Continuous Monitoring with JDK Flight Recorder

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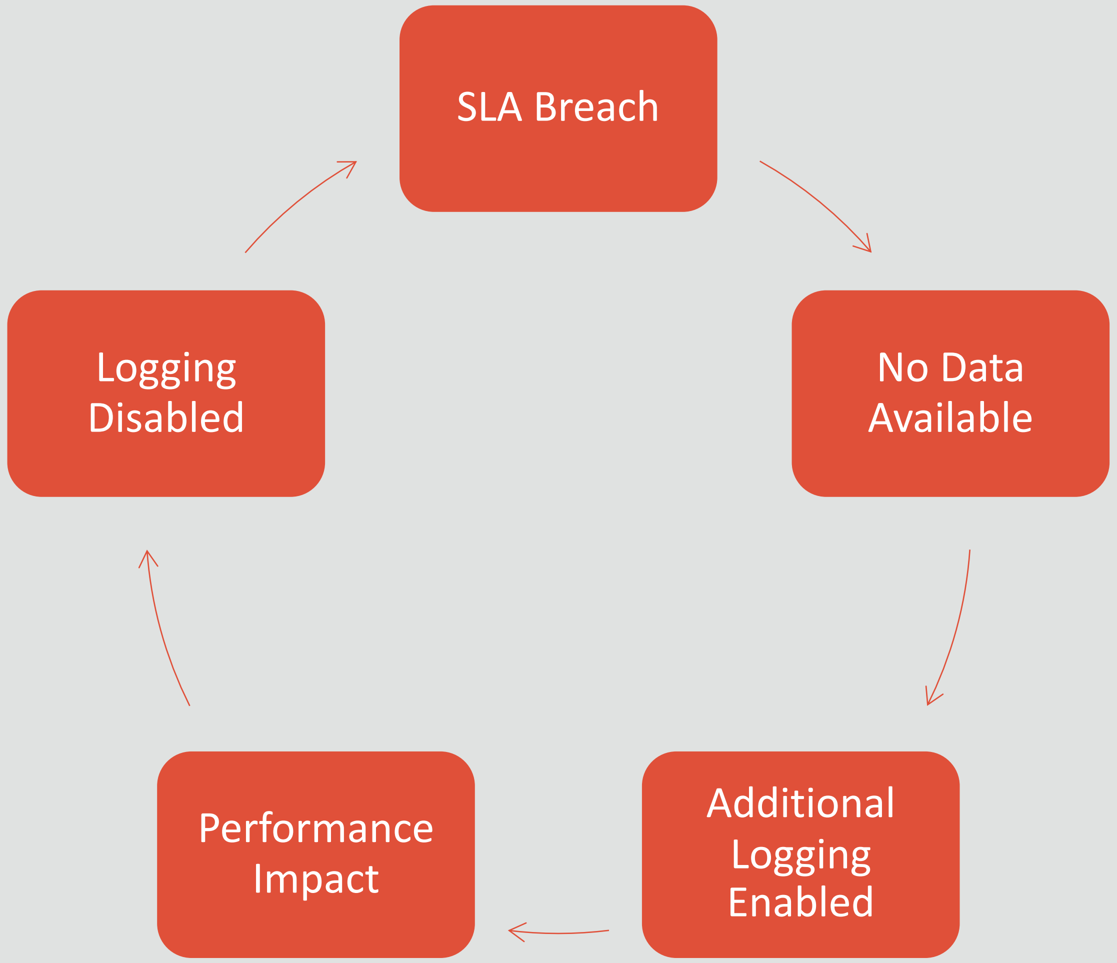
Safe Harbor


SLA Breach
No Data Available
Additional Logging Enabled
Performance Impact
Logging Disabled

FLIGHT
RECORDER
DO NOT
OPEN

Agenda

Overview: What is JDK Flight Recorder (JFR)?

JFR Events

Designed for use **in Production**

Using JFR

Future Work

What is JDK Flight Recorder?

