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Java Mission Control & Java Flight Recorder in JDK 9

A Sneak Peek

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Java Product Group
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@hirt

Java Your Next (Cloud)

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Program Agenda

1. Introduction to JFR/JMC
2. Java Flight Recorder in JDK 9
3. Java Mission Control 6
4. Summary
5. Q&A

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Introduction to JFR/JMC

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Production Time Profiling and Diagnostics

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Production Time Profiling and Diagnostics

"The big challenge is no longer really performance. The big challenge is profiling, and especially profiling in production."

- Tony Printezis, JVM engineer, Twitter
(Devoxx 2015, "Life of a Twitter JVM Engineer", 49:49)

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“Once more @javamissionctrl is saving my day! "
- Michael Nitschinger, SDK Engineer, Couchbase

"Java Mission Control is the best profiler by far.“
- T Jake Luciani, PMC Cassandra

“Java Mission Control is my current favourite profiler for the Oracle JVM."
- Nitsan Wakart, Azul

"JMC not only saves time trying to resolve performance issues and bugs, it can give you a detailed view on your application you cannot get with other commercial profilers"
- Peter Lawrey, CEO, Chronicle Software

“… Our real-time messaging products can publish millions of messages a second to many thousands of connections - only JMC can keep up with this level of load."
- Phil Aston, Product Architect, Push Technology

"For the record: Java Mission Control is the best profiler ever, I use it daily, and so should you"
- Marcus Lagergren, Lead Architect, Nasdaq

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"I am ACS engineer since 2008, delivering local Middleware support to several customers. Since I started to work with Java/JRockit Mission Control, it became a key tool for my work, helping me to troubleshooting, identifying root causes and bottlenecks, and also for doing proactive follow up services to customers. Without it, I would be blind."

- Iratxe Etxebarria, Oracle (ACS)

"In Fusion we create hundreds of thousands of Flight Recordings, and we can figure out 95% of the issues using nothing but the recordings."

- Joe Albowicz, Oracle (Fusion Application Development)

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“when someone sends me a screenshot of Java Mission Control I can't help but feel the need to respond w/ "in what year was this taken...90s? "”
- @autoletics

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Definitions

- Java Flight Recorder (JFR)
  - Highly Efficient Data Recorder, built into the Java Runtime
- Java Mission Control (JMC)
  - The client application
  - Visualization of Flight Recordings
  - JMX console
  - Heap dump analyzer
  - …

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Flight Recorder Helps You To...

- Resolve problems faster
- Find bottlenecks in applications
- Do post mortem analysis, even from crash dumps

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Flight Recorder Performance

Extremely Low Overhead

- Built into the JVM/JDK, by the people developing the JVM
- High performance flight recording engine and high performance data collection
  - Access to data already collected in the runtime
  - Thread local native buffers
  - Invariant TSC for time stamping
  - Method profiling data even from outside safe-points
  - Faster and more accurate allocation profiling (scalarization not undone by profiler)

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JMC & JFR Demo

JDK 8, JMC 5.5

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Improvements

- New **Supported** APIs
  - Easier to use
  - Moved namespace from oracle.jrockit.* to jdk.jfr.*
    - Not compatible with old unsupported APIs
  - Modularized
- Performance enhancements
  - Compressed Integers
  - Smarter Event Classes
    - Event reference does not escape into the generated code
    - No event object reuse required

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Improvements

Continued

- Can emit data to disk even in bad situations
  - Useful in fatal situation, e.g. OOM or crash
- New Events
  - More detailed safe point information
  - More detailed code cache information
  - New PLAB events
  - New compiler events for detailed inlining information
  - New G1 specific information for better visualization of region states
  - Module events (loaded module, full transitive closure)
  - NativeLibrary (load, periodic event, by default each chunk)

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Supported API for Custom Events

- Supported!
- Easy to correlate with events from the runtime
- Piggy back on the whole JFR infrastructure (jcmd, jmc, commandline)
- High performance
  - High precision, cheap timestamping
  - Cheap stack traces
  - Binary, compact data
- Self describing, easy to consume

