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Maximizing Applications Performance with GraalVM

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March 03, 2020

Safe harbor statement

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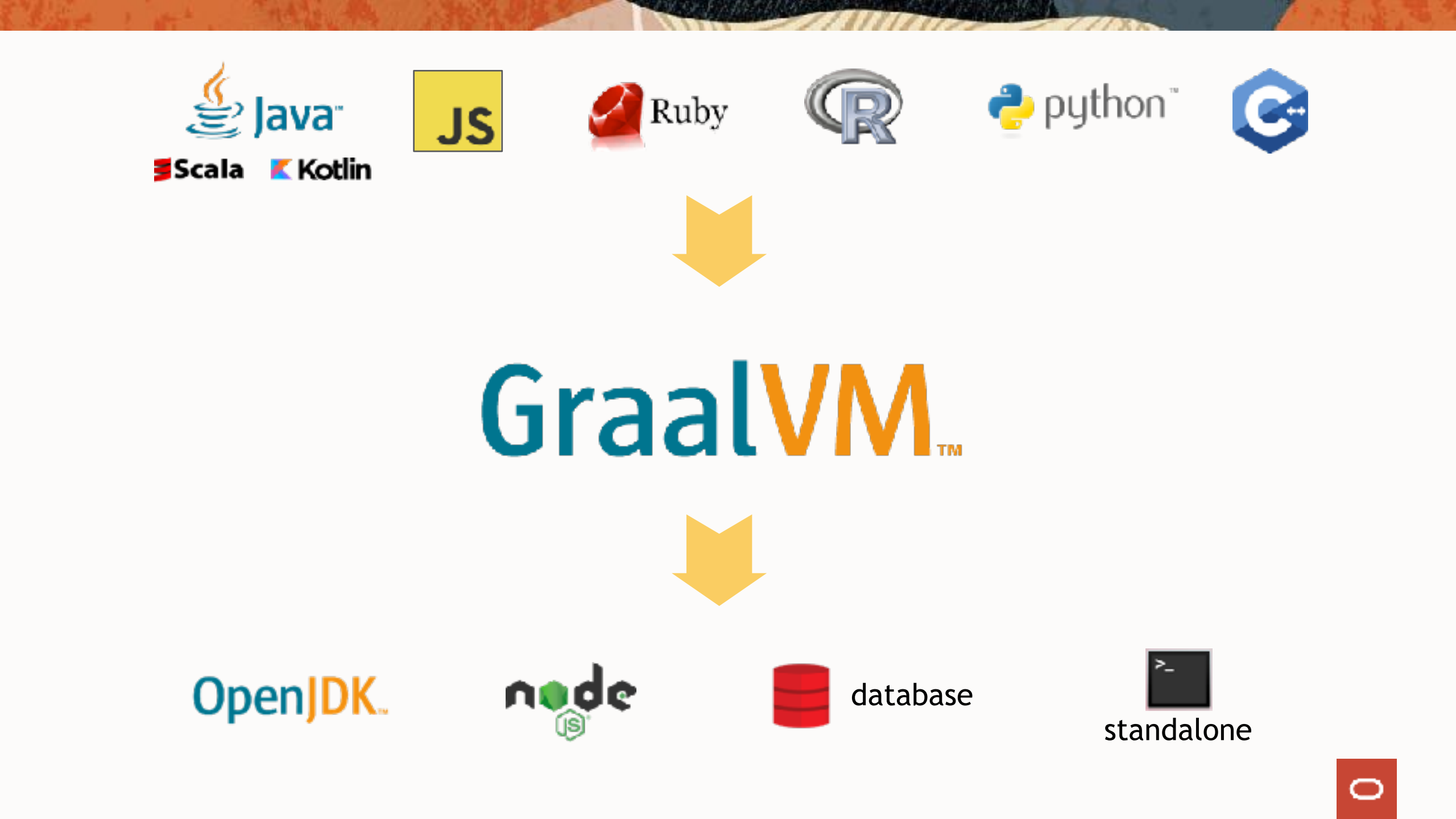
GraalVM Native Image technology (including Substrate VM) is Early Adopter technology. It is available only under an early adopter license and remains subject to potentially significant further changes, compatibility testing and certification.

Run programs faster anywhere

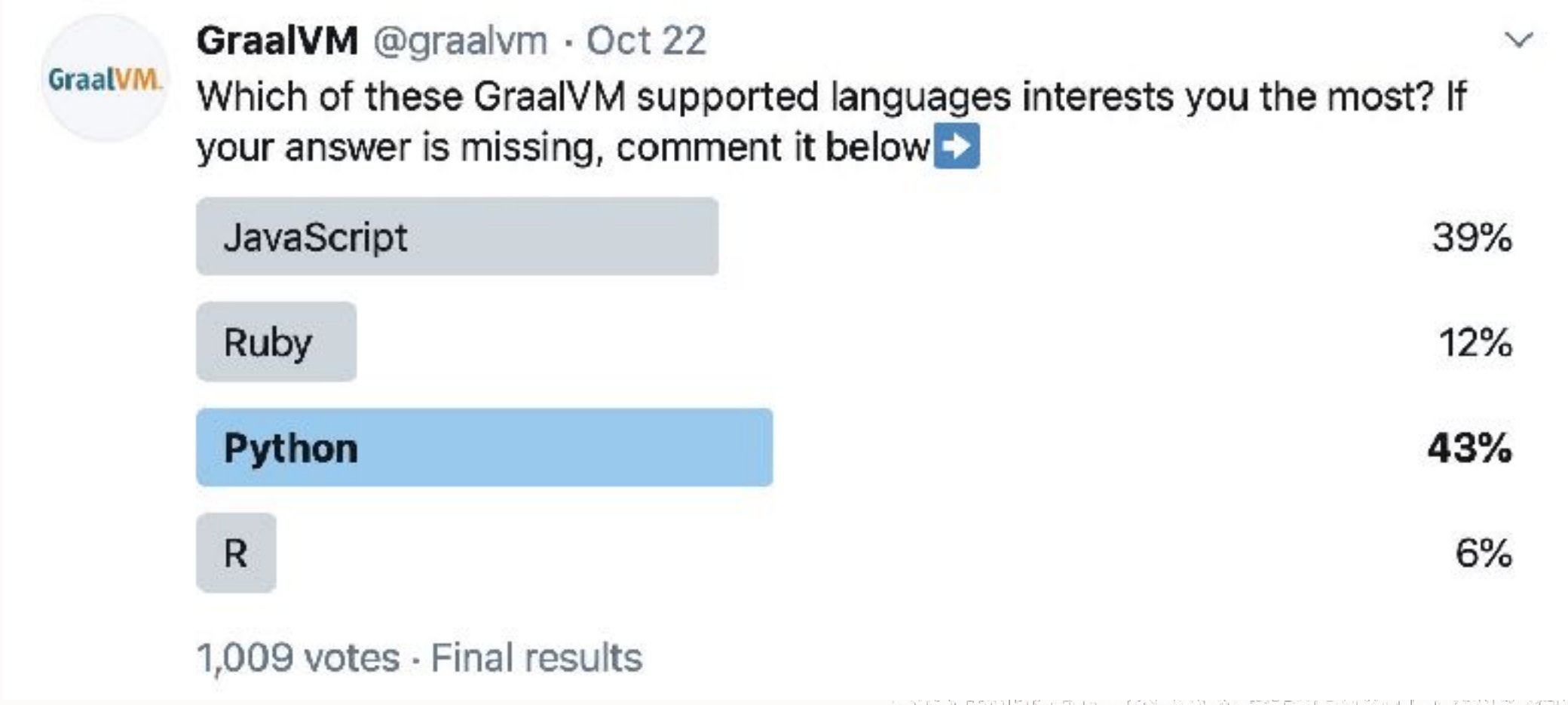
GraalVM™

1. High performance for abstractions of any language
2. Low-footprint AOT mode for JVM-based languages
3. Convenient language interoperability and polyglot tooling
4. Simple embeddability in native and managed programs


Java
JS
Ruby
R
python
Scala
Kotlin
GraalVM
OpenJDK
node
database
standalone

GraalVM @graalvm · Oct 22

Which of these GraalVM supported languages interests you the most? If your answer is missing, comment it below ➡️


GraalVM @graalvm · Oct 22
Which of these GraalVM supported languages interests you the most? If your answer is missing, comment it below
JavaScript 39%
Ruby 12%
Python 43%
R 6%
1,009 votes · Final results

Production-ready!🎉

Community Edition

GraalVM Community is available for free for evaluation, development and production use. It is built from the GraalVM sources available on GitHub. We provide pre-built binaries for Linux, macOS X, and Windows platforms on x86 64-bit systems. Windows support is experimental.

DOWNLOAD FROM GITHUB

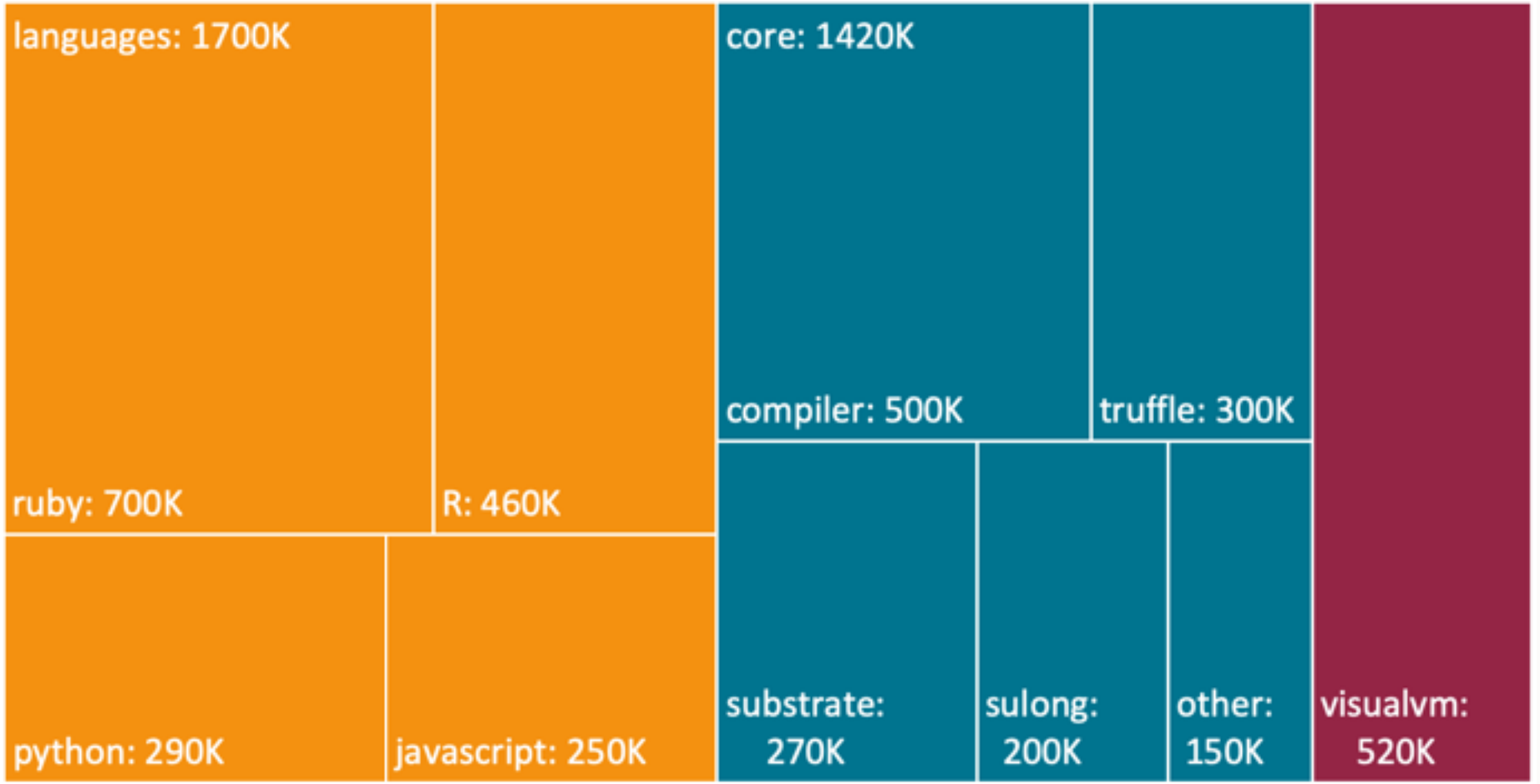
Enterprise Edition

GraalVM Enterprise provides additional performance, security, and scalability relevant for running applications in production. It is free for evaluation uses and available for download from the Oracle Technology Network. We provide binaries for Linux, macOS X, and Windows platforms on x86 64-bit systems. Windows support is experimental.

