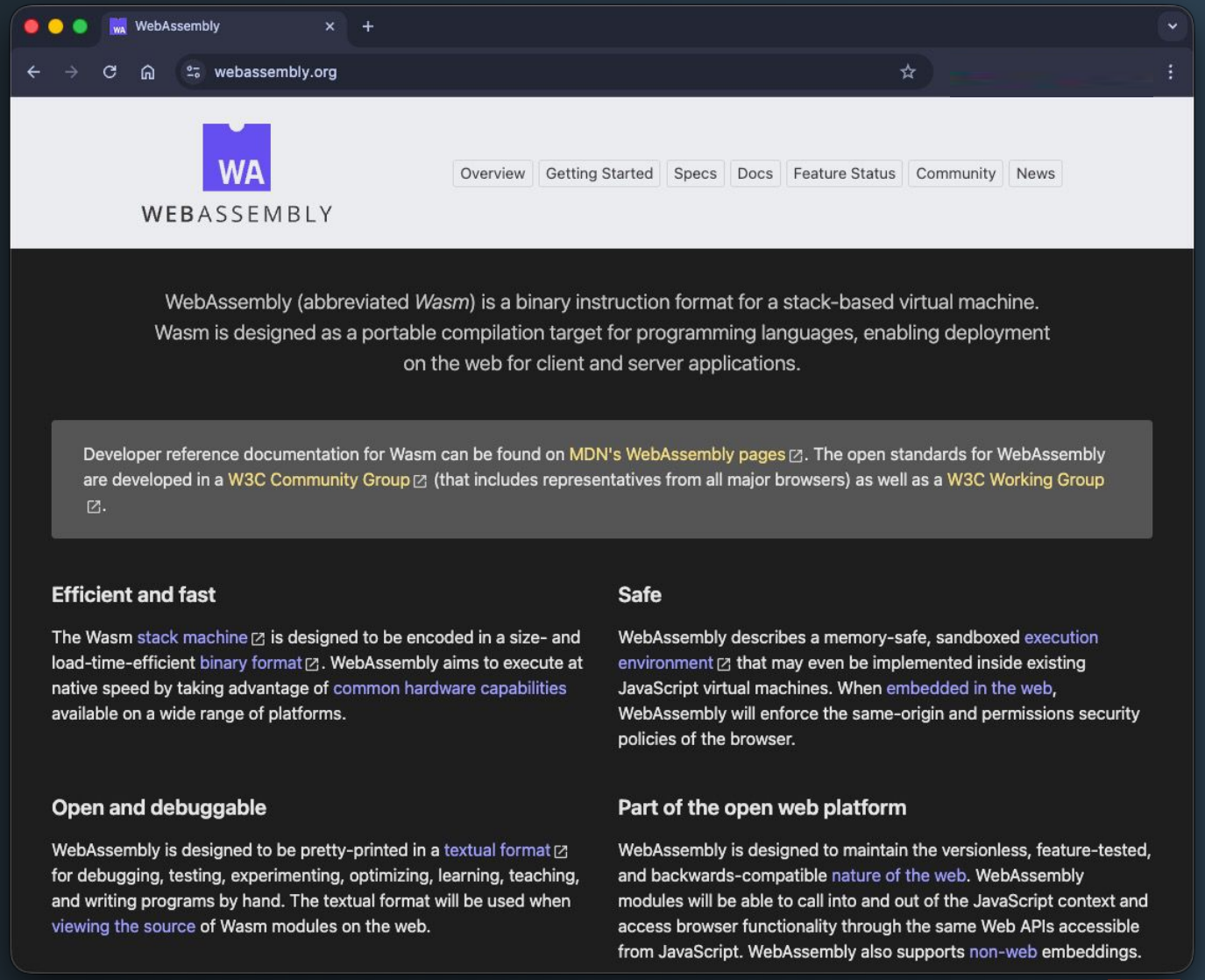
# GraalVM™ + Wasm

## Fast, Efficient, Portable Apps

**Fabio Niephaus (fniephaus.com)**
**Shaun Smith (@shaunmsmith)**

# WebAssembly (Wasm) in a nutshell

- Binary instruction format for a stack-based virtual machine
- Designed as a portable compilation target for programming languages
- Runs in modern web browsers and in server-side environments
- Can run in sandboxed environments for untrusted code execution