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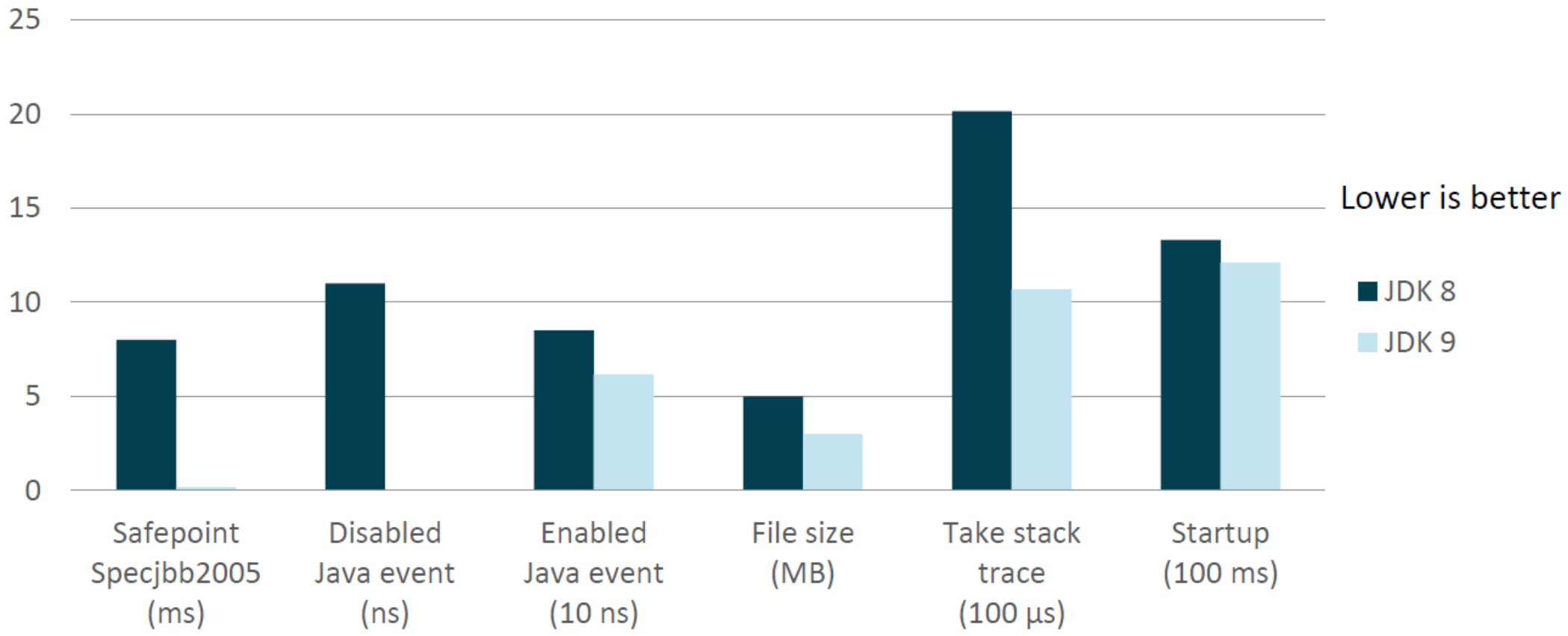
API Improvements, Performance



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Supported API for Custom Events

Continued

- Extensible
  - Custom settings can be defined for event types
  - User definable metadata using annotations
- Simplified Programming Model
  - EventTypes are self registering (no more Producers)
  - Life cycle follow the event type class
  - New event types are enabled by default
    - As a matter of fact event types can be fully configured with annotations
  - No need to be careful with event object creation

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New API for Custom Events

Example

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

public class Hello {

    @Label("Hello World")
    static class HelloWorldEvent extends Event {
       @Label("Message")
       String message;
    }

    public static void main(String... args) {
        HelloWorldEvent event = new HelloWorldEvent();
        event.message = "Hello World event message!";
        event.commit();
   }
}
```

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Example from jfr4junit

JFR plug-in for the upcoming JUnit 5

```
/**
 * Event for a test run and completed normally (without exception).
 *
 * @author Marcus Hirt
 */
@Label("Test Run")
@Description("JUnit test executed and completed normally without exception")
@Category("JUnit")
public class TestEvent extends Event {
    @Label("Display Name")
    @Description("The display name for the test")
    private String displayName;

    public void setDisplayName(String displayName) {
        this.displayName = displayName;
    }

    public String getDisplayName() {
        return displayName;
    }
}
```

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Example from jfr4junit

Another example