DOWNLOAD FROM OTN

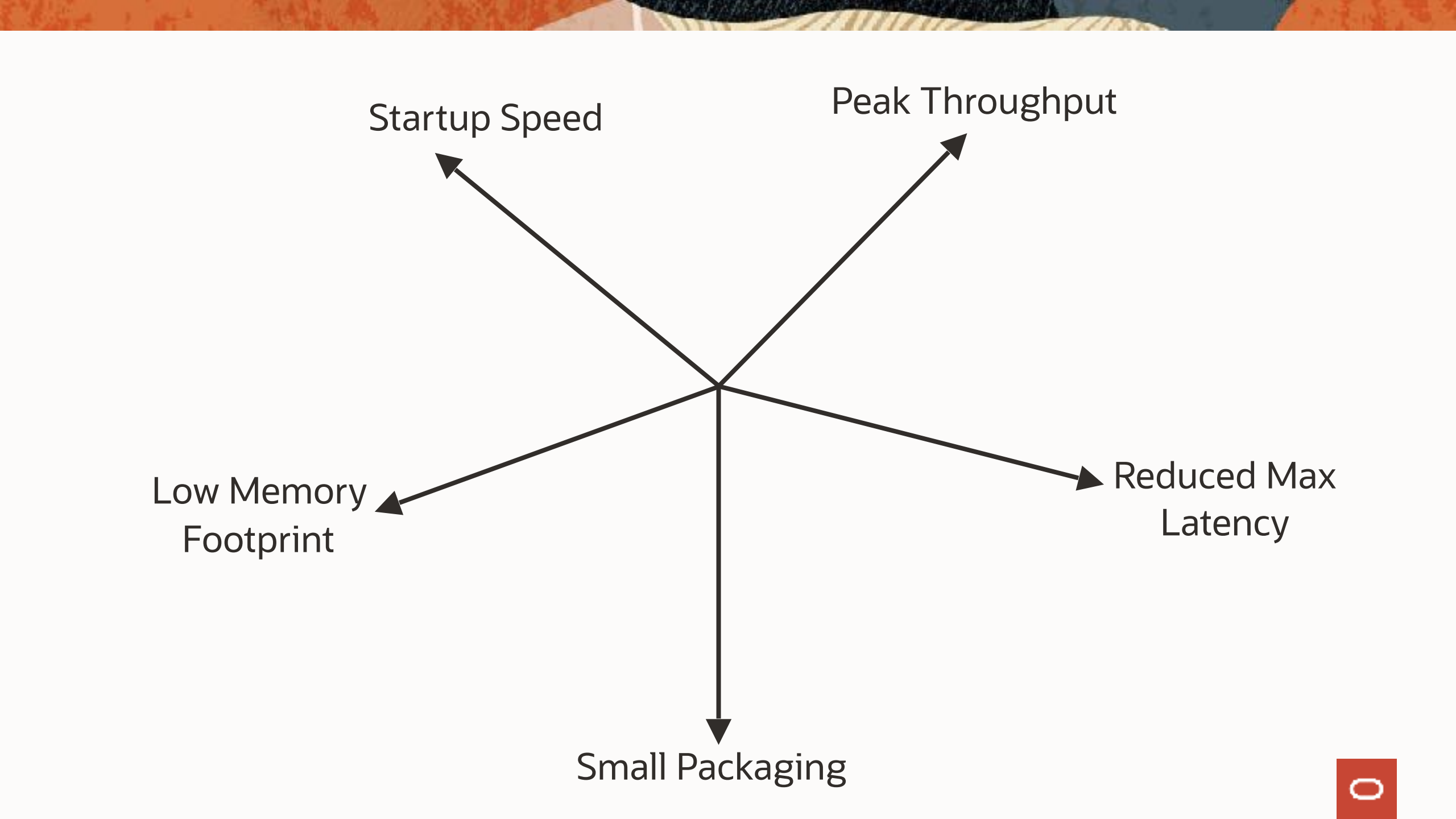
get both: graalvm.org

Open Source LOC actively maintained for GraalVM

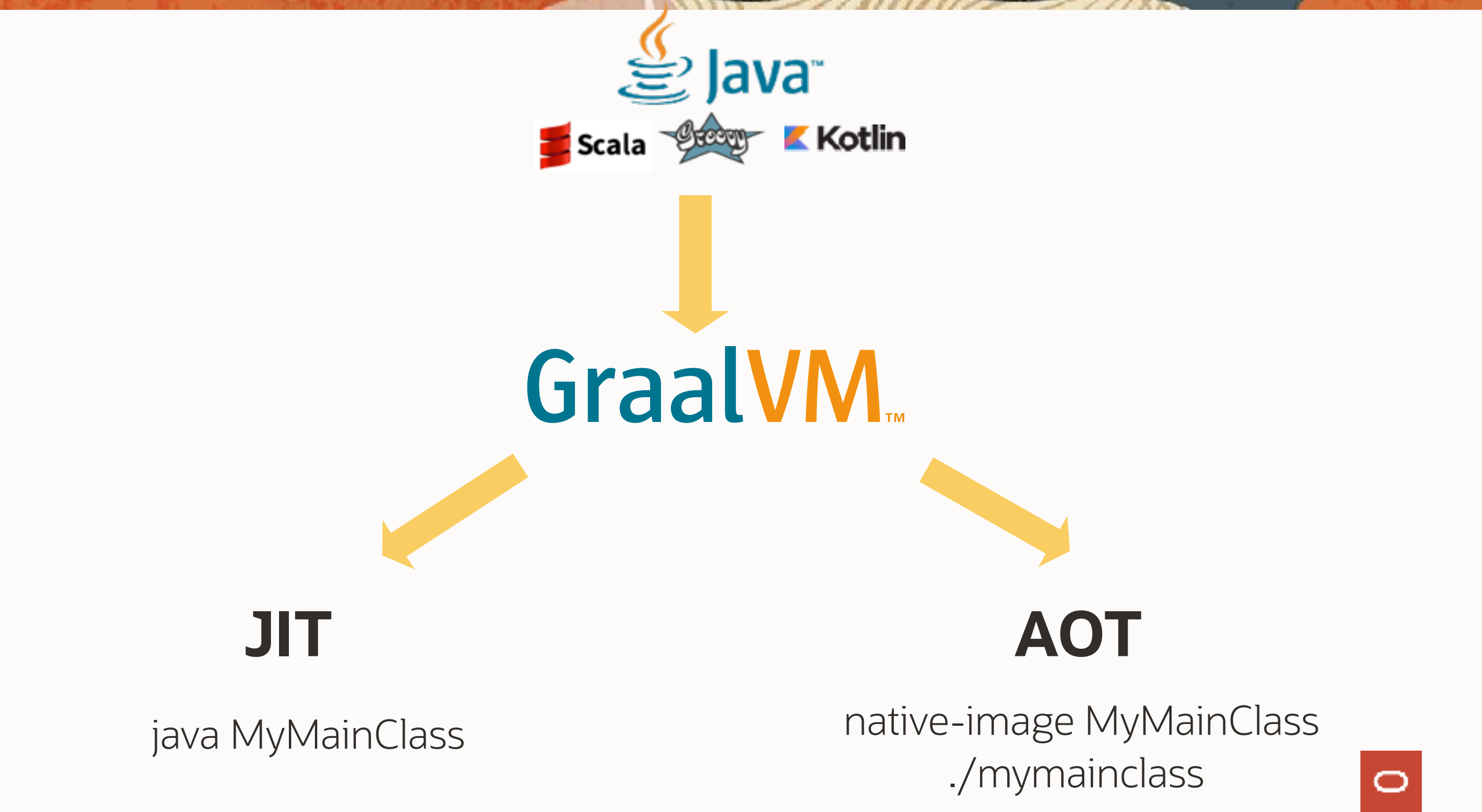


Total: 3,640,000 lines of code

Performance Metrics


Startup Speed
Peak Throughput
Low Memory Footprint
Reduced Max Latency
Small Packaging

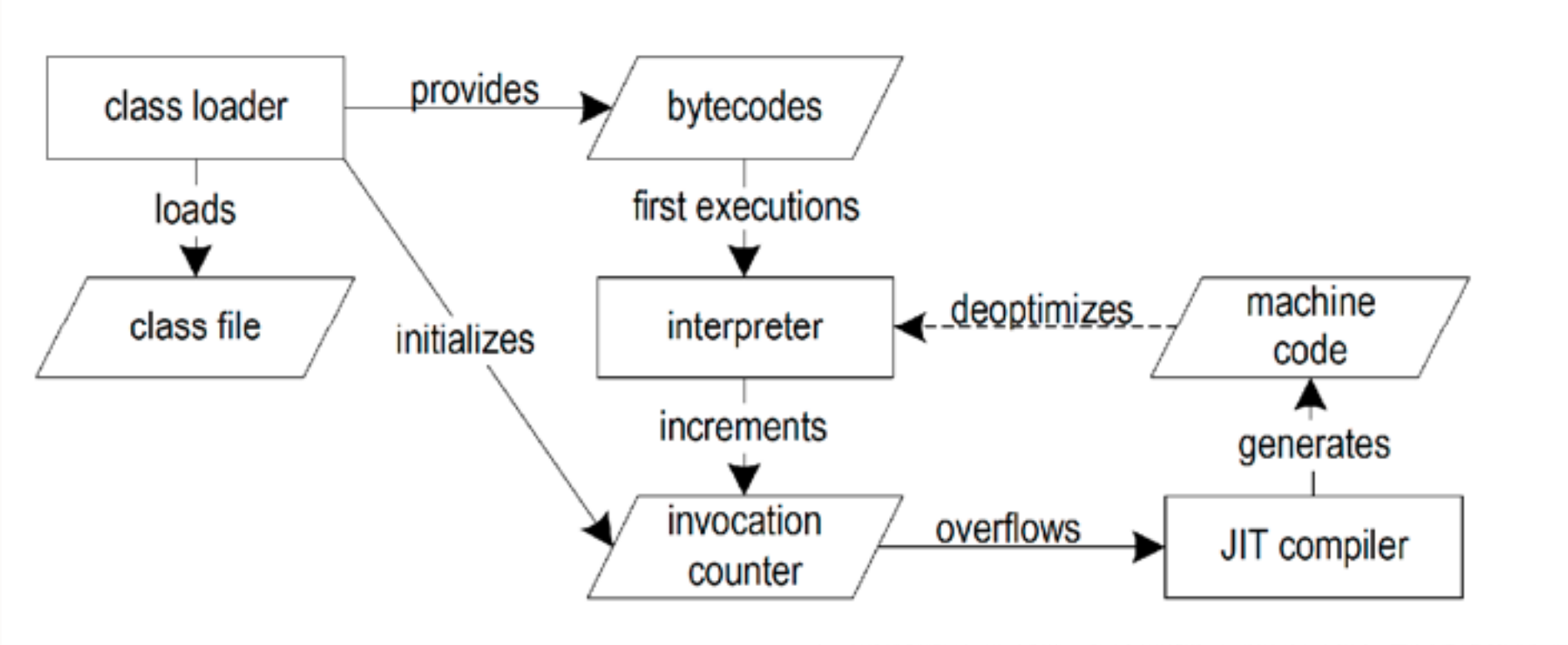
Optimizing Performance with GraalVM


Java
Scala
Groovy
Kotlin
GraalVM
JIT
java MyMainClass
AOT
native-image MyMainClass
./mymainclass

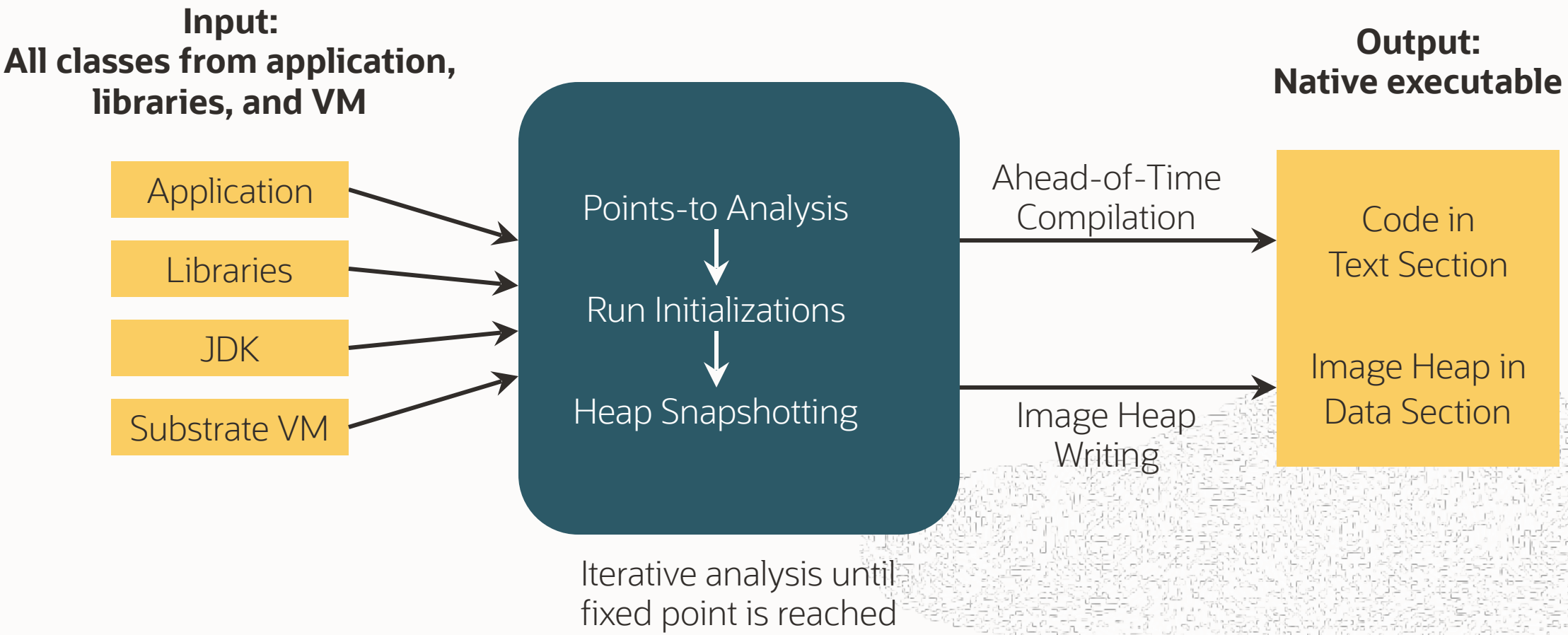
GraalVM Native Images

- Java program, compiled into a standalone native executable;
- Instant startup;
- Low memory footprint;
- AOT-compiled using the GraalVM compiler.

