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Preface

This document shows you how to use the Flight Recorder API for more comprehensive application monitoring; you can analyze in greater detail events generated by applications, the JVM, and the operating system. Also, you can create your own events, record your own data, and view and parse the recordings. In addition, this document shows you how to use the Flight Recorder event streaming API, which enables you to consume Flight Recorder data continuously.

Audience

This document is intended for experienced Flight Recorder users who want to monitor their applications in greater detail.

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Related Documents

• The jfr Command in the Java Development Kit Tool Specifications
• The jdk.jfr module

Conventions

The following text conventions are used in this document:

<table>
<thead>
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<th>Convention</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>boldface</td>
<td>Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.</td>
</tr>
<tr>
<td>italic</td>
<td>Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.</td>
</tr>
<tr>
<td>Convention</td>
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<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td>monospace</td>
<td>Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.</td>
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</table>
Part I

Why Use the API?

Use the Flight Recorder API for more comprehensive application monitoring; you can analyze in greater detail events generated by applications, the JVM, and the operating system. In addition, you can create your own events, record your own data, and view and parse the recordings.

For example, you might create events and recordings for the following scenarios:

- **To identify slow HTTP GET requests:** A client application sends a request to a web server and it takes a long time for the request to be processed. To troubleshoot this problem, you can create an event that triggers if the request takes more than five seconds to process. You can also correlate these requests with JVM events, such as garbage collection or thread contention, which might impact web server performance.

- **To track slow-running SQL queries:** Some SQL queries take a long time to execute in a database server. To identify the problem, you can create an event to log all the SQL queries, and then analyze the recordings to track the slowest-running queries.

**Flight Recorder API or Java Logging API?**

The Java Logging API (see the package `java.util.logging`) captures information such as security failures, configuration errors, performance bottlenecks, and bugs in the application or platform. However, compared with the Java Logging API, the Flight Recorder API provides you with more information in the recording it generates (and in the events it records), more information regarding the context in which an event occurs, and more control over the timing of events.
Part II
Create Events

This section shows you how to create and record events. It contains the following topics:

- Creating and Recording Your First Event
- Event Metadata
- Guidelines for Naming and Labeling Events
- Categories
- Measuring Time
- Data Types
- Dynamic Events
- Custom Annotations
- Inheritance of Annotations, Settings, and Fields
Creating and Recording Your First Event

The sample HelloWorldSample.java creates an event named com.oracle.Hello.

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

public class HelloWorldSample {
    @Name("com.oracle.Hello")
    @Label("Hello World!")
    static class Hello extends Event {
        @Label("Message")
        String message;
    }

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

Run HelloWorldSample with the following command:

```bash
java -XX:StartFlightRecording:filename=hw.jfr HelloWorldSample.java
```

It runs HelloWorldSample and creates a recording file named hw.jfr.

To view the contents of the recording file, run this command:

```bash
jfr print hw.jfr
```

It prints all events recorded by Flight Recorder.

If you only want to view the Hello event that you created, then run this command:

```bash
jfr print --events Hello hw.jfr
```

It prints output similar to the following:

```plaintext
com.oracle.Hello {
    startTime = 23:36:11.009
    duration = 0.0219 ms
    message = "Hello world!"
}
```
eventThread = "main" (javaThreadId = 1)
stackTrace = [
    HelloWorldSample.main(String[]) line: 60
]
Event Metadata

The example SetMetadataSample.java defines an event named com.oracle.Hello and sets the annotations @Name, @Description, @Label, and @Category. (Note that this sample is in the package frexamples.)

```java
class SetMetadataSample {
    @Name("com.oracle.Hello")
    @Label("Set Metadata Example")
    @Description("Demonstrates how to set the annotations @Name, @Description, @Label, and @Category")
    @Category({ "Demonstration", "Tutorial" })
    public static void main(String... args) {
        Hello event = new Hello();
        event.begin();
        event.message = "Hello Event!";
        event.commit();
    }
}
```

Ensure that the example is in a directory named frexamples, then run
SetMetadataSample from this directory with the following commands:

```bash
java -XX:StartFlightRecording:filename=sm.jfr SetMetadataSample.java
jfr print --events Hello sm.jfr
```

The last command prints output similar to the following:

```bash
com.oracle.Hello {
    startTime = 23:43:48.444
    duration = 0.0177 ms
    message = "Hello Event!"
```
You can also use the jfr print command to filter events that belong to one or more categories:

    jfr print --categories Demonstration sm.jfr

The @Name annotation overrides the default name for an event type. For example, the default name for the event created in this example would have been frexamples.SetMetadataSample$Hello if the @Name annotation hadn't been set. See Guidelines for Naming Events.

The @Description and @Label annotations enable you to add additional information about an event type. Note that you shouldn't use @Label as an identifier; use the @Name annotation instead. See Guidelines for Labeling Events.

The @Category annotation enables you to associate one or more categories with an event type. To specify one category, use a string. To specify more than one category, use a comma-separated list of strings surrounded by braces ({}). See Categories.
Guidelines for Naming and Labeling Events

You should name and label all of your events by setting the annotations @Name and @Label.

Guidelines for Naming Events

Use the following format for naming your events, where www.example.com is the domain of your organization and Name is the name of your event class:

com.example.Name

When naming your event class, omit the word "Event."

By default, an event gets its name from its fully qualified class name. For example, in the example SetMetadataSample.java (see Event Metadata), the default name of the event Hello is frexamples.SetMetadataSample$Hello.

This works well for experimentation, but avoid omitting the @Name annotation for production code. You might have to refactor your source code and move the event class to a different package. If you haven't specified the event's name with the @Name annotation, then refactoring an event class can break code or settings files that configure the event. It can also break code that parses recording files that use the default name to identify an event.

The fully qualified class name may also contain redundant or unnecessary strings such as jfr, internal, events, or Events that you should omit.

An event name should be short but not so short that it clashes with other organizations or products. The name should be easy to understand for users who want to configure the event. This is especially true if the event is part of a framework or library that is meant to be used by others. It's usually sufficient to put all the events for a library or product in the same namespace. For example, all the events for OpenJDK are in the jdk namespace. There are no sub-namespaces for hotspot, gc, or compiler as this would just complicate things. However, it's possible to divide events into categories with the @Category annotation, which you can freely change without disruption.

Guidelines for Labeling Events

For labels, use headline-style capitalization: Capitalize the first and last words and all nouns, pronouns, adjectives, verbs and adverbs. Do not include ending punctuation. As with event names, omit the word "Event." Note that you shouldn't use @Label as an identifier; use the @Name annotation instead.

Use labels to display events in user interfaces such as a custom visualization tool. For example, JDK Mission Control's Event Browser uses the label to display events in its Event Types Tree.
Categories

With the \@Category annotation, you can assign any number of categories to an event. Categories enable you to identify similar events that should be displayed together, for example, in a graph or a tree. Although you can assign any category to an event (a category is just a string), it's best to first determine your categories.

If there's a chance that two or more events can happen at the same time and in the same thread, even if their start and end times might be different, then they should belong to different categories to prevent overlap when they're represented in a graphical user interface.

For example, suppose that you want to monitor image uploads to a web server. You create an event named File Upload that begins when a user uploads a file and ends when an upload completes. For advanced diagnostics about image uploads, you create more detailed events named Image Read, Image Resize, and Image Write. During these detailed events, other low-level events occur, for example, Socket Read during Image Read and File Write during Image Write. In this example, the event File Upload would overlap the events Image Read, Image Resize, and Image Write, which means that the File Upload event might hide the detailed events in some event visualizers. The same issue might happen for Image Read and Socket Read, and Image Write and File Write.