# WebAssembly in Action

Live Demo

# Why WebAssembly is interesting for us

- Portable native extensions and libraries
  - Integrate C, C++, Rust, and Go libraries using Wasm as an alternative to JNI or FFM API
- Bringing JVM languages into WebAssembly ecosystem
  - Turn JVM code into Wasm components that can interoperate with others from other languages
- Server-side Wasm
  - Cost-effective deployments on managed, Wasm-enabled clouds
  - Fast startup, low resource usage, compact packaging, minimize attack surface, …
- Wasm in the browser
  - Run JVM applications on the client, including mobile devices



# GraalWasm in Action

Live Demo

# Introducing GraalWasm

## Wasm for the JVM

Load and use WebAssembly modules and functions

## WebAssembly 2.0 Support

Full WebAssembly 2.0 compatibility and WASI feature extensions

## Portable Native Extensions

Integrate C, C++, Rust, and Go libraries using platform-independent Wasm (as an alternative to JNI and Panama)


## JavaScript Integration

Simplifies use of WebAssembly modules with JavaScript wrappers via GraalJS

## Fastest Wasm on the JVM

Graal JIT compiles WebAssembly for native code speed

## 100% Java

Written in pure Java with zero native dependencies

# How to embed GraalWasm and other Graal Languages on JDK 21+

Just add to your build

Maven™

pom.xml

```xml
<dependency>
    <groupId>org.graalvm.polyglot</groupId>
    <artifactId>polyglot</artifactId>
    <version>25.0.2</version>
</dependency>
<dependency>
    <groupId>org.graalvm.polyglot</groupId>
    <artifactId>wasm</artifactId> <!-- or js, python, ... -->
    <version>25.0.2</version>
    <type>pom</type>
</dependency>
```


Just specify the language

Gradle

build.gradle.kts

```
implementation("org.graalvm.polyglot:polyglot:25.0.2")
implementation("org.graalvm.polyglot:wasm:25.0.2")
```

# GraalWasm at a glance

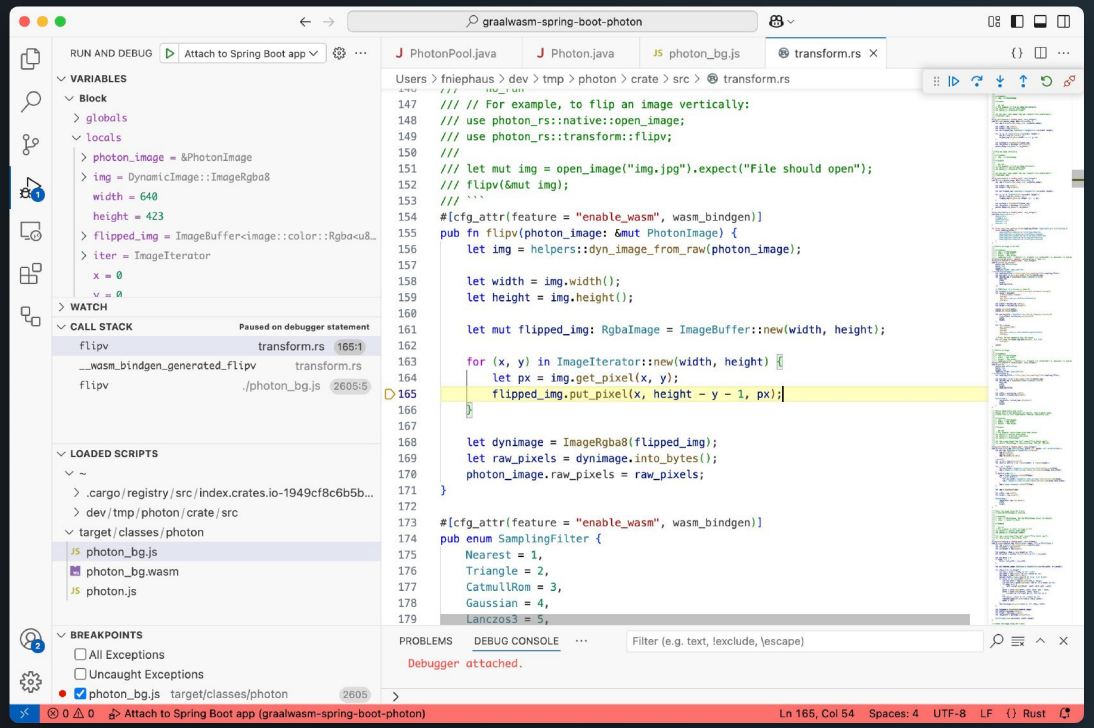
- Stable and ready for production
- Embeddable in JVM applications, Wasm, JS+Wasm, and Node standalone distributions available
- WebAssembly/ES module integration simplifies Java ↔ Wasm interop
- SIMD proposal and Dwarf debugging landed in latest 25.0 release
- WasmGC proposal soon in EA builds

