Task` API in Activiti. It's trivial to query the tasklist and start and complete tasks. The tasklist is meant to model work that a human being must perform. When the process reaches this state, it pauses, waiting to be explicitly completed by a human at some later state. Work flows from the `fix-errors` task back to the `checkForm` state. If the form is now fixed, work proceeds to the

❻ if the form is valid, then work flows to the `send-confirmation-email` service task. This simply delegates to another Spring bean to do its work, perhaps using SendGrid.

❼ It's not hard to imagine what has to happen here: the email should contain some sort of link that, when clicked, triggers an HTTP endpoint that then completes the outstanding task and moves the process to completion.

This process is trivial but it provides a clean representation of the moving pieces in the system. We can see that we will need *something* to take the inputs from the user, resulting in a customer record in the database and a valid `customerId` that we can use to retrieve that record in downstream components. The customer record may be in an invalid state (the email might be invalid), and may well need to be revisited by the user. Once things are in working order, state moves to the step where we send a confirmation email that, once received and confirmed, transitions the process to the terminal state.

Let's look at a simple REST API that drives this process along. For brevity, we've not extrapolated out an iPhone client or an HTML5 client, but it's certainly a natural next step. The REST API is kept as simple as possible for illustration. a *very* logical next step might be to use hypermedia to drive the clients interactions with the REST API from one state transition to another. For more on this possibility checkout the REST chapter and the discussion of hypermedia and HATEOAS.

Example 4-17. the `SignupRestController` that drives the process

```
package com.example;

import org.activiti.engine.RuntimeService;
import org.activiti.engine.TaskService;
import org.activiti.engine.task.TaskInfo;
import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.http.ResponseEntity;
import org.springframework.util.Assert;
import org.springframework.web.bind.annotation.*;

import java.util.Collections;
import java.util.List;
import java.util.stream.Collectors;

@RestController
@RequestMapping("/customers")
class SignupRestController {

        public static final String CUSTOMER_ID_PV_KEY = "customerId";

        private final RuntimeService runtimeService;
        private final TaskService taskService;
        private final CustomerRepository customerRepository;
        private Log log = LogFactory.getLog(getClass());

        ❶
        @Autowired
        public SignupRestController(RuntimeService runtimeService, TaskService task
Service,
```

```
                        CustomerRepository repository) {
                this.runtimeService = runtimeService;
                this.taskService = taskService;
                this.customerRepository = repository;
        }

        ❷
        @PostMapping
        public ResponseEntity<?> startProcess(@RequestBody Customer customer) {
                Assert.notNull(customer);
                Customer save = this.customerRepository.save(new Customer(cus
tomer.getFirstName(),
                                customer.getLastName(), customer.getEmail()));

                String processInstanceId = this.runtimeService.startProcessInstance
ByKey("signup",
                                Collections.singletonMap(CUSTOMER_ID_PV_KEY,
Long.toString(save.getId())))
                                .getId();
                this.log.info("started sign-up. the processInstance ID is " + proces
sInstanceId);

                return ResponseEntity.ok(save.getId());
        }

        ❸
        @GetMapping("/{customerId}/signup/errors")
        public List<String> readErrors(@PathVariable String customerId) {
                // @formatter:off
                return this.taskService
                                .createTaskQuery()
                                        .active()
                                        .taskName("fix-errors")
                                        .includeProcessVariables()
                                        .processVariableValueEquals(CUS
TOMER_ID_PV_KEY, customerId)
                                .list()
                                        .stream()
                                        .map(TaskInfo::getId)
                                .collect(Collectors.toList());
                // @formatter:on
        }

        ❹
        @PostMapping("/{customerId}/signup/errors/{taskId}")
        public void fixErrors(@PathVariable String customerId, @PathVariable String
taskId,
                        @RequestBody Customer fixedCustomer) {

                Customer customer = this.customerRepository.findOne(Long.parse
Long(customerId));
                customer.setEmail(fixedCustomer.getEmail());
```

```
                customer.setFirstName(fixedCustomer.getFirstName());
                customer.setLastName(fixedCustomer.getLastName());
                this.customerRepository.save(customer);

                this.taskService.createTaskQuery().active().taskId(taskId).include
ProcessVariables()
                                .processVariableValueEquals(CUSTOMER_ID_PV_KEY, cus
tomerId).list().forEach(t -> {
                                        log.info("fixing customer# " + customerId +
" for taskId " + taskId);
                                        taskService.complete(t.getId(), Collec
tions.singletonMap("formOK", true));
                                });
        }

        ❺
        @PostMapping("/{customerId}/signup/confirmation")
        public void confirm(@PathVariable String customerId) {
                this.taskService.createTaskQuery().active().taskName("confirm-
email")
                                .includeProcessVariables()
                                .processVariableValueEquals(CUSTOMER_ID_PV_KEY, cus
tomerId).list().forEach(t -> {
                                        log.info(t.toString());
                                        taskService.complete(t.getId());
                                });
                this.log.info("confirmed email receipt for " + customerId);
        }
}
```