JFR In a Nutshell

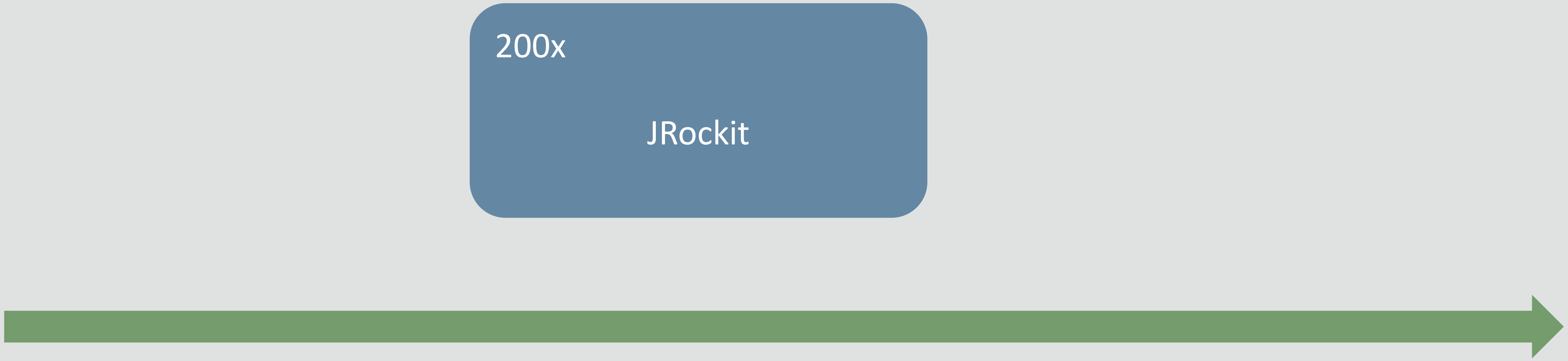
JFR = JDK Flight Recorder
Available **now**, in a JDK near you!

An **event based** tracing framework
Built **into** the Java Runtime
Extremely low overhead, suitable for **production** environments
Allows **correlation** of data from different subsystems/software layers
With **APIs** for

- Producing application level events
- Consuming event streams

Demo: Simple Monitoring

History



History

JDK 7u4 - 2012

Initial Hotspot version
(Oracle internal use only)

JDK 9 – 2017

Public APIs for creating and consuming data

JDK 11 – 2018

Open Sourced!

JFR Events

The Anatomy of a JFR Event

Event ID

Timestamp (CPU ticks)

Duration (CPU ticks)

Thread ID

StackTrace ID

Event Specific Payload

The Anatomy of a JFR Event

```java
import jdk.jfr.Event;

class MyEvent extends Event {
}
```

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```

```
void doThing() {
    // do important stuff here
}
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The Anatomy of a JFR Event

```
import jdk.jfr.Event;

class MyEvent extends Event {
}
```

```
void doThing() {
    MyEvent e = new MyEvent();

    e.begin();

    // do important stuff here

    e.end();
    e.commit();
}
```

The Anatomy of a JFR Event

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The Anatomy of a JFR Event

```
import jdk.jfr.Event;

class MyEvent extends Event {
}
```

```
void doThing() {
    MyEvent e = new MyEvent();

    e.begin();

    // do important stuff here

    e.end();
    e.commit(); // implicit end()
}
```

commit **// implicit end()**

The Anatomy of a JFR Event

```
import jdk.jfr.Event;

class MyEvent extends Event {
}
```

```
void doThing() {
    MyEvent e = new MyEvent();

    e.begin();

    // do important stuff here

    e.commit();
}
```

The Anatomy of a JFR Event

```java
import jdk.jfr.Event;

class MyEvent extends Event {
    String message;
    int value;
}
```

```java
void doThing() {
    MyEvent e = new MyEvent();

    e.message = “Hello”;
    e.value = 4711;

    e.begin();

    // do important stuff here

    e.commit();
}
```

The Anatomy of a JFR Event

```
import jdk.jfr.Event;
import jdk.jfr.Label;
import jdk.jfr.Name;

@Name(“com.oracle.foo.CoolThing”)
@Label(“Cool Thing”)
class MyEvent extends Event {
    @Label(“Message”)
    String message;

    @Label(“Value”)
    int value;
}
```

```
void doThing() {
    MyEvent e = new MyEvent();

    e.message = “Hello”;
    e.value = 4711;

    e.begin();

