WHITE PAPER

Supersonic Application Development & Delivery with Spring Boot and Pivotal Cloud Foundry

How to Accelerate Developer Productivity at Scale

By Corbett Martin and Jared Ruckle

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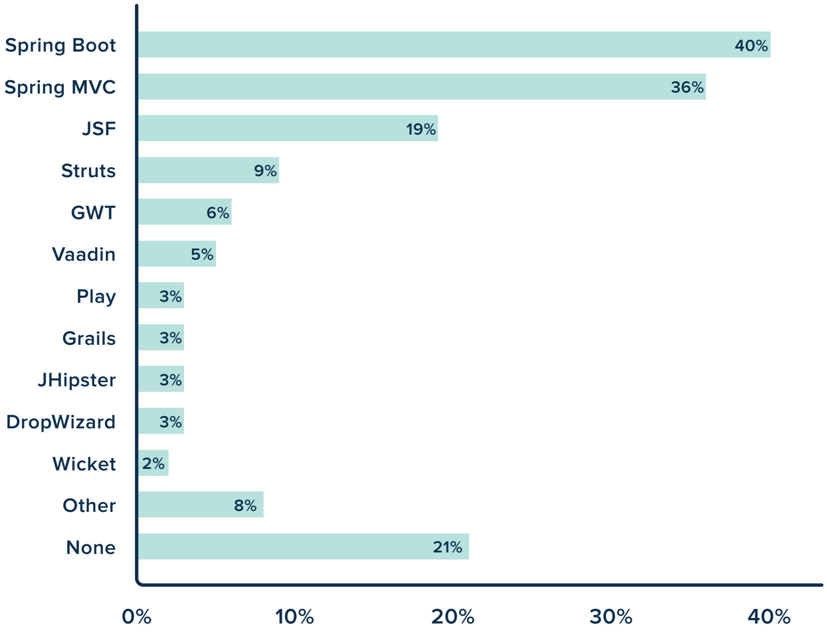
Introduction

> “Few words can better express the Spring domination in the Java ecosystem than this graph. With 4 in 10 developers using Spring Boot in their applications, it’s interesting to see it has overtaken the Spring MVC framework for the first time.”
>
> *JVM Ecosystem report 2018*



If you’re reading this paper, you’re probably using Spring Boot. It’s a terrific framework for building apps in cloud-native Java. By now, you probably have lots of Boot apps. And you might be thinking “where’s the best place to run them?”

Don’t take this decision lightly. With the right choice, you can achieve supersonic velocity on the JVM—the rapid delivery of high-quality software over and over again. In fact, a lot hinges on your ability to move to continuous delivery with Spring Boot. Consider the stakes for your enterprise.

New startups are coming after your customers with shiny new tech. The hyperscale web companies are entering new markets all the time. Meanwhile, you’re trying to figure out how you can become the disruptor in your industry, and use software to differentiate and gain market share.

The good news is that hundreds of organizations like yours have met this challenge head-on with Spring Boot and Pivotal Cloud Foundry (PCF). You already know what makes Boot wonderful. What’s so special about Pivotal Cloud Foundry? And why does it run Boot apps so well?

Objectives, Definitions, and Scope

Think of this paper as a reference guide. You should find value in individual sections, as well as the whole document.

Our goal is to explore the powerful one-two punch of Spring Boot microservices running atop PCF's flagship application platform, Pivotal Application Service (PAS). Rarely companies seek to go slower. Rather, that's a side effect of having too much risk and not enough options. The combination of PAS and Spring Boot are designed to provide you the least amount of risk with the greatest amount of productivity.

In this paper, we're going to put these claims to the test. How? First, we'll build out a small collection of apps. Then, we'll push every bit of it to PAS, our chosen cloud platform.

So let's learn a bit and have a dose of fun!

What’s an Application Platform Anyway?

An application platform is a popular way to run your custom code at scale. PAS is one example of this type of solution. Enterprise development teams use PAS and other application platforms to handle the entire software development lifecycle.

Why the term “application”? Well, with an application platform, the deployable artifact is often a compiled, deployable application library. For Java, you would push a *.jar file; for .NET you’d push a *.dll or *.exe. So instead of using a container image, you would just push your application to the platform, and the tool would do the rest of the work for you.

What do we mean by “the rest of the work”? Well, a modern app platform will do these things on your behalf:

- Network & Routing – load balancing, DNS, and other networking functions should be done for you
- Logs, Metrics, Monitoring – application telemetry to help you observe and troubleshoot your apps
- Services Marketplace – a structured way to add backing services to your apps
- Team, Quotas & Usage – useful governance features that help you adhere to common enterprise tenancy requirements

All of these elements round out a complete experience for development and operations teams—hence the platform moniker!

Does a good application platform use containers? You bet. In fact, app platforms will *build the container for you*. In the case of PAS, it uses the popular buildpack model to containerize your app. This approach helps the developer, because you don’t have to fiddle with the container lifecycle. (As it turns out, you can run your own Docker or OCI-compliant container images on PAS if you want to. But that’s a story for another time.)

At the end of the day, PAS just lets you focus on writing code that runs well at scale.

Now that you know a bit more about application platforms, let’s shift gears to talk about microservices.

Microservices Under the Microscope

Before we dig into the code, let's unpack microservices a tad. This pattern is essential for your success developing cloud native software.

Microservices don't imply a framework, language, or runtime per se. You have a lot of freedom. Given that, it's easy to see how a small development team, a startup, can manage microservices. But what about an enterprise? Can microservices really scale with thousands of developers? It's not hard to imagine microservices resulting in a macro mess.