To prevent event overlap, make sure that events that might overlap belong to different categories. The following diagram illustrates one categorization scheme that prevents event overlaps and how an event visualizer could display them:

Figure 4-1  Categorizing Concurrent Events to Prevent Overlaps

File Upload belongs to the category Upload. Image Read, Image Resize, and Image Write belong to the category Image Upload. Socket Read and File Write belong to the category Java Application.

The example CategoriesSample.java implements this categorization scheme and simulates the creation of events as illustrated in the figure:

```java
import jdk.jfr.Category;
import jdk.jfr.DataAmount;
import jdk.jfr.Event;
```
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.Percentage;

public class CategoriesSample {

    public static final String PROGRAMMERS_GUIDE_SAMPLES = "Programmer's Guide Samples";
    public static final String UPLOAD = "Upload";
    public static final String IMAGE_UPLOAD = "Image Upload";
    public static final String JAVA_APPLICATION = "Java Application";

    @Name("com.oracle.FileUpload")
    @Label("File Upload")
    @Category({PROGRAMMERS_GUIDE_SAMPLES, UPLOAD})
    private static class FileUpload extends Event { }

    @Name("com.oracle.ImageRead")
    @Label("Image Read")
    @Category({PROGRAMMERS_GUIDE_SAMPLES, IMAGE_UPLOAD})
    private static class ImageRead extends Event {
        @DataAmount(DataAmount.BYTES)
        long bytesUploaded;
    }

    @Name("com.oracle.ImageResize")
    @Label("Image Resize")
    @Category({PROGRAMMERS_GUIDE_SAMPLES, IMAGE_UPLOAD})
    private static class ImageResize extends Event {
        @Percentage
        double scale;
    }

    @Name("com.oracle.ImageWrite")
    @Label("Image Write")
    @Category({PROGRAMMERS_GUIDE_SAMPLES, IMAGE_UPLOAD})
    private static class ImageWrite extends Event {
        @DataAmount(DataAmount.BYTES)
        long bytesWritten;
    }

    @Name("com.oracle.SocketRead")
    @Label("Socket Read")
    @Category({PROGRAMMERS_GUIDE_SAMPLES, JAVA_APPLICATION})
    private static class SocketRead extends Event {
        @DataAmount(DataAmount.BYTES)
        long bytesRead;
    }

    @Name("com.oracle.FileWrite")
    @Label("File Write")
    @Category({PROGRAMMERS_GUIDE_SAMPLES, JAVA_APPLICATION})
    private static class FileWrite extends Event {
        @DataAmount(DataAmount.BYTES)
        long bytesWritten;
    }
public static void main(String... args) {
    FileUpload fu = new FileUpload();
    fu.begin();

    ImageRead ir = new ImageRead();
    ir.begin();
    ir.bytesUploaded = 2048;

    SocketRead sr1 = new SocketRead();
    sr1.begin();
    sr1.bytesRead = 1024;
    sr1.commit();

    SocketRead sr2 = new SocketRead();
    sr2.begin();
    sr2.bytesRead = 1024;
    sr2.commit();

    ir.commit();

    ImageResize irs = new ImageResize();
    irs.begin();
    irs.scale = 0.5;
    irs.commit();

    ImageWrite iw = new ImageWrite();
    iw.begin();
    iw.bytesWritten = 1024;

    FileWrite fw = new FileWrite();
    fw.begin();
    fw.bytesWritten = 1024;

    iw.commit();
    fu.commit();
}

Run CategoriesSample with the following command:

java -XX:StartFlightRecording:filename=categoriessample.jfr
CategoriesSample.java

Then, open categoriessample.jfr in JDK Mission Control. From the Event Types Tree in the Event Browser, find the events created by this sample in the category Programmer's Guide Samples:
JDK Mission Control categorizes events based on their `@Category` attribute and lists them by their `@Label` attribute.
5
Measuring Time

The example MeasureTimeSample.java shows you how to measure the time of an operation by calling the Event.begin and Event.commit methods.

```java
import jdk.jfr.Event;
import jdk.jfr.Label;
import jdk.jfr.Name;
public class MeasureTimeSample {
    @Name("com.oracle.MeasureDuration")
    @Label("Measure Duration")
    static class MeasureMyDuration extends Event {
    }

    public static void main(String... args) throws Exception {
        MeasureMyDuration event = new MeasureMyDuration();
        event.begin();
        Thread.sleep(42);
        event.commit();
    }
}
```

Note that the commit method ends the timing of an event without the need of an explicit call to the end method.

Run MeasureTimeSample with the following commands:

```bash
java -XX:StartFlightRecording:filename=mt.jfr MeasureTimeSample.java
jfr print --events MeasureDuration mt.jfr
```

The last command prints output similar to the following:

```java
com.oracle.MeasureDuration {
    startTime = 12:26:43.169
    duration = 45.3 ms
    ...
}
```
The example PersistFieldTypesSample.java shows which field types you can persist in an event, which are the following:

- java.lang.String, which may be null
- java.lang.Thread, which may be null
- java.lang.Class, which may be null
- byte
- short
- int
- long
- float
- double
- char
- boolean

Note:
Events don't support arrays.

The following is the PersistFieldTypesSample.java example:

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

public class PersistFieldTypesSample {

    @Name("com.oracle.FieldTypes")
    @Label("Allowed Field Types")
    static class FieldTypes extends Event {
        @Label("Class Value")
        Class<?> classValue;

        @Label("Thread Value")
        Thread threadValue; // thread must be started

        @Label("String Value")
        String stringValue;

        @Label("Byte Value")
```
byte byteValue;

@Label("Short Value")
short shortValue;

@Label("Int Value")
int intValue;

@Label("Long Value")
long longValue;

@Label("Float Value")
float floatValue;

@Label("Double Value")
double doubleValue;

@Label("Character Value")
char characterValue;

@Label("Boolean Value")
boolean booleanValue;

}

public static void main(String... args) {
    FieldTypes event = new FieldTypes();
    event.classValue = Math.class;
    event.threadValue = Thread.currentThread();
    event.stringValue = "Hello";
    event.byteValue = 42;
    event.shortValue = 4711;
    event.intValue = Integer.MAX_VALUE;
    event.longValue = Long.MAX_VALUE;
    event.doubleValue = Math.PI;
    event.floatValue = Float.NaN;
    event.characterValue = ©!©;
    event.booleanValue = true;
    event.commit();
}

Run PersistFieldTypesSample with the following commands:

java -XX:StartFlightRecording:filename=pft.jfr
PersistFieldTypesSample.java
jfr print --events FieldTypes pft.jfr

The last command prints output similar to the following:

com.oracle.FieldTypes {
    startTime = 12:33:12.434
    classValue = java.lang.Math (classLoader = bootstrap)
    threadValue = "main" (javaThreadId = 1)
    stringValue = "Hello"
byteValue = 42
shortValue = 4711
intValue = 2147483647
longValue = 9223372036854775807
floatValue = N/A
doubleValue = 3.141592653589793
characterValue = !
booleanValue = true
...
Dynamic Events

Dynamic events enable you to define events at run time, including their annotations and fields.

**Note:**
Only use dynamic events if you won’t know the layout of an event until you run your application.

The example `DynamicSample.java` creates a dynamic event named `com.oracle.RandomString`, which includes a field whose name is a random string:

```java
import java.util.ArrayList;
import java.util.Collections;
import java.util.List;
import jdk.jfr.AnnotationElement;
import jdk.jfr.Category;
import jdk.jfr.Description;
import jdk.jfr.Event;
import jdk.jfr.EventFactory;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.ValueDescriptor;

public class DynamicSample {

    private static String randomString(int n) {
        var ALPHA_NUMERIC_STRING = "ABCDEFGHIJKLMNOPQRSTUVWXYZ";
        var builder = new StringBuilder();
        while (n-- != 0) {
            int character = (int) (Math.random() * ALPHA_NUMERIC_STRING.length());
            builder.append(ALPHA_NUMERIC_STRING.charAt(character));
        }
        return builder.toString();
    }

    public static void main(String[] args) {

        String[] category = { "Demonstration", "Tutorial" };
        var eventAnnotations = new ArrayList<AnnotationElement>();
        eventAnnotations
            .add(new AnnotationElement(
                Name.class, "com.oracle.RandomString"));
```
eventAnnotations.add(new AnnotationElement(Label.class, "Field Named with Random String");
eventAnnotations.add(new AnnotationElement(Description.class, "Demonstrates how to create a dynamic event");
eventAnnotations.add(new AnnotationElement(Category.class, category));

var fields = new ArrayList<ValueDescriptor>();
var messageAnnotations = Collections.singletonList(new AnnotationElement(Label.class, "Message");
var randomFieldName = DynamicSample.randomString(8);
fields.add(new ValueDescriptor(String.class, randomFieldName, messageAnnotations));
var numberAnnotations = Collections.singletonList(new AnnotationElement(Label.class, "Number");
fields.add(new ValueDescriptor(int.class, "number", numberAnnotations));

var f = EventFactory.create(eventAnnotations, fields);

Event event = f.newEvent();
event.set(0, "hello, world!");
event.set(1, 100);
event.commit();
}
}

Run DynamicSample with the following commands:

java -XX:StartFlightRecording:filename=d.jfr DynamicSample.java
jfr print --events RandomString d.jfr

The last command prints output similar to the following:

com.oracle.RandomString {
  startTime = 12:56:32.782
  ZZETUGMTG = "hello, world!"
  number = 100
  ...
}

To create a dynamic event, call the static method EventFactory.create(List<AnnotationElement>, List<ValueDescriptor>):

var f = EventFactory.create(eventAnnotations, fields);

The first argument is a list of your event's annotations, which may include built-in annotations such as @Name and @Description.
The second argument is a list of your event's fields. Define them with the `ValueDescriptor` class.
Creating custom annotations for events is the same as creating Java annotations. The example `CustomAnnotationSample.java` demonstrates this.

```java
import java.lang.annotation.ElementType;
import java.lang.annotation.Retention;
import java.lang.annotation.RetentionPolicy;
import java.lang.annotation.Target;
import jdk.jfr.Description;
import jdk.jfr.Event;
import jdk.jfr.Label;
import jdk.jfr.MetadataDefinition;
import jdk.jfr.Name;
import jdk.jfr.Relational;

public class CustomAnnotationSample {

    @MetadataDefinition
    @Name("com.oracle.Severity")
    @Label("Severity")
    @Description("Value between 0 and 100 that indicates " + "severity. 100 is most severe."
    @Retention(RetentionPolicy.RUNTIME)
    @Target({ ElementType.TYPE })
    public @interface Severity {
        int value() default 50;
    }

    @MetadataDefinition
    @Name("com.oracle.TransactionId")
    @Label("Transaction ID")
    @Relational
    @Retention(RetentionPolicy.RUNTIME)
    @Target({ ElementType.FIELD })
    public @interface TransactionId {

    }

    @Name("com.oracle.TransactionBlocked")
    @Severity(80)
    @Label("Transaction Blocked")
    static class TransactionBlocked extends Event {
        @TransactionId
        @Label("Transaction")
        long transaction;

        @TransactionId
        @Label("Transaction Blocker")
        long transactionBlocker;
    }
```

---

8

Custom Annotations
public static void main(String... args) {
    TransactionBlocked event = new TransactionBlocked();
    event.begin();
    event.transaction = 1;
    event.transactionBlocker = 2;
    event.commit();
}

Run CustomAnnotationSample with the following command:

java -XX:StartFlightRecording:filename=ca.jfr
CustomAnnotationSample.java

To view annotations, categories, field layouts, and other information about all the events in customannotationsample.jfr, run the following command:

jfr metadata ca.jfr

The output of the previous command includes the following:

@Name("com.oracle.Severity")
@Label("Severity")
@Description("Value between 0 and 100 that indicates severity. 100 is most severe.")
class Severity extends java.lang.annotation.Annotation {
    int value;
}

@Name("com.oracle.TransactionId")
@Label("Transaction ID")
@Relational
class TransactionId extends java.lang.annotation.Annotation {
}
...

@Name("com.oracle.TransactionBlocked")
@Severity(80)
@Label("Transaction Blocked")
class TransactionBlocked extends jdk.jfr.Event {
    @Label("Start Time")
    @Timestamp("TICKS")
    long startTime;

    @Label("Duration")
    @Timespan("TICKS")
    long duration;

    @Label("Event Thread")
    @Description("Thread in which event was committed in")
    Thread eventThread;
To access values of custom annotations, use the `EventType.getAnnotation` method, which takes one argument, the `Class` object that corresponds to the annotation type. For example, the following code prints the events whose severity is greater than 50:

```java
for (var e : RecordingFile.readAllEvents(file)) {
    EventType t = e.getEventType();
    Severity s = t.getAnnotation(Severity.class);
    if (s != null && s.getValue() > 50) {
        System.out.println(e);
    }
}
```

See [Declaring an Annotation Type](https://docs.oracle.com/javase/tutorial/java/ann/annTypes.html) in *The Java Tutorials*. 

@Label("Stack Trace")
@Description("Stack Trace starting from the method the event was committed in")
StackTrace stackTrace;

@TransactionId
@Label("Transaction")
long transaction;

@TransactionId
@Label("Transaction Blocker")
long transactionBlocker;
Inheritance of Annotations, Settings, and Fields

When a class extends an event, it inherits the event's annotations, settings, and fields. However, a class doesn't inherit private fields or annotations that lack the `@java.lang.Inherited` meta-annotation.

The example `InheritanceSample.java` demonstrates this. It defines three events: `FileAction`, `FileUpload`, and `ImageUpload`.