    // do important stuff here

    e.commit();
}
```

JFR Annotations

Annotation	Description	Default
@Name	Set explicit name. Recommended for all event classes. Recommended format: [org|com|net].[organization|product].EventName	Full class name, e.g.: com.coolproj.CoolEvent com.oracle.internal.bar$MyEvent
@Label	Human readable name	N/A
@Description	More detailed description (~1-2 sentences)	N/A
@Category	Category to which this event logically belongs	N/A
@Threshold	Default minimum duration for the event to be included in the recording	0 ns
@Enabled	Controls whether the event should be enabled by default	true (enabled)
@StackTrace	Controls whether the stack trace should be included in the event by default	true (enabled/included)

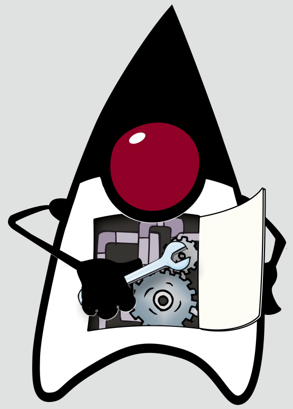
Note: List is not exhaustive, see jdk.jfr.* javadoc for more annotations and information

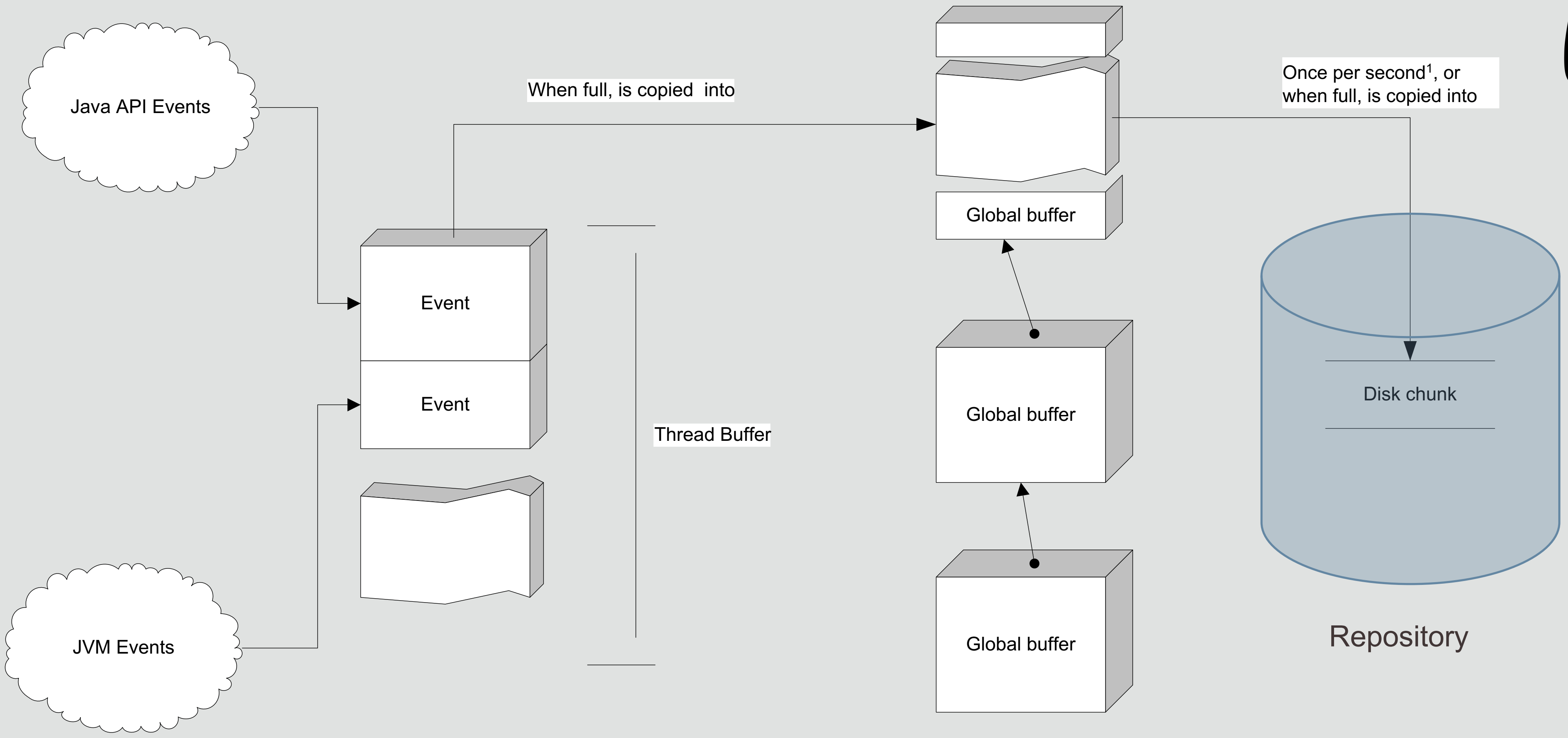
Events Generated by the Java Runtime

~140 event types in Java Runtime (and growing)

Examples of events in Java Runtime	
Category	Event
Environment	Command line JDK Version Information OS CPU