```
/**
 * Event for when a test ended with an exception being thrown.
 *
 * @author Marcus Hirt
 */
@Label("Test Exception")
@Description("Test ended with an exception being thrown")
@Category("JUnit")
public class ExceptionEvent extends Event {
	@Label("Display Name")
	@Description("The display name for the test")
	private String displayName;

	@Label("Exception Message")
	@Description("The exception message for the exception")
	private String exceptionMessage;

	@Label("Exception class")
	@Description("The class of the exception")
	private Class<?> exceptionClass;

	public String getDisplayName() {
		return displayName;
	}

	public void setDisplayName(String displayName) {
		this.displayName = displayName;
	}
.
.
.
```

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New APIs for Controlling the Flight Recorder

- New Java POJO API
  - Supported!
  - Makes it possible to use JFR on JMX-less profiles
  - Cleaner and more expressive for in-process use
- New JMX API
  - Supported!
  - In a separate module
  - Cleaner and easier to use
    - Uses MXBeans and type mapping instead of CompositeData directly

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New API for Parsing Flight Recorder Files

```
public class ParserExample {
    public static void main(String[] args) throws IOException {
        long maxNanos = Long.MIN_VALUE;
        RecordedEvent maxEvent = null;
        for (RecordedEvent event : RecordingFile.readAllEvents(Paths.get(args[0]))) {
            if (event.getEventType().getName().equals("se.hirt.jfr4junit.TestEvent")) {
                long nanos = event.getDuration();
                if (nanos > maxNanos) {
                    maxNanos = nanos;
                    maxEvent = event;
                }
            }
        }
        System.out.printf("Longest running test was: %s for %ds\n",
             maxEvent.getValue("displayName"), maxNanos / 1_000_000);
        System.out.println("Event was:\n" + maxEvent);
    }
}
```

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Control API and Parsing Example

```
public class RecordAndConsume {
    public static void main(String[] args) throws IOException {
        Path path = Paths.get(args[0]);
        try (Recording recording = new Recording()) {
            recording.setName("Fibonacci Recording");
            recording.start();
            recording.enable(FibonacciEvent.class);
            for (int n = 0; n < 50; n++) {
                FibonacciEvent event = new FibonacciEvent();
                event.number = n;
                event.begin();
                event.value = Fibonacci.fibonacciIterative(n);
                event.commit();
            }
            recording.stop();
            recording.dump(path);
            for (RecordedEvent event : RecordingFile.readAllEvents(path)) {
                int number = event.getValue("number");
                long value = event.getValue("value");
                System.out.printf("fibonacci(%d) = %d (time: %dns)\n", number, value, event.getDuration());
            }
        }
    }
}
```

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Changed Command Line Flags

In-memory example

JDK 8

```
-XX:+UnlockCommercialFeatures
-XX:+FlightRecorder
-XX:FlightRecorderOptions=defaultrecording=true,
dumponexit=true,dumponexitpath=/home/hirt/myrecording.jfr
```

JDK 9

```
-XX:+UnlockCommercialFeatures -XX:StartFlightRecording=
dumponexit=true,filename=/home/hirt/myrecording.jfr
```

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Changed Command Line Flags

Disk Repository Example

JDK 8

```
-XX:+UnlockCommercialFeatures
-XX:+FlightRecorder
-XX:FlightRecorderOptions=defaultrecording=true,
dumponexit=true,dumponexitpath=/home/hirt/myrecording.jfr,disk=true,
maxsize=500M,maxage=20m
```

JDK 9

```
-XX:+UnlockCommercialFeatures -XX:StartFlightRecording=
dumponexit=true,filename=/home/hirt/myrecording.jfr,maxsize=500M,maxage=20m
```

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JCMD

JCMD will continue to work the same, for example:

```
>jcmd 4711 VM.unlock_commercial_features
>jcmd 4711 JFR.start duration=2m,filename=/home/hirt/myrecording.jfr
```

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Performance

JFR enabled, event disabled

```
private static long calculateFibonacci(int n) {
    FibonacciEvent event = new FibonacciEvent();
    event.begin();
    event.number = n;
    long fibValue = Fibonacci.fibonacciIterative(n);
    event.value = fibValue;
    event.commit();
    return fibValue;
}
```