Microservices at Enterprise Scale

Microservices at scale is worth considering if you need an architecture that's stable, flexible, scalable, and secure. Consider asking these questions before you opt for microservices:

- Does your system need to evolve at different speeds or directions?
- Does a module have a completely independent life cycle?
- Does part of the system need to independently scale?
- Does part of the system need failure isolation?
- Does part of the system need isolation from external components?
- Do you need the freedom to choose the right tech for the job?
- Do your developers waste time waiting for someone else to unblock them?

If you answer "yes" to any of these questions, microservices can be worth the extra complexity.

Once you decide where microservices make sense, how can you adopt this pattern with a bare minimum of complexity? You need the digital scaffolding to make microservices work properly. You will have far greater success with microservices if you run them on a modern, automated platform. Just ask your peers!

Platforms like PAS include "guardrails" to keep services running smoothly on the platform, even as they change constantly. PAS also makes several "promises" about its behavior. Developers, operators, InfoSec professionals, and architects find these "promises"—and the corresponding predictability—useful.

So take stock of what's important before continuing. What's important is...you. Your business, your app idea, and your mindshare are baked into a software artifact. Focus and invest here heavily. Invest in your microservices, apps, and modern development practices. Leverage frameworks and platforms to handle infrastructure and other undifferentiated lifting. After all, what matters to your business is the rapid delivery of high quality software that your customers love!

All that said, let's move on to our collection of Spring Boot apps!

Booting Up with Spring Boot: A Quick Start

Baseline Apps

Spring has come a long way since Rod Johnson created it in 2003. Spring Boot, now its second generation, is providing useful pre-configured Beans for core abstractions such as web servers, security, data-access and connectivity. The addition of Spring Boot was simply the catalyst to make Spring the de facto choice for development on the JVM.

These days, Java developers can build cloud-native apps with a rich ecosystem of tools, projects, and JVM-based languages. The "convention over configuration" approach is overwhelmingly popular, and helps enterprise developers get on with the job of writing great software without tiresome, upfront configuration.

About Spring Beans

A 'Spring Bean'—or sometimes just 'Bean'—is a term that refers to a piece of code that is managed and created by Spring. For example, you may have a piece of code that manages a shopping cart function or account settings. You may refer to these as your "Cart Bean" and "Account Bean." It's common to hear Spring developers discuss their Spring Beans. Spring Boot can automatically configure your application and create an ApplicationContext with a set of Beans managed by Spring. This opinionated manner of building applications frees developers from hand-configuring things like Servlet Containers, Data Sources, and Security elements.

Under this backdrop, let's explore some of the finer details of Spring Boot from the application developer's perspective. Non-developers should get something out of this too, especially when it comes to running these examples in PAS on your chosen cloud infrastructure.

Ok, oil those protractors! Let's get started with a picture of what we're building. Figure 1 below shows our base collection of microservices. As we go, we'll add features to this baseline. For our grand finale, we'll push it all to PAS.

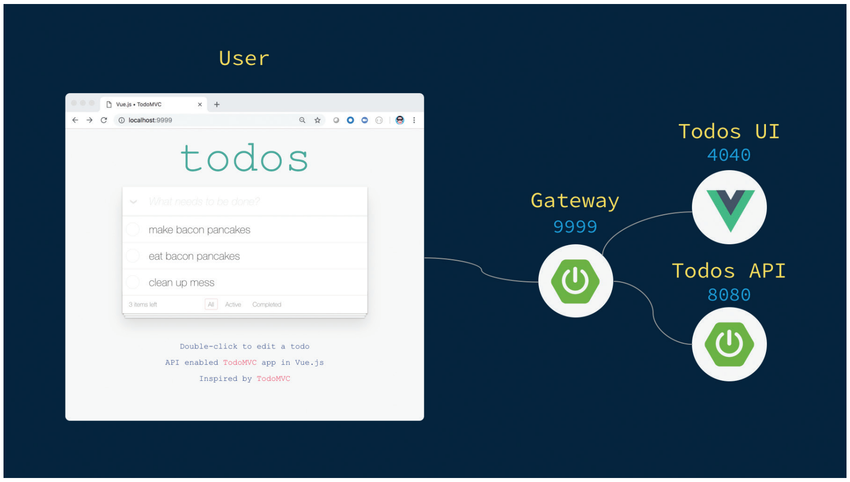


Figure 1: Our basic building blocks.

You can see we have a simple frontend UI with a backend API, represented by these pieces:

- **Todos UI** implemented in Vue.js (a fork of todomvc.com)
- **Todos Cloud Gateway** in Spring Cloud Gateway
- **Todos API** implemented in Spring Boot

Let's take a closer look at each app.

Todos Cloud Gateway

Todo(s) Cloud Gateway is a Spring Boot microservice that functions as an API gateway and router for Todo(s) microservices. Based on Spring Cloud Gateway, it runs a gateway defined by routes in application.yml by default. When Todo(s) gateway boots into a Spring Cloud environment, it syncs with Service Discovery and loads microservice routes dynamically as they come online. Similarly, it removes microservice routes when they go offline. (We'll discuss Spring Cloud in more detail later.)

Todos UI

Todos UI is a Vue.js implementation of todomvc.com. We'll use it to interact with Todo(s) API directly through the Todo(s) Cloud Gateway. There is a major difference between this version and the one on todomvc.com. Our flavor calls a backing API to create, retrieve, update, and delete Todo(s). We perform this action with VueResource, which makes HTTP calls to create, read, update, and delete Todos. (And thus a few log statements are different here compared to the Vue.js app on todomvc.com.)

