

Using the Spring Framework for Aspect-Oriented Programming

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New Aspects of Software

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This Talk Is About...

- Spring Overview
- Aspect-Oriented Development
 - Concepts
 - Tools and integration
- Applications of AOP
 - Exploration & enforcement
 - Infrastructure
 - Domain-Specific
- Conclusion
 - Adoption
 - Lifecycle Use



The Crosscutting Problem

- Auxiliary concerns are scattered and tangled
 - data security
 - performance monitoring
 - business rules
 - error handling
- 80% of problems come from this 20% of code
 - inflexibility
 - redundancy
 - incomprehensibility



The AOP Solution

- Crosscutting is natural
 - can't decompose requirements in one-dimension
- The problem is a lack of support
- Aspects provide *modular support* for crosscutting
- Evolutionary step for software development:
 - structured → objects → aspects



Benefits

- Greater product flexibility
- Reduced development costs
- Enforcement of policy...
Reliable implementation of policy
- Fewer intractable bugs



Spring Refresher

- <http://www.springframework.org>
- Open Source (Apache License)
- Inversion of Control Container
 - Injects dependencies into POJOs
 - Separates environment from core logic
 - Supports testing
- Bean definitions
 - Usually XML beans file
- Additional services and wrapping layers
 - Servlet MVC, JDBC, EJB, ...



Spring Bean Class: *A POJO*

```
public class EmailValidator {  
    private ValidationService remoteService;  
    private List validDomains;  
  
    public ValidationService getValidationService() {  
        return remoteService;  
    }  
  
    public void setValidationService(ValidationService sv) {  
        remoteService = sv;  
    }  
  
    ...  
}
```



Spring Bean Definition XML

```
<beans>
  <bean id="emailValidator" class="EmailValidator">
    <property name="validationService" ref="validation"/>
    <property name="validDomains">
      <list><value>.com</value><value>.net</value></list>
    </property>
  </bean>

  <bean id="validation" class="org.hitcopper.Validator"/>
</beans>
```

- Bean properties can be strings, numbers, collections, or references to other beans



Spring Client Coding

```
...  
ApplicationContext context =  
    new ClassPathXmlApplicationContext("beans.xml");  
  
EmailValidator test =  
    (EmailValidator) factory.getBean("emailValidator");  
  
List domains = test.getDomains();  
...
```

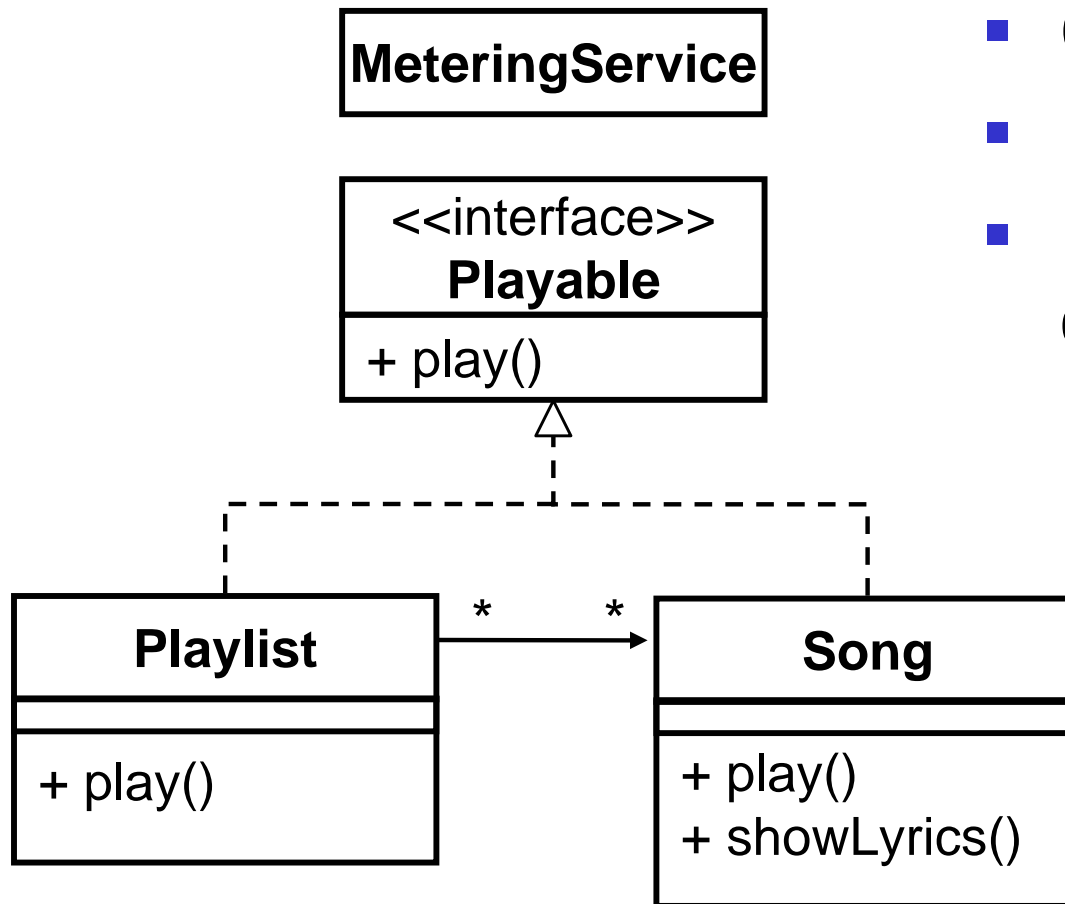
- ApplicationContexts look up Beans by name
 - Is normally used in a Session or Domain Factory
- Typical implementations read Spring XML configuration file for Bean Definitions