Java Dynamic Execution



Native Image Build Process



Startup Performance

AOT vs JIT: Startup Time

JIT

- Load JVM executable
- Load classes from file system
- Verify bytecodes
- Start interpreting
- Run static initializers
- First tier compilation (C1)
- Gather profiling feedback
- Second tier compilation (GraalVM or C2)
- Finally run with best machine code

AOT

- Load executable with prepared heap
- Immediately start with best machine code

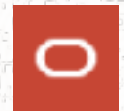
AOT vs JIT: Memory Footprint

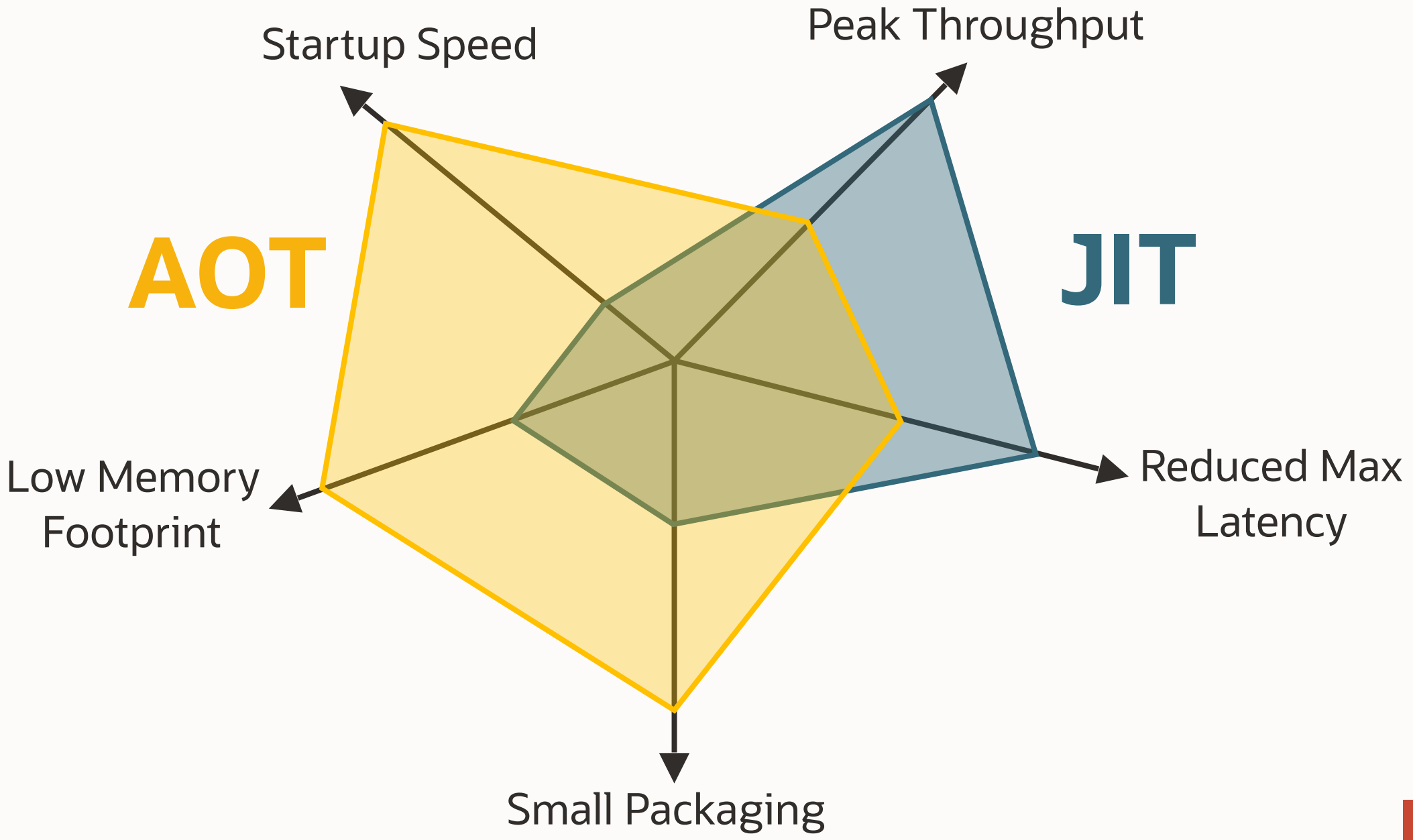
JIT

- Loaded JVM executable
- Application data
- Loaded bytecodes
- Reflection meta-data
- Code cache
- Profiling data
- JIT compiler data structures

AOT

- Loaded application executable
- Application data

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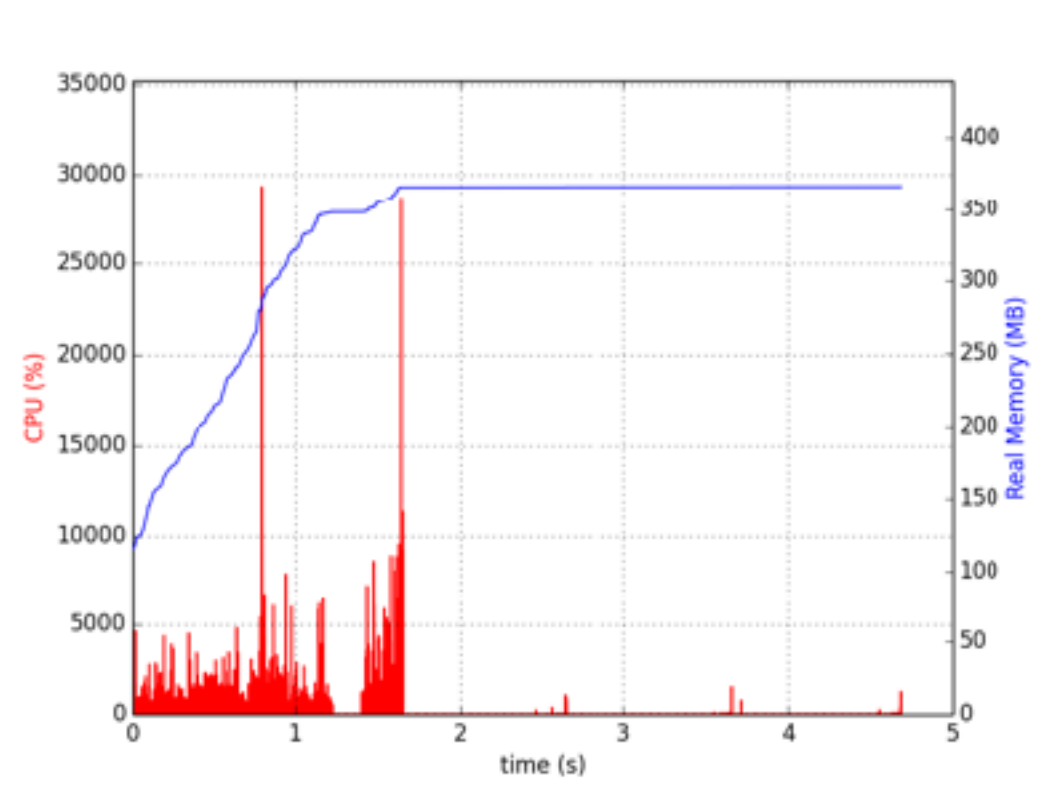
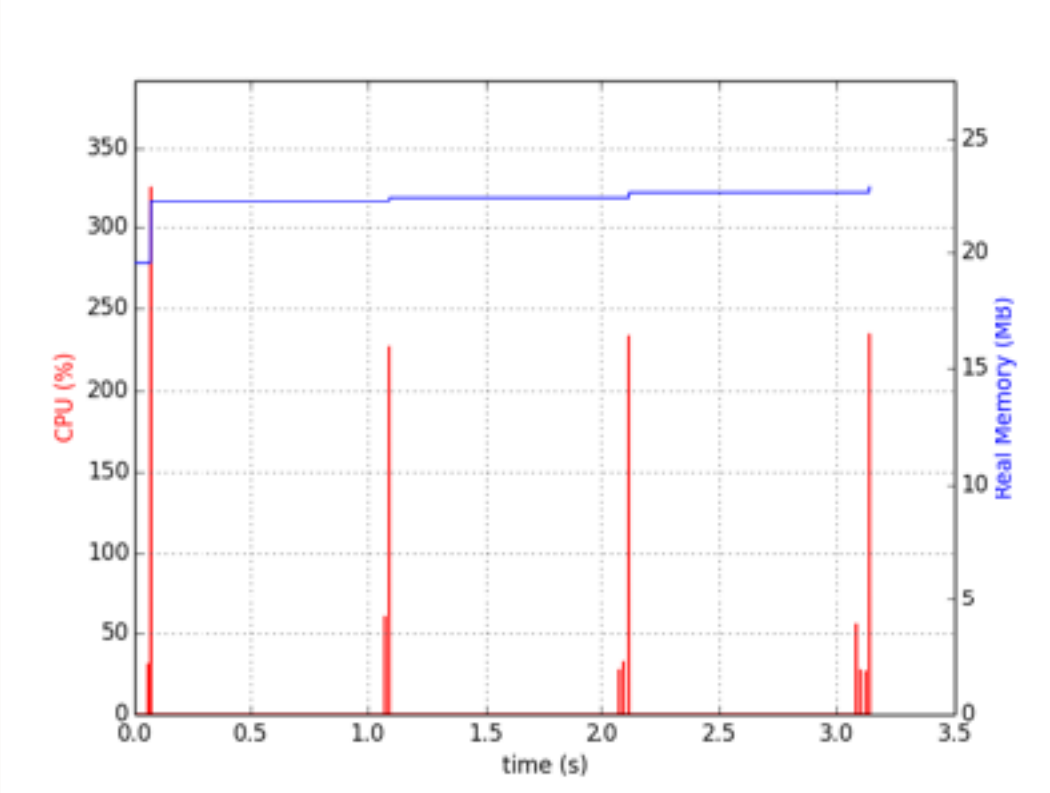
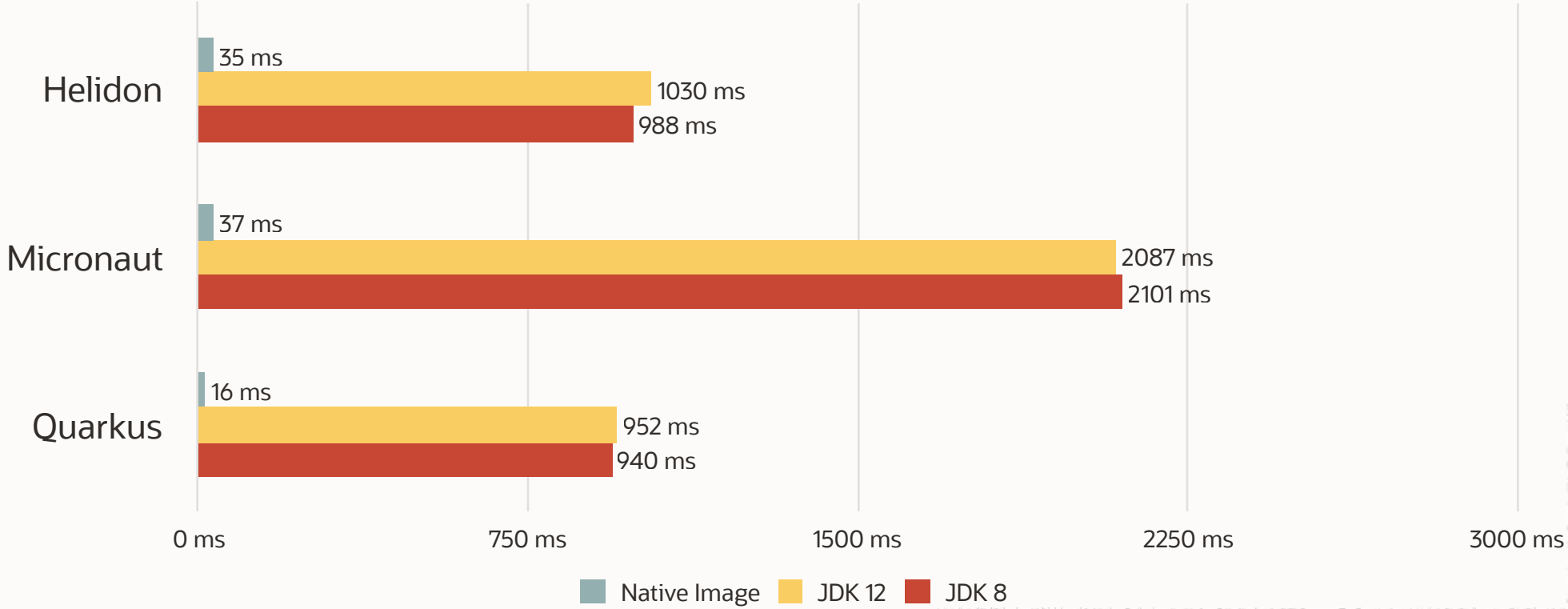
Demo: startup and memory footprint