PAS: A Flexible App Platform that Supports a Range of Frameworks

Todos UI is simply HTML, JavaScript, and CSS. It's not based on the JVM. This showcases another attribute of PAS: the platform supports a wide range of apps. We believe that every app can benefit from a modern platform. PAS connects frontend and backend developers, and enables full-stack software delivery using your favorite frameworks.

Todos API

Todos API shows how easy it is to build API-driven microservices using Spring Boot. If you're just getting started with Spring Boot, then Todos API is a useful way to learn. It implements an API backend for Todo(s) UI. By default, the API saves Todos in a Map which is sized according to the todos.api.limit property. (In the next section, we'll see how to change size limits using Spring Cloud Config Server.)

With @RestController and @RequestMapping annotations on a class, we can encapsulate and provide context for an API. Todos API maps HTTP requests on the root context / to CRUD methods. The Todo(s) Data microservice exposes a similar CRUD API but with zero code from us. Instead, it uses Spring Data Rest to blanket a data model with a CRUD API. Check out Todo(s) Data for more information on Spring Boot and how Spring Data Rest can expose your data-model as a set of REST endpoints.

API Operations

The TodosAPI class contains methods that get called from TodosUI. As you can see, it's very simple to define RequestMappings to handle HTTP requests. Likewise, it's just as easy to define the same RequestMappings as non-blocking endpoints using Spring Boot 2.0's reactive stack.

New to Reactive? Welcome to the Party!

If you're just now hearing about a 'reactive stack' you're right on time! While the premises for reactive development patterns have existed for quite some time, we now have practical experience at a new level of scale. Reactive architectures allow applications to act in response to something in an asynchronous manner. This way, creators and users of data can scale independently. You might have used a messaging system at some point in your career. That sounds familiar, right? Now imagine if your application code was also written with a 'response to events' mindset. Well, that would probably be classified as a reactive application.

Spring MVC

```
@PostMapping("/")
public Todo create(
    @RequestBody Todo todo) { }

@GetMapping("/")
public List<Todo> retrieve() { }

@GetMapping("/{id}")
public Todo retrieve(
    @PathVariable Integer id) { }

@PatchMapping("/{id}")
public Todo update(
    @PathVariable Integer id,
    @RequestBody Todo todo) { }


@DeleteMapping("/{id}")
public void delete(
    @PathVariable Integer id) { }
```

Spring WebFlux

```
@PostMapping("/")
public Mono<Todo> create(
    @RequestBody Mono<Todo> todo) { }

@GetMapping("/")
public Flux<Todo> retrieve() { }

@GetMapping("/{id}")
public Mono<Todo> retrieve(
    @PathVariable Integer id) { }

@PatchMapping("/{id}")
public Mono<Todo> update(
    @PathVariable Integer id,
    @RequestBody Mono<Todo> todo) { }

@DeleteMapping("/{id}")
public Mono<Todo> delete(
    @PathVariable Integer id) { }
```

Now that we've outlined the base parts, let's get to the fun stuff—pushing our app to PAS!

Time to Push Our Code to Pivotal Application Service

Before we blast off, make sure you've installed the cf-cli and covered off on the simple prerequisites here.

The first thing we need to do: login to PAS. (Need a quick option? We recommend Pivotal Web Services—it's great and has a free trial.)

The only artifacts we need (besides our code) are a manifest and an optional vars file. Both items describe our soon-to-be-live cloud app, both pay huge dividends on Day 2 when we're running in production. See this repo for more information on pushing these apps to PAS.

The vars file

Our vars file contains the dynamic elements of our deployment. It's where we put details about the things we expect to change. For example, we include the public route for each application, and the corresponding app artifacts. There's a sublime detail here that developers love: we give our apps to PAS in their ***native*** form. Then, PAS bakes and runs them as real-world things! Any developer-centric platform should offer a paper-thin atmospheric layer between source to software and that's just what PAS is built for.

Here's an example vars file that defines property values specific to our push.

```
api:
  route: https://todos-api.cfapps.io
  artifact: todos-api/target/todos-api-1.0.0.SNAP.jar
ui:
  route: https://todos-ui.cfapps.io
  artifact: todos-ui/
gateway:
  route: https://todos-cloud-gateway.cfapps.io
  artifact: todos-cloud-gateway/target/todos-cloud-gateway-1.0.0.SNAP.jar
```

The Manifest

A manifest provides a simple definition of our app. These files are easy to control and update via configuration management.

Let's now create a manifest to declare how our 3 applications should be deployed. Variables from the vars file are injected into the placeholders ((())). These 2 files are all we need to push. The manifest is what PAS uses to know how to containerize your application. (This is defined with the buildpack property.) Buildpacks provide the necessary application runtime bits (such as a JVM or an NGinx server) for the container. Want to know more about buildpacks? Checkout this overview and our technical docs. As you may expect, the Java Buildpack is a rock-solid way to deliver your JVM-based workloads to PAS.

`part-1-manifest.yml - app deployment`

```
---
applications:
- name: todos-api
  routes:
  - route: ((api.route))
  path: ((api.artifact))
  buildpack: java_buildpack
- name: todos-ui
  routes:
  - route: ((ui.route))
  path: ((ui.artifact))
  buildpack: staticfile_buildpack
- name: todos-cloud-gateway
  routes:
  - route: ((gateway.route))
  path: ((gateway.artifact))
  buildpack: java_buildpack
  env:
    TODOS_UI_ENDPOINT: ((ui.route))
    TODOS_API_ENDPOINT: ((api.route))
```

Now it's time to use the most magical command in cloud, cf push!