```java
import jdk.jfr.Category;
import jdk.jfr.Description;
import jdk.jfr.Event;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.StackTrace;

public class InheritanceSample {
    @Category("Files")
    @StackTrace(false)
    abstract static class FileAction extends Event {
        @Label("In Progress")
        boolean inProgress;
    }

    @Name("com.oracle.FileUpload")
    @Description("Uploaded file that might be a text file")
    @Label("File Upload")
    static class FileUpload extends FileAction {
        @Label("Text file")
        private boolean isText;
    }

    @Name("com.oracle.ImageUpload")
    @Label("Image Upload")
    static class ImageUpload extends FileUpload {
    }

    public static void main(String... args) {
        FileUpload fu = new FileUpload();
        fu.inProgress = true;
        fu.isText = false;
        fu.commit();

        ImageUpload iu = new ImageUpload();
        iu.inProgress = false;
        iu.commit();
    }
}
```
Run `InheritanceSample` with the following commands:

```java
java -XX:StartFlightRecording:filename=i.jfr InheritanceSample.java
jfr print --events FileUpload,ImageUpload i.jfr
```

The last command prints output similar to the following:

```java
com.oracle.FileUpload {
  startTime = 15:22:28.794
  isText = false
  inProgress = true
  ...
}

com.oracle.ImageUpload {
  startTime = 15:22:28.822
  inProgress = false
  ...
}
```

Abstract event classes, such as `FileAction` are not registered, so their metadata is never available for inspection.

Classes don't inherit annotations that lack the `@java.lang.Inherited` annotation, such as `@Name` and `@Description`.

Because the field `isText` is private, `ImageUpload` doesn't inherit it.
Part III

Configure Events and Flight Recorder

This section describes how to configure events and Flight Recorder to optimize their performance and control their behavior.

Each event has the following predefined settings:

- @Enabled: Specifies whether the event is recorded. The default value is true. See Enable and Disable Events.
- @Threshold: Specifies the duration below which an event is not recorded. The default is 0 (no limit). See Event Threshold.
- @Period: Specifies the interval at which the event is emitted, if it is periodic. The default value is everyChunk, which means that the periodic event will be emitted at least once in the recording. See Periodic Events.
- @StackTrace: Specifies whether the stack trace from the Event::commit() method is recorded. The default value is true. See Printing Event Stack Trace.

Flight Recorder provides various options to filter events; see Filter Events with SettingDefinition.

It's recommended that you specify a preconfigured configuration, which contains a collection of settings that control how much information Flight Recorder generates; see Flight Recorder Configurations. If you don't specify a preconfigured configuration, then Flight Recorder records information about all events; it monitors the running system at an extremely high level of detail and produces enormous amounts of data.
Enable and Disable Events

You can enable and disable events with the `@Enabled` annotation. The example `EnablementSample.java` demonstrates this.

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

public class EnablementSample {
    public static void main(String... args) throws Exception {
        WontSeeMe event1 = new WontSeeMe();
        event1.commit();
        WillSeeMe event2 = new WillSeeMe();
        event2.commit();
    }

    @Name("com.oracle.WontSeeMe")
    @Label("Won't See Me")
    @Enabled(false)
    static class WontSeeMe extends Event {
    }

    @Name("com.oracle.WillSeeMe")
    @Label("Will See Me")
    @Enabled(true)
    static class WillSeeMe extends Event {
    }
}
```
Event Threshold

Setting a threshold on an event means that Flight Recorder won't record it if its duration is less than the threshold. This enables you to limit the number of events that Flight Recorder records. By default, events have a threshold of 0 ms. It's recommended to set a threshold if an operation occurs frequently and outliers are of greatest concern.

The SetThresholdSample.java example creates ten events with a random duration. Flight Recorder records only those events whose duration is greater than 50 ms.

```java
import java.util.Random;
import jdk.jfr.Event;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.Threshold;

public class SetThresholdSample {
    @Name("com.oracle.RandomSleep")
    @Label("Random Sleep")
    @Threshold("50 ms")
    static class RandomSleep extends Event {
        @Label("Event number")
        int eventNumber;
        @Label("Random Value")
        int randomValue;
    }

    public static void main(String... args) throws Exception {
        Random randNum = new Random();
        for (int i = 0; i < 10; i++) {
            RandomSleep event = new RandomSleep();
            event.begin();
            event.eventNumber = i;
            event.randomValue = Math.abs(randNum.nextInt() % 100);
            System.out.println("Event "+ i +": " +
            event.randomValue);
            Thread.sleep(event.randomValue);
            event.commit();
        }
    }
}
```

Note that the `commit` method ends the timing of an event without the need of an explicit call to the `end` method.
Run SetThresholdSample with the following commands:

```
java -XX:StartFlightRecording:filename=st.jfr SetThresholdSample.java
jfr print --events RandomSleep st.jfr
```

The first command prints output similar to the following:

```
Event #0: 97
Event #1: 15
Event #2: 25
Event #3: 73
Event #4: 38
Event #5: 11
Event #6: 5
Event #7: 28
Event #8: 42
Event #9: 37
```

The last command prints output similar to the following:

```
com.oracle.RandomSleep {
  startTime = 23:17:42.050
  duration = 103.813 ms
  eventNumber = 0
  randomValue = 97
  ...
}
com.oracle.RandomSleep {
  startTime = 23:17:42.197
  duration = 77.726 ms
  eventNumber = 3
  randomValue = 73
  ...
}
```

The shouldCommit Method

You can reduce the overhead of expensive operations with the `Event.shouldCommit` method, which only commits an event if its duration is within a specified threshold.

The example `ShouldCommit.java` creates ten events with a random duration. Flight Recorder commits only those events whose duration is greater than 20 ms.

```java
import java.util.Random;
import jdk.jfr.Event;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.Threshold;
```
public class ShouldCommitSample {

    @Name("com.oracle.RandomSleep")
    @Label("Random Sleep")
    @Threshold("20 ms")
    static class RandomSleep extends Event {
        @Label("ID")
        int id;
        @Label("Value Kind")
        String valueKind;
    }

    public static void main(String... args) throws Exception {
        Random randNum = new Random();
        for (int i = 0; i < 10; i++) {
            RandomSleep event = new RandomSleep();
            event.begin();
            event.id = i;
            int value = randNum.nextInt(40);
            System.out.println("ID " + i + ": " + value);
            Thread.sleep(value);
            event.end();
            if (event.shouldCommit()) {
                // Format message outside timing of event
                if (value < 10) {
                    event.valueKind = "It was a low value of " + value + "!";
                } else if (value < 20) {
                    event.valueKind = "It was a normal value of " + value + "!";
                } else {
                    event.valueKind = "It was a high value of " + value + "!";
                }
                event.commit();
            }
        }
    }
}

Run this example with the following commands:

java -XX:StartFlightRecording:filename=shouldcommit.jfr ShouldCommit.java
jfr print --events RandomSleep shouldcommit.jfr

The first command prints output similar to the following:

ID 0: 8
ID 1: 2
ID 2: 34
ID 3: 0
ID 4: 11
ID 5: 2
The last command prints output similar to the following:

```java
com.oracle.docs.ShouldCommit.RandomSleep {
    startTime = 23:27:10.642
    duration = 36.711 ms
    id = 2
    valueKind = "It was a high value of 34!"
    ...
}
```

```java
com.oracle.docs.ShouldCommit.RandomSleep {
    startTime = 23:27:10.711
    duration = 29.390 ms
    id = 7
    valueKind = "It was a high value of 28!"
    ...
}
```

```java
com.oracle.docs.ShouldCommit.RandomSleep {
    startTime = 23:27:10.741
    duration = 28.475 ms
    id = 8
    valueKind = "It was a high value of 27!"
    ...
}
```
Periodic Events