❶ the controller will work with a simple Spring Data JPA repository as well as two services that are auto-configured by the Activiti Spring Boot support. The `RuntimeService` lets us interrogate the process engine about running processes. The `TaskService` lets us interrogate the process engine about running human tasks and tasklists.

❷ the first endpoint accepts a new `customer` record and persists it. The newly minted customer is fed as an input process variable into a new process, where the customer's `customerId` is specificed as a process variable. Here, the process flows to the `check-form` `serviceTask` which will nominally check that the input email is valid, If the email is valid, then a confirmational email is sent. Otherwise, the customer will need to address any errors in the input data.

❸ if there are any errors, we want the user's UI experience to arrest forward progress, so the process queues up a user task. This endpoint queries for any outstanding tasks for this particular user and then returns a collection of outstanding tasks IDs. Ideally, this might also return validation information that

can drive the UX for the human using some sort of interactive experience to enroll.

❹ Once the errors are addressed client-side, the updated entity is persisted in the database and the outstanding task is marked as complete. At this point the process flows the `send-confirmation-email` state which will send an email that includes a confirmation link that the user will have to click to confirm the enrollment.

❺ The final step, then, is a REST endpoint that queries any outstanding email confirmation tasks for the given customer.

We start this process with a potentially invalid entity, the customer, whose state we need to ensure is correct before we can proceed. We model this process to support iteration on the entity, backtracking to the appropriate step for so long as there's invalid state.

Let's complete our tour by examining the beans that power the two `serviceTask` elements, `check-form`, and `send-confirmation-email`, in the process.

Both the `CheckForm` and `SendConfirmationEmail` beans are uninteresting. They're simple Spring beans. `CheckForm` implements a trivial validation that ensures the first name and last name are not null and then uses the Mashape email validation REST API introduced in the discussion on Spring Batch to validate that the email is of a valid form. The `CheckForm` bean is used to validate the state of a given `Customer` record and then contributes a process variable to the running `ProcessInstance`, a boolean called `formOK`, that then drives a decision as to whether to continue with the process or force the user to try again.

Example 4-18. the `CheckForm` bean that validates the customer's state

```
package com.example;

import com.example.email.EmailValidationService;
import org.activiti.engine.RuntimeService;
import org.activiti.engine.impl.pvm.delegate.ActivityExecution;
import org.springframework.beans.factory.annotation.Autowired;
import org.springframework.stereotype.Service;

import java.util.Collections;
import java.util.Map;

import static org.apache.commons.lang3.StringUtils.isEmpty;

@Service
class CheckForm {
```

```
        private final RuntimeService runtimeService; ❶
        private final CustomerRepository customerRepository;
        private final EmailValidationService emailValidationService;

        @Autowired
        public CheckForm(EmailValidationService emailValidationService,
                         RuntimeService runtimeService, CustomerRepository customerRe
pository) {
                this.runtimeService = runtimeService;
                this.customerRepository = customerRepository;
                this.emailValidationService = emailValidationService;
        }

        ❷
        public void execute(ActivityExecution e) throws Exception {
                Long customerId = Long.parseLong(e.getVariable("customerId",
String.class));
                Map<String, Object> vars = Collections.singletonMap("formOK",
                                validated(this.customerRepository.findOne(custom
erId)));
                this.runtimeService.setVariables(e.getId(), vars); ❸
        }

        private boolean validated(Customer customer) {
                return !isEmpty(customer.getFirstName()) && !isEmpty(customer.get
LastName())
                                && this.emailValidationService.isEmailValid(cus
tomer.getEmail());
        }

}
```

❶ inject the Activiti `RuntimeService`

❷ the `ActivityExecution` is a context object. You can use it to access process variables, the process engine itself, and other interesting services.