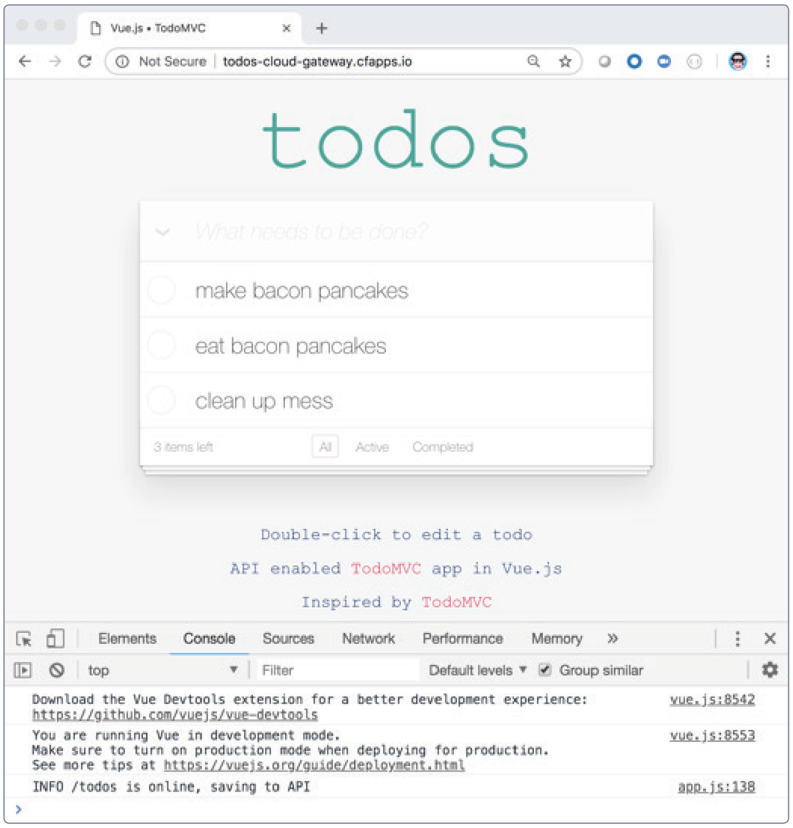
```
cf push -f part-1-manifest.yml --vars-file part-1-vars.yml
```

This command launches a task on PAS to containerize our applications using the aforementioned buildpack abstraction. PAS takes our application bits, then lays down the appropriate operating system and application stack in a droplet. The platform then boots our app into existence. PAS and the cf push command also do many other nifty things for you like:

- Create a secure, hardened container for you, without unnecessary OS bits
- Setting up a route (or URL) for your application
- Creating a load balancing entry for your application

- Creating SSL termination for your application
- Creating health monitoring and logging subsystems for your application
- Starting your application in a healthy state with the desired number of instances
- Binding any backing services needed to your application by injecting the service credentials

Once the push completes, we can pull up Todos UI in a browser and make a list of really important to-dos.



todos

What needs to be done?

make bacon pancakes

eat bacon pancakes

clean up mess

3 items left All Active Completed

Double-click to edit a todo

API enabled TodoMVC app in Vue.js

Inspired by TodoMVC

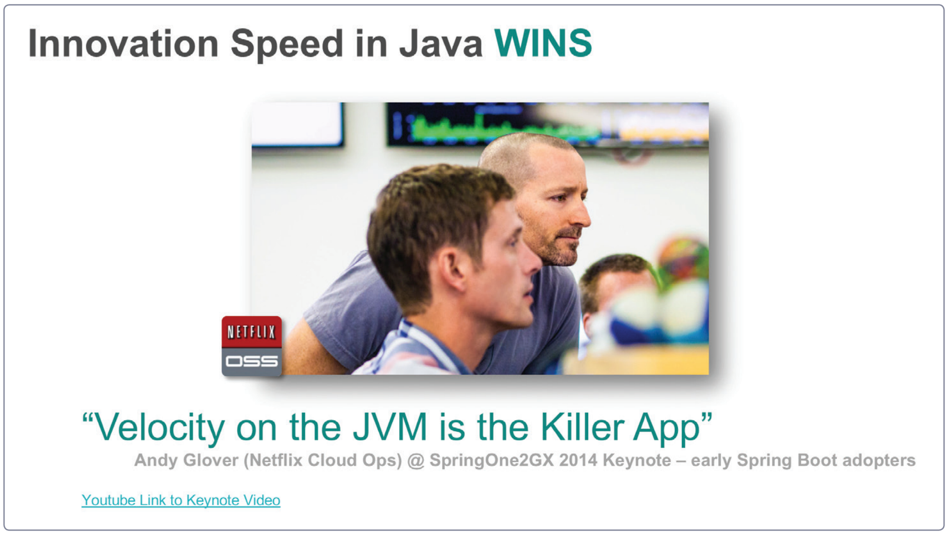
```
Download the Vue Devtools extension for a better development experience:      vue.js:8542
https://github.com/vuejs/vue-devtools
You are running Vue in development mode.                                      vue.js:8553
Make sure to turn on production mode when deploying for production.
See more tips at https://vuejs.org/guide/deployment.html
INFO /todos is online, saving to API                                            app.js:138
```

Figure 2: Our app is live!

Take a moment to reflect on what we've just done. We've gone from zero to a full-stack, cloud-deployed application that's darn close to feature complete. (Yes, we'll need to add single sign-on. No, we won't do that here.)

