JavaOne™

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Java Flight Recorder Behind the Scenes

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FUTURE
JAVA

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Java Flight Recorder

- Tracer and Profiler
- Non-intrusive
- Built into the JVM itself
- On-demand profiling
- After-the-fact capture and analysis

- First released in 7u40

Photograph by Jeffrey Milstein
http://butdoesitfloat.com/In-the-presence-of-massive-gravitational-fields-this-perfect

Tracer and Profiler

- Captures both JVM and application data
  - Garbage Collections
  - Synchronization
  - Compiler
  - CPU Usage
  - Exceptions
  - I/O
- Sampling-based profiler
  - Very low overhead
  - Accurate data

Non-Intrusive

- Typical overhead in benchmarks: 2-3% (!)
- Often not noticeable in typical production environments
- Turn on and off in runtime
- Information already available in the JVM
  - Zero extra cost

Photograph: Andrew Rivett
http://www.flickr.com/photos/veggiefrog/3435380297/

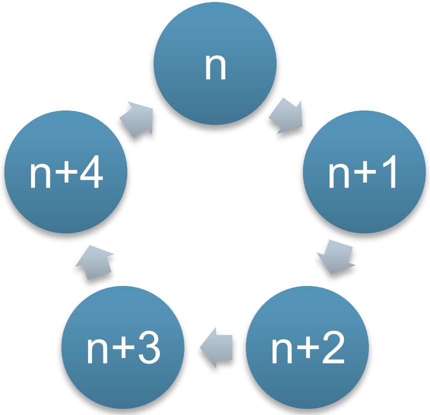
Built into the JVM itself

- Core of JFR is inside the JVM
- Can easily interact with other JVM subsystems
- Optimized C++ code
- Supporting functionality written in Java

On-Demand Profiling

- Start from Java Mission Control
  - Or from the command line
- Easily configure the amount of information to capture
- For a profile, a higher overhead can be acceptable
- When done, no overhead
- Powerful GUI for analysis

After-the-Fact Analysis



- In its default mode, very low overhead
- Designed to be always-on
- Uses circular buffers to store data
  - In-memory or on-disk
- When an SLA breach is detected, dump the current buffers
- Dump will have information **leading up to** the problem

DEMO

Agenda

- Overview of JFR
- Demo!
- Configuration topics
- Implementation details

Configuration

- Enable

```
-XX:+UnlockCommercialFeatures -XX:+FlightRecorder
```

- Start

```
-XX:StartFlightRecording=filename=<path>,duration=<time>
```

- Or

```
jcmd <pid> JFR.start filename=<path> duration=<time>
```

Advanced Configuration

Per Recording Session	
Max age of data	**maxage=**<time>
Max size to keep	**maxsize=**<size>

Global Settings (-XX:FlightRecorderOptions)	
Max stack trace depth	**stackdepth=**<n> (default 64)
Save recording on exit	**dumponexit=**true
Logging	**loglevel=**[ERROR|WARN|INFO|DEBUG|TRACE]
Repository path	**repository=**<path>