| | Your browser | Chrome | Firefox | Safari | Node.js | Deno | GraalWasm |
|---|---|---|---|---|---|---|---|
| **Phase 5 - The Feature is Standardized** | | | | | | | |
| JS BigInt to Wasm i64 Integration | ✓ | 85 | 78 | 15 [k] | 15.0 | 1.1.2 | 21.3 |
| Branch Hinting | ? | [a] | [g] | 16 | [p] | [y] | × |
| Bulk Memory Operations | ✓ | 75 | 79 | 15 | 12.5 | 0.4 | 23.0 |
| Custom Text Format Annotations | ? | N/A | N/A | N/A | N/A | N/A | N/A |
| Extended Constant Expressions | ✓ | 114 | 112 | 17.4 | 21.0 | 1.33 | [ag] |
| Garbage Collection | ✓ | 119 | 120 | 18.2 | 22.0 | 1.38 | × |
| Multiple Memories | ✓ | 120 | 125 | × | 22.0 | 1.38 | [ai] |
| Multi-value | ✓ | 85 | 78 | 13.1 | 15.0 | 1.3.2 | 22.3 |
| Import/Export of Mutable Globals | ✓ | 74 | 61 | 12 | 12.0 | 0.1 | 21.3 |
| Reference Types | ✓ | 96 | 79 | 15 | 17.2 | 1.16 | 23.0 |
| Relaxed SIMD | ✓ | 114 | [i] | [m] | 21.0 | 1.33 | × |
| Non-trapping float-to-int Conversions | ✓ | 75 | 64 | 15 | 12.5 | 0.4 | 22.3 |
| Sign-extension Operators | ✓ | 74 | 62 | 14.1 [n] | 12.0 | 0.1 | 22.3 |
| Fixed-width SIMD | ✓ | 91 | 89 | 16.4 | 16.4 | 1.9 | 24.1 |
| Tail Call | ✓ | 112 | 121 | 18.2 | 20.0 | 1.32 | × |
| Typed Function References | ✓ | 119 | 120 | 18 | 22.0 | 1.38 | × |
| **Phase 4 - Standardize the Feature** | | | | | | | |