“Velocity on the JVM is the Killer App”

So we’ve cobbled a useful Spring Boot app. And we’ve pushed it to production with relatively little gruntwork. Isn’t this what we’re after? What we want was artfully articulated in 2014 by Andy Glover of Netflix Cloud:



Innovation Speed in Java WINS

“Velocity on the JVM is the Killer App”

Andy Glover (Netflix Cloud Ops) @ SpringOne2GX 2014 Keynote – early Spring Boot adopters

Youtube Link to Keynote Video

Yes indeed! Velocity on the JVM gives us the capability to quickly release code, learn from it, then release more code based on this feedback. It’s a virtuous cycle, and it’s the lifeblood of a successful enterprise in the cloud era.

Choose Where to Run Your Java Apps, But Choose Wisely

You have lots of different ways to run a JVM workload. What’s going to give us the best velocity? Well, the ideal runtime would:

- Automate a lot of the things you have to do bring your app online
- Have a simple, consistent, and configurable development experience
- Automate containerization
- Provide robust tools and methods for troubleshooting when things go wrong
- Offer a configurable and consistent operational model
- Allow my app to be deployed on different cloud infrastructure environments

That…looks a lot like PAS right? Let’s contrast this with other places you can run your JVM-based workloads. Say we have our same baseline set of Todos apps. How would we go about getting the same outcome we just had with PAS?

Consider the numerous ways to start a JVM-based application. You can use various techniques and conventions to pass JVM and application arguments. There's little uniformity and standardization. That makes it harder to go fast.

Let's turn to the Todos UI frontend app. It needs a web-server such as NGinx. In a full-stack environment, a lot of time and effort can be spent configuring and maintaining simple web-servers. With PAS, we can easily deploy front-end web apps on forged web-servers like NGinx and have routing and load-balancing done for us.

What about docker containers? Sure, folks use it to layer the correct OS and middleware stack together. Once all the apps have the proper dockerfile, you'd need to build and upload each container image to a container repository. Implementing consistent containerization alone is a huge investment—just ask someone who has tried! What's more, this is a nightmare for InfoSec as there are an overwhelming number of ways to layer containers. You have no idea what's in a given container, or what its vulnerabilities might be. That's why you'll hear folks call hand-built containers "mystery meat." At their best, containers are the output of a scalable, automated process.

Finally, Kubernetes. Kubernetes is great tech—Pivotal even has a product based on it! In general, though, we don't recommend Kubernetes for your most important Spring workloads. There's plenty of toil engineers have to take on. This distracts from the unique business value you want to deliver with your custom code.

Resist the Urge to Build Your Own Platform. Buy a Platform, and Get on with Transforming Your Business!

Companies that decide to roll their own platform quickly realize a cold truth: it's more expensive than they thought. In working with numerous Fortune 500 companies, we've found that even a minimal DIY platform effort can take 2 years to build and cost $14M in payroll alone (for 60 engineers). And that's just to get to a minimum viable product. Can your company wait two years to start your cloud-native transformation in earnest?

Of course, once the platform is live in production, the costs continue to grow. As architecture patterns and technologies continue to evolve, the demand for new features can prove challenging to keep up with. Developers may demand that capabilities to support emerging patterns—like the use of a service mesh or functions as a service—be evaluated and added. In addition to any new features, platform operations teams must also manage the lifecycle of the underlying software components and operating systems images. They have to quickly take action in response to any vulnerability threats and apply the latest security patches.

Adding these new features to a custom platform and keeping it secure requires a corresponding investment in engineering staff. After a while, your platform team starts to look a lot like a cloud platform software company, with one important difference:

The platform you have built doesn't actually generate revenue for your core business. It generates expense and quickly accrues technical debt.

This expense can't be justified, unless your core business is selling cloud platform services. You don't want your most talented technologists building a platform. You want them working on adding unique, differentiating business value. Thankfully, the problem of creating a vibrant, scalable, and secure enterprise platform has already been solved by Pivotal with Pivotal Cloud Foundry.

Pivotal customers like Boeing, Mastercard, T-Mobile, StubHub, Rabobank, Dick's Sporting Goods, Liberty Mutual, and Comcast are all using our cloud-native platform to ship high-quality software faster than ever before, enabling their businesses to innovate and thrive as a result.

So of course you **can** accomplish the same outcomes with docker, Kubernetes, or a homebrew stack you built yourself. But the out-of-box experience of PAS is uniquely simple and elegant. Remember, we don't just want a JVM in the cloud, we want velocity and delivery of great software! PAS provides a great platform experience and allows pattern-oriented extension.

Spring and PAS offer unique developer productivity, especially when compared to other alternatives.

Spring Cloud: A Simple Way to Expand Our Capabilities

As we've just seen, PAS is a feature rich application platform. As your application deployments increase in size or velocity PAS provides the infrastructure and a consistent DevOps experience and application environment. For example when looking at our Spring Boot apps, we see a nice alignment around properties and the environment PAS bakes. Let's say you declare an application property such as todos.api.limit=128. That property can be externally hydrated from the environment PAS creates like so: `cf set-env your-app TODOS_API_LIMIT 128.`

Wonderful stuff, but inevitably as your application portfolio grows you'll require more than just a consistent environment, for example cloud primitives such as configuration, discoverability, resiliency and traceability. The goal of course is to provide a means for apps and Microservices to interact in a digital ecosystem and that's just what Spring Cloud enables so you can focus on writing meaningful code not boilerplate.

Spring Cloud rises to the rescue with handy building blocks like Config Management, Service Discovery, Circuit Protection, Routing, and Tracing in a simple to reason about framework. Cloud Native development on the JVM has never been so easy and extensible.