```
0x000001524f68c8a0: sub     rsp,18h
0x000001524f68c8a7: mov     qword ptr [rsp+10h],rbp  ;*synchronization entry
                    ; - se.hirt.jdk9.enabledisable.EnableDisableTesterFibonacci::calculateFibonacci@-1 (line 54)

0x000001524f68c8ac: movsxd  r10,edx          ;*i2l {reexecute=0 rethrow=0 return_oop=0}
                    ; - se.hirt.jdk9.enabledisable.EnableDisableTesterFibonacci::calculateFibonacci@18 (line 57)

0x000001524f68c8af: test    r10,r10
0x000001524f68c8b2: jle     1524f68c8fah     ;*iflt {reexecute=0 rethrow=0 return_oop=0}
                    ; - se.hirt.jdk9.enabledisable.Fibonacci::fibonacciIterative@37 (line 14)
                    ; - se.hirt.jdk9.enabledisable.EnableDisableTesterFibonacci::calculateFibonacci@19 (line 57)

0x000001524f68c8b4: mov     eax,1h
0x000001524f68c8b9: mov     r11d,2h
0x000001524f68c8bf: mov     r8d,1h
0x000001524f68c8c5: mov     r9d,1h
0x000001524f68c8cb: jmp     1524f68c8e3h
.
.
.
```

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Performance

JFR enabled, event enabled

```
0x00000194572ba0c0: mov     dword ptr [rsp+0ffffffffffffa000h],eax
0x00000194572ba0c7: push    rbp
0x00000194572ba0c8: sub     rsp,20h          ;*synchronization entry
                                  ; - se.hirt.jdk9.enabledisable.EnableDisableTesterFibonacci::calculateFibonacci@-1 (line 54)
.
.
.

0x00000194572ba125: mov     rbp,rax          ;*invokespecial <init> {reexecute=0 rethrow=0 return_oop=0}
                                  ; - se.hirt.jdk9.enabledisable.EnableDisableTesterFibonacci::calculateFibonacci@4 (line 54)

0x00000194572ba128: mov     rdx,rbp
0x00000194572ba12b: call    194503f8060h      ; ImmutableOopMap{rbp=Oop }
                                  ;*invokevirtual begin {reexecute=0 rethrow=0 return_oop=0}
                                  ; - se.hirt.jdk9.enabledisable.EnableDisableTesterFibonacci::calculateFibonacci@9 (line 55)
                                  ;   {optimized virtual_call}

.
.
.
```

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Summary of JDK 9 JFR Features

- Easy to use supported APIs for all things Flight Recorder
  - Allows for custom events
  - Programmatic access for reading Flight Recordings
  - Programmatic access for controlling the Flight Recorder
  - Modularized, works on smaller profiles
- New events
- Improved command line ergonomics
- Can dump on crashes and OOM

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Java Mission Control 6

Highlights

- Major changes to JFR
  - Support for both the JDK 7/8 and JDK 9 JFR file formats
  - Support for connecting to JDK 7/8 and JDK 9
- Automated analysis of Flight Recordings
- Only released with JDK 9
- Only minor changes to the rest of JMC

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Automated Analysis of Flight Recordings

- Recordings contain quite a bit of runtime specific data
- Java promises an abstraction that hide implementation specifics
- Attempts to:
  - Flag information that is relevant
  - Provide links to documentation to explain relevant concepts (e.g. safe points, code caches, PLABs etc)
- Individual rules can be disabled

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Automated Analysis of Flight Recordings

Components and API

- POJO components usable outside of JMC
  - Parser
  - Rules engine
  - JDK 7
- Extensible through a Java API
  - Using the standard Java Service Loader mechanism
  - Experimental PDE plug-in which generates the boilerplate
  - Unsupported but documented in JMC 6
  - If there is enough interest -> supported in a future version

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Automated Analysis of Flight Recordings

Components and API, continued

- Can be associated with existing pages
- API features help simplify the development of rules
  - Filters
  - Aggregators
- The rules engine can be run outside JMC
  - Oracle internal PoC cloud service – upload JFR, get JSON back
  - Oracle internal analysis web application
    (API testing, rules testing and also great fun)
  - Used in Oracle Enterprise Manager for automated analysis of recordings

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Example Rule

```
public class EnvironmentVariableRule implements IRule {
    private static final TypedPreference<String> PREFERENCE_ENVIRONMENT_VARIABLE_NAME = new TypedPreference<>(
        "environmentVariable", "Environment Variable",
        "The name of the environment variable to check for a floating point score",
        UnitLookup.PLAIN_TEXT.getPersister(), "JFR_RULE_TEST");