Demo: startup and memory footprint

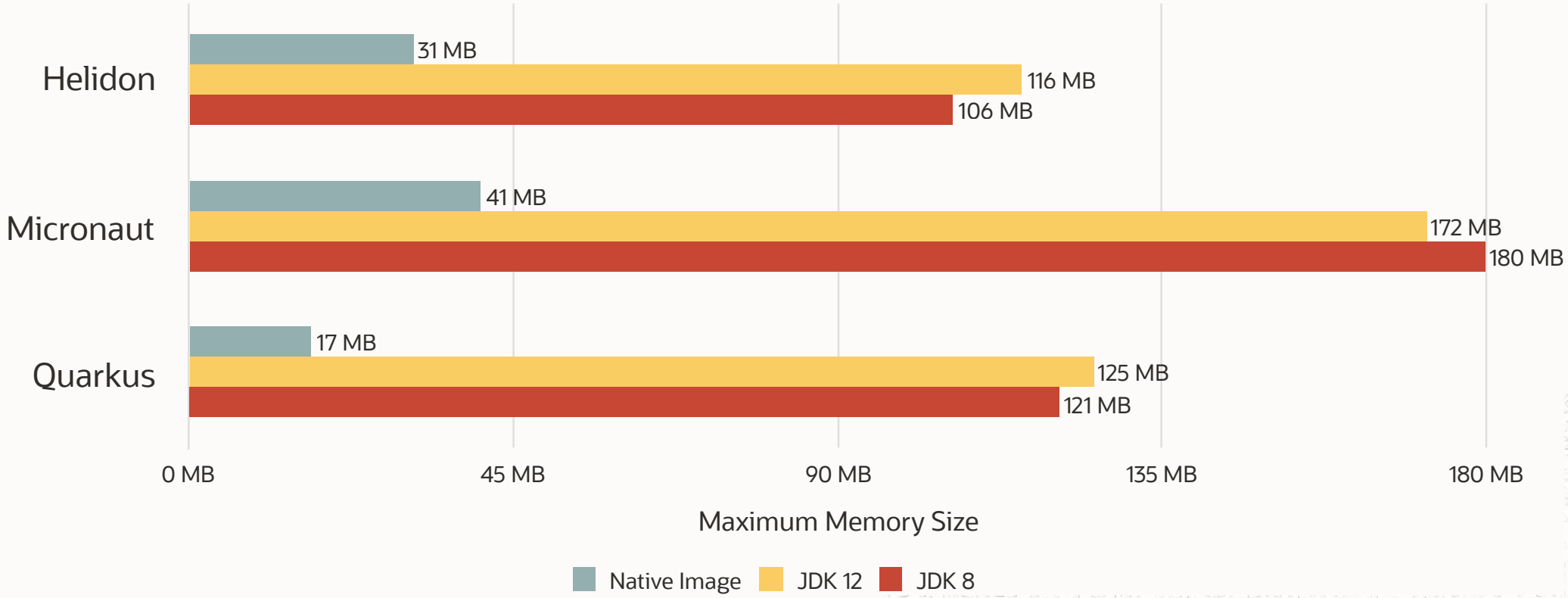




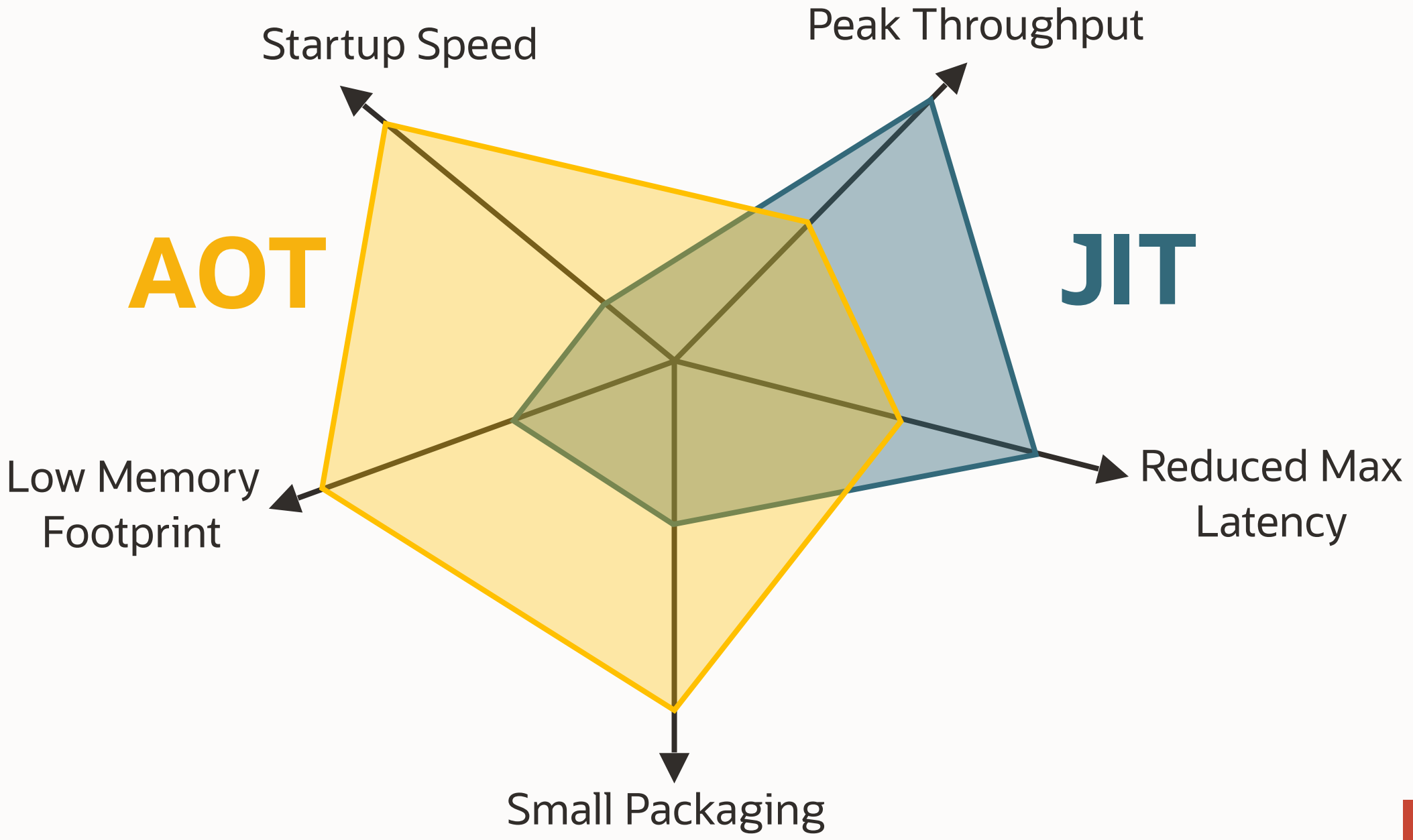
Microservice Frameworks: Startup Time



Microservice Frameworks: Memory Usage



Peak Performance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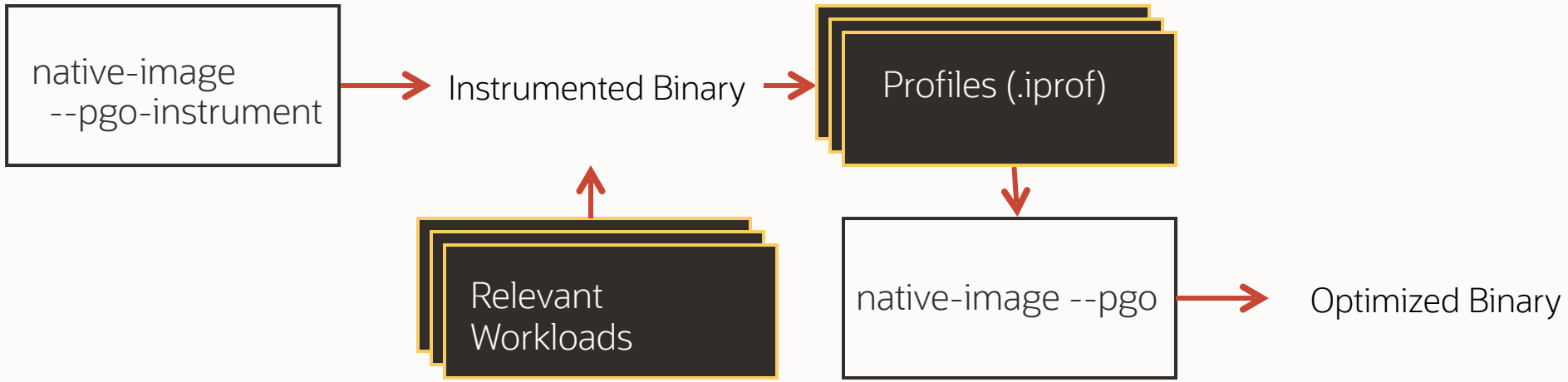
AOT vs JIT: Peak Throughput

JIT

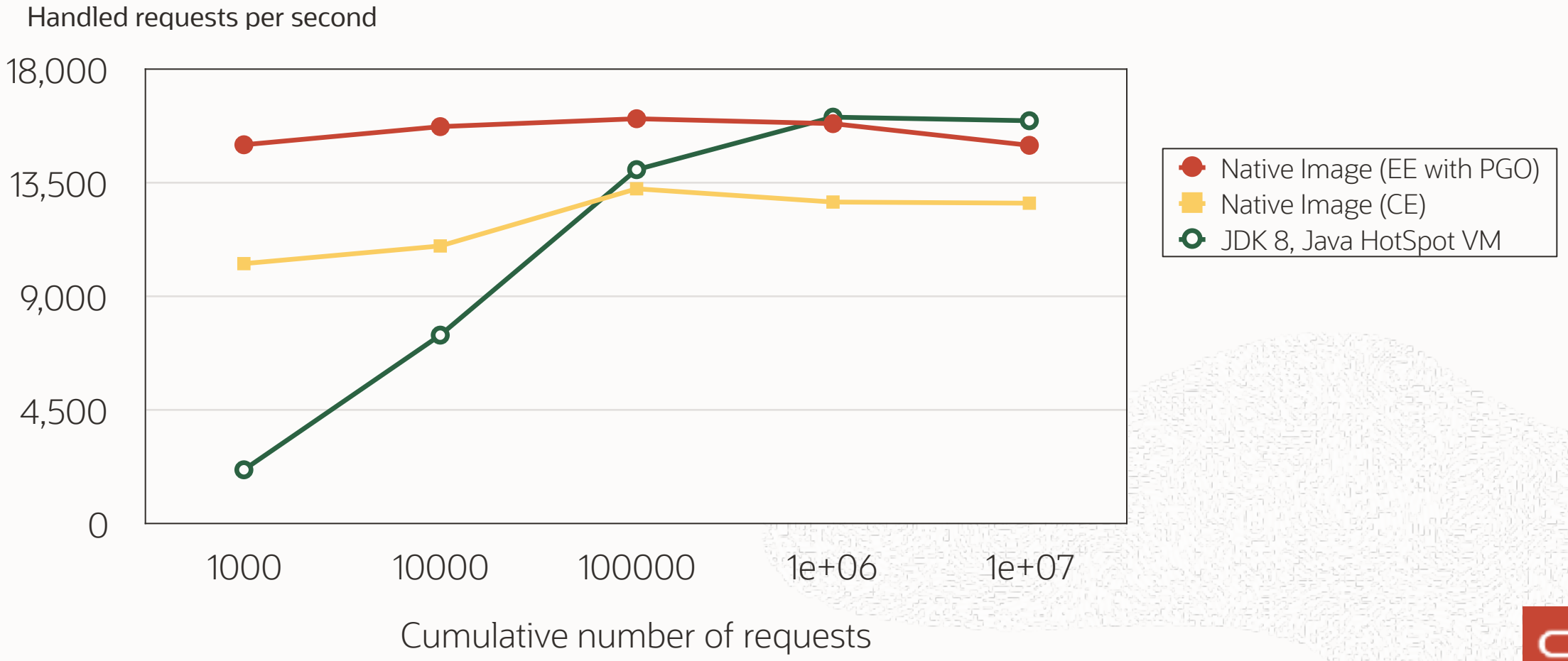
- Profiling at startup enables better optimizations
- Can make optimistic assumptions about the profile and deoptimize

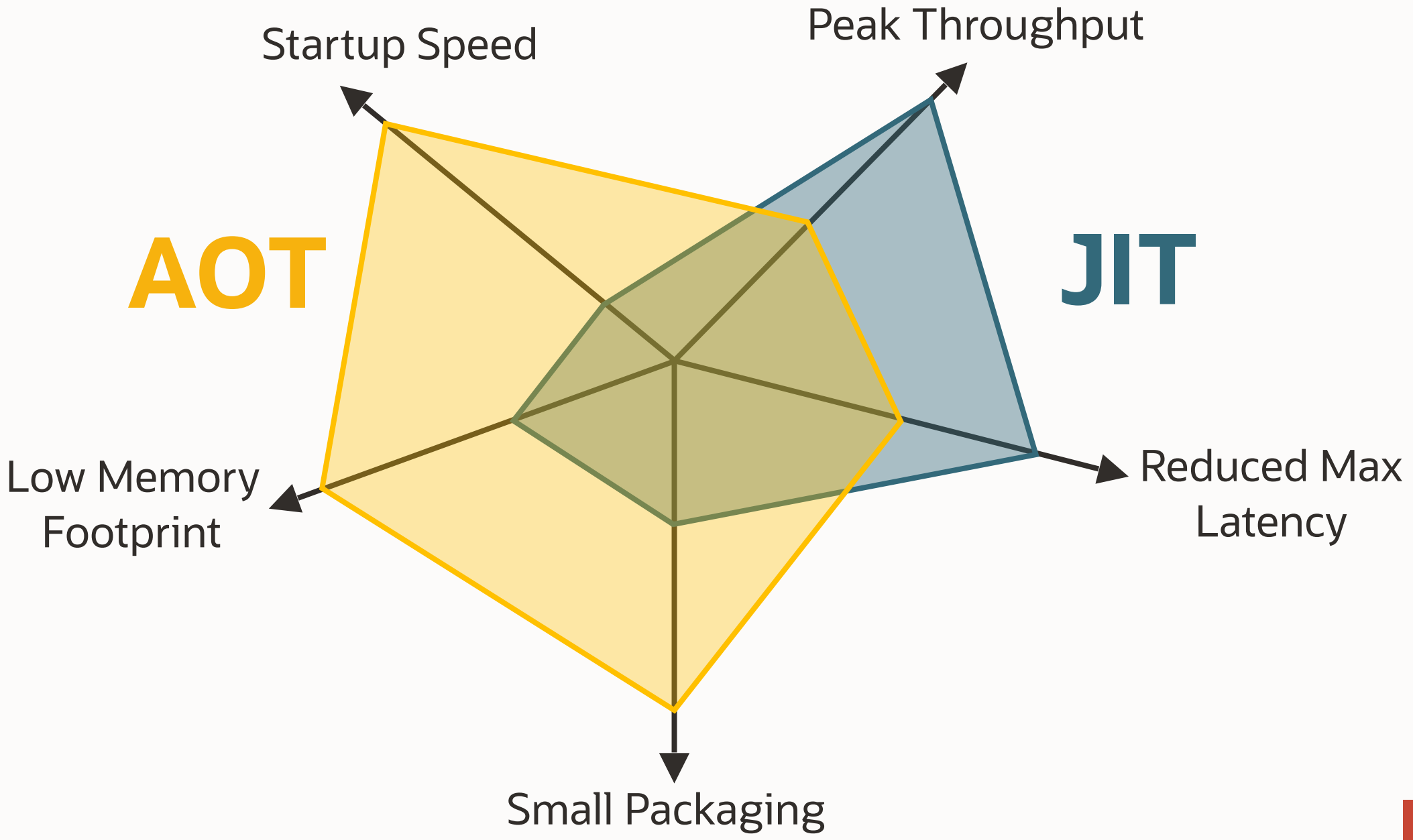
- AOT
- Needs to handle all cases in machine code
- Predictable performance
- Profile-guided optimizations help

Profile-Guided Optimizations (PGO)