Recording Sessions

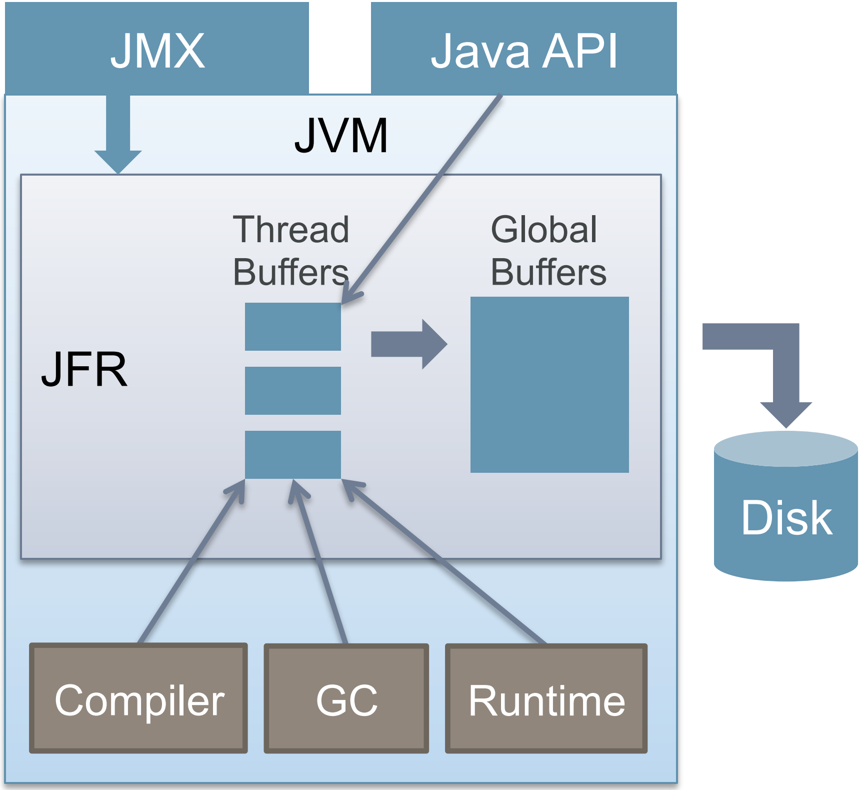
- Recordings can specify exactly which information to capture
  - ~80 events with 3 settings each
- But: two preconfigured settings
  - “default”: provides as much information as possible while keeping overhead to a minimum
  - “profile”: has more information, but also higher overhead
- You can configure your own favorites in Mission Control

Many Simultaneous Recording Sessions

- This works great
- Each session can have its own settings
- Caveat: If there are multiple sessions all of them get the **union** of the enabled events
  - Ex: If event A is enabled in on recording, all recordings will see event A
  - Ex: If event B has two different thresholds, the lower value will apply

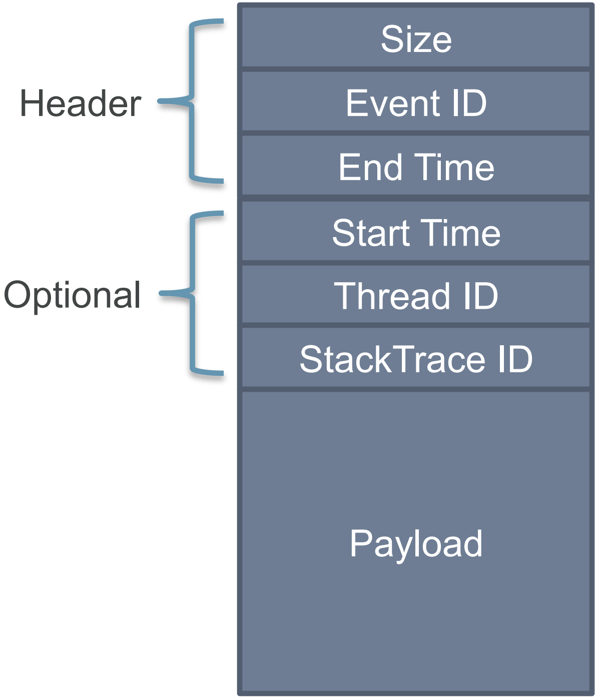
How Is It Built?

- Information gathering
  - Instrumentation calls all over the JVM
  - Application information via Java API
- Collected in Thread Local buffers
  - ⇢ Global Buffers ⇢Disk
- Binary, proprietary file format
- Managed via JMX



“Everything Is an Event”

- Header
- Payload
  - Event specific data



Event Types

- Instant
  - Single point in time
  - Ex: Thread starts
- Duration
  - Timing for something
  - Ex: GC
- Requestable
  - Happens with a specified frequency
  - Ex: CPU Usage every second

Event Meta Data

- For every event
  - Name, Path, Description
- For every payload item
  - Name, Type, Description, Content Type

“Content Type”

- Describes the **semantics** of a value
- Used to correctly display the value in the UI

Content Type	Displayed as
Bytes	4 MB
Percentage	34 %
Address	0x23CDA540
Millis	17 ms
Nanos	4711 ns

Event Definition in Hotspot

```
<event  id="ThreadSleep"
        path="java/thread_sleep"
        label="Java Thread Sleep" ...>
   <value  field="time"
           type="MILLIS"
           label="Sleep Time"/>
</event>
```