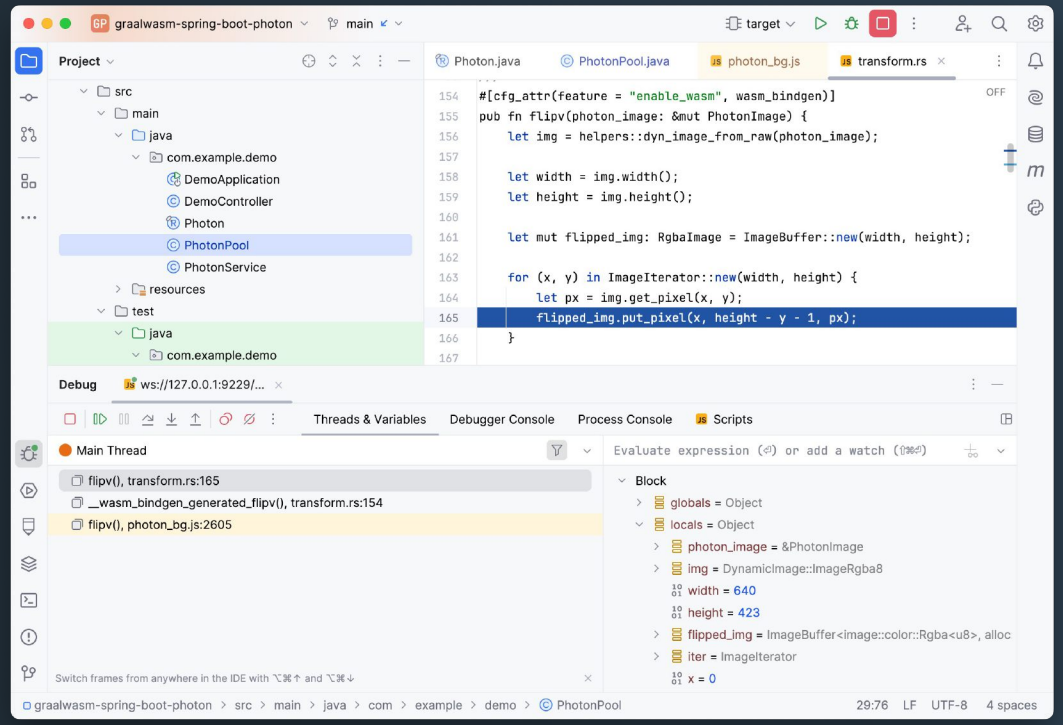
webassembly.org/features/

# Debugging Rust compiled to Wasm embedded in Spring Boot

## using VS Code via Debug Adapter Protocol



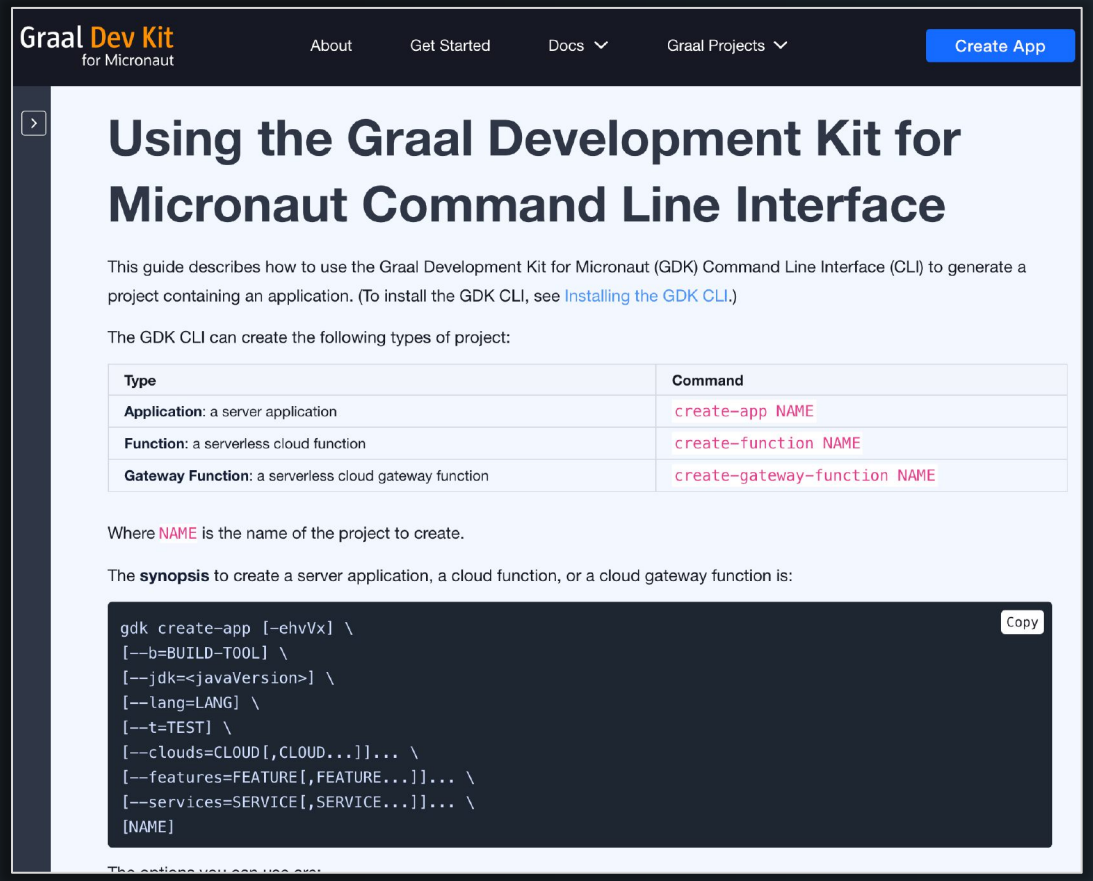

## using IntelliJ IDEA via Chrome Inspector Protocol

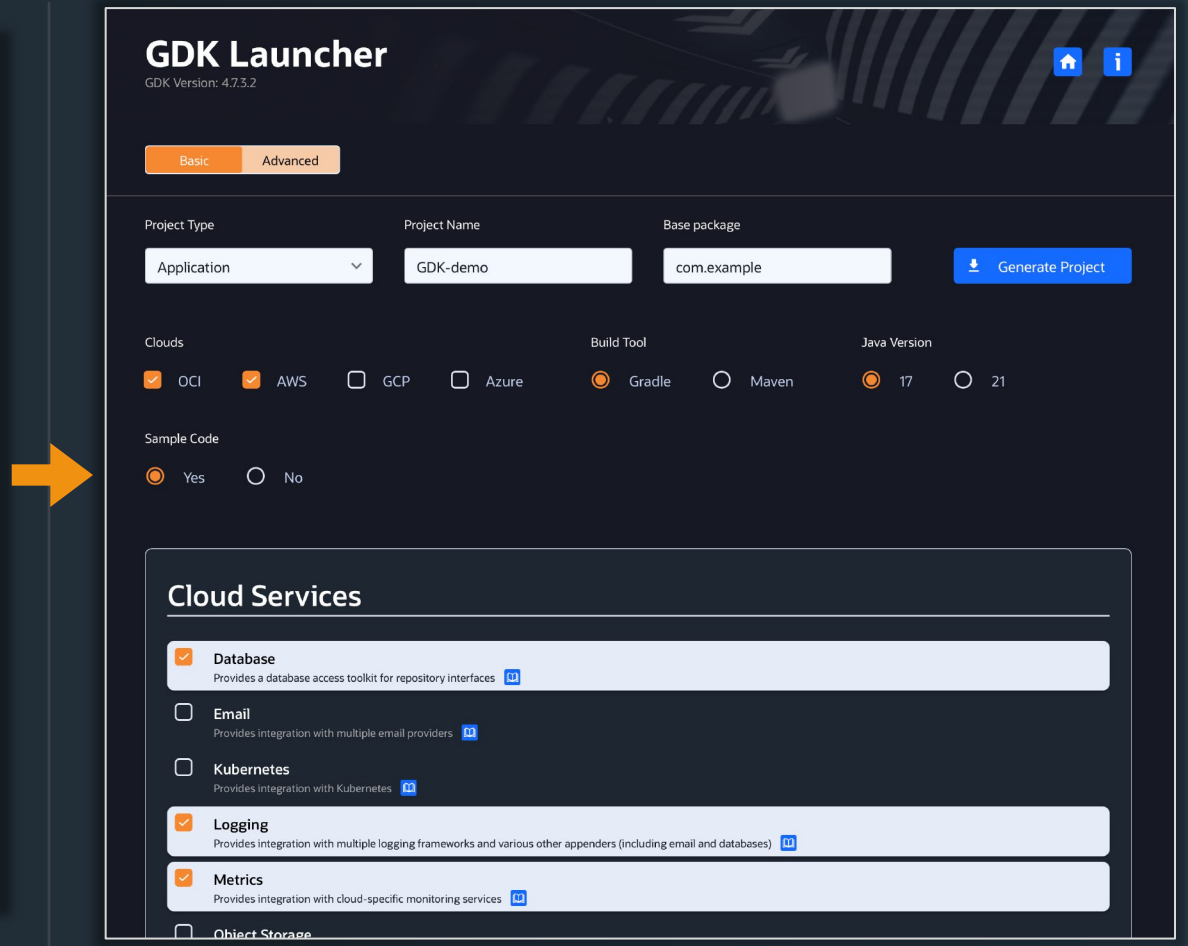


# GraalVM™ Web Image in Action

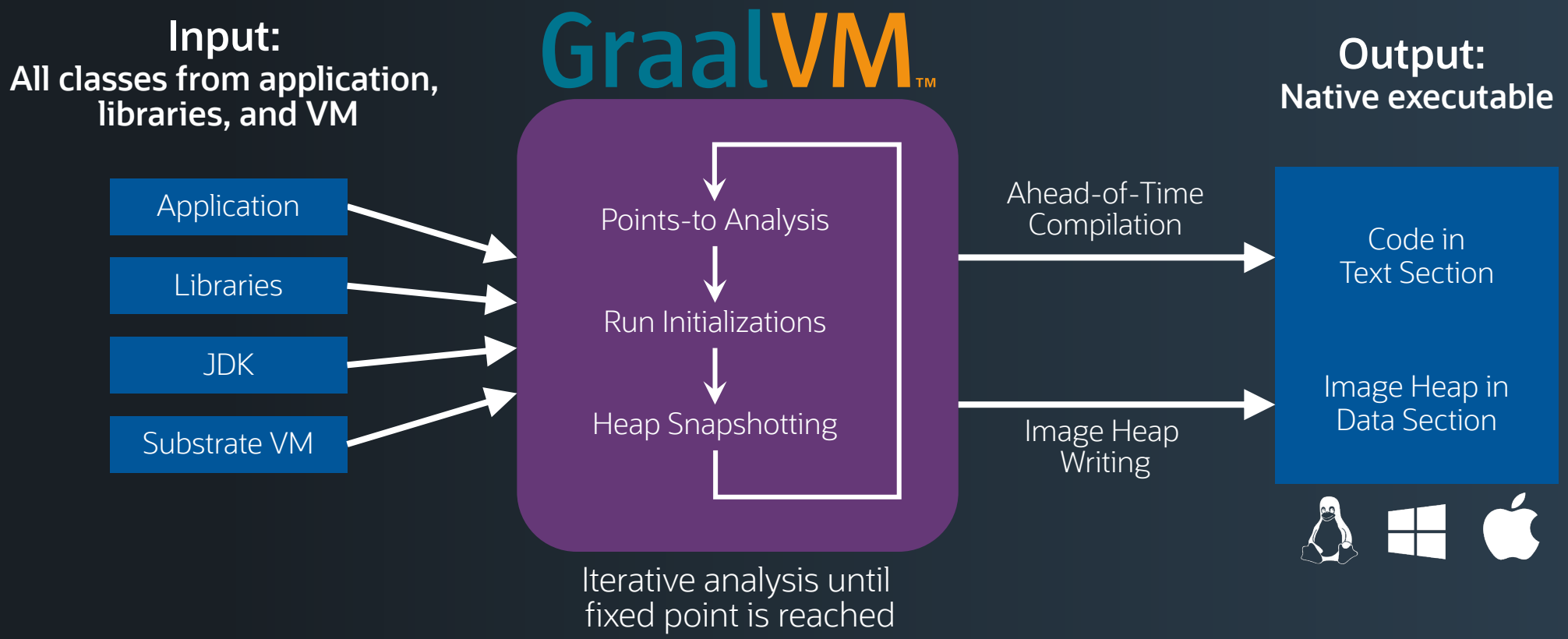
Live Demo

# From CLI tool to client-side web application

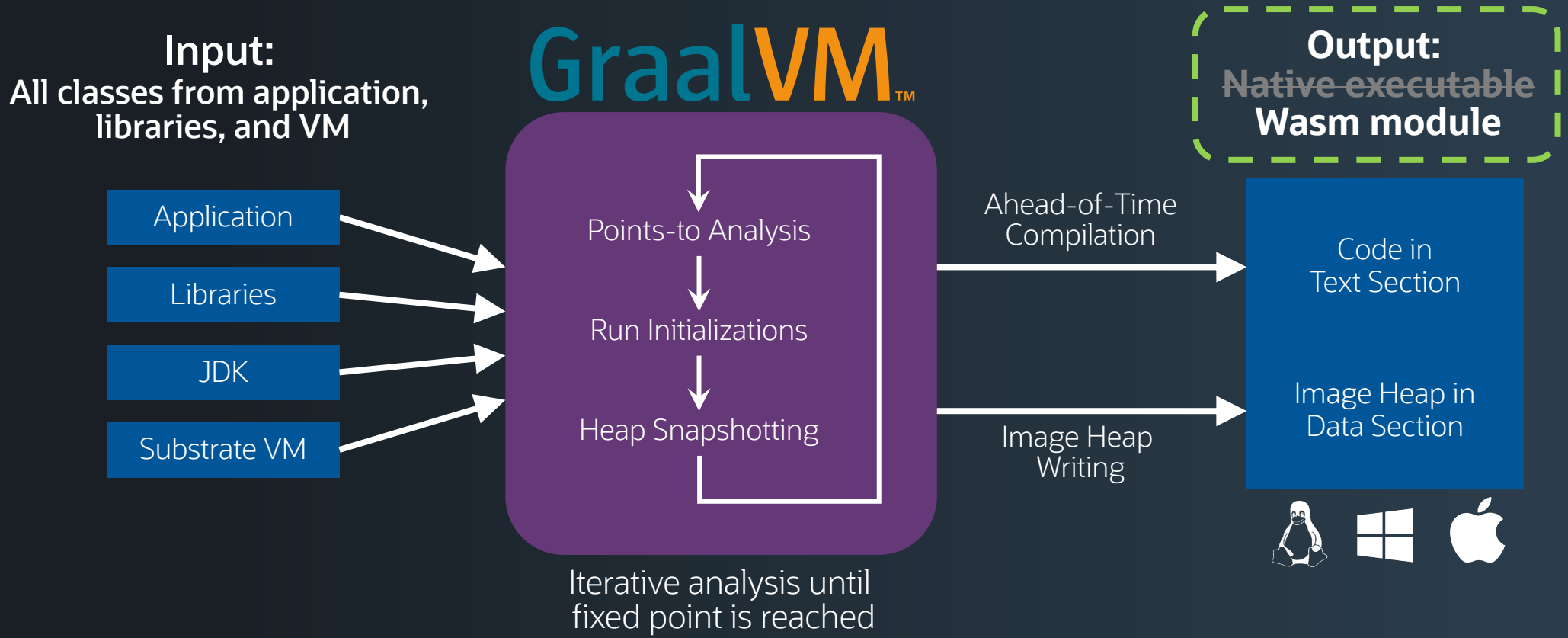


# GraalVM Native Image Compilation



# GraalVM ~~Native~~ Web Image Compilation



# GraalVM Web Image at a glance

- Graal compiler targets WasmGC in a JavaScript embedding