AOT vs JIT: Peak Throughput

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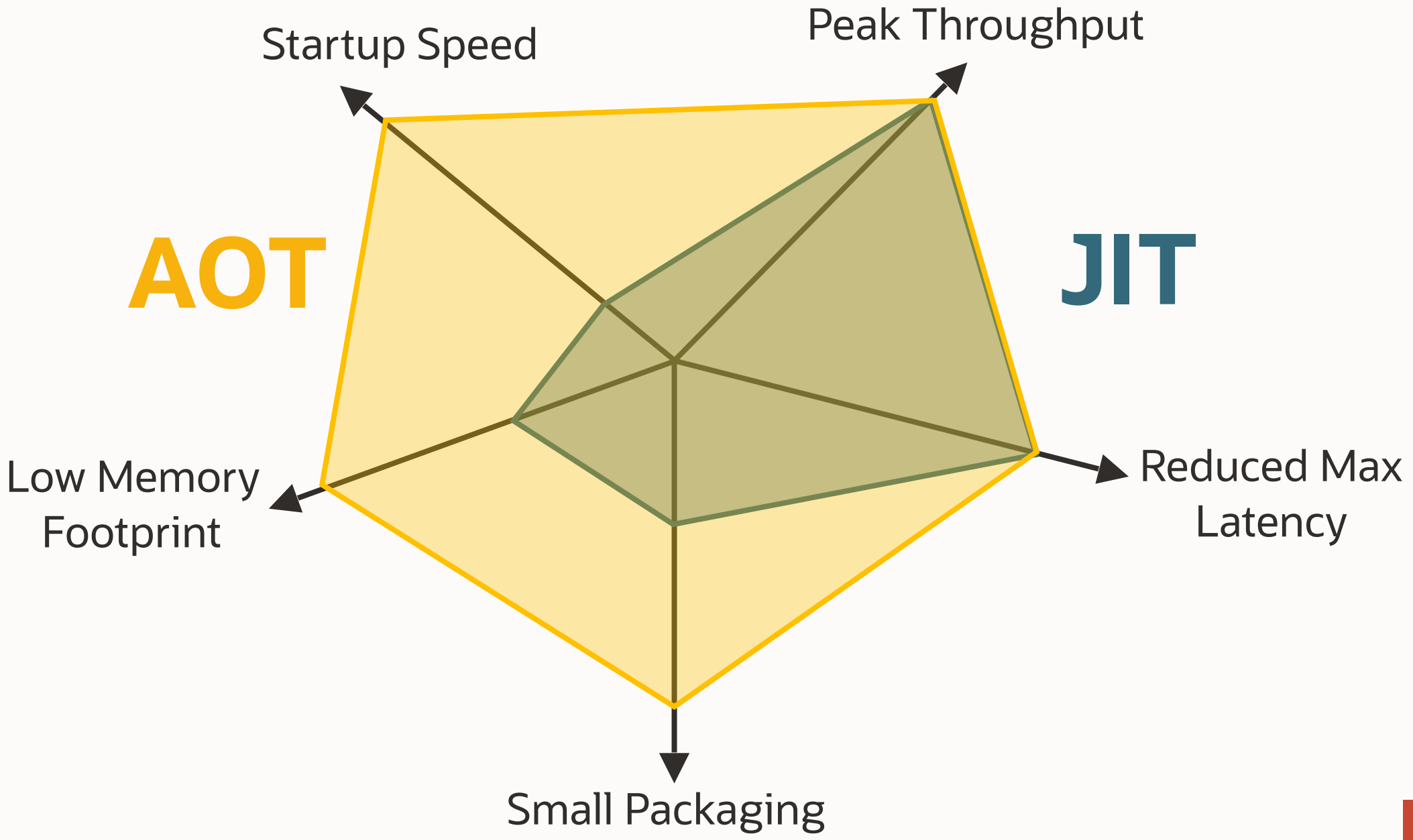
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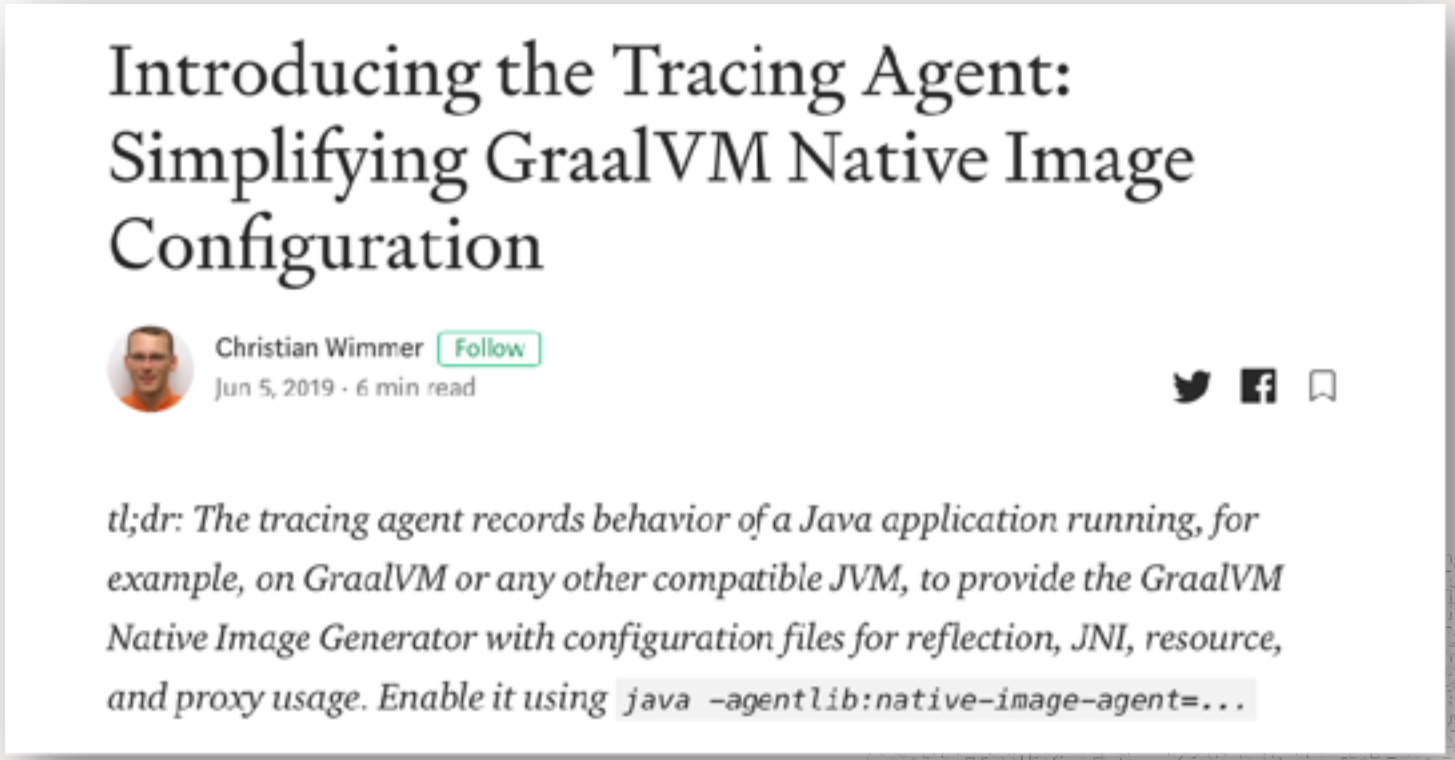
GraalVM native image for real-world projects

Simplify Native Image Configuration



Introducing the Tracing Agent: Simplifying GraalVM Native Image Configuration

Christian Wimmer Follow
Jun 5, 2019 · 6 min read

tl;dr: The tracing agent records behavior of a Java application running, for example, on GraalVM or any other compatible JVM, to provide the GraalVM Native Image Generator with configuration files for reflection, JNI, resource, and proxy usage. Enable it using `java -agentlib:native-image-agent=...`

medium.com/graalvm/introducing-the-tracing-agent-simplifying-graalvm-native-image-configuration-c3b56c486271

Simplifying native-image generation with Maven plugin and embeddable configuration

Paul Wögerer Follow
Mar 19, 2019 · 6 min read

In this blog post we show two features recently added to GraalVM to simplify the generation of native images. One is a Maven plugin so you can include the native image generation in your build without calling the command line utilities manually. Then we look at `native-image.properties` as a way to include the configuration for your library in the jar file to avoid manual configuration.

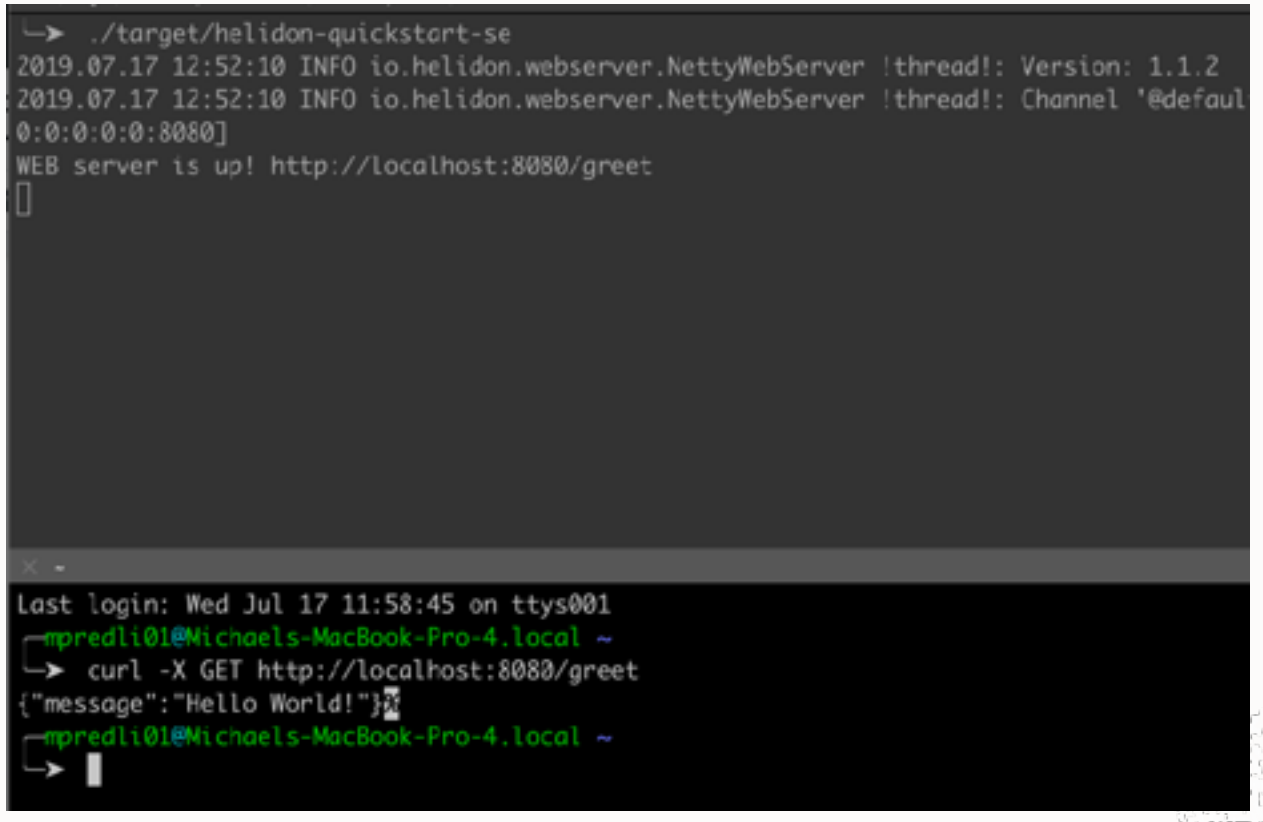
https://medium.com/graalvm/simplifying-native-image-generation-with-maven-plugin-and-embeddable-configuration-d5b283b92f57

Micronaut

Create your first Micronaut GraalVM application:

https://guides.micronaut.io/micronaut-creating-first-graal-app/guide/index.html

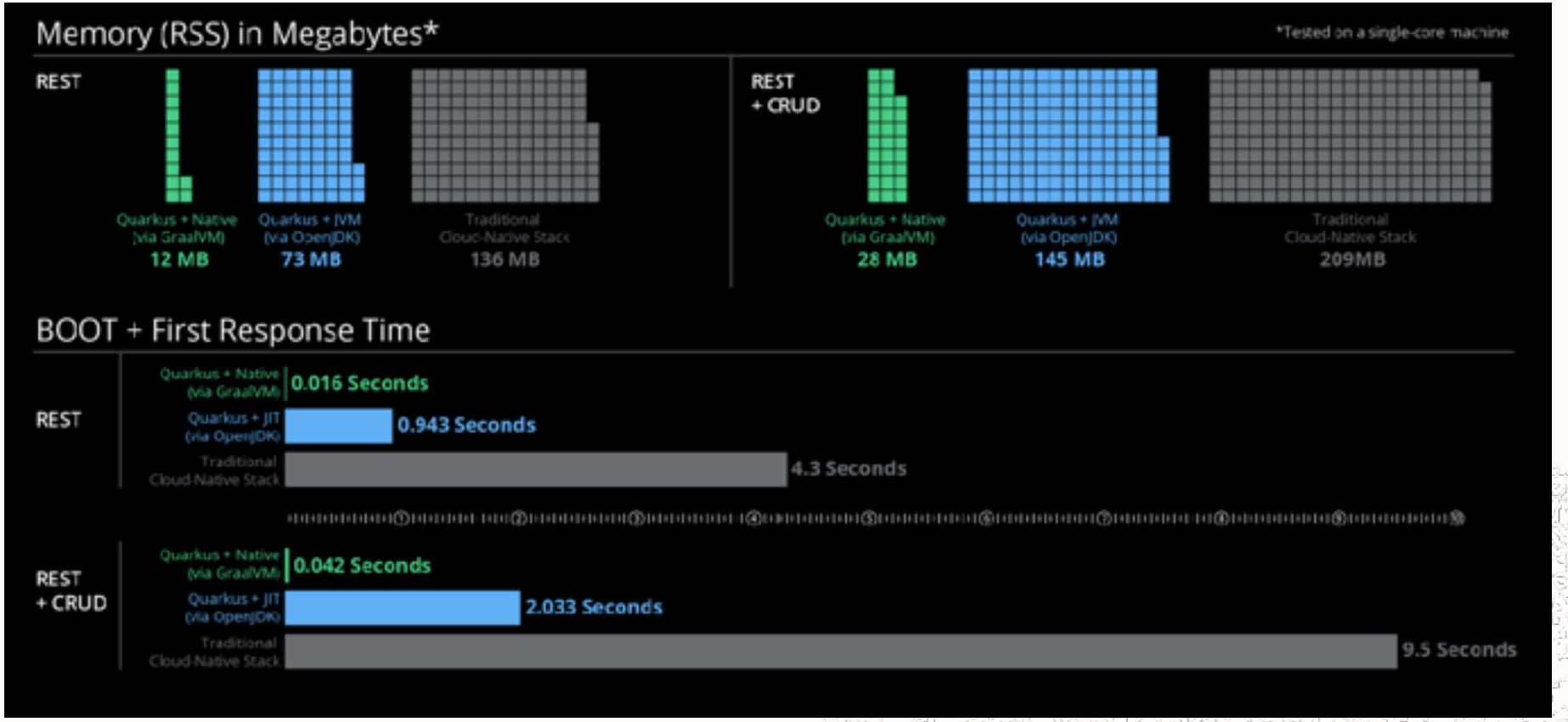
Helidon



Helidon and GraalVM:

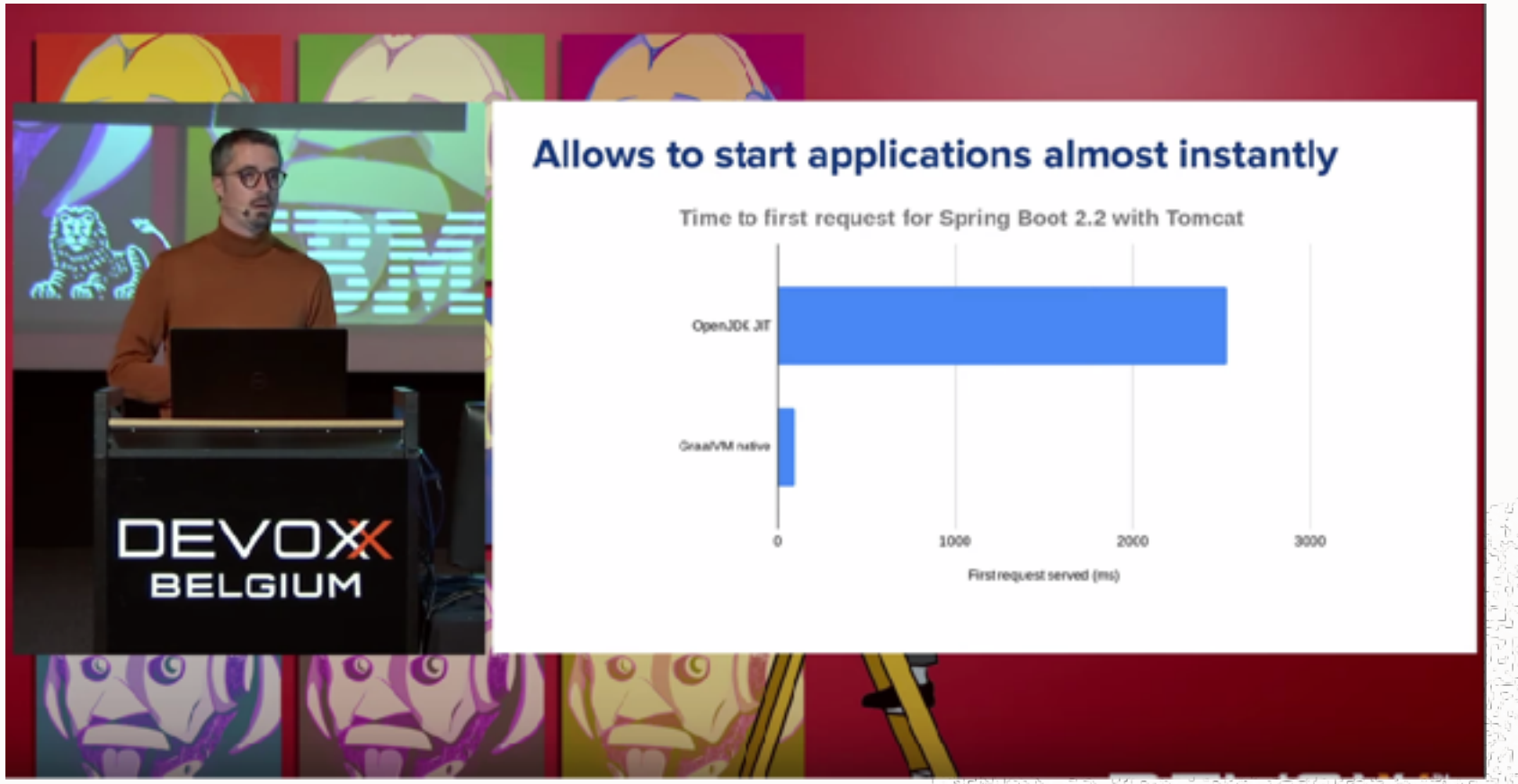
https://helidon.io/docs/latest/#/guides/36_graalnative

Quarkus



https://quarkus.io/guides/building-native-image

Spring Boot Applications as GraalVM Native Images



https://www.youtube.com/watch?v=3eoAxphAUIg

Spring Boot Applications as GraalVM Native Images

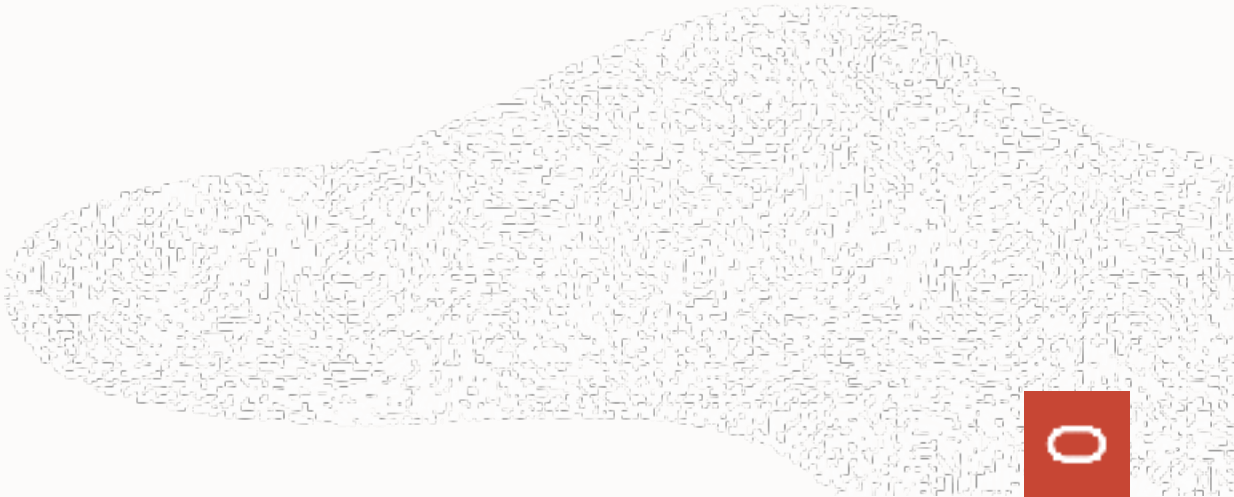
```
Alinas-MacBook-Pro:~/spring-graal-native/spring-graal-native-samples$ ls
commandlinerunner       spring-petclinic-jpa    vanilla-orm2
commandlinerunner-maven springmvc-tomcat        vanilla-rabbit
kotlin-webmvc           vanilla-grpc            vanilla-thymeleaf
logger                  vanilla-jpa             vanilla-tx
messages                vanilla-orm             webflux-netty
```

"Spring Graal Native" project: https://github.com/spring-projects-experimental/spring-graal-native

GraalVM Native Image vs GraalVM JIT

- Use GraalVM Native Image when
  - Startup time matters
  - Memory footprint matters
    - Small to medium-sized heaps (100 MByte – a few GByte)
  - All code is known ahead of time

- Use GraalVM JIT when
  - Heaps size is large
    - Multiple GByte – TByte heap size
  - Classes are only known at run time



GraalVM
Language Ecosystem

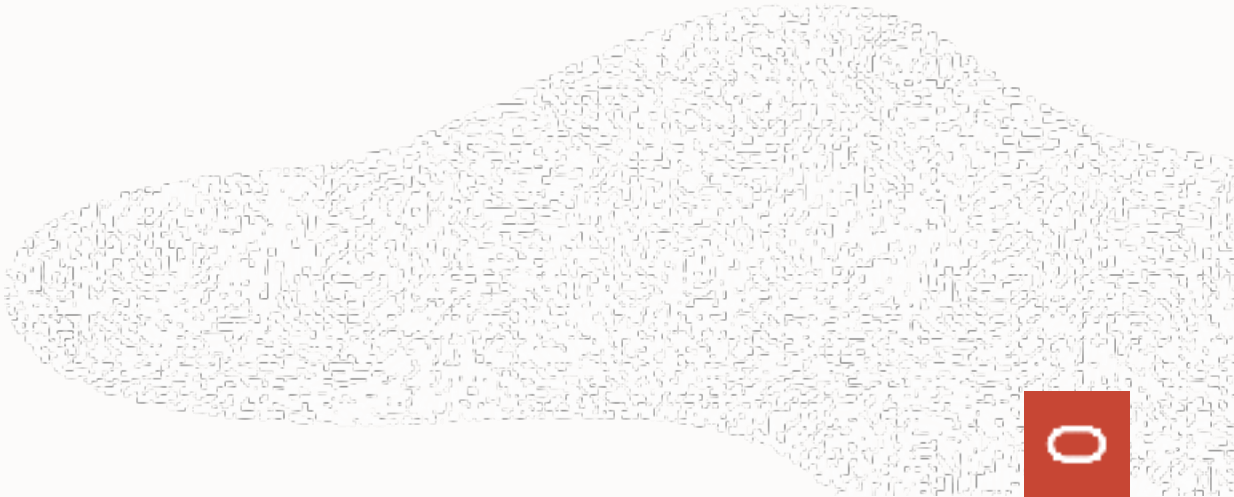
Multiplicative Value-Add of GraalVM Ecosystem

Languages	*	GraalVM	*	Embeddings
Java JavaScript Ruby R Python C/C++, FORTRAN, …		Optimizations Tooling Interoperability Security		HotSpot JVM Oracle RDBMS Node.js Standalone …

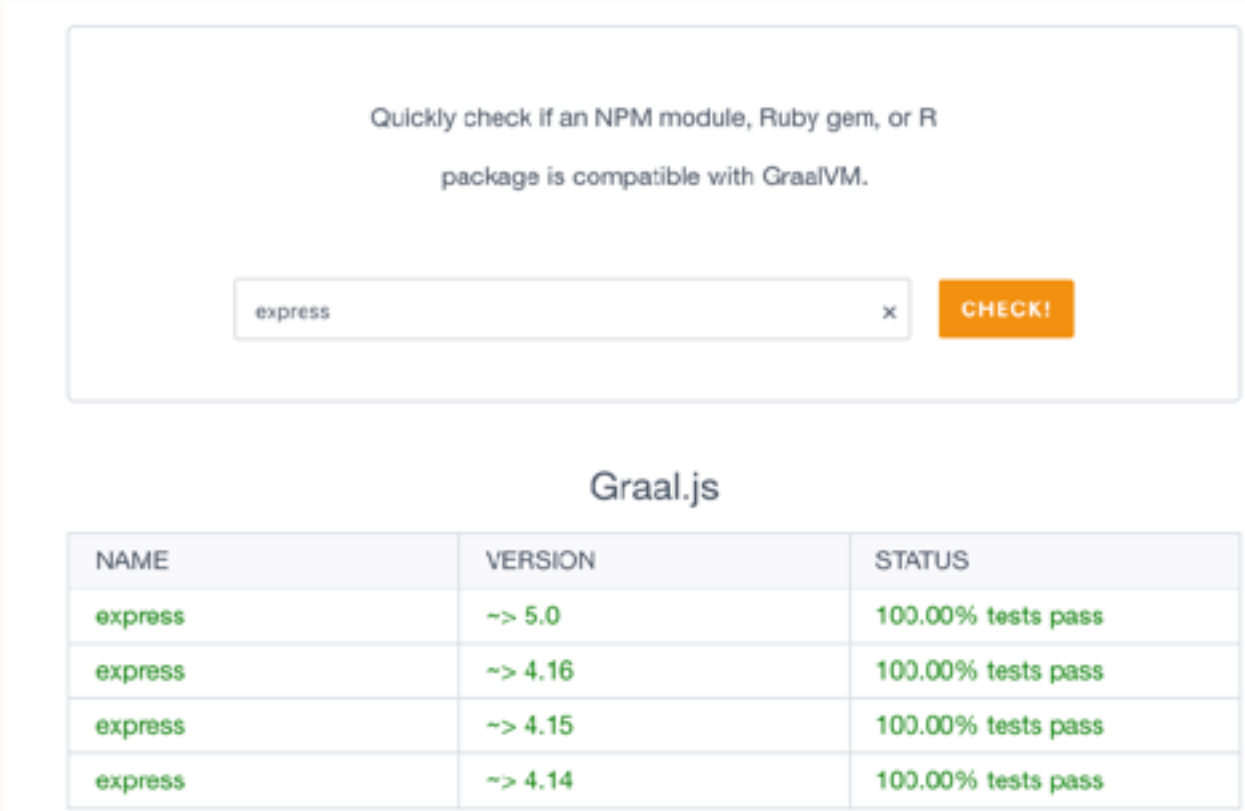
Add your own language or embedding or language-agnostic tools!

JavaScript & Node.js

- ECMAScript 2019 complaint JavaScript engine;
- Access to GraalVM language interoperability and common tooling;
- Constantly tested against 90,000+ npm modules, `including express, react, async, request`

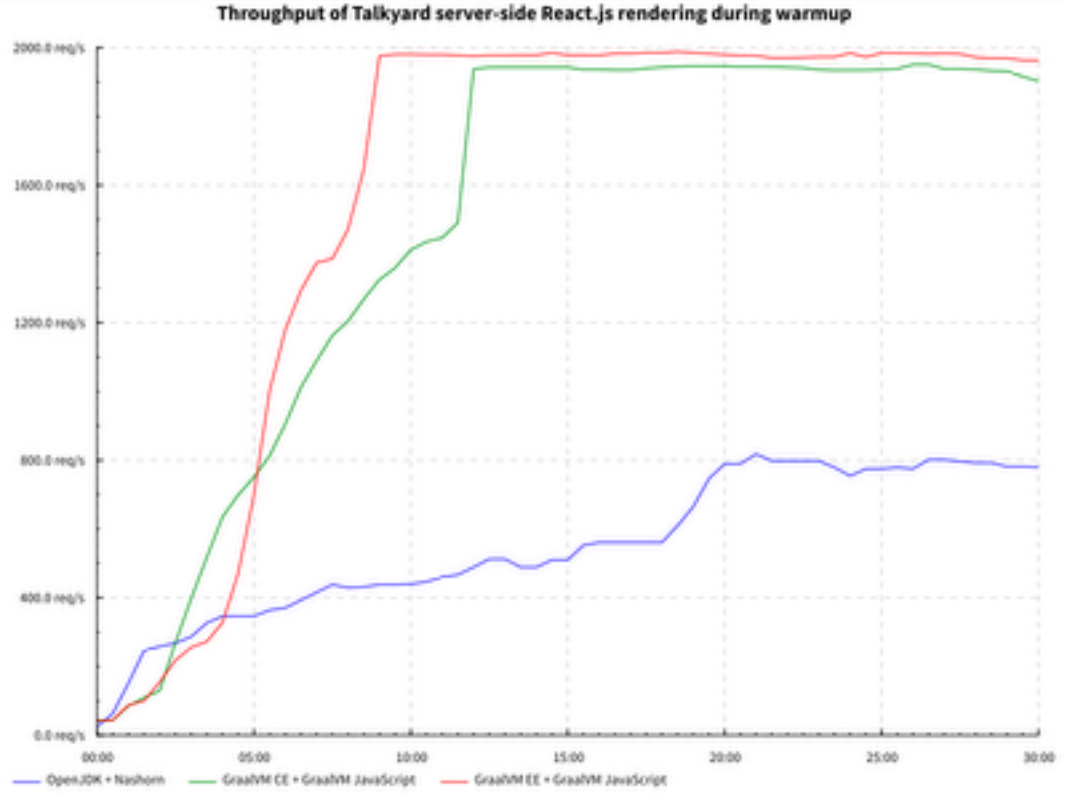


Compatibility Tool



https://www.graalvm.org/docs/reference-manual/compatibility

React.js Server Side Rendering



- Example app: Talkyard.io
- Server-side part written in Scala, client side: React.js;
- Nashorn: ~800 renders per second;
- GraalVM: ~2000 renders per second.

https://medium.com/graalvm/improve-react-js-server-side-rendering-by-150-with-graalvm-58a06ccb45df

Nashorn Migration Guide

Migration guide from Nashorn to GraalVM JavaScript

This document serves as migration guide for code previously targeted to the Nashorn engine. See the JavaInterop.md for an overview of supported Java interoperability features.