- XML definitions are processed into C++ classes

Event Emission in Hotspot

```
JVM_Sleep(int millis) {
   EventThreadSleep event;

   ... // actual sleep happens here

   event.set_time(millis);
   event.commit();
}
```

- Done! Data is now available in JFR

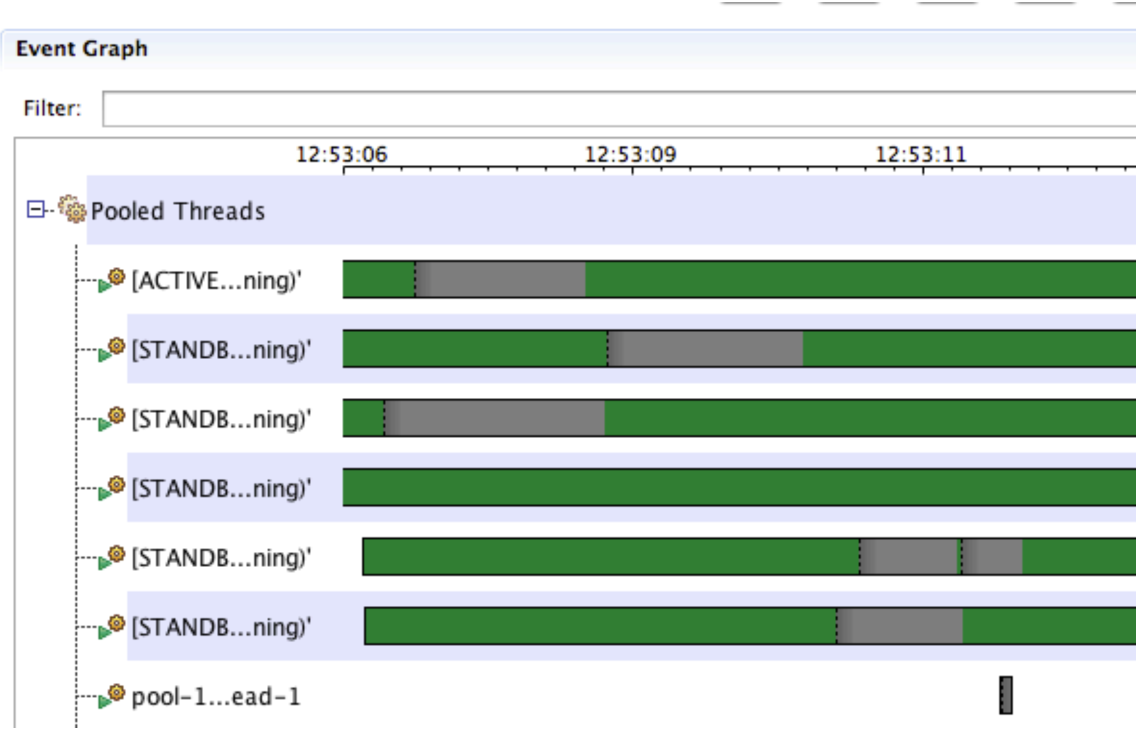
Thread Park

```
<event id="ThreadPark" path="java/thread_park"
      label="Java Thread Park"
      has_thread="true" has_stacktrace="true" is_instant="false">
   <value type="CLASS" field="klass" label="Class Parked On"/>
   <value type="MILLIS" field="timeout" label="Park Timeout"/>
   <value type="ADDRESS" field="address"
          label="Address of Object Parked"/>
</event>
```