Spring AOP Live

DEMO

Example: Online Music Service



- Online music streaming
- Playlists have Songs
- Both Songs and Playlists can be played by a User

Inspired by the "Implementing Observer in .NET" example at MSDN and Figures from the original AspectJ tutorial

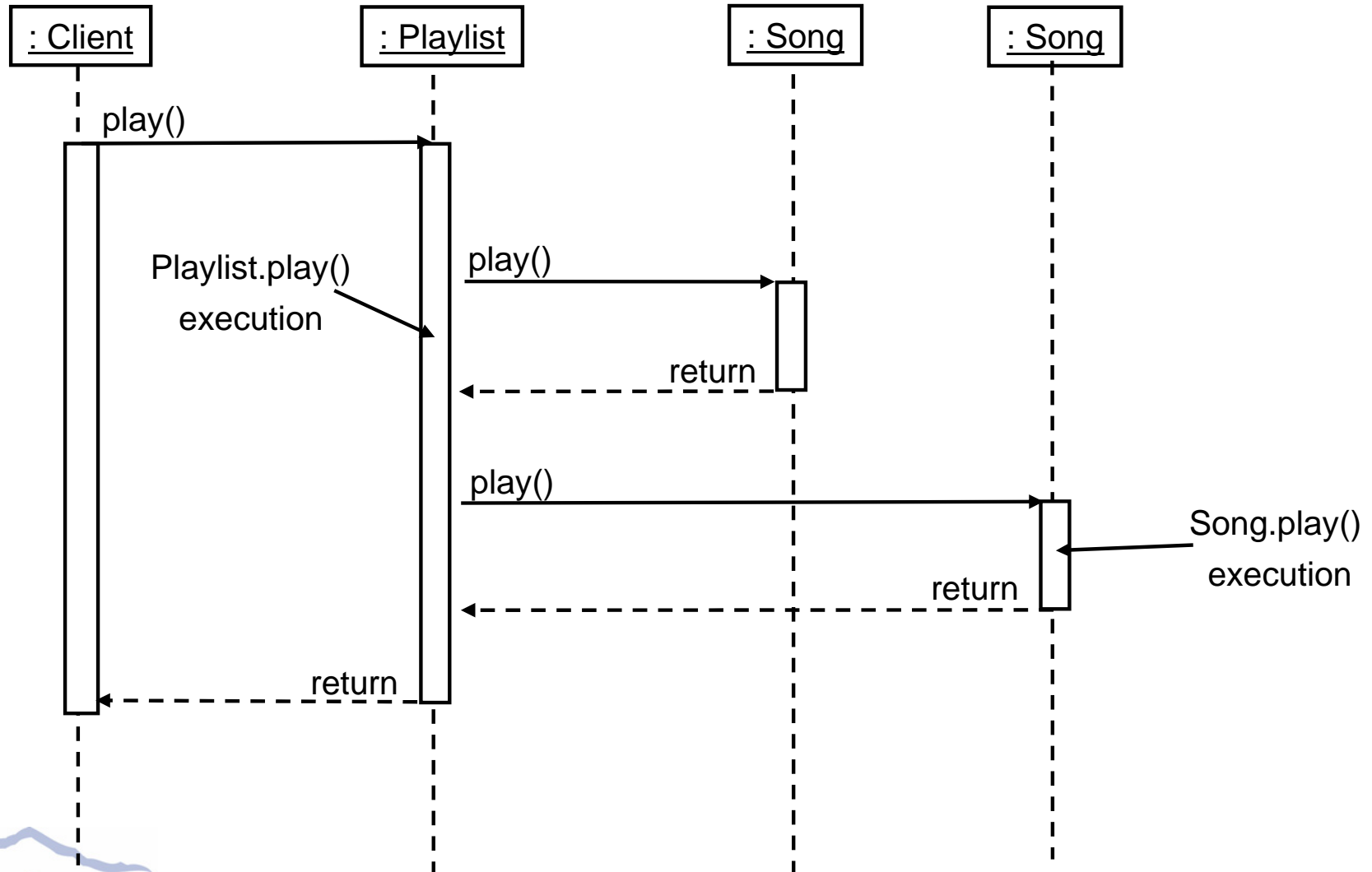


New Requirement: Metering User Activity

- When using titles
 - Individual songs... including lyrics
 - Playing play lists
- Should track usage to allow charging user account
- Billing may vary on a number of factors
 - Monthly subscription
 - Daily pass
 - Per title
 - Promotions...

key points in dynamic call graph

Join Points



Pointcuts: Queries over Join Points

Execution of Song.play() method

```
@Pointcut("execution(void model.Song.play()) ||
execution(void model.Song.showLyrics())")
void useTitle() {}
```