❸ then use it to artifculate the outcome of the test

The `SendConfirmationEmail` is of the same basic form.

So far, we've looked at workflow in the context of a single node. We've ignored one of the most promising aspects of the cloud: scale! Modeling a workflow helps us identify embarrassingly parallel processing opportunities. Every state in the process expects inputs (in the form of process variables and pre-conditions) and provides outputs (in the form of side-effects and process variables). The workflow manages the process state.

Our business logic is executed at the right time, depending on state. Thus far everything we've done has happened either in the same node or on whatever node the cli-

ent is using to interact with the system to satisfy the user-assigned tasklists. If the automatic processing takes any non-trivial amount of time, it's safer to move that work to another node. Any node! This is the cloud, after all. We have the capacity, it's just a matter of using it.

In a BPMN process, the `serviceTask` element is a wait-state: the engine will pause there (and dispose of any held resources) until it is explicitly *signaled*. Anything out of band could signal the process: a message from an Apache Kafka broker arrives, an email, a button click, or the conclusion of long-running process. We can take advantage of this behavior and move potentially long-running processing to another node and then, on completion, signal that the process should be resumed. The workflow engines keeps track of all this state so its possibly to query for any orphaned processes, and to act accordingly. Workflow gives us the ability to naturally break apart involved business processes, decompose them into isolated steps, distribute them across a cluster *and* it provides the tools to be able to recover should something go wrong in the distribution of work.

Let's look at how to farm execution out to worker nodes in terms of Spring Cloud Stream's `MessageChannel` definitions. As we did in the remote-partitioning Spring Batch job, we'll think of the solution in terms of the leader node and worker nodes. The leader node is simply the node that originates the processing. The leader node features an HTTP endpoint (`http://loclahost:8080/start`) to initiate processing. The process is necessarily trivial so we can focus on the distribution.

Example 4-19. an asynchronous business process, `async.bpmn20.xml`

```
<?xml version="1.0" encoding="UTF-8"?>
<definitions xmlns:activiti="http://activiti.org/bpmn"
             id="definitions"
             xmlns="http://www.omg.org/spec/BPMN/20100524/MODEL"
             typeLanguage="http://www.w3.org/2001/XMLSchema"
             expressionLanguage="http://www.w3.org/1999/XPath"
             targetNamespace="http://www.activiti.org/bpmn2.0">

    <process id="asyncProcess">

        <startEvent id="start"/>

        <sequenceFlow id="f1" sourceRef="start" targetRef="spring-gateway"/>

        ❶
        <serviceTask id="spring-gateway" activiti:delegateExpression="#{gateway}"/>

        <sequenceFlow id="f2" sourceRef="spring-gateway" targetRef="confirm-
movement"/>

        ❷
```

```
        <scriptTask id="confirm-movement" scriptFormat="groovy">
            <script>
                println 'Moving on..'
            </script>
        </scriptTask>

        <sequenceFlow id="f3" sourceRef="confirm-movement" targetRef="end"/>

        <endEvent id="end"/>

    </process>

</definitions>
```

❶ As soon as the process begins, it enters a `serviceTask` state and here we use an Activiti delegate, a Spring bean called `gateway`, to process this state. The process will stop in that handler until it is signalled.

❷ Once signaled, the process will continue to the `scriptTask` and we'll see `Moving on!` recorded on the console.

The `gateway` bean is the key. It is an implementation of the Activiti `ReceiveTaskActivityBehavior` that writes a message to a Spring Cloud Stream powered `leaderRequests MessageChannel`. The `executionId` is the payload for the message. The `executionId` is required to later signal the request. We must take care to perpetuate it in either the message headers or the payload (as we do in this example). When a reply message is received on another Spring Cloud Stream-powered `MessageChannel`, the `repliesFlow` calls `RuntimeService#signal(executionId)` which in turn resumes the execution of the process.