The example PeriodicSample.java creates a periodic event named StartedThreadCount that records the total number of threads that have been created and started every second.

```java
import java.lang.management.ManagementFactory;
import java.lang.management.ThreadMXBean;

import jdk.jfr.Event;
import jdk.jfr.FlightRecorder;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.Period;

public class PeriodicSample {

    private static ThreadMXBean tBean = 
            ManagementFactory.getThreadMXBean();

    @Name("com.oracle.StartedThreadCount")
    @Label("Total number of started threads")
    @Period("1 s")
    static class StartedThreadCount extends Event {
        long totalStartedThreadCount;
    }

    public static void main(String[] args) throws InterruptedException {
        Runnable hook = () -> {
            StartedThreadCount event = new StartedThreadCount();
            event.totalStartedThreadCount = 
                    tBean.getTotalStartedThreadCount();
            event.commit();
        };

        FlightRecorder.addPeriodicEvent(StartedThreadCount.class, hook);

        for (int i = 0; i < 4; i++) {
            Thread.sleep(1500);
            Thread t = new Thread();
            t.start();
        }

        FlightRecorder.removePeriodicEvent(hook);
    }
}
```
Run PeriodicSample with the following commands:

```
java -XX:StartFlightRecording:filename=periodic.jfr PeriodicSample.java
jfr print --events StartedThreadCount periodic.jfr
```

The last command prints output similar to the following:

```java
com.oracle.StartedThreadCount {
    startTime = 00:59:40.769
    totalStartedThreadCount = 12
    ...
}
com.oracle.StartedThreadCount {
    startTime = 00:59:41.816
    totalStartedThreadCount = 12
    ...
}
com.oracle.StartedThreadCount {
    startTime = 00:59:42.866
    totalStartedThreadCount = 13
    ...
}
com.oracle.StartedThreadCount {
    startTime = 00:59:43.918
    totalStartedThreadCount = 14
    ...
}
com.oracle.StartedThreadCount {
    startTime = 00:59:44.962
    totalStartedThreadCount = 14
    ...
}
```

To create a periodic event, follow these two steps:

1. Specify how often the event should be emitted with the @Period annotation:

   ```java
   @Name("com.oracle.StartedThreadCount")
   @Label("Total number of started threads")
   @Period("1 s")
   static class StartedThreadCount extends Event {
       long totalStartedThreadCount;
   }
   ```

   **Valid units for a period are:** ns, us, ms, s, m, h, and d.

   You can also specify one of the following:
   - everyChunk: A periodic event will be emitted at least once in the recording.
   - beginChunk: A periodic event will be emitted in the beginning of a recording.
2. Add the periodic event with the
   FlightRecorder.addPeriodicEvent(Class<? extends Event>,
   Runnable) static method. The first argument is the name of the periodic event's
class. The second argument is a callback method that's represented by a lambda
expression that creates and commits the event:

   Runnable hook = () -> {
      StartedThreadCount event = new StartedThreadCount();
      event.totalStartedThreadCount =
         tBean.getTotalStartedThreadCount();
      event.commit();
   };

   FlightRecorder.addPeriodicEvent(StartedThreadCount.class, hook);

The method FlightRecorder.removePeriodicEvent(Runnable) removes the
lambda expression associated with a periodic event. In most cases, you won't
need this method; if you want to disable a periodic event, you can call
Recording.disable(Class<? extends Event>). However, one reason to call
removePeriodicEvent is to avoid memory leaks. For example, suppose you have
an application server where data is loaded and unloaded. If the callback method
references data that the server loads and unloads, then it may prevent that data from
being garbage collected. You can avoid this by removing the callback method when
the data is unloaded.
Printing Event Stack Trace

The example StackTraceSample.java prints an event's stack trace. It calls the method firstFunc six times.

StackTraceSample uses the Event Streaming API (see Monitor Events with Flight Recorder Event Streaming API) to print stack trace information of WithStackTrace events.

```java
import java.util.List;
import java.util.function.Consumer;
import jdk.jfr.Event;
import jdk.jfr.EventType;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.StackTrace;
import jdk.jfr.consumer.RecordedEvent;
import jdk.jfr.consumer.RecordedFrame;
import jdk.jfr.consumer.RecordedStackTrace;
import jdk.jfr.consumer.RecordingStream;

public class StackTraceSample {
    @Name("com.oracle.WithStackTrace")
    @Label("With Stack Trace")
    @StackTrace(true)
    static class WithStackTrace extends Event {
        String message;
    }

    public static void main(String... args) throws Exception {
        Consumer<RecordedEvent> myCon = x -> {
            EventType et = x.getEventType();
            System.out.println("Label: " + et.getLabel());
            System.out.println("Message: " + x.getValue("message"));
            RecordedStackTrace rst = x.getStackTrace();
            if (rst != null) {
                List<RecordedFrame> frames = rst.getFrames();
                System.out.println("Number of frames: " + frames.size());
                for (RecordedFrame rf : frames) {
                    System.out.println("Method, line number: "
                        + rf.getMethod().getName() + ", "
                        + rf.getLineNumber());
                }
            }
            System.out.println("\n");
        };
```
try (RecordingStream rs = new RecordingStream()) {
    rs.onEvent("com.oracle.WithStackTrace", myCon);
    rs.startAsync();
    firstFunc(5);
    rs.awaitTermination();
}

static void firstFunc(int n) {
    if (n > 0) {
        secondFunc(n - 1);
    }
    WithStackTrace event = new WithStackTrace();
    event.message = "n = " + n;
    event.commit();
}

static void secondFunc(int n) {
    firstFunc(n);
}

The example StackTraceSample prints output similar to the following:

Label: With Stack Trace
Message: n = 0
Number of frames: 12
Method, line number: firstFunc, 97
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: main, 86

Label: With Stack Trace
Message: n = 1
Number of frames: 10
Method, line number: firstFunc, 97
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
Method, line number: secondFunc, 102
Method, line number: firstFunc, 93
An event's stack trace, an instance of `RecordedStackTrace`, consists of a list of `RecordedFrame` instances. You can obtain the following information from a `RecordedFrame` with these methods:

- `getMethod()`: Returns the method from which the event was run.
- `getLineNumber()`: Returns the line number from which the event was run.
- `isJavaFrame()`: Indicates whether the `RecordedFrame` is a Java frame.
- `getBytecodeIndex()`: Returns the bytecode index from which the event was run.
- `getType()`: Returns the frame type; possible values include `Interpreted`, `JIT compiled`, and `Inlined`.
Flight Recorder uses a default stack depth of 64 method calls, which is more than enough for this example. You can change this with the `stackdepth` command-line option:

```
-XX:FlightRecorderOptions:stackdepth=depth
```

Note that values greater than 64 could create significant overhead and reduce performance.
Filter Events with SettingDefinition

The example `FilteringSample.java` (along with `RegExpControl.java`) uses a `SettingDefinition` to filter which events Flight Recorder records. In this example, it records `Hello` events that have a value that starts with `g` in its `message` field.

```java
import java.io.IOException;
import jdk.jfr.Description;
import jdk.jfr.Event;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.Recording;
import jdk.jfr.SettingDefinition;

public class FilteringSample {

    @Name("com.oracle.FilteredHello")
    @Label("Hello With Message Filter")
    static class FilteredHello extends Event {
        @Label("Message")
        String message;

        @Label("Message Filter")
        @Description("Filters messages with regular expressions")
        @SettingDefinition
        protected boolean messageFilter(RegExpControl control) {
            return control.matches(message);
        }
    }

    public static void main(String[] args) throws IOException {
        try (Recording r = new Recording()) {
            r.enable(FilteredHello.class).with("messageFilter", "g.*")
                .start();
            FilteredHello greenEvent = new FilteredHello();
            FilteredHello yellowEvent = new FilteredHello();
            FilteredHello redEvent = new FilteredHello();
            greenEvent.message = "green";
            yellowEvent.message = "yellow";
            redEvent.message = "red";
            greenEvent.commit();
            yellowEvent.commit();
            redEvent.commit();
        }
    }
}
```
The example FilteringSample requires RegExpControl.java:

```java
import java.util.Set;
import java.util.regex.Pattern;
import jdk.jfr.SettingControl;

public class RegExpControl extends SettingControl {
    private Pattern pattern = Pattern.compile(".*");

    @Override
    public void setValue(String value) {
        this.pattern = Pattern.compile(value);
    }

    @Override
    public String combine(Set<String> values) {
        return String.join("|", values);
    }

    @Override
    public String getValue() {
        return pattern.toString();
    }

    public boolean matches(String s) {
        return pattern.matcher(s).find();
    }
}
```