or

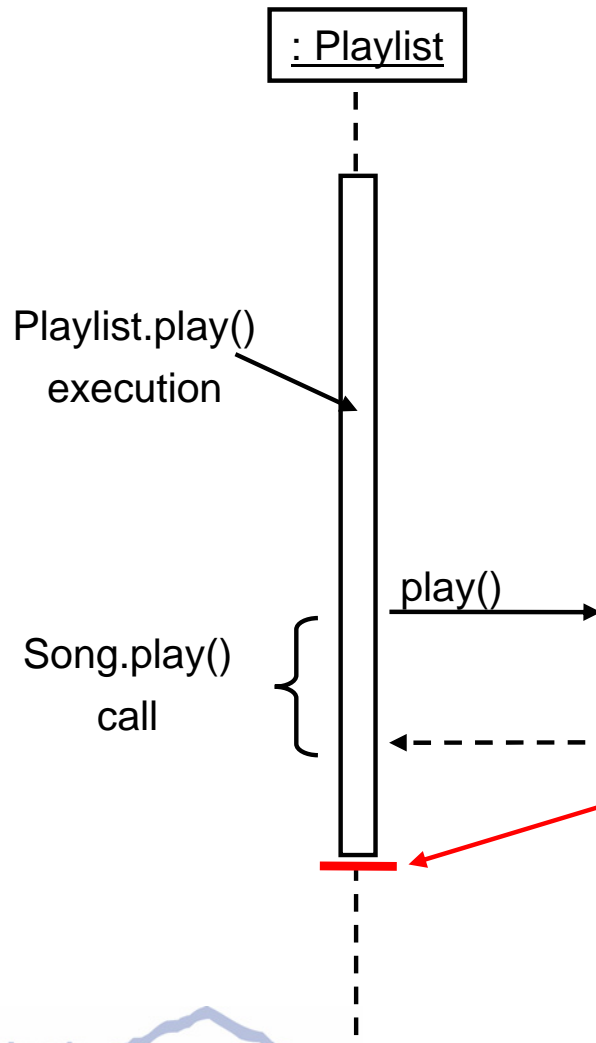
Name and Parameters

Execution of Song.showLyrics() method

- This pointcut captures the method execution join points of play() and showLyrics()



Advice



- Code that runs before, after, or instead of a join point

```
@Pointcut("
  execution(void m. Song. play()) ||
  execution(void m. Song. showLyrics())")
void useTitle() {}
```

```
@AfterReturning("useTitle()")
public void trackTitleUse() {
  //code to run after using a title
}
```



An *Aspect* for Metering

```
@Aspect
public class MeteringPolicy {
    @Pointcut("execution(void model . Song. play()) ||
              execution(void model . Song. showLyrics())")
    void useTitle() {}

    @AfterReturning("useTitle()")
    public void trackTitleUse() {
        MeteringService.trackUse();
    }
}
```

- An aspect is a special type
 - Like a class that crosscuts other types
 - Can contain constructs like pointcuts and advice



Metering Playables

@Aspect

```
public class MeteringPolicy {
    @Pointcut("execution(void model . Playable.play()) ||
              execution(void model . Song.showLyrics())")
    void useTitle() {}

    @AfterReturning("useTitle()")
    public void trackTitleUse() {
        MeteringService.trackUse();
    }
}
```

- Aspect now applies to Playlist and any other Playables (including Song)



Exposing Context

@Aspect

```
public class MeteringPolicy {
    @Pointcut(" (execution(void model.Playable.play()) ||
                execution(void model.Song.showLyrics())) &&
              this(playable) ")
    void useTitle(Playable playable) {}

    @AfterReturning("useTitle(playable)")
    public void afterUseTitle(Playable playable) {
        MeteringService.trackUse(playable);
    }
}
```

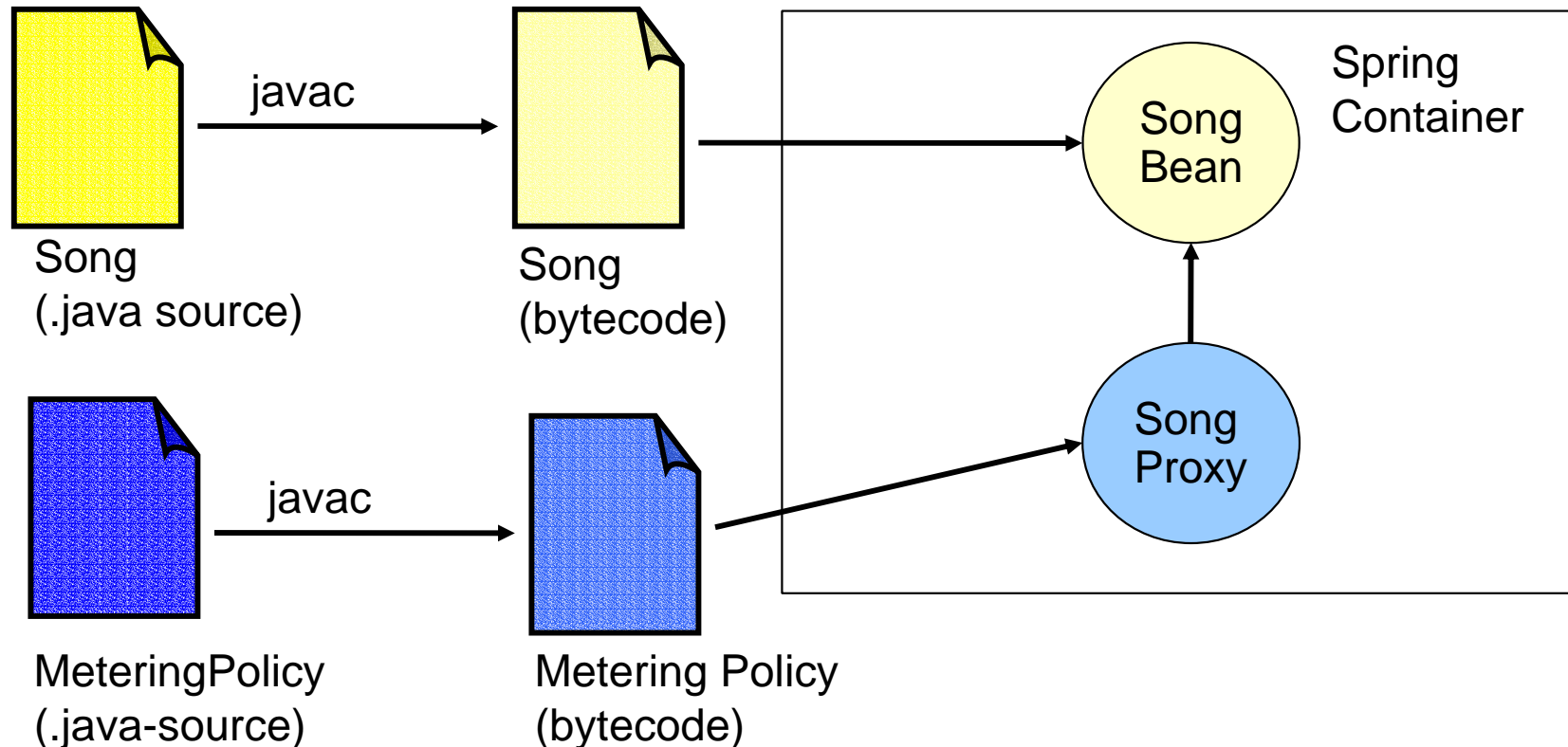
- This version exposes the currently executing object at each join point (*i.e.* the Playlist or Song) using `this()`