Java Execution	I/O: File & Network Thread Sampling
JVM Operations	Class Loading GC JIT Compiler

Behind the Scenes: Event Data Flow





[1] with event streaming

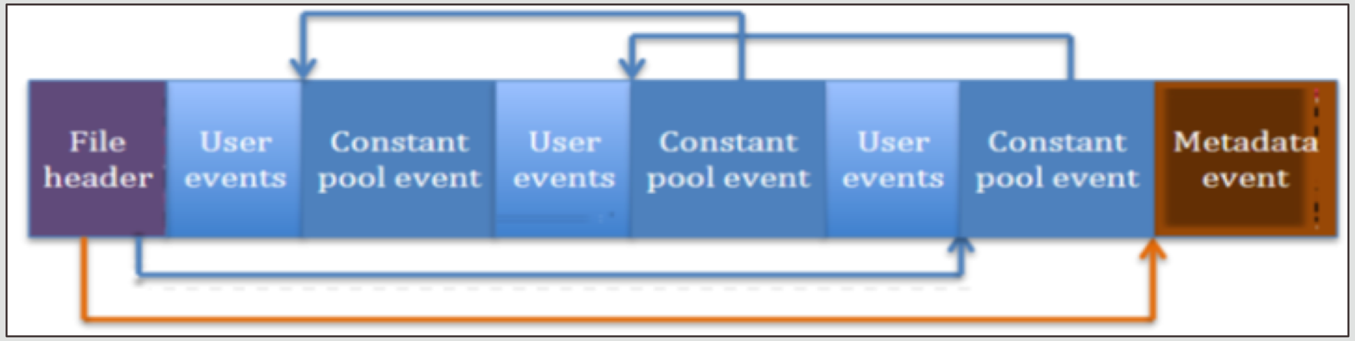
The JFR File Format

Compact binary format

- Varint 128 LEB encoding (JDK 9+)
- Self-describing

Metadata information describing how to interpret events

- Data necessary for resolving the preceding events



Event Filtering

Events can be filtered by

- Type / Name
- Duration

Event Correlation

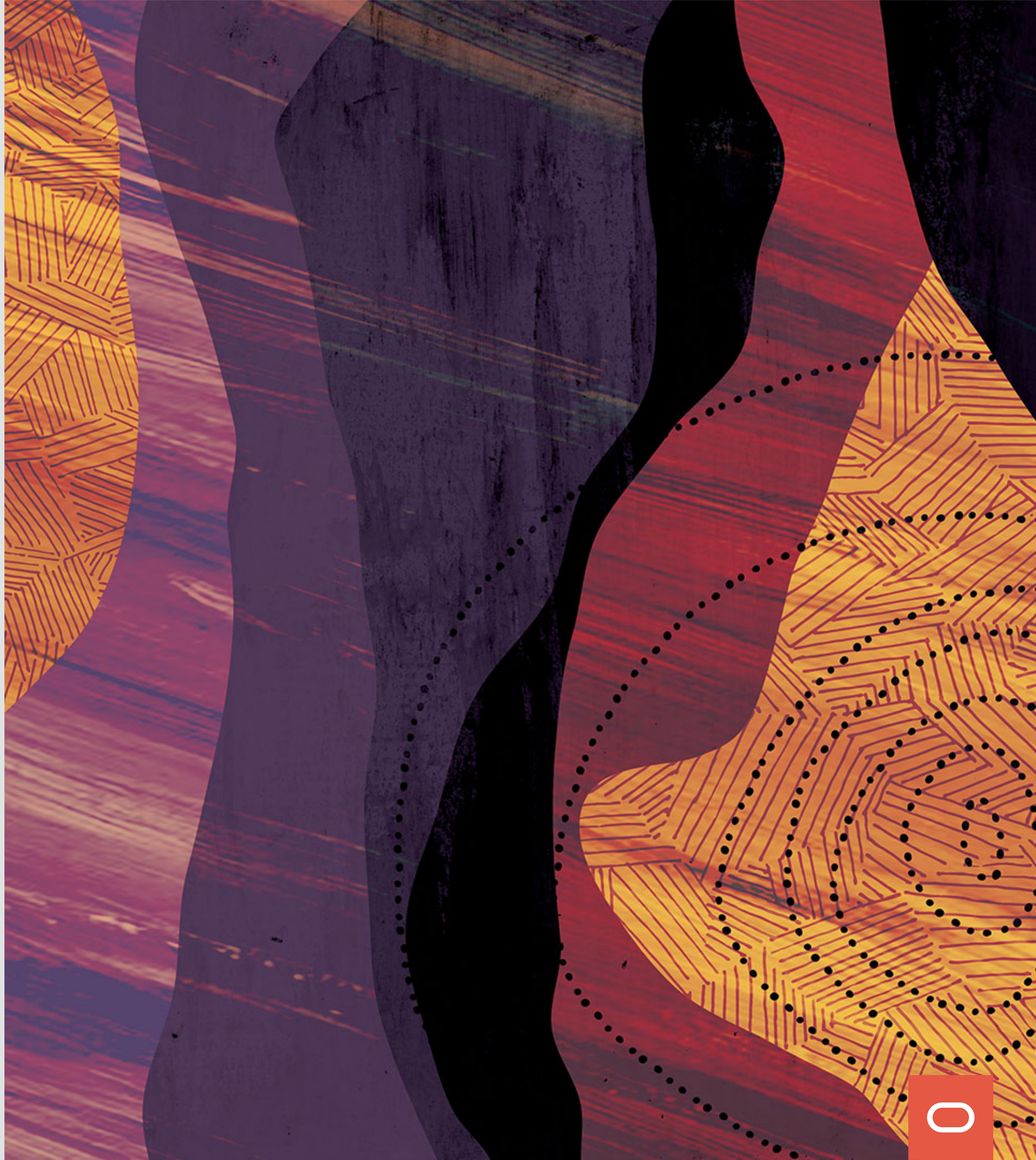
Events from **multiple levels** of the stack in the same stream

- Application, Java Runtime libraries, JVM, OS

Enables powerful in-depth analysis

- Start on high level, go as deep as needed

Designed for Use in Production



Designed for Production

Designed from the start **for use in production**

- **Extremely** low overhead
- Piggy-backs on JVM operations
- Events generated into thread-local buffers

Default on in Oracle Fusion applications

Several large companies use JFR **extensively**

But what about performance…?

But what about performance…?