For a more detailed look into Spring Cloud consider these resources:

- Spring Cloud Services for PCF – let PAS create and manage Spring Cloud Config Server, Service Discovery, and Circuit Protection so you don't have to!
- Spring Cloud Data Flow for PCF – again let PAS automate provisioning Spring Cloud Data Flow to orchestrate Spring Cloud Streams and Tasks allowing you to focus more on "what" the Stream or Task should do and less on "how" it's being done.
- An expanded Todos sample from Part 1 with Spring Cloud goodness ready to cf push. This sample set brings together pieces from the larger Spring ecosystem including Spring Cloud Config, Service Discovery, Circuit Protection, Spring Cloud Gateway, Spring Cloud Sleuth, Spring Cloud Streams, Spring Data JPA and Spring Data Redis. All essential tools for the cloud-native developer.

Running Your Apps on Pivotal Application Service: What Developers Need to Know

Earlier we talked about the experience of **building** an app, and pushing it to PAS. Now, let's examine how we can **run** our apps in the cloud, with little to no effort on our part.

Let's continue on with PWS as our deployment target. If you'd like to try out a different flavor of PAS, you can choose other options like PCF Dev (a local VM), Pivotal Application Service (small footprint) or Pivotal Application Service (the full-featured app platform).

Go ahead and login. Remember, you need the cf-cli installed and the prerequisites covered off.

So what commands will we need to run our app on PAS? Glad you asked! Let's step through them now.

Apps are First Class Citizens

PAS is an application platform. That means the denomination of PAS is...an app. This may seem obvious, but it's a key point. Almost every interaction we have with PAS will require us to specify the "app," along with the relevant operation.

Pushing

Push an application to PAS using vars-file to set variables specific to a push operation. We use—vars-file quite a bit with the samples.

```
cf push --vars-file vars.yml
```

Events

This command lists the life cycle events for an application. You'll use this often, as it's handy to see when, what, who, and why an event occurred on your app.

```
cf events todos-api
```

SSH

Hopefully you don't need to SSH into the container. But when you do need to, it's easy to securely jump into the container running our application.

```
cf ssh todos-api
```

Once SSH'd into the container, it's helpful to know your way around. By default, you land in $HOME for the user vcap (whoami=vcap). Listing $HOME will reveal /app which is where our application bits live. Since most of our samples are based on Spring Boot, you'll notice a .java-buildpack directory. This contains the whole JVM middleware stack.

Starting, Stopping, Restarting, and Restaging

PAS give you life cycle control of your apps. You can start, stop, restart, and restage each app independently. Starting and restarting are a simple commands. Both will apply any new environment variables and services bound to the application.

```
cf start todos-api
```

```
cf restart todos-api
```

Restaging an application is a repave operation. That means the container will be recreated from the existing application bits and the buildpack. And similar to start and restage, this operation will apply any new environment variables and services bound to the application.

```
cf restage todos-api
```

Buildpacks

As we hinted at earlier, buildpacks provide runtime support for applications. They do this by detecting the type of application, paving the required app framework and integrating your code into a well-formed container. PAS takes your application in its native form as input, and applies the buildpack during the cf push process. The output is a container image that's running on the platform.

PAS comes out-of-the-box with a set of system buildpacks ready to automate the source-to-container process for a wide array of languages such as Java, Kotlin, Groovy, .NET, Node.js, Python, and Ruby. Developers have the freedom to use their preferred framework - this is a "must have" if you want to go fast at scale. Lots of choices for developers and streamlined code to container automation, which is essential for going fast especially within a large enterprise. Big companies have thousands of apps. That means you have a lot of variation at the application layer when it comes to frameworks, dependencies, and security artifacts. Buildpacks help normalize how these things are containerized. This pays huge dividends for developer productivity and also operationally, especially when it comes to consistency and compliance.

Java Buildpack

The Java Buildpack containerizes JVM-based applications. It supports a set of standard container components such as:

- Java main()
- Servlet Containers - Apache Tomcat
- Application Frameworks such as Spring Boot, Ratpack and Play

Additional application framework components are baked into the container to support a wide range of handy features like application performance management (APM), cloud auto reconfiguration, and container security. Last but not least, the Java Buildpack comes with Standard JREs ready to use as is, or with custom settings.

Spring Boot and Java Buildpack

As described above, the Java Buildpack provides full container automation for Spring Boot apps, you can push packaged Spring Boot jars or distZip files. Convenient, huh? There's more. The Java Buildpack automatically configures the injection of the Spring "cloud" profile, if present. In turn, this auto-configures "cloud" scoped Beans and configuration.

Let's Sum It All Up

Buildpacks strike a nice balance between developer freedom and operational consistency. They automate the otherwise hard to build and manage pieces, and abstract away a huge chunk of middleware complexity. Now that's true DevOps enablement!

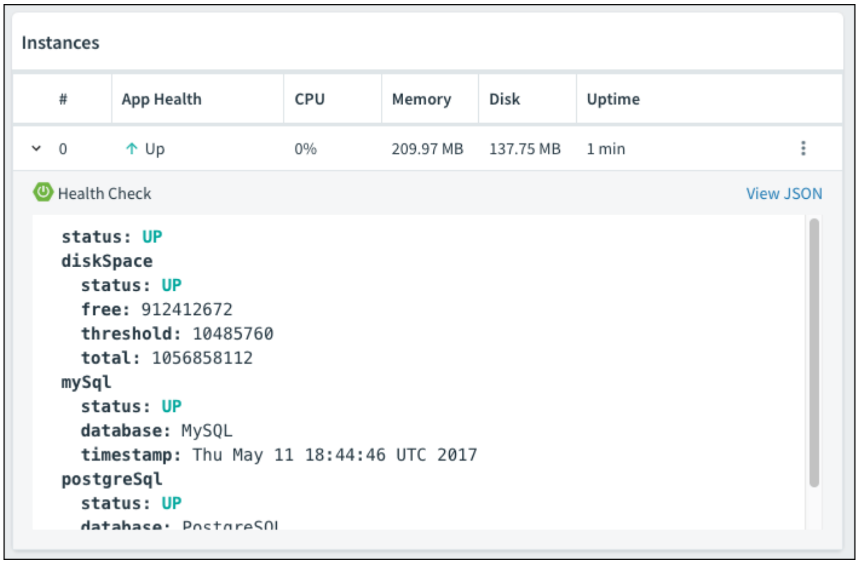
Get Visibility into Your Production Apps with Spring Boot Actuators