What Is Spring 2.0 AOP?

- Proxy-based AOP support for Java
 - Integrated with Spring Bean Container
 - Proxies generated at runtime
 - Avoids time and complexity of weaving many classes
 - Provides instance-based configuration
- Two styles for defining Aspects:
 - @AspectJ style with Java 5 Annotations
 - XML Schema-based in Spring config file
- Supported Pointcuts
 - execution, within, this, target, args,
@within, @target, @args, @annotation

Spring AOP Mechanisms



- Dynamic proxy creation per instance of advised *beans*



Spring AOP Configuration

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns=http://www.springframework.org/schema/beans
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:aop="http://www.springframework.org/schema/aop"
       xsi:schemaLocation="
         http://www.springframework.org/schema/beans
         http://www.springframework.org/schema/beans/spring-beans.xsd
         http://www.springframework.org/schema/aop
         http://www.springframework.org/schema/aop/spring-aop.xsd" >

  <aop:aspectj-autoproxy/> <!-- apply @AspectJ Beans -->

</beans>
```

- An empty Spring Beans config file with AOP support.

Configuration 2



Spring AOP Configuration

```
<?xml version="1.0" encoding="UTF-8"?>
<beans ...>

  <aop: aspectj -autoproxy/>

  <!-- include Aspect -->
  <bean class="model.metering.MeteringPolicy" />

</beans>
```

- Referencing an `@AspectJ` annotated class
 - Spring will automatically proxy advised Beans

Configuration 2

Spring AOP Configuration

```
<beans ... >
  <aop: aspectj -autoproxy/>
  <bean class="MeteringPolicy" />

  <!-- Beans will be auto-proxied with Aspect -->
  <bean name="abbyRoad" class="music.model.Song">
    <property name="name" value="Abby Road" />
  </bean>

  <bean name="playList" class="music.model.PlayList"
    scope="prototype">
    <property name="entries">
      <list value-type="music.model.Playable">
        <ref bean="abbyRoad" />
        <ref bean="rockLobster" />
      </list>
    </property>
  </bean>...
```

- Song and PlayList beans will be autoproxied by the MeteringPolicy Aspect: database later



Java Implementation

```
class Playlist{
    private String name;
    private List<Playable> entries =
        new ArrayList<Playable>();

    public void play() {
        for (Playable entry : entries) {
            entry.play();
        }
    }
}

class Song{
    private String name;

    public void play() {
        // play song
    }

    public void showLyrics(){
        // show lyrics
    }
}
```


Metering 1

Java Implementation

```
class Playlist{
    private String name;
    private List<Playable> entries =
        new ArrayList<Playable>();

    public void play() {
        for (Playable entry : entries) {
            entry.play();
        }
    }
}

class Song{
    private String name;

    public void play() {
        // play song
        MeteringService.trackUse();
    }

    public void showLyrics(){
        // show lyrics
        MeteringService.trackUse();
    }
}
```



Metering 2

Java Implementation

```
class Playlist{
    private String name;
    private List<Playable> entries =
        new ArrayList<Playable>();

    public void play() {
        for (Playable entry : entries) {
            entry.play();
        }
        MeteringService.trackUse();
    }
}

class Song{
    private String name;

    public void play() {
        // play song
        MeteringService.trackUse();
    }

    public void showLyrics(){
        // show lyrics
        MeteringService.trackUse();
    }
}
```





Java Implementation

```
class Playlist{
  private String name;
  private List<Playable> entries =
    new ArrayList<Playable>();

  public void play() {
    for (Playable entry : entries) {
      entry.play();
    }
    MeteringService.trackUse(this);
  }
}

class Song{
  private String name;

  public void play() {
    // play song
    MeteringService.trackUse(this);
  }

  public void showLyrics(){
    // show lyrics
    MeteringService.trackUse(this);
  }
}
```

- Metering code scattered through domain objects
- No module captures intent and implementation of metering policy
- Evolution of metering behavior cumbersome
 - Each caller must be changed
 - Easy to introduce bugs



Spring AOP Implementation

```
class Playlist{
    private String name;
    private List<Playable> entries =
        new ArrayList<Playable>();

    public void play() {
        for (Playable entry : entries) {
            entry.play();
        }
    }
}

class Song{
    private String name;

    public void play() {
        // play song
    }

    public void showLyrics(){
        // show lyrics
    }
}
```

The logo consists of several overlapping squares in yellow, red, and blue, with a vertical black line passing through them.

Spring AOP Implementation