Thread Park

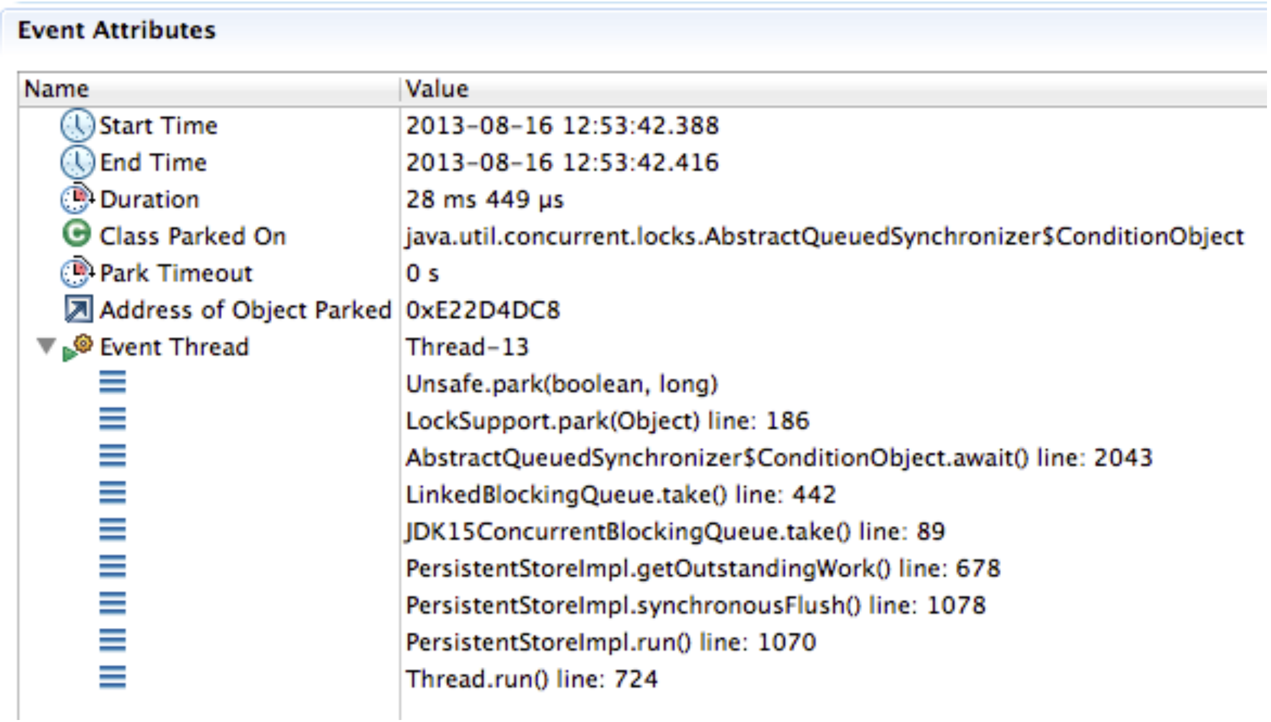
```
UnsafePark(jboolean isAbsolute, jlong time) {
  EventThreadPark event;
  JavaThreadParkedState jtps(thread, time != 0);
  thread->parker()->park(isAbsolute != 0, time);
  if (event.should_commit()) {
    oop obj = thread->current_park_blocker();
    event.set_klass(obj ? obj->klass() : NULL);
    event.set_timeout(time);
    event.set_address(obj ? (TYPE_ADDRESS)obj : 0);
    event.commit();
  }
}
```

Event Graph



Event Graph
Filter:
12:53:06
12:53:09
12:53:11
Pooled Threads
[ACTIVE...ning)'
[STANDB...ning)'
[STANDB...ning)'
[STANDB...ning)'
[STANDB...ning)'
[STANDB...ning)'
pool-1...ead-1