As Pivotal advocate Mark Heckler wrote "applications are just projects until they're live in production. And once they are live, both developers and operators need the best visibility possible into those critical apps in order to track provenance, monitor health, and rapidly troubleshoot indicators of unexpected behavior."

Spring Boot Actuator endpoints are a useful way to gain this information. So Pivotal Application Service integrates several of these endpoints into its Apps Manager module. These integrations provide helpful visibility into the state of your apps running in prod. Here's a list of the Actuator endpoints supported in PAS today:

- /info: Exposes details about app environment, git, and build.
- /health: Shows health status or detailed health information over a secure connection.
- /loggers: Lists and allows modification of the levels of the loggers in an app.
- /dump: Generates a thread dump.
- /trace: Displays trace information from your app for each of the last 100 HTTP requests.
- /heapdump: Generates a heap dump and provides a compressed file containing the results.
- /mappings: Displays the endpoints an app serves and other related details.

And because a picture is worth a thousand words, here's a screenshot that shows how this data is bubbled up for you.



Instances

#	App Health	CPU	Memory	Disk	Uptime
0	↑ Up	0%	209.97 MB	137.75 MB	1 min

```
status: UP
diskSpace
  status: UP
  free: 912412672
  threshold: 10485760
  total: 1056858112
mySql
  status: UP
  database: MySQL
  timestamp: Thu May 11 18:44:46 UTC 2017
postgreSql
  status: UP
  database: PostgreSQL
```

Figure 3: A view of the /health Actuator endpoint in Apps Manager.

Quickly Troubleshoot Cloud-Native Applications with PCF Metrics

Remember when we said microservices get easier when you have a platform that handles a good chunk of complexity for you? PCF Metrics, the integrated metrics module for PAS is one great example of this principle at work. Pivotal product manager Mukesh Gadiya writes:

> *Today's architectures have exponentially more complexity. The question to answer isn't "what's wrong with my source code?" Instead, teams need to address a series of questions when issues arise:*
>
> *Which component of the workload is having a problem?*
>
> *How do we trace the relevant requests through the entire workload?*
>
> *How do we find all diagnostic information from the components that processed that request?*
>
> *And how do we do all of this as soon as possible?*
>
> *The situation is compounded further when different teams own different pieces of the workload. Why? A select few have an end-to-end understanding of the entire workload.*
>
> *But just as the industry has rallied around microservices, so too have we rallied to simplify the troubleshooting of these modern, distributed systems.*

PCF Metrics is an essential tool to help you run microservices at scale.

Use PCF Metrics, and you can answer these questions more quickly:

- **What went wrong and when?** Application metrics provide the answer. Metrics reveals the time window when high network latency occurs and average response times.
- **Why did it go wrong?** Logs and metrics - such as API calls, exact response times, parameters passed, etc. - together usually provide enough information to figure out why latency occurred.
- **Who is the culprit behind what went wrong**? Events include external bits of information such as when app source code was changed and whether an app was moved to another container on an underperforming cell. Correlating events with metrics and logs is often the final piece of the puzzle.

Telemetry data for your apps (logs, metrics, and events) is rendered visually, along an interactive timeline. Consequently, it's easier to understand sources of latency and system failure. PCF Metrics also includes distributed tracing capabilities (Trace Explorer) for Spring Cloud Sleuth enabled applications. This help you understand the sequence of method calls across microservices.

PCF Metrics has a special bonus for Spring Boot developers. Remember Spring Boot Actuator endpoints from the previous section? PCF Metrics ingests all Actuator metrics. This information combines with the data already visualized in PCF Metrics to give you deeper context. You gain even more insight into how your Spring Boot apps are running in production. Use this feature, and reduce the mean-time-to-resolution (MTTR) for your Spring Boot apps!