```
class Playlist{
    private String name;
    private List<Playable> entries =
        new ArrayList<Playable>();

    public void play() {
        for (Playable entry : entries) {
            entry.play();
        }
    }
}

class Song{
    private String name;

    public void play() {
        // play song
    }

    public void showLyrics(){
        // show lyrics
    }
}
```

```
@Aspect
class MeteringPolicy {
    @Pointcut("execution(void Song.showLyrics())
        || execution(void Song.play())")
    void useTitle() {}

    @AfterReturning("useTitle()")
    public void trackTitleUse() {
        MeteringService.trackUse();
    }
}
```

Metering 2

Spring AOP Implementation

```
class Playlist{
  private String name;
  private List<Playable> entries =
    new ArrayList<Playable>();

  public void play() {
    for (Playable entry : entries) {
      entry.play();
    }
  }
}
```

```
class Song{
  private String name;

  public void play() {
    // play song
  }

  public void showLyrics(){
    // show lyrics
  }
}
```

```
@Aspect
class MeteringPolicy {
  @Pointcut("execution(void Song.showLyrics())
    || execution(void Playable.play())")
  void useTitle() {}

  @AfterReturning("useTitle()")
  public void trackTitleUse() {
    MeteringService.trackUse();
  }
}
```



Spring AOP Implementation

```

class Playlist{
    private String name;
    private List<Playable> entries =
        new ArrayList<Playable>();

    public void play() {
        for (Playable entry : entries) {
            entry.play();
        }
    }
}

class Song{
    private String name;

    public void play() {
        // play song
    }

    public void showLyrics(){
        // show lyrics
    }
}

```

```

@Aspect
class MeteringPolicy {
    @Pointcut("(execution(void Song.showLyrics())
        || execution(void Playable.play()))"
        && this(Playable)")
    void useTitle(Playable playable) {}

    @AfterReturning("useTitle(Playable)")
    public void trackTitleUse(Playable playable) {
        MeteringService.trackUse(playable);
    }
}

```

Metering code centralized in MeteringPolicy

- Intent of metering behavior is clear
- Changes to policy only affect aspect
- *Modular* evolution



Double Billing

- Don't want to meter twice for songs played within the context of playing a Playlist
- A ThreadLocal can be used to only meter top-level advice
- Can also accomplish using AspectJ control flow pointcuts (AspectJ is discussed later)
 - `cflow()` and `cflowbelow()`



Avoiding Double Billing

```

ThreadLocal <Integer> callDepth=...;

@Around("useTi tle(playabl e)")
Public void aroundUseTi tle(Proceedi ngJoi nPoi nt jp,
    Playabl e playabl e) {
    try {
        callDepth. set (callDepth. get ()+1); //i ncrement counter
        jp. proceed(); //conti nue joi npoi nt

        if (callDepth. get ()==1) //if fi rst call
            Meteri ngServi ce. trackUse(playabl e);
    } fi nally {
        callDepth. set (callDepth. get ()-1); //decrement counter
    }
}

```



Configuring Spring Aspects

- Aspects can reference externally defined services

@Aspect

```
public class MeteringPolicy {  
    private AccountManager accountManager;  
    private MeteringService meteringService;  
  
    public void setAccountManager(AccountManager actManager) {  
        this.accountManager = actManager;  
    }  
  
    public void setMeteringService(MeteringService mtrSvc) {  
        this.meteringService = mtrSvc;  
    }  
}
```



Configuring Spring Aspects

- @AspectJ Aspects can be directly configured in Spring standard <property> declarations

```
<?xml version="1.0" encoding="UTF-8"?>
<beans ... >
  <aop: aspectj -autoproxy/>

  <bean class="model.metering.MeteringPolicy">
    <property name="accountManager" bean="ldapActManager" />
    <property name="meteringService" bean="titleMetering" />
  </bean>

</beans>
```



Schema style Aspects

- Spring Aspects can be defined with XML declarations
 - instead of `@AspectJ` annotated classes
- Useful when Java 5 Annotations aren't available, *e.g.*, Java 1.4
- Less capable than `@AspectJ` style
 - Can't combine named pointcuts
 - Only singleton lifecycle supported



MeteringPolicy as POJO

```
public class MeteringPolicy {  
    public void afterUseTitle(Playable playable) {  
        MeteringService.trackUse(playable);  
    }  
}
```

- The MeteringPolicy class is coded without Annotations
 - No Pointcuts are defined
 - Advice is implemented, but not declared



Spring Configuration

```
<aop: config>  
  <aop: aspect id="meteringPolicyAspect" ref="meteringPolicy" />  
</aop: config>  
  
<bean id="meteringPolicy" class="metering.MeteringPolicy" />
```

- The MeteringPolicy Bean is declared with a standard `<bean>` declaration.
- An `<aop:aspect>` is defined referring to the MeteringPolicy Bean



Spring Configuration

```
<aop: config>
  <aop: aspect id="meteringPolicyAspect" ref="meteringPolicy">
    <aop: pointcut id="useTitle"
      expression="(execution(void model.Playable.play())
        or execution(void model.Song.showLyrics()))
        and this(playable)"/>
  </aop: aspect>
</aop: config>

<bean id="meteringPolicy" class="metering.MeteringPolicy"/>
```

- An `<aop:pointcut>` is defined as `useTitle`
- Note: "and", "or", and "not" are substituted in XML syntax to avoid char escaping issues



Spring Configuration

```
<aop: config>  
  <aop: aspect id="meteringPolicyAspect" ref="meteringPolicy">  
    <aop: pointcut id="useTitle" expression="execution..." />  
    <aop: after-returning pointcut-ref="useTitle"  
      method="trackTitleUse" />  
  </aop: aspect>  
</aop: config>  
  