Example 4-20. the `LeaderConfiguration` defines how requests are sent out to, and what happens when the replies come back from, the worker nodes

```
package com.example;

import org.activiti.engine.ProcessEngine;
import org.activiti.engine.impl.bpmn.behavior.ReceiveTaskActivityBehavior;
import org.activiti.engine.impl.pvm.delegate.ActivityBehavior;
import org.activiti.engine.impl.pvm.delegate.ActivityExecution;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.Profile;
import org.springframework.integration.dsl.IntegrationFlow;
import org.springframework.integration.dsl.IntegrationFlows;
import org.springframework.integration.support.MessageBuilder;
import org.springframework.messaging.Message;

@Configuration
```

```
@Profile(Profiles.LEADER)
class LeaderConfiguration {

        ❶
        @Bean
        ActivityBehavior gateway(LeaderChannels channels) {
                return new ReceiveTaskActivityBehavior() {

                        @Override
                        public void execute(ActivityExecution execution) throws
Exception {

                                Message<?> executionMessage = MessageBuilder.withPay
load(execution.getId())
                                                .build();

                                channels.leaderRequests().send(executionMessage);
                        }
                };
        }

        ❷
        @Bean
        IntegrationFlow repliesFlow(LeaderChannels channels, ProcessEngine engine) {
                return IntegrationFlows.from(channels.leaderReplies())
                                .handle(String.class, (executionId, map) -> {
                                        engine.getRuntimeService().signal(executio
nId);
                                        return null;
                                }).get();
        }
}
```

❶ as soon as the process begins, it enters a `serviceTask` state and here we use an Activiti delegate, a Spring bean called `gateway`, to process this state. The process will stop in that handler until it is signalled.

❷ Once signaled, the process will continue to the `scriptTask` and we'll see `Moving on!` recorded on the console.

The worker node works only with `MessageChannel` instances: there is no awareness (beyond the String `executionId` header) of Activiti or of the workflow engine. The worker nodes are free to do whatever they want: perhaps they launch a Spring Batch `Job` or a Spring Cloud `Task`. Workflow is ideal for any long-running processes, so whatever you want to do could be done here: video transcoding, document generation, image analysis, etc.

Example 4-21. the `WorkerConfiguration` defines how requests are sent out to, and what happens when the replies come back from, the worker nodes

```
package com.example;

import org.apache.commons.logging.Log;
import org.apache.commons.logging.LogFactory;
import org.springframework.context.annotation.Bean;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.Profile;
import org.springframework.integration.dsl.IntegrationFlow;
import org.springframework.integration.dsl.IntegrationFlows;
import org.springframework.integration.dsl.support.GenericHandler;

@Configuration
@Profile(Profiles.WORKER)
class WorkerConfiguration {

        @Bean
        IntegrationFlow requestsFlow(WorkerChannels channels) {

                Log log = LogFactory.getLog(getClass());

                ❶
                return IntegrationFlows.from(channels.workerRequests())
                                .handle((GenericHandler<String>) (executionId, head
ers) -> {
                                                ❷
                                                        headers.entrySet().forEach(e ->
log.info(e.getKey() + '=' + e.getValue()));
                                                        log.info("sending executionId (" +
executionId + ") to workerReplies.");
                                                        return executionId;
                                        }).channel(channels.workerReplies()) ❸
                                .get();
        }
}
```

❶ whenever a new message arrives..

❷ enumerate the headers and do whatever other business logic we want, ensuring we perpetuate the `executionId` payload

❸ which gets sent on the `workerReplies` channel, back to the leader node.

Distribution with Messaging

Though this chapter has talked a lot about long-running processes (Spring Batch, Spring Cloud Task and workflow), *messaging* is what makes these topics worthy of discussion in a book about going cloud-native! These old-guard disciplines become

very useful tools when we can leverage the opportunity for scale that the cloud presents us.

Next Steps

We've only begun to scratch the surface of the possibilities in data processing. Naturally, each of these technologies speaks to a large array of different technologies themselves. We might, for example, use Apache Spark or Apache Hadoop in conjunction with Spring Cloud Data Flow. They also compose well. It's trivial to scale out processing of a Spring Batch `job` across a cluster using Spring Cloud Stream as the messaging fabric.