Compile FilteringSample.java and RegExpControl.java, then run FilteringSample with the following commands:

```bash
java -XX:StartFlightRecording:filename=filteringsample.jfr FilteringSample
jfr print --events FilteredHello filteringsample.jfr
```

The last command prints output similar to the following:

```java
com.oracle.FilteredHello {
    startTime = 23:38:28.364
    message = "green"
    ...
}
```

The annotation @SettingDefinition specifies which method Flight Recorder calls to determine whether it records a particular event. In this example, it calls messageFilter(RegExpControl):

```java
@SettingDefinition
protected boolean messageFilter(RegExpControl control) {
```
    return control.matches(message);
}

This method's parameter, RegExpControl, extends the class SettingControl. In this example, RegExpControl.java implements a regular expression setting control; the method matches(String) returns true when its string matches the field pattern (which an application can change with the setValue(String) method).

The methods setValue(), getValue() and combine(Set<String>) methods are invoked when a setting value changes, which typically happens when a recording is started or stopped. The combine(Set<String>) method is invoked to resolve what value to use when multiple recordings are running at the same time.
Exclude Fields from Being Persisted with the transient Keyword

You can exclude fields from being persisted with the `transient` keyword. The example `ExcludeFieldsSample.java` demonstrates this.

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

public class ExcludeFieldsSample {
    @Name("com.oracle.Message")
    @Label("Message")
    static class Message extends Event {
        String messageA;
        transient String messageB;
        String messageC;
    }

    public static void main(String... args) {
        Message event = new Message();
        event.messageA = "hello";
        event.messageB = "world"; // will not be persisted.
        event.messageC = "!";
        event.commit();
    }
}
```

Run `ExcludeFieldsSample` with the following commands:

```
java -XX:StartFlightRecording:filename=excludefieldssample.jfr
ExcludeFieldsSample.java
jfr print --events Message excludefieldssample.jfr
```

The last command prints output similar to the following:

```
com.oracle.Message {
    startTime = 23:41:15.425
    messageA = "hello"
    messageB = "world"
    messageC = "!"
    ...
}
```
Manually Register and Unregister an Event

By default, an event is automatically registered when the event class is initialized. Alternatively, you can manually register an event with the @Registered annotation. One reason to do this is to take control of the security context in which the event is initialized.

The difference between the @Enabled annotation and the @Registered annotation is that when an event is unregistered, its metadata, such as the field layout, is not available for inspection. A call to FlightRecorder::register can ensure that an event class is visible for configuration, for example, to a Java Management Extensions (JMX) client.

The example RegistrationSample.java demonstrates this:

```java
import jdk.jfr.Event;
import jdk.jfr.FlightRecorder;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.Registered;

public class RegistrationSample {
    @Name("com.oracle.Message")
    @Label("Message")
    @Registered(false)
    static class Message extends Event {
        String message;
    }

    public static void main(String... args) {
        Message event1 = new Message();
        event1.message = "Not registered, so you won't see this";
        event1.commit();

        FlightRecorder.register(Message.class);
        Message event2 = new Message();
        event2.message = "Now registered, so you will see this!";
        event2.commit();

        FlightRecorder.unregister(Message.class);

        Message event3 = new Message();
        event3.message = "Not registered again, so you won't see this";
        event3.commit();
    }
}
```
Flight Recorder Configurations

Flight Recorder configurations control the amount of data that is recorded.

Flight Recorder uses two preconfigured configurations, default.jfc and profile.jfc. These configurations have predefined settings for each event type. Both of these configurations are located in <java_home>/lib/jfr. By default, Flight Recorder uses the default.jfc configuration when you start a recording. The default.jfc configuration is recommended for continuous recordings. It gives a good balance between data and performance (typically, less than 1% overhead). The profile.jfc configuration records more events and is useful while profiling an application.

In most cases, the preconfigured configurations are sufficient. However, there might be a scenario while analyzing a recording that some events are disabled by default. To enable these events, create a custom configuration. Use JDK Mission Control to configure the event settings by using one of the existing configurations. Make a copy of an existing configuration and then modify it. Don’t modify the default configurations. Specify which configuration to use with the settings command-line option when starting a recording. For example:

- XX:StartFlightRecording:filename=recording.jfr,dumponexit=true,settings=default.jfc
- XX:StartFlightRecording:filename=recording.jfr,dumponexit=true,settings=my settings.jfc
Monitor Events with Flight Recorder Event Streaming API

The Flight Recorder event streaming API enables you to consume Flight Recorder data continuously. This section shows you three ways you can do this:

- **Create Event Stream in Process, Active**: Creates an event stream at the same time a recording is created
- **Create Event Stream in Process, Passive**: Creates a passive stream that listens for events, but what gets recorded is controlled by external means
- **Create Event Stream from External Process**: Creates an event stream from a separate Java process
Create Event Stream in Process, Active

The sample StreamEventsSample.java creates an event stream at the same time a recording is created.

The class RecordingStream starts a recording at the same time as the stream. The sample calls Thread.sleep(1000) three times, which creates three jdk.ThreadSleep events. The Event Streaming API prints the jdk.ThreadSleep events when they occur:

```java
import jdk.jfr.Configuration;
import jdk.jfr.consumer.RecordingStream;

public class StreamEventsSample {
    public static void main(String... args) throws Exception {
        Configuration c = Configuration.getConfiguration("profile");
        try (RecordingStream rs = new RecordingStream(c)) {
            rs.onEvent("jdk.ThreadSleep", System.out::println);
            System.out.println("Starting recording stream ...");
            rs.startAsync();
            for (int i = 0; i < 3; i++) {
                System.out.println("Sleeping for 1s...");
                Thread.sleep(1000);
            }
        }
    }
}
```

Run StreamEventsSample with the following command:

```
java -XX:StartFlightRecording StreamEventsSample.java
```

It prints output similar to the following:

Started recording 1. No limit specified, using maxsize=250MB as default.

Use jcmd 7400 JFR.dump name=1 filename=FILEPATH to copy recording data to file.
Starting recording stream ...
Sleeping for 1s...
Sleeping for 1s...
jdk.ThreadSleep {
    startTime = 00:26:42.463
    duration = 2.14 s
    time = 1.00 s
    ...
}
Sleeping for 1s...
jdk.ThreadSleep {
    startTime = 00:26:44.602
    duration = 1.04 s
    time = 1.00 s
    ...
}

Follow these steps to create an event stream from a recording with the
RecordingStream class:

1. Optionally specify a predefined configuration ("default" or "profile") with the
   Configuration class.

2. Create a RecordingStream instance with
   either the Configuration.getConfiguration() or
   Configuration.getConfiguration(Configuration) method.

3. Optionally enable events that you want to include in the event stream with the
   RecordingStream::enable(String) method.

4. Specify actions to perform on events in the stream. To specify an action to perform
   on all events, use the onEvent(Consumer<RecordedEvent>) method. For
   example, the following statement prints the name of all events in the stream to
   standard output:

   ```java
   rs.onEvent(e ->
       System.out.println(e.getEventType().getName());
   );
   ```

   Use the onEvent(String, Consumer<RecordedEvent>) to specify an action
   to perform on a specific event. For example, the following statement prints events
   whose name matches jdk.ThreadSleep:

   ```java
   rs.onEvent("jdk.ThreadSleep", System.out::println);
   ```

5. Start the event stream with either the start() or startAsync() method. This
   sample calls startAsync(), which runs the stream in a background thread. If
   you call the start() method, then the application will not proceed pass this
   method call until the stream is closed.
Create Event Stream in Process, Passive

The sample `PassiveEventStreamSample.java` starts a passive stream with the method `EventStream.openRepository()`. This stream listens for events (in particular, `jdk.CPULoad`, but what gets recorded is controlled by external means, for example, by the command-line option `-XX:StartFlightRecording`, the `jcmd` command `JFR.start` or an API (for example, `Recording::start()`).

The sample `PassiveEventStreamSample.java` creates an event stream not with `RecordingStream` but with `EventStream.openRepository()`. An event stream requires a recording; this sample obtains it from the command-line option `-XX:StartFlightRecording`.

```java
import java.util.concurrent.atomic.AtomicInteger;
import jdk.jfr.consumer.EventStream;

public class PassiveEventStreamSample {
    static int NUMBER_CPULOAD_EVENTS = 3;

    public static void main(String... args) throws Exception {
        AtomicInteger timer = new AtomicInteger();

        try (EventStream es = EventStream.openRepository()) {
            es.onEvent("jdk.CPULoad", event -> {
                System.out.println("CPU Load " + event.getEndTime());
                System.out.println(" Machine total: " + 100 * event.getFloat("machineTotal") + "%");
                System.out.println(" JVM User: " + 100 * event.getFloat("jvmUser") + "%");
                System.out.println(" JVM System: " + 100 * event.getFloat("jvmSystem") + "%");
                System.out.println();
                if (timer.incrementAndGet() == NUMBER_CPULOAD_EVENTS) {
                    System.exit(0);
                }
            });
            es.start();
        }
    }
}
```
Run `PassiveEventStreamSample` with the following command:

```java
java -XX:StartFlightRecording PassiveEventStreamSample.java
```

It prints output similar to the following:

Started recording 1. No limit specified, using maxsize=250MB as default.

Use `jcmd 12352 JFR.dump name=1 filename=FILEPATH` to copy recording data to file.

CPU Load 2020-01-24T05:34:36.265584686Z
  Machine total: 19.3799%
  JVM User: 5.2175264%
  JVM System: 1.8634024%

CPU Load 2020-01-24T05:34:37.310049859Z
  Machine total: 5.2533073%
  JVM User: 0.0%
  JVM System: 0.3899041%

CPU Load 2020-01-24T05:34:38.373796070Z
  Machine total: 7.242967%
  JVM User: 0.0%
  JVM System: 1.1451485%
Create Event Stream from External Process

The sample `StreamExternalEventsWithAttachAPISample.java` creates an event stream from a separate Java process, the sample `.SleepOneSecondIntervals.java`. `SleepOneSecondIntervals` repeatedly sleeps for 1 second intervals; as demonstrated in Create Event Stream in Process, Active, every time `Thread.sleep()` is called, a `jdk.ThreadSleep` event occurs.

```java
public class SleepOneSecondIntervals {
    public static void main(String... args) throws Exception {
        long pid = ProcessHandle.current().pid();
        System.out.println("Process ID: " + pid);
        while(true) {
            System.out.println("Sleeping for 1s...");
            Thread.sleep(1000);
        }
    }
}
```

`StreamExternalEventsWithAttachAPISample` uses the Attach API to obtain the virtual machine in which `SleepOneSecondIntervals` is running. From this virtual machine, `StreamExternalEventsWithAttachAPISample` obtains the location of its Flight Recorder repository though the `jdk.jfr.repository` property. It then creates an `EventStream` with this repository through the `EventStream::openRepository(Paths)` method.

```java
import java.nio.file.Paths;
import java.util.Optional;
import java.util.Properties;
import com.sun.tools.attach.VirtualMachine;
import com.sun.tools.attach.VirtualMachineDescriptor;
import jdk.jfr.consumer.EventStream;

public class StreamExternalEventsWithAttachAPISample {
    public static void main(String... args) throws Exception {
        Optional<VirtualMachineDescriptor> vmd =
            VirtualMachine.list().stream()
            .filter(v -> v.displayName()
                .equals("SleepOneSecondIntervals"))
            .findFirst();

        if (vmd.isEmpty()) {
```
throw new RuntimeException("Cannot find VM for SleepOneSecondIntervals");

VirtualMachine vm = VirtualMachine.attach(vmd.get());

// Get system properties from attached VM
Properties props = vm.getSystemProperties();
String repository = props.getProperty("jdk.jfr.repository");
System.out.println("jdk.jfr.repository: " + repository);

try (EventStream es = EventStream.openRepository(Paths.get(repository))) {
    System.out.println("Found repository ..."));
    es.onEvent("jdk.ThreadSleep", System.out::println);
    es.start();
} catch (IOException e) {
    throw new RuntimeException("Cannot find repository");
}

Compile SleepOneSecondIntervals.java and StreamExternalEventsWithAttachAPISample.java. Then run SleepOneSecondIntervals with this command:

java -XX:StartFlightRecording SleepOneSecondIntervals

In a new command shell, run StreamExternalEventsWithAttachAPISample:

java StreamExternalEventsWithAttachAPISample

It prints output similar to the following:

jdk.jfr.repository: C:\Users\<your user name>\AppData\Local\Temp\2019_12_08_23_32_47_5100
Found repository ...
Found repository ...
jdk.ThreadSleep {
    startTime = 00:46:55.208
    duration = 1.05 s
    time = 1.00 s
    ...
}

jdk.ThreadSleep {
    startTime = 00:46:56.257
    duration = 1.04 s
    time = 1.00 s
    ...
}
The sample StreamExternalEventsWithJcmdSample.java is similar to StreamExternalEventsWithAttachAPISample except it starts Flight Recorder for SleepOneSecondIntervals with the Attach API. With this API, the sample runs the command jcmd <PID> JFR.start with the PID of SleepOneSecondIntervals:

```java
import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStreamReader;
import java.nio.file.Paths;
import java.util.Properties;
import java.util.function.Consumer;
import com.sun.tools.attach.VirtualMachine;
import jdk.jfr.consumer.EventStream;
import jdk.jfr.consumer.RecordedEvent;

public class StreamExternalEventsWithJcmdSample {
    public static void main(String... args) throws Exception {
        if (args[0] == null) {
            System.err.println("Requires PID of process as argument");
            System.exit(1);
        }

        String pid = args[0];

        Process p = Runtime.getRuntime().exec("jcmd " + pid + " JFR.start");

        printOutput(p);