```
void doThing() {
    MyEvent e = new MyEvent();

    e.begin();

    // do important stuff here

    e.commit();
}
```

But what about performance…?

```
// Warning: pseudo-code – this is NOT what commit() actually looks like!!
void Event::commit() {
    if (isEnabled()) {
        // now() reads CPU clock register
        long duration = now() – startTime;
        if (duration > THRESHOLD) {
            if (shouldCommit()) {
                // Cheap – Thread local writes
                actuallyCommit();
            }
        }
    }
}
```

But what about performance…?

```
void doThing() {
    MyEvent e = new MyEvent();

    e.begin();


    // do important stuff here


    e.commit();
}
```

But what about performance...?

```
void doThing() {
    MyEvent e = new MyEvent();

    e.startTime = now();


    // do important stuff here


    e.commit();
}
```

But what about performance…?

```
void doThing() {
    MyEvent e = new MyEvent();

    e.startTime = <JVM intrinsic>;


    // do important stuff here


    e.commit();
}
```

But what about performance...?

```
void doThing() {
    MyEvent e = new MyEvent();

    e.startTime = <JVM intrinsic>;


    // do important stuff here


    if (e.isEnabled()) {
        // perform additional checks and possibly call actuallyCommit()
    }
}
```

But what about performance…?

```
void doThing() {
    MyEvent e = new MyEvent();

    e.startTime = <JVM intrinsic>;


    // do important stuff here


    if (false) {
        // perform additional checks and possibly call actuallyCommit()
    }
}
```

But what about performance...?

```
void doThing() {
    MyEvent e = new MyEvent();

    e.startTime = <JVM intrinsic>;


    // do important stuff here
}
```

But what about performance...?

```
void doThing() {
    MyEvent e = new MyEvent();

    long startTime = <JVM intrinsic>;


    // do important stuff here
}
```

But what about performance...?

```
void doThing() {
    long startTime = <JVM intrinsic>;