Event Details

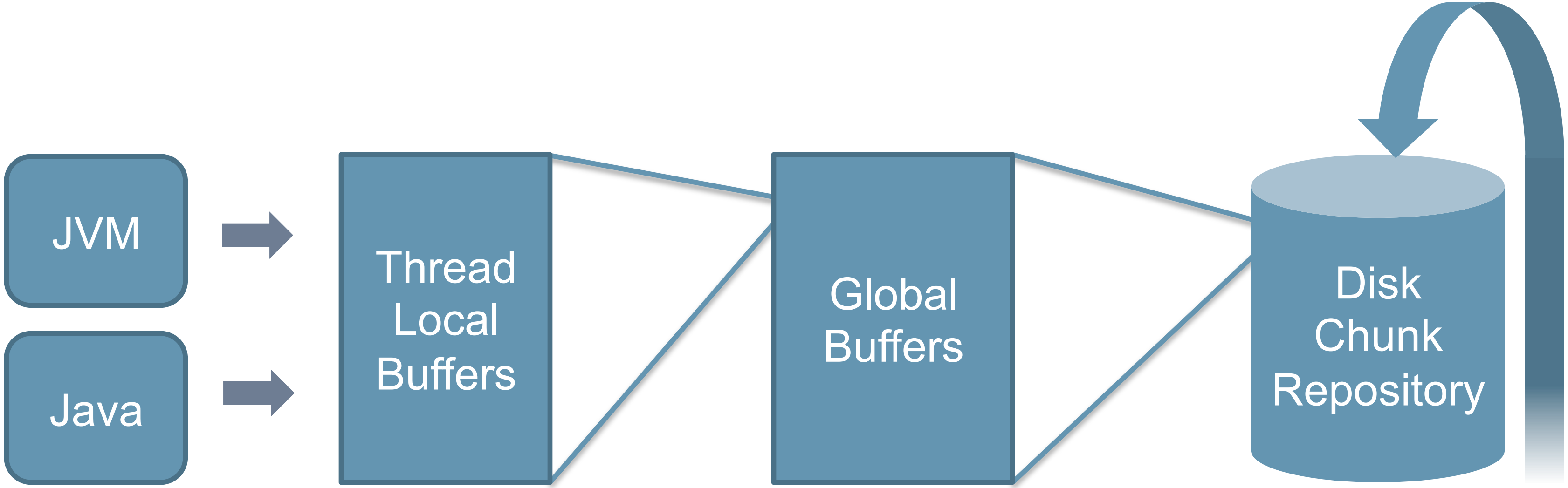


Event Attributes

Name	Value
Start Time	2013-08-16 12:53:42.388
End Time	2013-08-16 12:53:42.416
Duration	28 ms 449 µs
Class Parked On	java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject
Park Timeout	0 s
Address of Object Parked	0xE22D4DC8
▼ Event Thread	Thread-13
☰	Unsafe.park(boolean, long)
☰	LockSupport.park(Object) line: 186
☰	AbstractQueuedSynchronizer$ConditionObject.await() line: 2043
☰	LinkedBlockingQueue.take() line: 442
☰	JDK15ConcurrentBlockingQueue.take() line: 89
☰	PersistentStoreImpl.getOutstandingWork() line: 678
☰	PersistentStoreImpl.synchronousFlush() line: 1078
☰	PersistentStoreImpl.run() line: 1070
☰	Thread.run() line: 724

Buffers

- “Circular”
- Designed for low contention

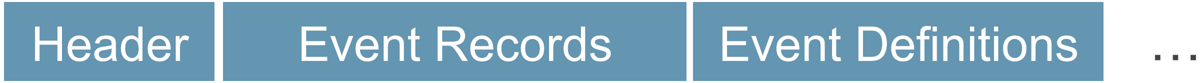


Filtering Early

- Enable/disable event
- Thresholds
  - Only if duration is longer than X
- Enable/disable stack trace
- Frequency
  - Sample every X

File Format

- Self-contained
  - Everything needed to parse an event is included in the file
  - New events instantly viewable in the UI
- Binary, proprietary
- Designed for fast writing
- Single file, no dependencies



Header

Event Records

Event Definitions

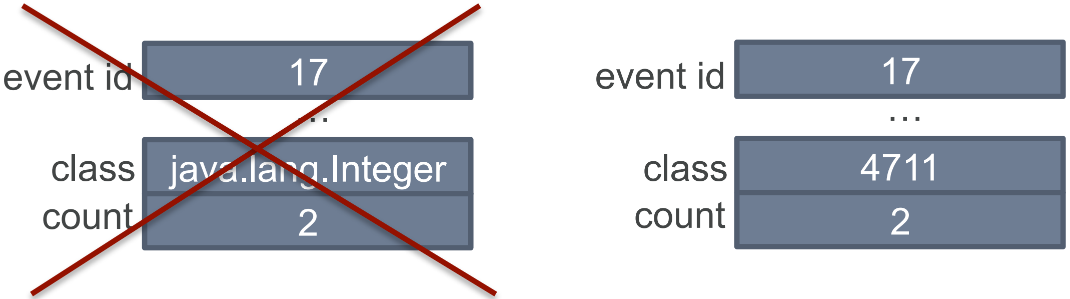
…

Dynamic Runtime and Long-Running Recordings

- Can’t leak memory
  - Can’t aggregate information eternally
  - Can’t keep references that prohibits class unloading
- Dynamic Runtime
  - Classes can come and go
  - Threads can come and go
- Solutions: Constant Pools, Checkpoints