<bean id="meteringPolicy" class="metering.MeteringPolicy" />
```

- `<aop:after-returning>` advice is declared
 - Referencing the useTitle pointcut
 - and MeteringPolicy.afterUseTitle() method



Creating Playables from DAOs

```
public class MusicService {
    public void play (String title) {
        Playable playable = dao.find(user, title);
        playable.play();
    }

    public void setDao(PlayableDao dao) {
        this.dao = dao;
    }

    ...

    private PlayableDao dao;
    private User user;
}
```



Configuring Database Access

```
<beans ...>
...
  <bean id="playableDao" class="music.dao.PlayableDaoImpl">
    <property name="sessionFactory"
      ref="sessionFactory" />
  </bean>

  <bean id="sessionFactory"
class="org.springframework.orm.hibernate.LocalSessionFactory
Bean">
  <property name="dataSource" ref="musicDB" />
  <property name="mappingResources">
    <list><value>music.hbm.xml</value></list>
  </property>
</bean>
...
```

@AspectJ Metering with Database Persistence

```
@Aspect public class MeteringPolicy {
... <as before>

    @Pointcut("execution(music.model.Playable
        music.model.PlayableDao.find*(..))")
    void createPlayable() {
    }

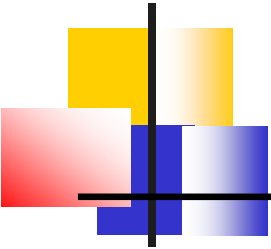
    @Around("createPlayable()")
    public Playable proxyPlayable(ProceedingJoinPoint pj)
        throws Throwable {
        Playable created = (Playable) pj.proceed();
        return proxyPlayable(created);
    }
...
}
```

Playable Creation From a Database - @AspectJ Style

```
private Playable proxyPlayable(Playable playable) {
    AspectJProxyFactory factory =
        new AspectJProxyFactory(playable);
    factory.addAspect(this);
    if (playable instanceof PlayList)
        proxyChildren((PlayList)playable);
    return (Playable)factory.getProxy();
}

private void proxyChildren(PlayList playList) {
    for (ListIterator<Playable> it = playList
        .getEntries().listIterator(); it.hasNext();) {
        Playable child = it.next();
        Playable proxy = proxyPlayable(child);
        it.remove();
        it.add(proxy);
    }
}
```





Part II: Sample Applications

- Exploration & Enforcement
- Transactions
- Error Handling



Enforcing State Transitions

```
@Aspect
public class StateTracker {
    @Pointcut("execution(* close()) && this(resource)")
    public void closingResource(Resource resource);

    @Before("closingResource(resource)")
    public void callingModelFromDataAccess(Resource resource) {
        if (resource.hasPendingRequests()) {
            throw new InvalidCallException(resource);
        }
    }
}
...
}
```



Spring Transactions

- Spring provides declarative transaction management with
 - XML Declarations, or
 - @Transactional Annotation
- Relies on a PlatformTransactionManager
 - Implementations for JDBC, JTA, Hibernate, ...
- Programmatic Transaction Management can be implemented with AspectJ Aspects



AOP Transactions Setup

```
<tx: advice id="tx-advice" transaction-manager="txManager" >
  <tx: attributes>
    <tx: method name="*" propagation="REQUIRED" />
  </tx: attributes>
</tx: advice>

<bean id="txManager"
      class="..jdbc.datasource.DataSourceTransactionManager" >
  <property name="dataSource" ref="dataSource" />
</bean>
```

- `<tx:advice>` binds to a Transaction Manager
Legacy concept
- `<tx:attributes>` configures the Advice
- Here the "txManager" is a JDBC Manager



Apply AOP Transactions

```
<aop: config>
  <aop: advisor
    pointcut="execution(public * service.Service+. *(..))"
    advice-ref="tx-advice" />
</aop: config>

<tx: advice id="tx-advice" transaction-manager="txManager">
```

- An `<aop:advisor>` binds the Service Layer pointcut to the Transactional Advice
Legacy concept: aspect with one advice
- This declares the entire Service Layer to be Transactional



@Transactional

```
@Transactional
public interface Service {
    public boolean acceptOrder(Order order);
}
```

- The @Transactional annotation marks types as requiring Transaction semantics.
- Optional properties for @Transactional:
 - propagation, isolation, readOnly, rollbackFor, rollbackForClassname, noRollbackFor, noRollbackForClassname



@Transactional Config

```
<bean name="orderService" class="service.ServiceImpl">
  <property ...
</bean>