Both Nashorn and GraalVM JavaScript support a similar set of syntax and semantics for Java interoperability. The most important differences relevant for migration are listed here.

Nashorn features available by default:

- `Java.type`, `Java.typeName`
- `Java.from`, `Java.to`
- `Java.extend`, `Java.super`
- Java package globals: `Packages`, `java`, `javafx`, `javax`, `com`, `org`, `edu`

Nashorn compatibility mode

GraalVM JavaScript provides a Nashorn compatibility mode. Some of the functionality necessary for Nashorn compatibility is only available when the `js.nashorn-compat` option is enabled. This is the case for Nashorn-specific extensions that GraalVM JavaScript does not want to expose by default. Note that you have to enable [experimental options](Options.md#Stable and Experimental options) to use this flag.

The `js.nashorn-compat` option can be set using a command line option:

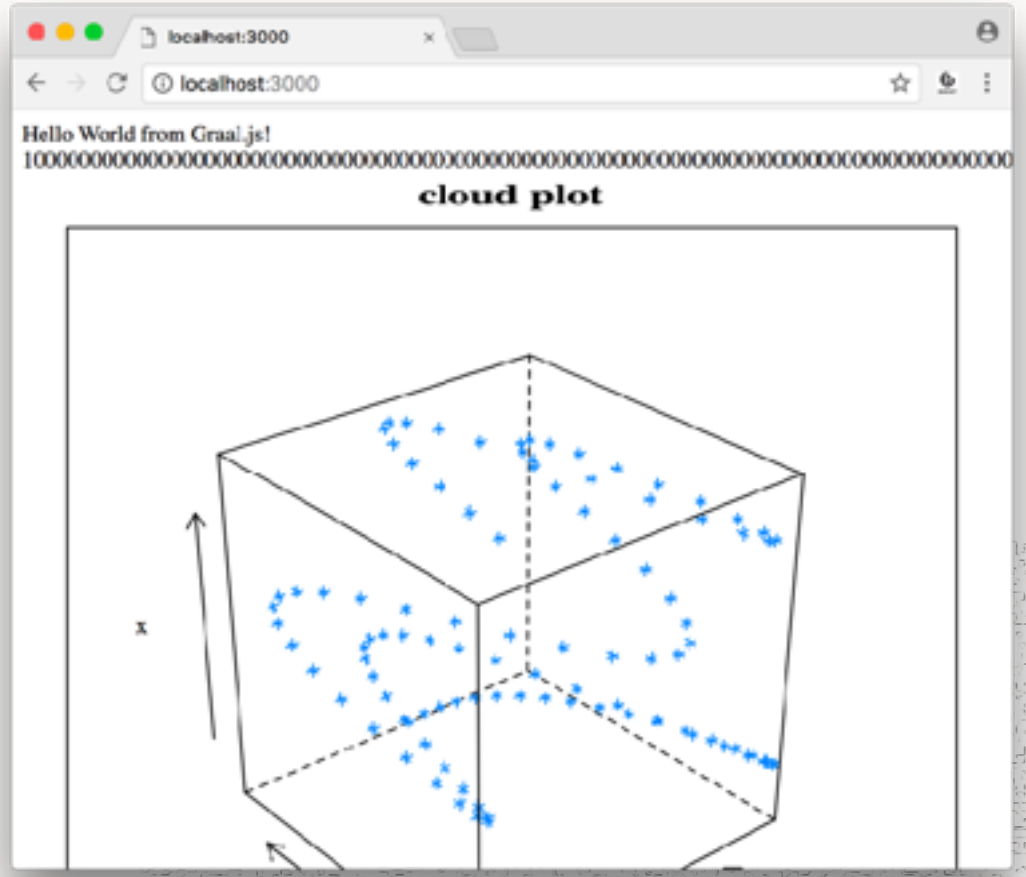
```
$ js --experimental-options --js.nashorn-compat=true
```

https://github.com/graalvm/graaljs/blob/master/docs/user/NashornMigrationGuide.md

JavaScript + Java + R

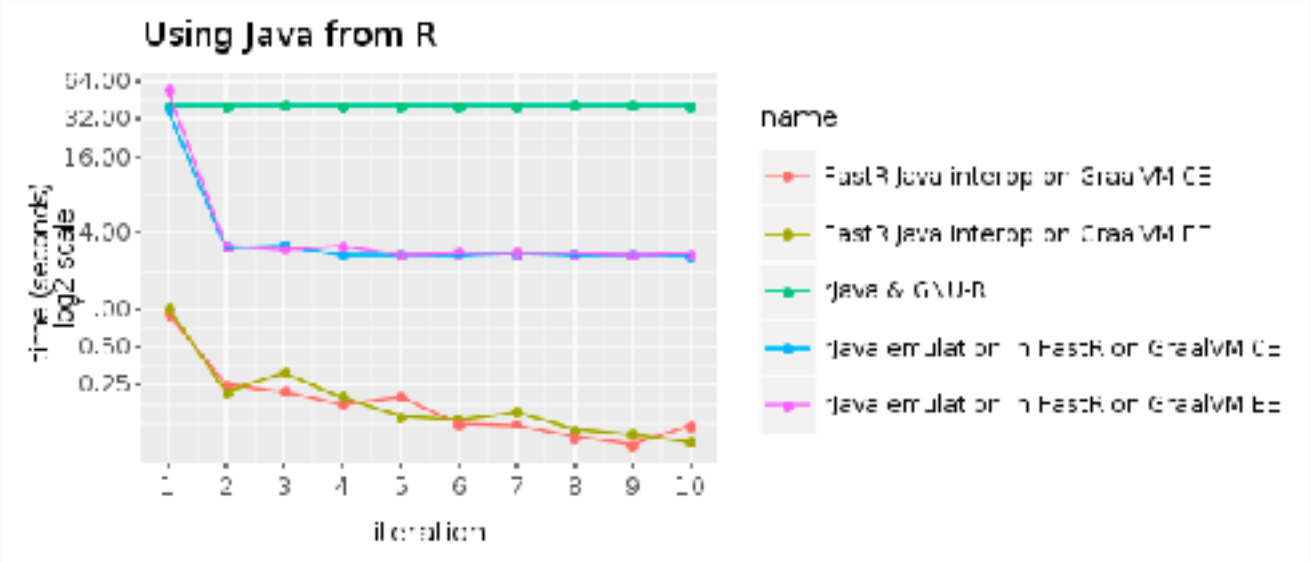
server.js

```
41
42  const express = require('express')
43  const app = express()
44
45  const BigInteger = Java.type('java.math.BigInteger')
46
47
48  app.get('/', function (req, res) {
49    var text = '<h1>Hello from Graal.js!</h1>'
50
51    // Using Java standard library classes
52    text += BigInteger.valueOf(10).pow(100)
53                .add(BigInteger.valueOf(43)).toString() + '<br>'
54
55    // Using R methods to return arrays
56    text += Polyglot.eval('R',
57      'ifelse(1 > 2, "no", paste(1:42, c="|"))') + '<br>'
58
59    // Using R interoperability to create graphs
60    text += Polyglot.eval('R',
61      `svg();
62      require(lattice);
63      x <- 1:100
64      y <- sin(x/10)
65      z <- cos(x^1.3/(runif(1)+5+10))
66      print(cloud(x~y*z, main="cloud plot"))
67      grDevices:::svg.off()
68      `);
```



FastR

- GNU-R compatible R implementation
  - Including the C/Fortran interface
- Built on top of the GraalVM platform
  - Leverages GraalVM optimizing compiler
  - Integration with GraalVM dev tools
  - Zero overhead interop with other GraalVM languages

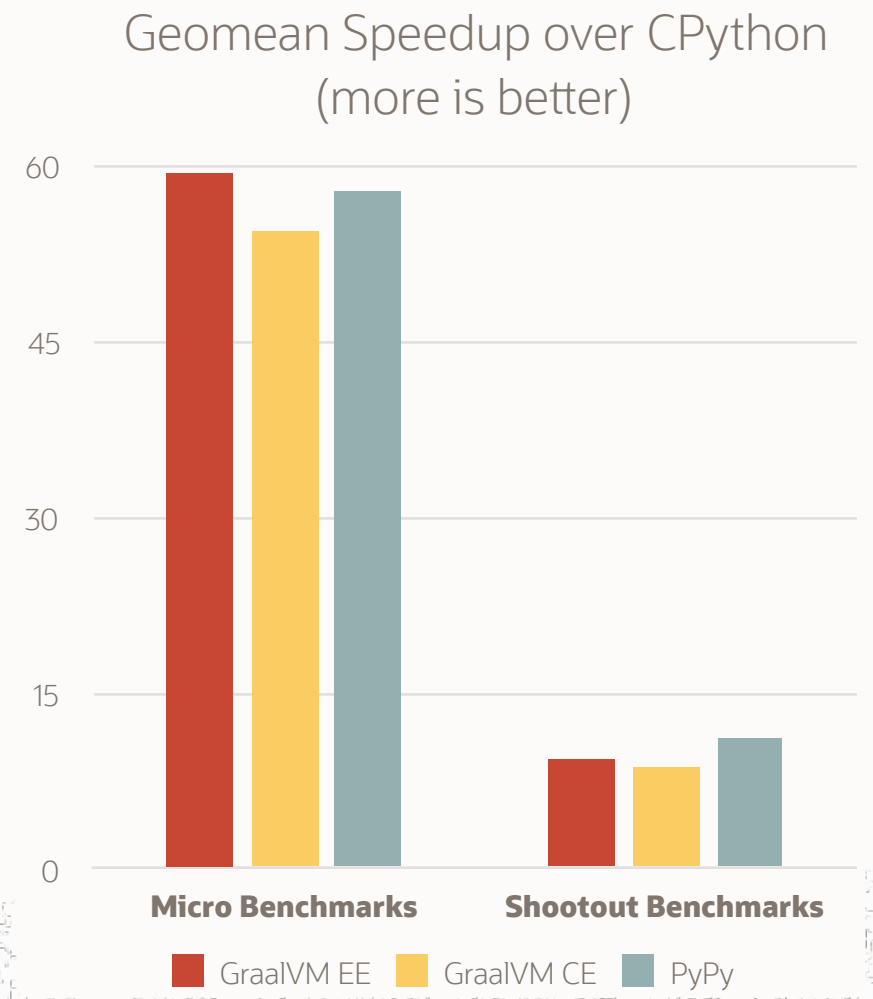


warm-up curves, i.e. lower is better, of rJava on GNU-R, FastR and the native Java interoperability in FastR

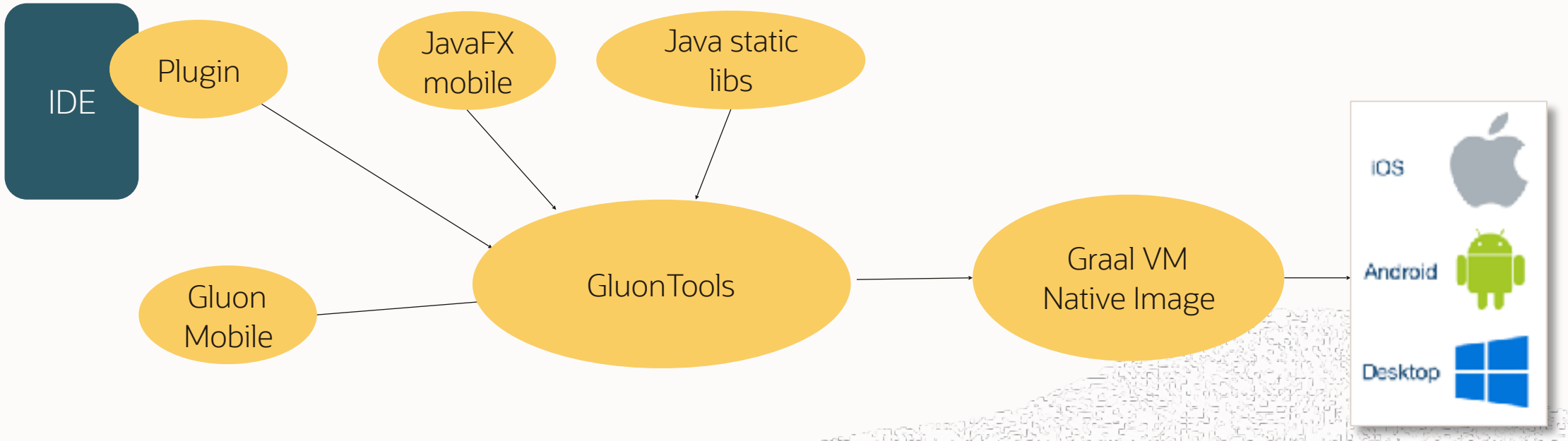
GraalVM Python

- Python 3 implementation;
- High performance;
- Focus on supporting SciPy and its constituent libraries;
- Easy interop with Java and the rest of GraalVM languages.