Problem: Many Events Reference Classes

- If every event contained the class name as a string, we would waste lots of space
- Solution: Class IDs



```
class Klass {
    …
    u8 _trace_id;
    …
}
```

Problem: When Do We Write the Class IDs?

- IDs need to be part of the file
- Classes can be unloaded at any time
  - Class may not be around until end of recording
- Solution: write Class ID when classes are unloaded

Problem: Size of the Class List

- Many classes are loaded, not all are referenced in events, we want to save space
- Solution: when a class ID is referenced, the class is also “tagged”
  - Write only tagged classes in the JFR file

```
#define CLASS_USED 1

void use_class_id(Klass* const klass) {
  klass->_trace_id |= CLASS_USED;
}
```

Problem: Leaking Memory

- Over time many classes will be tagged, the size of the class list will increase
- Solution: reset the tags each time a class list is written to disk
- We call this a “Checkpoint”

- A recording file may contain many class lists, each one is only valid for the data immediately preceding it

Constant Pools

- The Class List is a special case of a Constant Pool

- Classes
- Methods
- Threads
- Thread Groups
- Stack Traces
- Strings

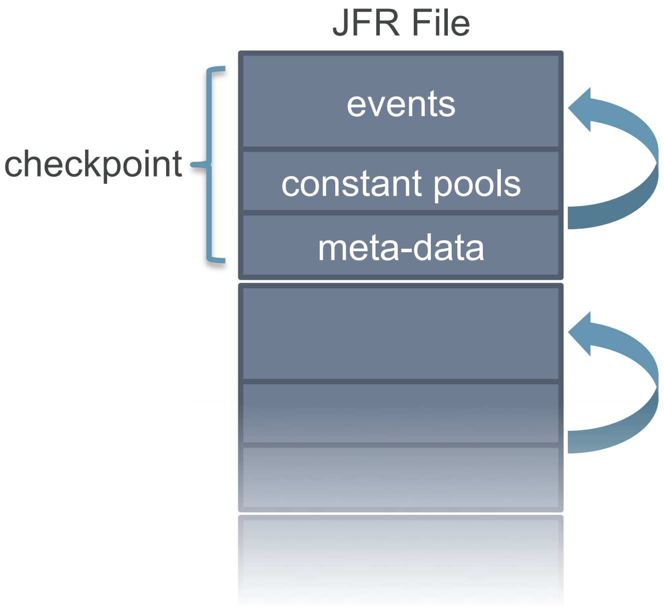
```
class_pool.lookup(4711)
  → java.lang.Integer

method_pool.lookup(1729)
  → java.lang.Math:pow()
```

Checkpoints

- At regular intervals, a “checkpoint” is created in the recording
- Has everything needed to parse the recording since the last checkpoint

checkpoint =
events
+ constant pools
+ event meta-data



Optimizations

- Fast Timestamps
  - Fast, high resolution CPU time where available
  - Invariant TSC instructions

- Stack Traces
  - Each event stores the thread’s stack trace
  - Pool of stack traces

Differences vs. JRockit

- I/O: File path, Socket address
- Exceptions
- Reverse call trace view in Mission Control
- Easier configuration in Mission Control
- Deeper (configurable) stack traces
- Internal JVM differences: GC

More Information

- Whitepaper

  http://www.oracle.com/missioncontrol

- User Guide

  http://docs.oracle.com/javase/7/docs/technotes/guides/jfr/index.html

- Forum

  https://forums.oracle.com/community/developer/english/java/java_hotspot_virtual_machine/java_mission_control

Remember

```
-XX:+UnlockCommercialFeatures
-XX:+FlightRecorder
```

Q&A

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