    // do important stuff here
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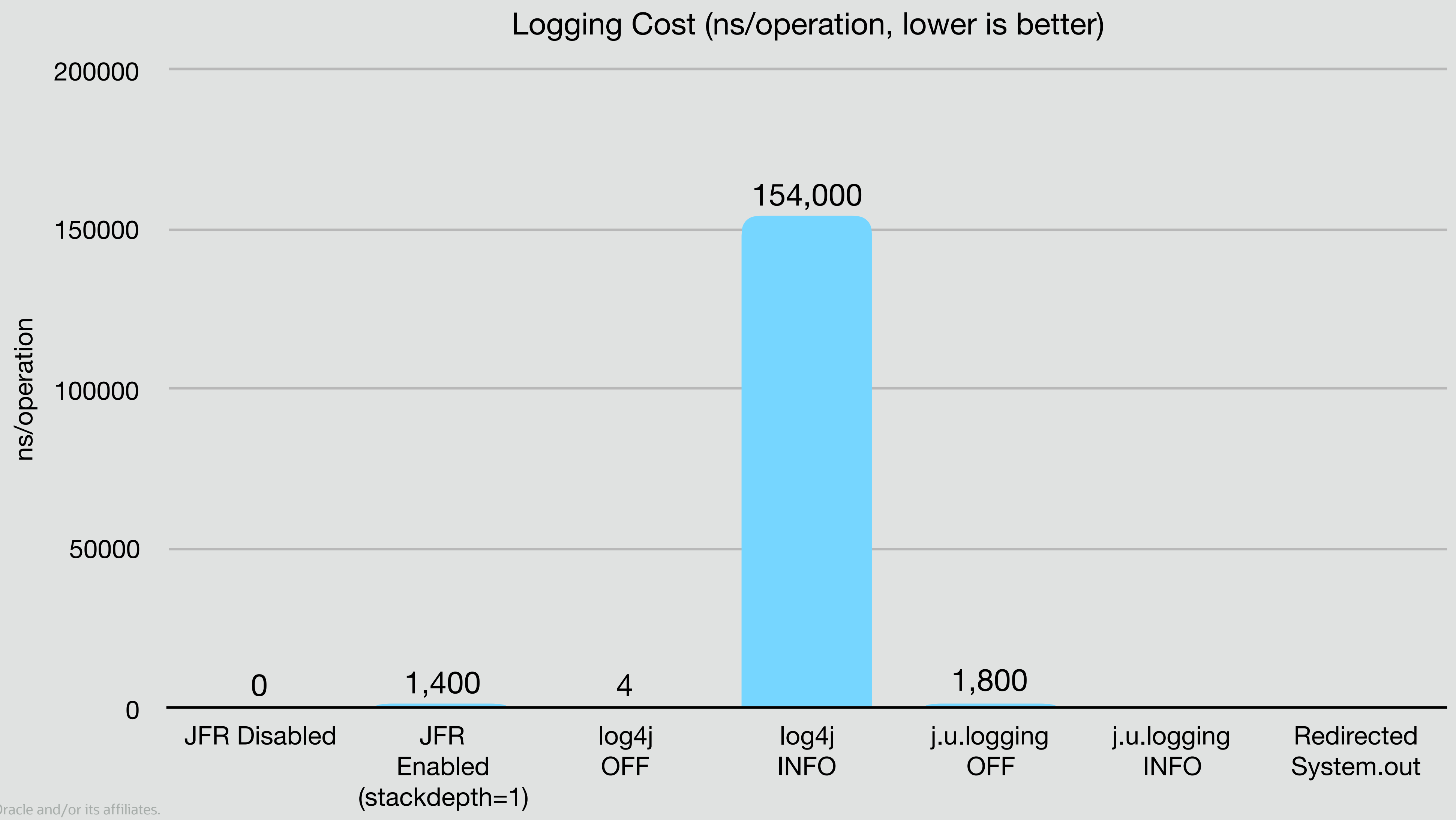
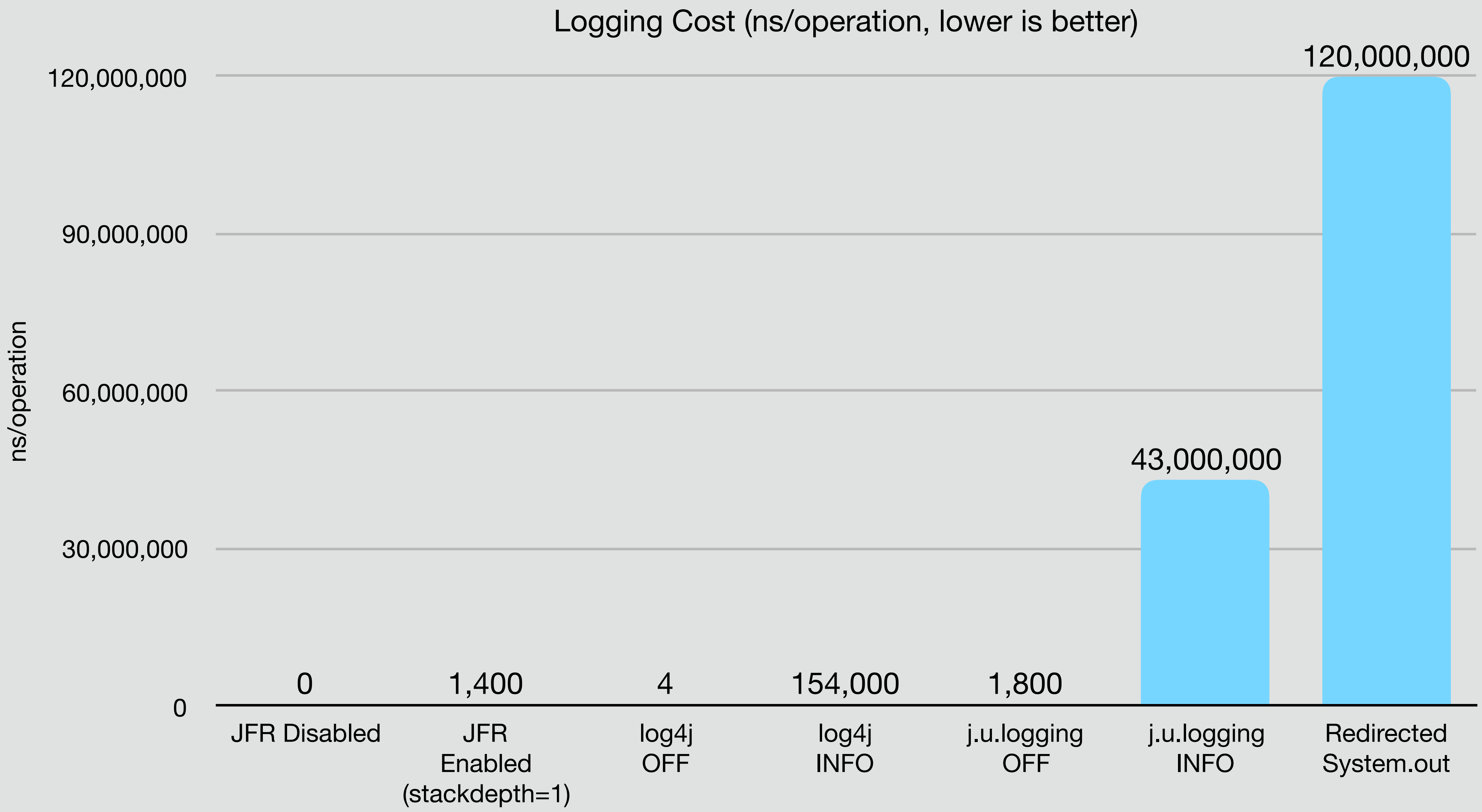
Performance (YMMV)