<tx:annotation-driven/>

<bean id="transactionManager"
      class="..jdbc.datasource.DataSourceTransactionManager">
  <property name="dataSource" ref="dataSource"/>
</bean>
```

- The `<tx:annotation-driven>` element enables the `@Transactional` processing of beans
- A `TransactionManager` is still needed
 - Default id is "transactionManager"



Annotations and Pointcuts

- Annotations: a little goes a long way
 - Useful to pick out key characteristics (business operation, immutable, *etc.*)
 - Brittle if scattered and tangled macro invocations: not an improvement over inline code calls
- AOP supports robust, maintainable, testable use
 - Structural pointcuts (the best)
 - Can derive implementation from core domain abstractions
 - Can annotate exceptions
 - Shows the forest and the trees

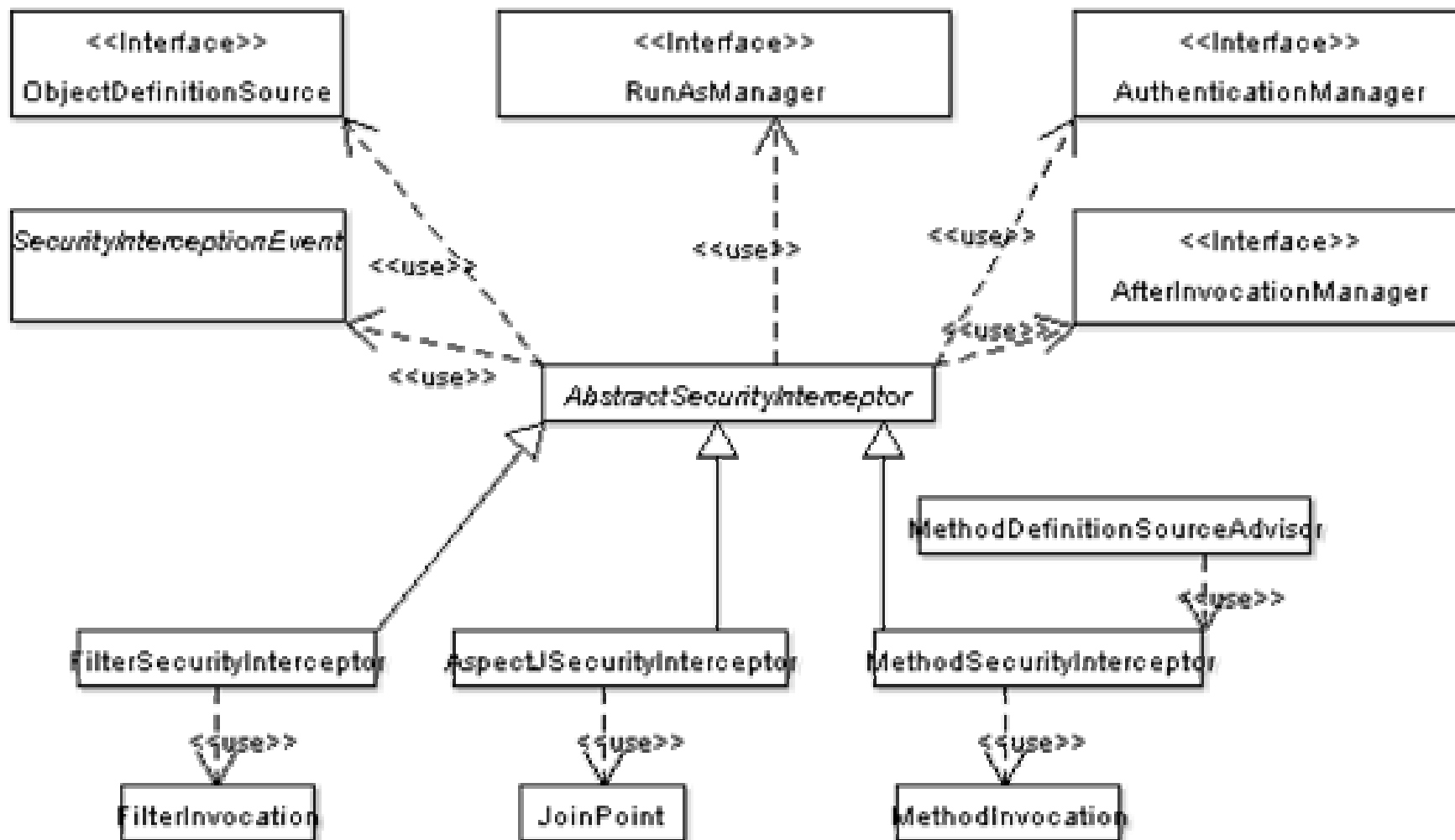


Error Handling

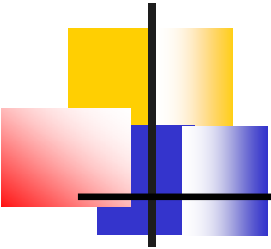
@Aspect

```
public class ModelErrorHandling {  
    @Pointcut("execution(public * model..*(..))")  
    void model () {}  
  
    @AfterThrowing("model()", throwing="e")  
    public void modelErrors(JoinPoint jp, Throwable e){  
        if (!(e instanceof ModelException)) {  
            ModelException me = new ModelException(e);  
            me.setModel(jp.getTarget());  
            me.setArgs(jp.getArgs());  
            throw me;  
        }  
    }  
}
```

Spring Security



Source: <http://www.acegisecurity.org>



Part III: AspectJ Integration

- Fine-Grained Configuration
- Other Examples



Configuring Entities

- Some objects are created outside of the bean container, *e.g.*, persistent objects created by Hibernate.

```
public class Account {  
    private TaxCalculator taxCalculator;  
    ...  
  
    public void update() {  
        taxOwed += taxCalculator.computeTax();  
        ...  
    }  
    ...  
}
```




Enter AspectJ...

- The original AOP implementation for Java
 - Language extension, @AspectJ, and XML options
 - Java platform compatible
 - Performance comparable to hand-written equivalent
- Tool support
 - Compiler, linker, classloader-based weaving
 - IDE support: Eclipse, JBuilder, JDeveloper, NetBeans
 - Ant, Maven, ajdoc, Java debugger
- Open source: <http://eclipse.org/aspectj>



Configure by *Annotation*...

- Enable load-time weaving: add JVM arg
 - `-javaagent:lib/aspectjweaver.jar`

```
@Configurable
public class Account { ... }
```

- Spring will automatically configure

```
<beans...>
  <bean class="com.example.app.domain.Account"
        scope="prototype">
    <property name="taxCalculator" ref="taxCalculator"/>
  </bean>
...

```



Configure by *Pointcut*