    @Override
    public Collection<TypedPreference<?>> getConfigurationAttributes() {
        return Arrays.<TypedPreference<?>> asList(PREFERENCE_ENVIRONMENT_VARIABLE_NAME);
    }

   @Override
   public String getId() {
       return "se.hirt.envrule.EnvironmentVariableRule";
   }

   @Override
   public String getName() {
       return "Configurable Rule Demo";
   }

   @Override
   public String getTopic() {
       return JfrRuleTopics.ENVIRONMENT_VARIABLES_TOPIC;
   }

.
.
.
```

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Example Rule

Cont'd

```
.
.
.

    @Override
    public Result evaluate(IItemCollection items, IPreferenceValueProvider valueProvider) {
        String variableName = valueProvider.getPreferenceValue(PREFERENCE_ENVIRONMENT_VARIABLE_NAME);
        String environmentVariableValue = getEnvironmentVariable(variableName, items);
        if (environmentVariableValue == null) {
            return new Result(this, 100, "Could not find the environment variable named " + variableName);
        }
        double score = 0;
        try {
            score = Double.parseDouble(environmentVariableValue);
        } catch (NumberFormatException e) {
            return new Result(this, 100, "Could not parse the environment variable named " + variableName);
        }
        return new Result(this, score, "The score in " + variableName + " was " + score);
    }

    private String getEnvironmentVariable(String variableName, IItemCollection items) {
        IItemCollection envItems = items.apply(ItemFilters.and(JfrFilters.ENVIRONMENT_VARIABLE,
            ItemFilters.equals(JfrAttributes.ENVIRONMENT_KEY, variableName)));
        return envItems.getAggregate(JfrAggregators.first(JfrAttributes.ENVIRONMENT_VALUE));
    }
}
```

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Updated User Interface

- All new, separate and configurable Stack Trace View
  - By default showing the most common path (a full stacktrace)
  - Can be reconfigured to have the old tree representation
  - May take a bit of getting used to, but much easier to work with
- New configurable ”Java Application” page
  - Shows several key metrics together with per thread event lanes
  - Easier to focus on points of interest
- Requires JDK 8
  - UI uses streams and other JDK 8 language and API additions
  - If running in Eclipse – must be running on a JDK 8 JVM

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Updated User Interface

Cont'd

- New navigation
  - Uses the outline view
  - No tabs-in-tabs
  - Cleaner and more intuitive
- Advanced - Filters
  - Can build advanced filters through boolean operations (intersection, union)
  - Can be recording independent
  - Operative Set is no more -> Selections & Aspects

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Updated User Interface

Cont'd

- No more GUI builder
  - Embryo for easily adding custom event pages instead
  - Something similar, but supported, may resurge if there is enough interest
- Instead easy to create custom pages directly in the UI

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JMC UI Demo

JMC 6 / JDK 9

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Running the Rules

Simple example

```
public class RateFile {
    public static void main(String[] args) throws IOException, CouldNotLoadRecordingException {
        IItemCollection events = JfrLoaderToolkit.loadEvents(new File(args[0]));

        for (IRule rule : RuleRegistry.getRules()) {
            Result result = rule.evaluate(events, IPreferenceValueProvider.DEFAULT_VALUES);
            if (result.getScore() > 50) {
                System.out.printf("(%.0f) [%s]: %s\n", result.getScore(), result.getRule().getId(),
                    result.getShortDescription());
            }
        }
    }
}
```

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jfrscore

Oracle Internal Example

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Summary

- JFR APIs are ***SUPPORTED*** in JDK 9
  - Controlling the recorder
  - Creating custom events
  - Parsing the recordings
- JMC 6 JFR part greatly revised
  - Automated analysis of recordings
  - Plug-in for easily adding custom rules
  - Will work on JDK 7, 8 and 9 recordings
  - Can be used stand alone for scripting (initially unsupported)

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Additional Resources (JMC 5.5 and JDK 7 & 8)

- JMC Homepage
  http://oracle.com/missioncontrol
- Hirt's blog
  http://hirt.se/blog
- Twitter
  @javamissionctrl, @hirt
- JMC Tutorial
  http://hirt.se/blog/?p=611

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Q&A

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