Performance (YMMV)



Performance Considerations

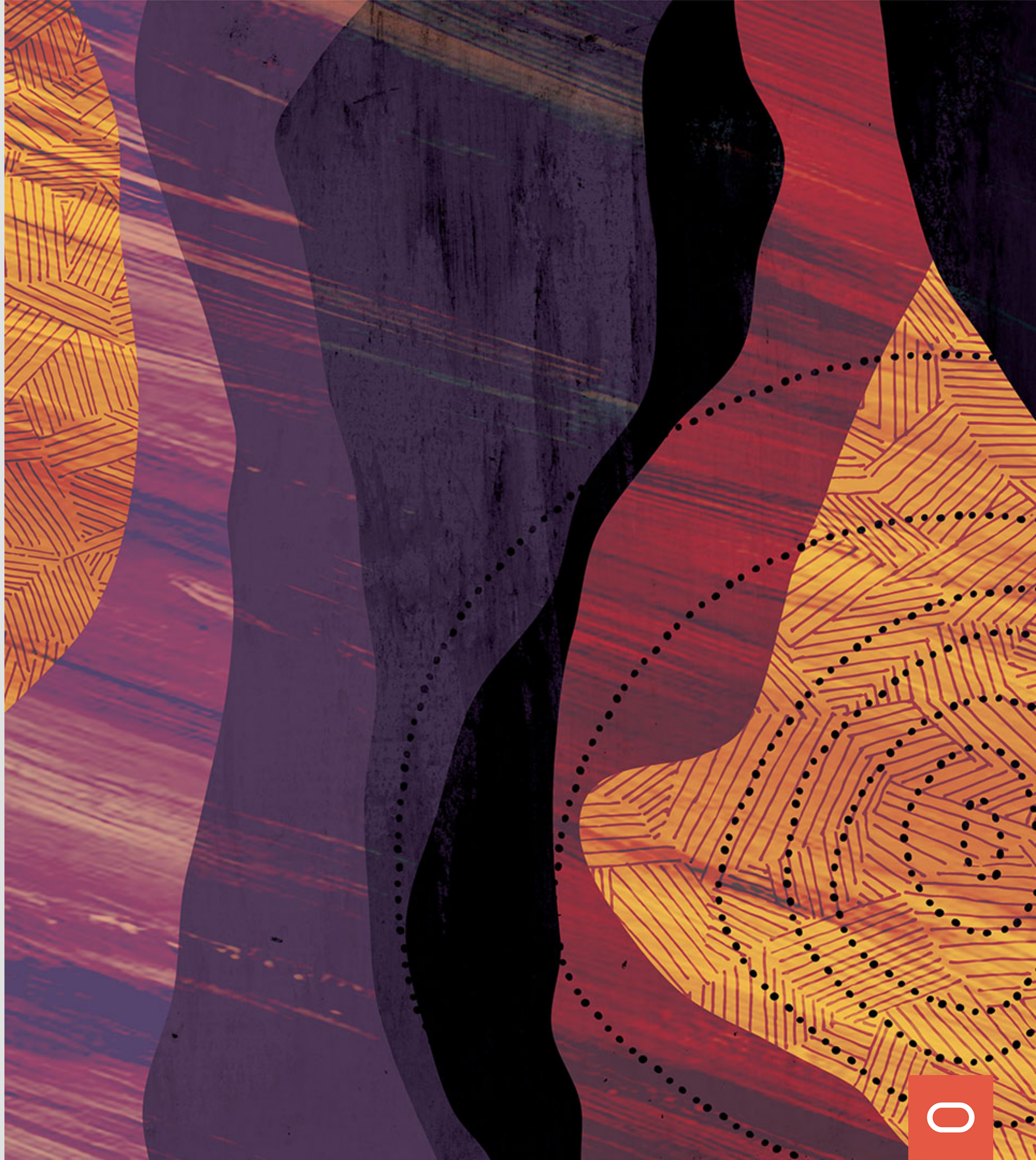
Default configuration designed to have **less than 1%** overhead