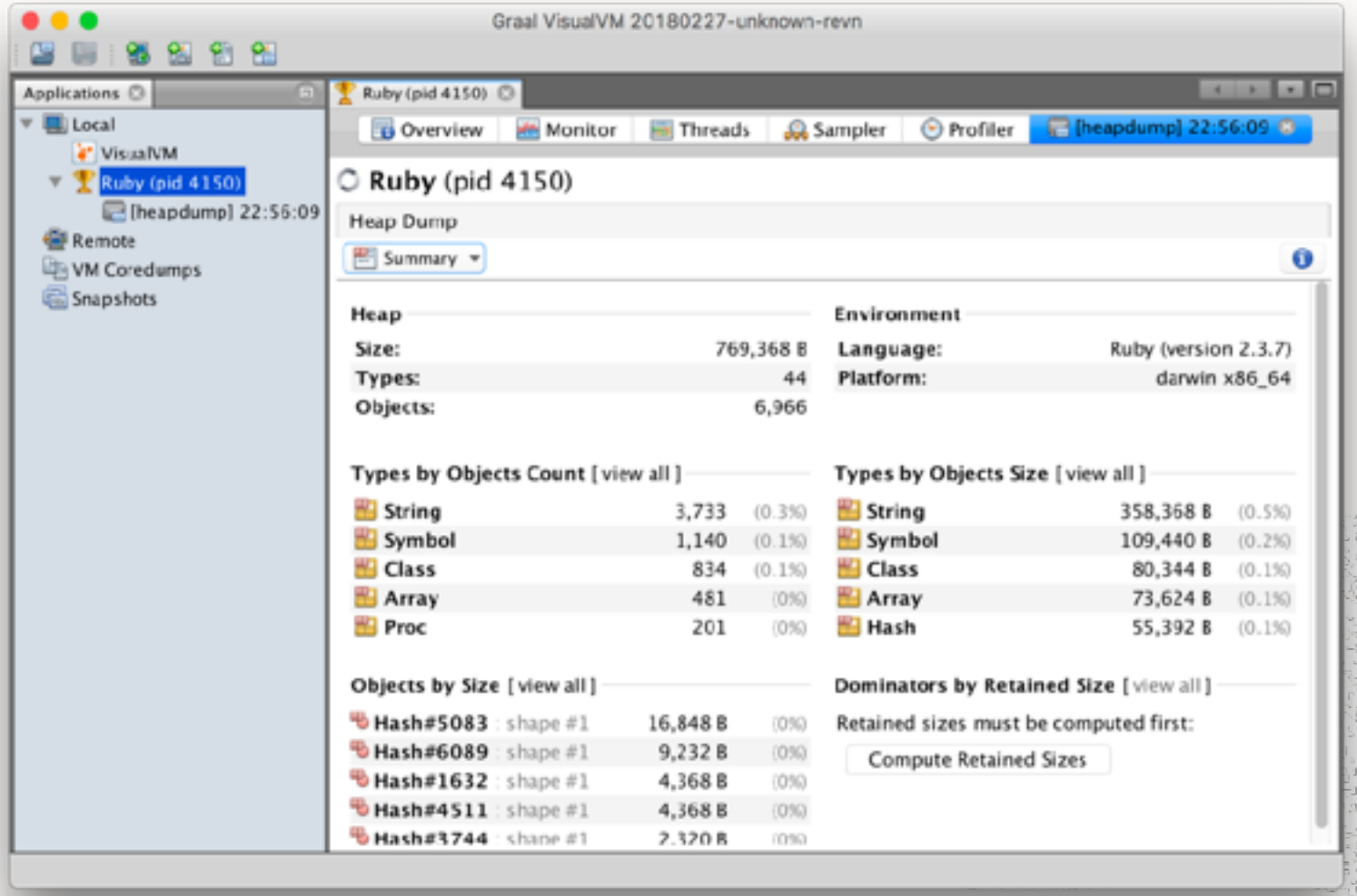
```
$ graalpython [options] [-c cmd | filename]
```



Do even more with GraalVM: Cross-Platform Development



Polyglot tools: GraalVM VisualVM



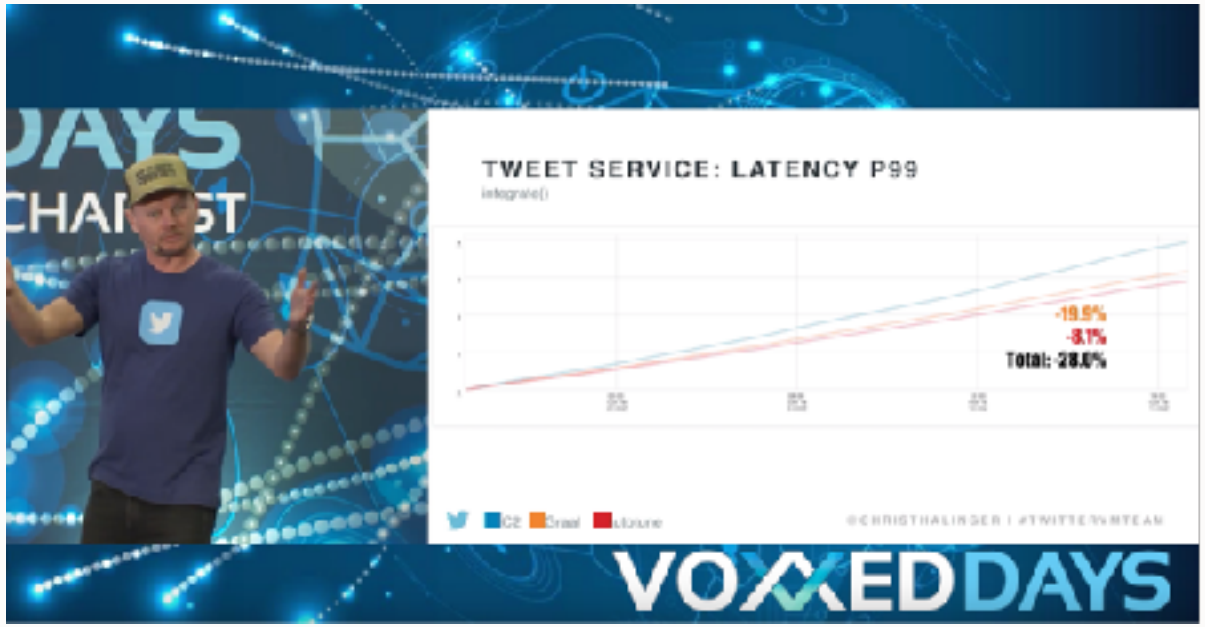
Using grCUDA to Access Nvidia GPUs

- Efficient exchange of data between host language and GPU without burdening the programmer
- Expose GPU resources in ways that are native in the host language, e.g., as arrays
- Allow programmers to invoke existing GPU code from their host language
- Allow programmers to define new GPU kernels on the fly
- Polyglot interface: uniform bindings across several programming languages

- Implemented as a “Truffle Language”
  (although “CUDA” is a platform, not a language)

- Developed by NVIDIA in collaboration
  with Oracle Labs
- BSD 3-clause license

Twitter uses GraalVM compiler in production to run their Scala microservices



GraalVM in practice at the Dutch National Police

https://www.youtube.com/watch?v=poNlwZjoYjs

- Peak performance: +10%
- Garbage collection time: -25%
- Seamless migration

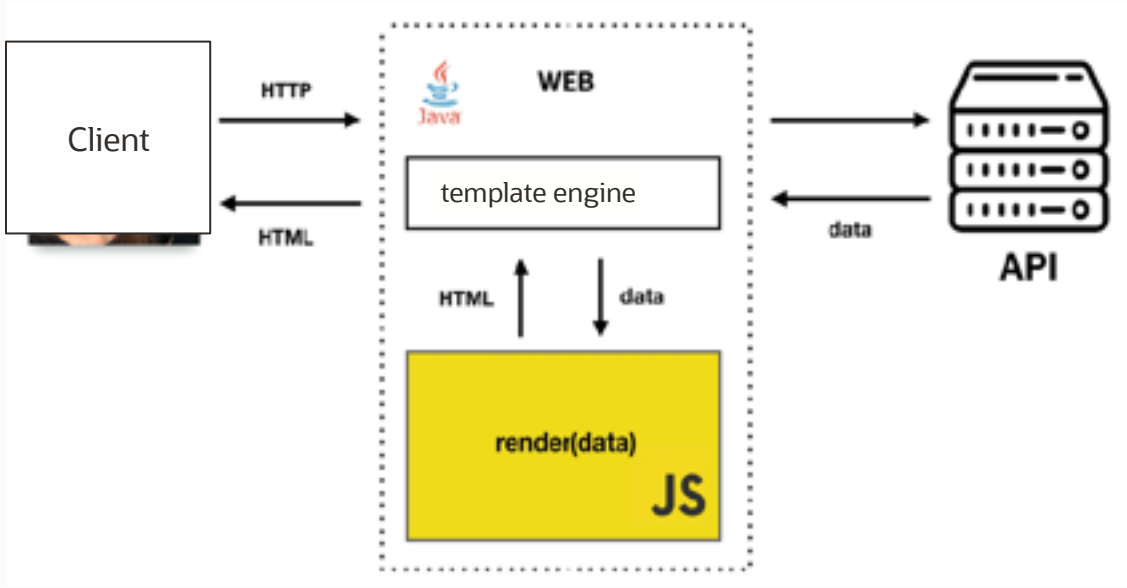
ORACLE
Cloud Infrastructure

The rich ecosystem of CUDA-X libraries is now available for GraalVM applications.

GPU kernels can be directly launched from GraalVM languages such as R, JavaScript, Scala and other JVM-based languages.

Learn more: https://devblogs.nvidia.com/grcuda-a-polyglot-language-binding-for-cuda-in-graalvm/

Odnoklassniki use GraalVM in a production Java workload (70 mln users, ~600K req/min, ~7K servers) for React sever-side rendering

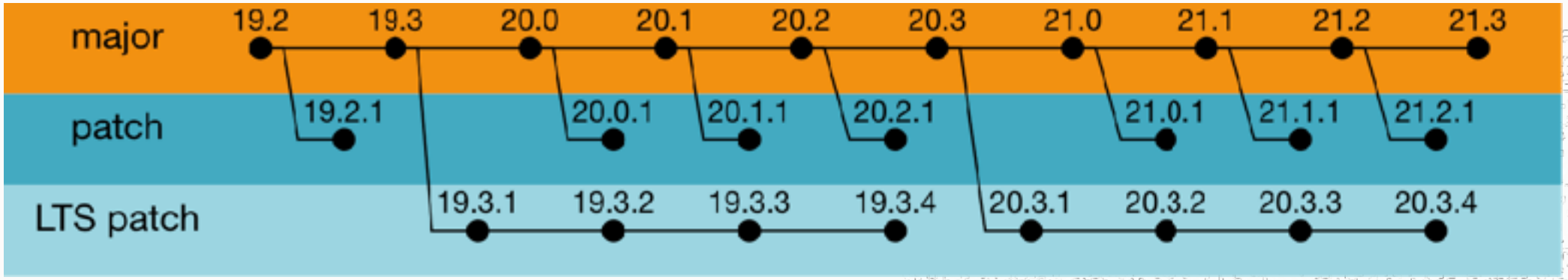


https://prog.world/new-odnoklassniki-frontend-launching-react-in-java-part-i/

Project Roadmap

Version Roadmap

- Latest release: GraalVM 20.0;
  - includes JDK8- and JDK11-based builds;
- Predictable release schedule;
- LTS releases: last major release of the year.



https://www.graalvm.org/docs/release-notes/version-roadmap

Recent Updates

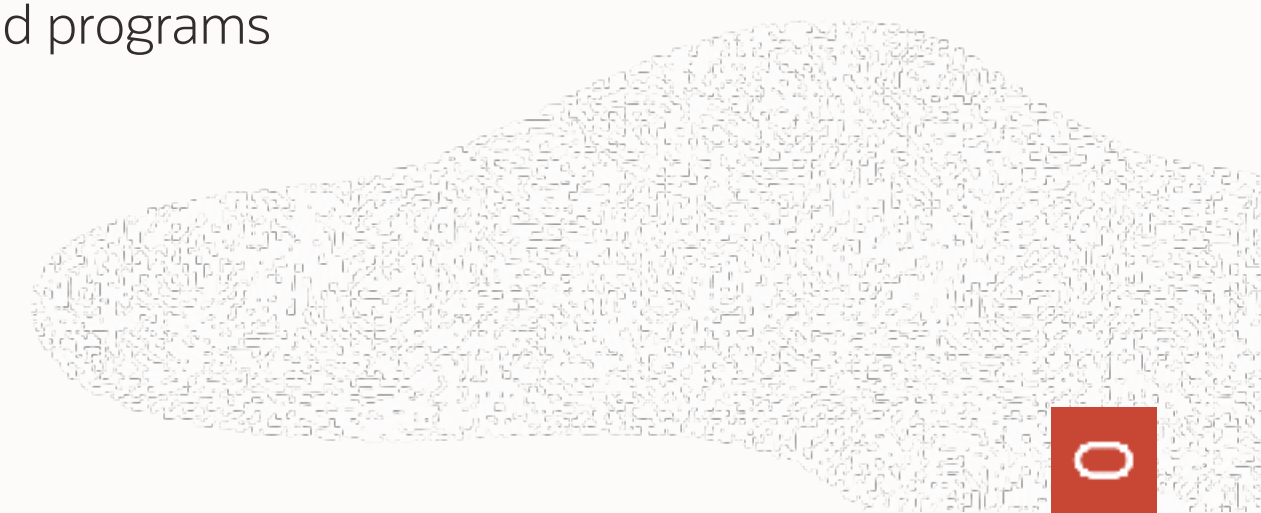
- ✅ JDK-11 based builds;
- ✅ Extended Windows support;
- ✅ New GC option in native image: try it with `-H:+UseLowLatencyGC`;
- ✅ WebAssembly support;
- ✅ Support for JFR in GraalVM VisualVM;
- ✅ VS Code plugin preview;
- ✅ Class Initialization changes in native images.

Contributions are welcome!

- How to contribute:
- Report an issue: https://github.com/oracle/graal/issues
- Submit your PR: https://github.com/oracle/graal/pulls
- Extend libraries support: graalvm.org/docs/reference-manual/compatibility/
- Contribute to documentation: https://www.graalvm.org/docs/

When to consider GraalVM

1. High performance for abstractions of any language
2. Low footprint ahead-of-time mode for JVM-based languages
3. Convenient language interoperability and polyglot tooling
4. Simple embeddability in native and managed programs



Where to Get Started

- Download:

  graalvm.org/downloads

- Follow updates:

  @GraalVM / #GraalVM

- Get help:
- graalvm.org/slack-invitation/
- graalvm-users @oss.oracle.com

Thank you!

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