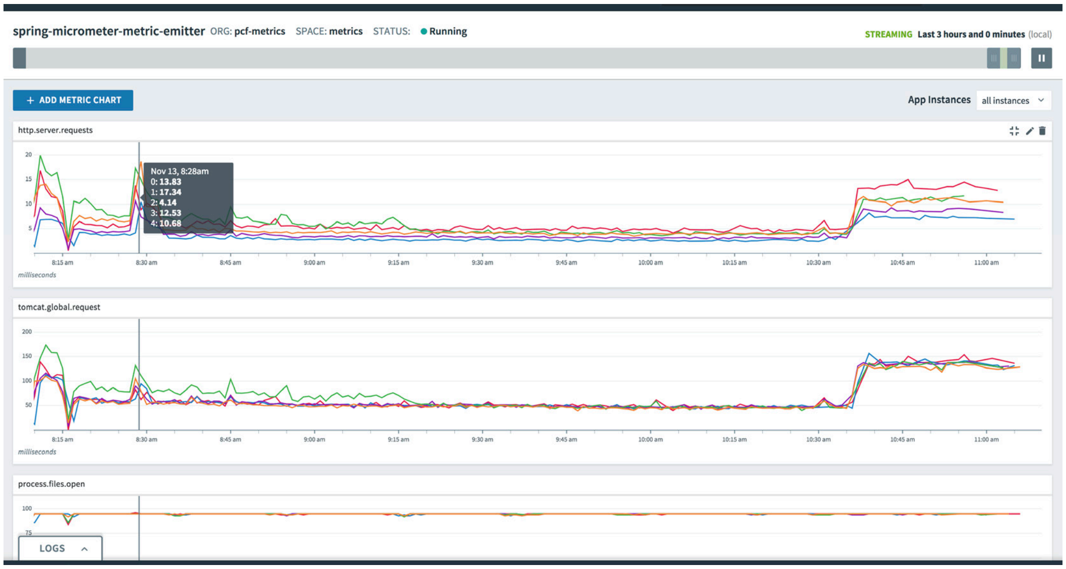


Figure 4: Add Spring Boot Actuator metrics as custom charts in PCF Metrics.

Effortlessly Scale Your Apps to Meet Customer Demand with App Autoscaler

There's a good chance your applications will experience variable load. How can you scale your app up and down under unpredictable circumstances? Use App Autoscaler! This module automates horizontal scaling for your apps. Add more capacity to your applications when traffic spikes. Scale down as traffic returns to normal. Best of all, you can set thresholds and triggers, so the platform does the scaling for you, according to rules you configure.

Built-In Application Logging with Loggregator

Logs are an essential tool when you need to troubleshoot your apps. That's why PCF includes Loggregator, a system that gathers and streams logs and metrics. App developers can use Loggregator to "tail" their application logs or dump the recent logs from the Cloud Foundry Command Line Interface (cf CLI), or stream these to a third-party log archive and analysis service.

Keep Your Apps Online Serving Traffic with Four Layers of High Availability

PCF includes redundancy and resiliency across four layers of the stack: monitored processes, health management for app instances, health management for virtual machines (VMs), and availability zones. In case of failure in any of these layers, PCF automatically recovers to keep serving traffic.

Need a Cache, Message Broker, or Relational Database? Use Service Brokers!

To do anything interesting with your app, you're going to need backing services. The Open Service Broker API gives you a standard set of commands and behaviors that are identical across hundreds of different add-on capabilities. All services provided by PAS implement this API. Thus, you can create and bind a cornucopia of services using the same repeatable motions. Do you need a cache, message-broker, NoSQL store or relational database? You can instantly add them to your app. PAS offers ready to use service brokers for Redis, RabbitMQ, and MySQL. All of these brokers support an array of server-side use-cases so you can focus on your code and easily add what you need, when you need it.

Hear that Sonic Boom? That's You Going from Idea to Working Software in Less than a Day

Time to recap!

We started off the paper seeking answers to a few questions, namely "What's so special about Pivotal Cloud Foundry?" And "why does it run Boot apps so well?" Well, by now you know that PAS:

- Automates a lot of the things you have to do bring your app online
- Has a simple, consistent, and configurable development experience
- Automates containerization
- Offers a configurable and consistent operational model

And you can run your Spring Boots on PAS as is, with little or no modification. Plus, PAS plays nicely with the larger Spring ecosystem of projects, so you have an easy way to add more capabilities to your apps over time.

Speaking of "apps"—just how many apps do you have in your enterprise by now? Hundreds? Thousands? No matter the number of apps, PAS is up to the task. Buildpacks and service brokers give you plenty of flexibility to run all kinds of apps on the platform.

Use Spring Boot and PCF, and you're on your way to supersonic development velocity. Of course, there's always more to be done. Check out our links in Recommended Reading for more best practices that can help you go even faster!

Recommended Reading

Blogs

- Should that be a Microservice? Keep These Six Factors in Mind
- Getting Started with Spring Cloud Services on Pivotal Application Service
- Love Spring and Spring Boot? Then, You're Going to Love These Projects, Too
- Spring Boot 2.0 goes GA
- Opening Doors with Spring Boot 2.0
- How PCF Metrics Helps You Reduce MTTR for Spring Boot Apps (and Save Money too)
- TUTORIAL: Using Spring Boot Actuator Integrations With Pivotal Cloud Foundry 1.11

Slides

- Spring on PAS

Videos

- Flight of the Flux: A Look at Reactor Execution Model
- Full Stack Reactive with React and Spring WebFlux
- Getting Super Productive with Spring Tools 4 and Spring Boot 2
- Guide to "Reactive" for Spring MVC Developers
- Reactive Apps and Data, SpringOne Platform 2018
- Scaling Spring Boot Applications in Real-Time
- Spring, the Kotlin and Functional Way
- Spring Boot 2.0 Web Applications
- Spring Cloud Stream – Developer Recipes, What's New and What's Next?
- Springing into Kotlin: How to Make the Magic Even More Magical
- Upgrading to Spring Boot 2.0

Whitepapers

- An Inside Look at the Open Service Broker API
- A Developer Primer for Pivotal Application Service: Get Ready to "cf push"
- Crossing the Value Stream: Improving Development with Pivotal and Cloud Foundry
- Standing on the Shoulders of Giants: Supercharging Your Microservices With NetflixOSS and Spring Cloud
- From Months to Hours: Accelerating Software Deployment with PCF
- Running Microservices on Pivotal Cloud Foundry
- Speed Thrills: How to Harness the Power of CI/CD for Your Development Team
- The Upside-Down Economics of Building Your Own Platform