- Other configurations can have more overhead

Stack depth (default: 64)

- Deep call stacks can impact performance

Using JFR



Using JFR (JDK 11+)

```
# Start a recording
java -XX:StartFlightRecording ...

# Start a recording, and store it to file
java -XX:StartFlightRecording:filename=/tmp/foo.jfr ...

# Enable recording in an already running VM (pid 4711)
# jcmd <pid | main class name> JFR.start [options]
jcmd 4711 JFR.start     OR     jcmd MyApplication JFR.start

# Dump a recording from running VM (pid 4711), at most 50MB of data
jcmd 4711 JFR.dump maxsize=50MB
```

Demo: Looking at JFR recordings

Using bin/jfr

```
# Print summary of recording
jfr summary myrecording.jfr

# Print events
jfr print myrecording.jfr

# Print events in JSON format
jfr print --json myrecording.jfr

# Print GC related events
jfr print --categories "GC" myrecording.jfr
```

JFR: Use Cases

- Production
  - Troubleshooting / Root-cause analysis
- Development
  - Optimizing hot methods
  - Allocation profiling
- Testing
  - Regression testing/monitoring execution profile changes
    - Allocation, Lock Contention, …

Future Work

Future Work

Consuming Events **Today**

To access JFR data a recording must be

1. Started
2. Stopped
3. Dumped to a separate file

Reasonable for profiling

Not friendly to monitoring/continuous consumption

- Copying data out from disk repository creates overhead
- Recordings have same (redundant) information

Enter: JFR Event Streaming (JEP 349)

Goal: Make it trivial to consume and act on events **continuously**

API to read data directly from the disk repository

- Even when recordings are in progress
- Data flushed to repository continuously
  - Default: once a second

Simple Event Stream Consumer

```
try (var rs = new RecordingStream()) {
    rs.enable("jdk.JavaMonitorEnter").withThreshold(Duration.ofMillis(10));
    rs.onEvent("jdk.JavaMonitorEnter", event -> {
        System.out.println(event.getClass("monitorClass"));
    });

    rs.start();
}
```

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        System.out.println(event.getClass("monitorClass"));
    });

    rs.start(); // “Blocking” call, will process events until stream ends/is closed
}
```

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    rs.enable("jdk.JavaMonitorEnter").withThreshold(Duration.ofMillis(10));
    rs.onEvent("jdk.JavaMonitorEnter", event -> {
        System.out.println(event.getClass("monitorClass"));
    });
    rs.enable("jdk.CPULoad").withPeriod(Duration.ofSeconds(1));
    rs.onEvent("jdk.CPULoad", event -> {
        System.out.println(event.getFloat("machineTotal"));
    });

    rs.start();
}
```

Demo: Continuous Monitoring

Other

Access event stream over JMX

Additional JDK events

OpenJDK Project “Loom”: Fibers Support

Improve command line configuration

Event throttling – Record every n:th event

Deep tracing – Record **Everything** for a short period

JFR Integration Opportunities

Development

- IntelliJ, VisualVM, …

Monitoring

- APM, …

Frameworks

- Kafka, RxJava, Open Tracing, …

Life on the (not so) Bleeding Edge

Please **help us** by trying out the new features!

JDK 14 Early-Access builds: http://jdk.java.net/14/
Feedback: hotspot-jfr-dev@openjdk.java.net

Summary

JFR = JDK Flight Recorder
Available **now**, in a JDK near you!

An **event based** tracing framework
Built **into** the Java Runtime
Extremely low overhead, suitable for **production** environments
Allows **correlation** of data from different subsystems/software layers
With **APIs** for
- Producing application level events
- Consuming event streams

Thank You!

Questions?

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