        // Wait for jcmd to start the recording
        Thread.sleep(1000);

        VirtualMachine vm = VirtualMachine.attach(pid);
        Properties props = vm.getSystemProperties();
        String repository = props.getProperty("jdk.jfr.repository");
        System.out.println("jdk.jfr.repository: " + repository);

        try (EventStream es = EventStream.openRepository(Paths.get(repository))) {
            System.out.println("Found repository ...");
            es.onEvent("jdk.ThreadSleep", System.out::println);
            es.start();
        }
    }

    private static void printOutput(Process proc) throws IOException {
        BufferedReader stdInput = new BufferedReader(new InputStreamReader(proc.getInputStream()));
```

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BufferedReader stdError = new BufferedReader(
    new InputStreamReader(proc.getErrorStream()));

// Read the output from the command
System.out.println(
    "Here is the standard output of the command:\n");
String s = null;
while ((s = stdInput.readLine()) != null) {
    System.out.println(s);
}

// Read any errors from the attempted command
System.out.println(
    "Here is the standard error of the " + "command (if any):\n");
    while ((s = stdError.readLine()) != null) {
    System.out.println(s);
}

Compile SleepOneSecondIntervals.java and StreamExternalEventsWithJcmdSample.java. Then run SleepOneSecondIntervals with this command:

    java -XX:StartFlightRecording SleepOneSecondIntervals

It prints output similar to the following:

Started recording 1. No limit specified, using maxsize=250MB as default.

Use jcmd 5100 JFR.dump name=1 filename=FILEPATH to copy recording data
to file.
Process ID: 5100
Sleeping for 1s...
Sleeping for 1s...
Sleeping for 1s...
...

Note the PID for SleepOneSecondIntervals (in this example, it's 5100). While this sample is running, in a new command shell, run
StreamExternalEventsWithJcmdSample with this command:

    java StreamExternalEventsWithJcmdSample <PID of SleepOneSecondIntervals>
The example ParseRecordingFileSample.java describes various ways you can parse a recording file. It starts a recording to record several Hello and Message events.

```java
import java.io.IOException;
import java.nio.file.Files;
import java.nio.file.Path;
import jdk.jfr.Event;
import jdk.jfr.EventType;
import jdk.jfr.Label;
import jdk.jfr.Name;
import jdk.jfr.Recording;
import jdk.jfr.consumer.EventStream;
import jdk.jfr.consumer.RecordingFile;

public class ParseRecordingFileSample {

    @Name("com.oracle.Hello")
    @Label("Hello World!")
    static class Hello extends Event {
        @Label("Greeting")
        String greeting;
    }

    @Name("com.oracle.Message")
    @Label("Message")
    static class Message extends Event {
        @Label("Text")
        String text;
    }

    public static void main(String... args) throws IOException {
        try (Recording r = new Recording()) {
            r.start();
            for (int i = 0; i < 3; i++) {
                Message messageEvent = new Message();
                messageEvent.begin();
                messageEvent.text = "message " + i;
                messageEvent.commit();

                Hello helloEvent = new Hello();
                helloEvent.begin();
                helloEvent.greeting = "hello " + i;
                helloEvent.commit();
            }
            r.stop();
        }
    }
}
```
Path file = Files.createTempFile("recording", ".jfr");
        r.dump(file);

        try (var recordingFile = new RecordingFile(file)) {
            System.out.println("Reading events one by one");
            System.out.println("=========================");
            while (recordingFile.hasMoreEvents()) {
                var e = recordingFile.readEvent();
                String eventName = e.getEventType().getName();
                System.out.println("Name: " + eventName);
            }
            System.out.println();
            System.out.println("List of registered event types");
            System.out.println("==============================");
            for (EventType eventType :
                recordingFile.readEventTypes())
                System.out.println(eventType.getName());
            }
            System.out.println();
            System.out.println("Reading all events at once");
            System.out.println("===============================");
            for (var e : RecordingFile.readAllEvents(file)) {
                String eventName = e.getEventType().getName();
                System.out.println("Name: " + eventName);
            }
            System.out.println();
            System.out.println("Reading events one by one, printing
only "
                + "com.oracle.Message events");
            System.out.println("=====================================
                + "=====================================");
            try (EventStream eventStream = EventStream.openFile(file)) {
                eventStream.onEvent("com.oracle.Message", e -> { System.out.println(
                        "Name: " + e.getEventType().getName());
                    });
                eventStream.start();
            }
        }
    }

Run ParseRecordingFileSample with this command:

java ParseRecordingFileSample.java
When running ParseRecordingFileSample, you don't have to start Flight Recorder with the command-line option \(--XX:StartFlightRecording\); the method \(\text{Recording.start()}\) starts it. ParseRecordingFileSample prints the following:

Reading events one by one
=================================
Name: com.oracle.Message
Name: com.oracle.Hello
Name: com.oracle.Message
Name: com.oracle.Hello
Name: com.oracle.Message
Name: com.oracle.Hello
Name: com.oracle.Hello

List of registered event types
=================================
jdk.ThreadStart
jdk.ThreadEnd
jdk.ThreadSleep
...
jdk.X509Validation
com.oracle.Message
com.oracle.Hello

Reading all events at once
=================================
Name: com.oracle.Message
Name: com.oracle.Hello
Name: com.oracle.Message
Name: com.oracle.Hello
Name: com.oracle.Message
Name: com.oracle.Hello
Name: com.oracle.Hello

Reading events one by one, printing only com.oracle.Message events
=================================
Name: com.oracle.Message
Name: com.oracle.Message
Name: com.oracle.Message

Write Recording Data to a File

ParseRecordingFileSample demonstrates several ways you can parse a recording file. However, you first need a recording file, and this sample doesn't create one at the command line. Instead, it calls \(\text{Recording.dump(Path)}\) to write recording data to a temporary file:

\[
\text{Path file = Files.createTempFile("recording", ".jfr");}
\text{r.dump(file);}
\]

Note that the recording must be started but not necessarily stopped.

Read Events One by One

Use this technique for large recordings and if you need to access metadata.
The method `RecordingFile.readEvent()` reads the next event in the recording while `RecordingEvent.hasMoreEvents()` returns true if unread events exist in the recording file:

```java
while (recordingFile.hasMoreEvents()) {
    var e = recordingFile.readEvent();
    String eventName = e.getEventType().getName();
    System.out.println("Name: "+ eventName);
}
```

**List Registered Event Types**

The method `RecordingFile.readEventTypes()` returns a list of all event types in the recording.

**Read All Events at Once**

Use this technique for smaller recordings that fit in memory.

The method `RecordingFile.readAllEvents(Path)` returns a list of all events in the recording file. It's intended for small recording files where it's more convenient to read all events in a single operation. It's not intended for reading large recording files.

**Read Only Specific Events with Event Streaming API**

To process only specific events, you could read events one by one with `RecordingFile.readEvent()`, as described previously, then check the event's name. However, if you use the event streaming API, then event objects of the same type are reused to reduced allocation pressure.

This technique involves creating an event stream with `EventStream.openFile(Path)`, then calling `EventStream.onEvent(String eventName, Consumer)` to register an action that will be performed if `eventName` matches the event's name:

```java
try (EventStream eventStream = EventStream.openFile(file)) {
    eventStream.onEvent("com.oracle.Message", e -> {
        System.out.println("Name: "+ e.getEventType().getName());
    });
    eventStream.start();
}
```