  - `helloworld` program ~1MB in size, before `wasm-opt` or compression
- Programs can include arbitrary JDK code, which is substituted appropriately where necessary (for example for filesystem access)
  - Support for threading, networking, graphics, and others are still missing
- Not targeting the Component Model and System Interface (WASI) yet
- Developed as part of the open-source GraalVM Community Edition

# Web Image API Preview for JavaScript Interoperability

## Package org.graalvm.webimage.api

`package org.graalvm.webimage.api`

This package provides an interface between Java code and the embedding JavaScript code.

This functionality is limited to the WebAssembly backend for Native Image.

Any functionality specified here is experimental, subject to change, and may not fully work yet.

**Since:**

25.0

```
<dependency>
    <groupId>org.graalvm.sdk</groupId>
    <artifactId>webimage-preview</artifactId>
    <version>25.0.2</version>
</dependency>
```

**All Classes and Interfaces** | **Classes** | **Exception Classes** | **Annotation Interfaces**

| Class | Description |
|---|---|
| JS | Replaces the body of a Java method with JavaScript code. |
| JS.Code | A snippet of JavaScript code that must be included in the image. |
| JS.Code.Include | Designates the path to the JavaScript file with the code that must be included in the image. |
| JS.Code.Include.Group | |
| JS.Coerce | When this annotation is used together with the JS annotation, the arguments and return values of the respective method undergo implicit Java-to-JavaScript and JavaScript-to-Java conversions. |
| JS.Export | Denotes that the annotated Java class should be exported from the VM class. |
| JS.Import | Denotes that the annotated class represents a JavaScript class from the global scope. |

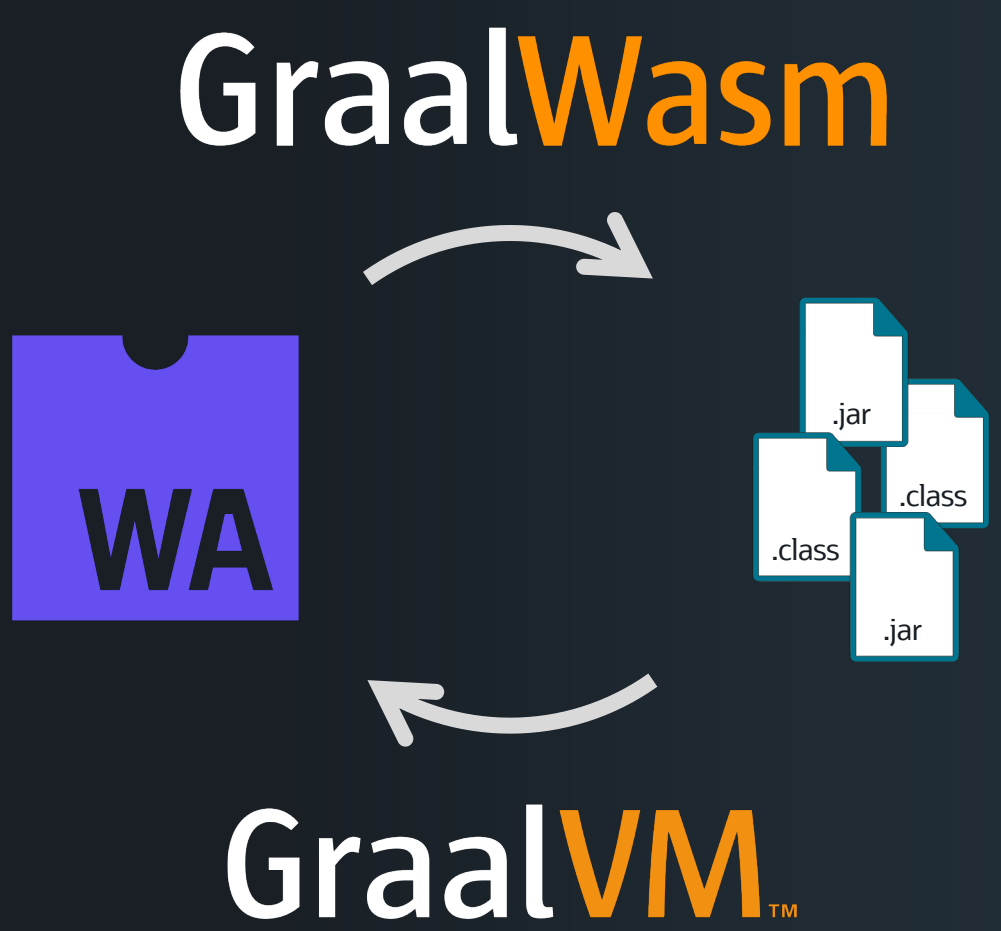
# How to try it out today

1. Install the Oracle GraalVM 25 release
   For example, using SDKMAN!: `sdk install java 25.0.2-graal`
2. Make sure the Binaryen toolchain is on the system path
   For example, using Homebrew: `brew install binaryen`
3. Compile JVM bytecode to Wasm using the `--tool:svm-wasm` option:

```
$ native-image --tool:svm-wasm HelloWasm
========================================================================
GraalVM Native Image: Generating 'hellowasm' (executable)...
========================================================================
...
Build artifacts:
/Users/janedoe/dev/hellowasm.js (executable)
/Users/janedoe/dev/hellowasm.js.wasm (executable)
/Users/janedoe/dev/hellowasm.js.wat (build_info)
========================================================================
Finished generating 'hellowasm' in 5.3s.
```

# Conclusion

# The GraalWasm runtime and GraalVM Web Image




- GraalWasm makes it easy to extend JVM applications with portable Wasm modules
- GraalJS allows use of JavaScript bindings for Java ↔ Wasm interactions
- Oracle GraalVM 25 can generate WasmGC now!

  *(experimental but already useful)*
- Give them a try, provide feedback, and contribute!

# The GraalWasm runtime and GraalVM Web Image

*GraalWasm, GraalJS, GraalPy demos on GitHub:*

*`javac` on WebAssembly demo:*