```
@Aspect
class ConfigureDomain extends AbstractBeanConfigurerAspect
{
    @Pointcut("execution(new(..)) && this(instance) &&
              within(com.example.app.domain..*)")
    public void beanCreation(Object instance) {}
}
```

- Also uses AspectJ weaving
 - Load-time (or *build-time...*)
- Annotation vs. pointcut trade-offs
 - Just as with Spring AOP



Configure with Declaration

```
aspect ConfigureDomain {  
    declare @type: com.example.app.domain..*: @Configurable;  
}
```

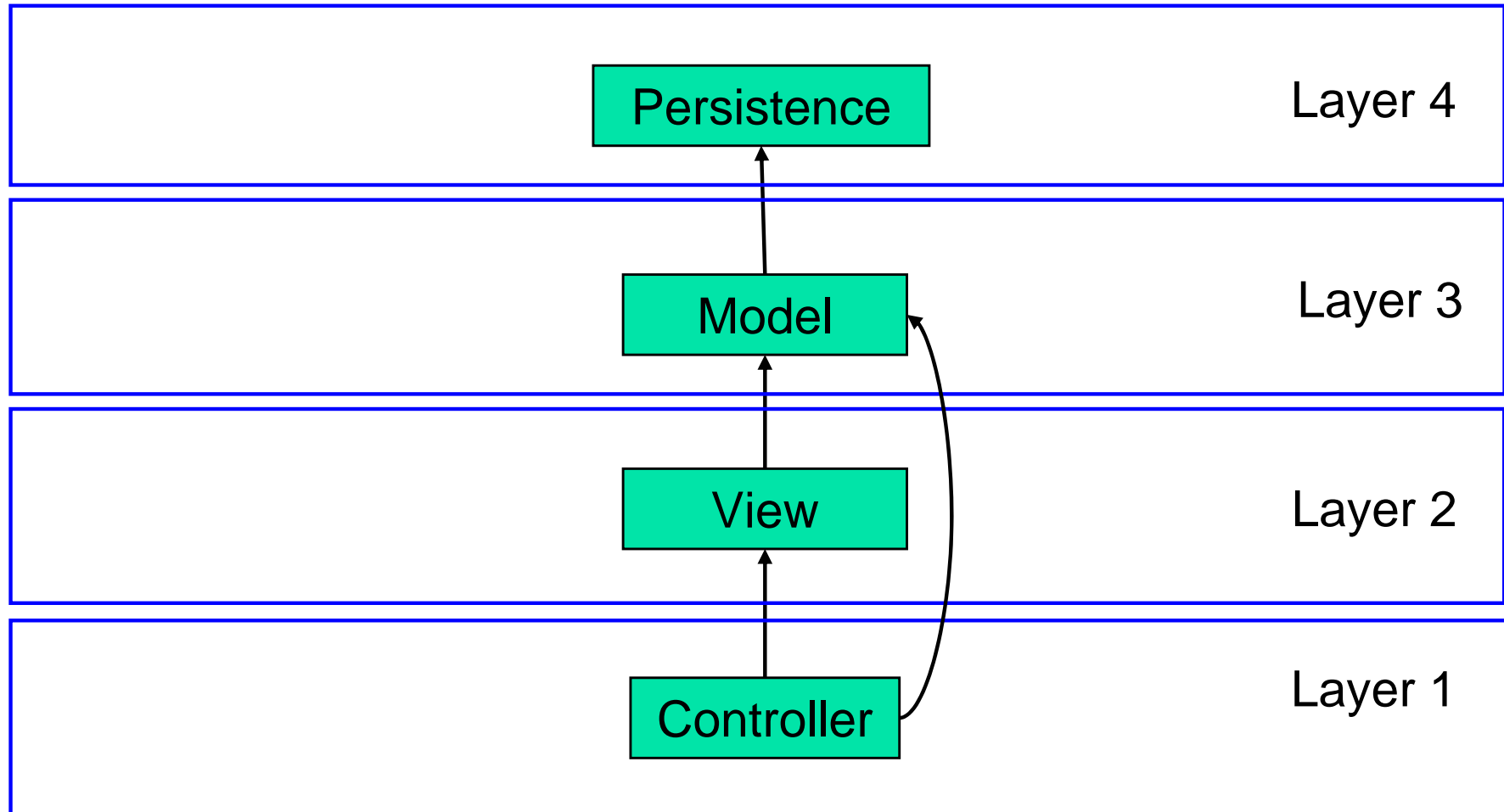
- Uses *AspectJ language syntax*
- Adds annotations to all types based on a type pattern
- Also useful for other annotation-driven APIs
 - EJB3 persistence, JAX-WS, ...



AspectJ Advising *Playables*

- In our earlier example, we had to manually proxy persistent objects returned from Hibernate
- If we are using AspectJ, it will advise instances of Playable and Song when created
 - Since these are our domain types it will work with build-time or load-time weaving

Architectural Policy: Layering





Architectural Layers

@Aspect

```
public abstract class Architecture { // abstract aspect for reuse

    @Pointcut("within(junit.framework.TestCase+) ||
              within(*..test..*)")
    public void inTest() {}

    @Pointcut("!inTest()")
    public void scope() {}

    @Pointcut("call(public * com.example.app.model..*(..))")
    public void modelCall() {}

    @Pointcut("within(com.example.app.persistence..*)")
    public void inDataAccess() {}

    @Pointcut("call(public * org.hibernate..*(..))")
    public void persistenceCall() {}

}
```



Enforcing Layering at Weave Time

```
@Aspect
```

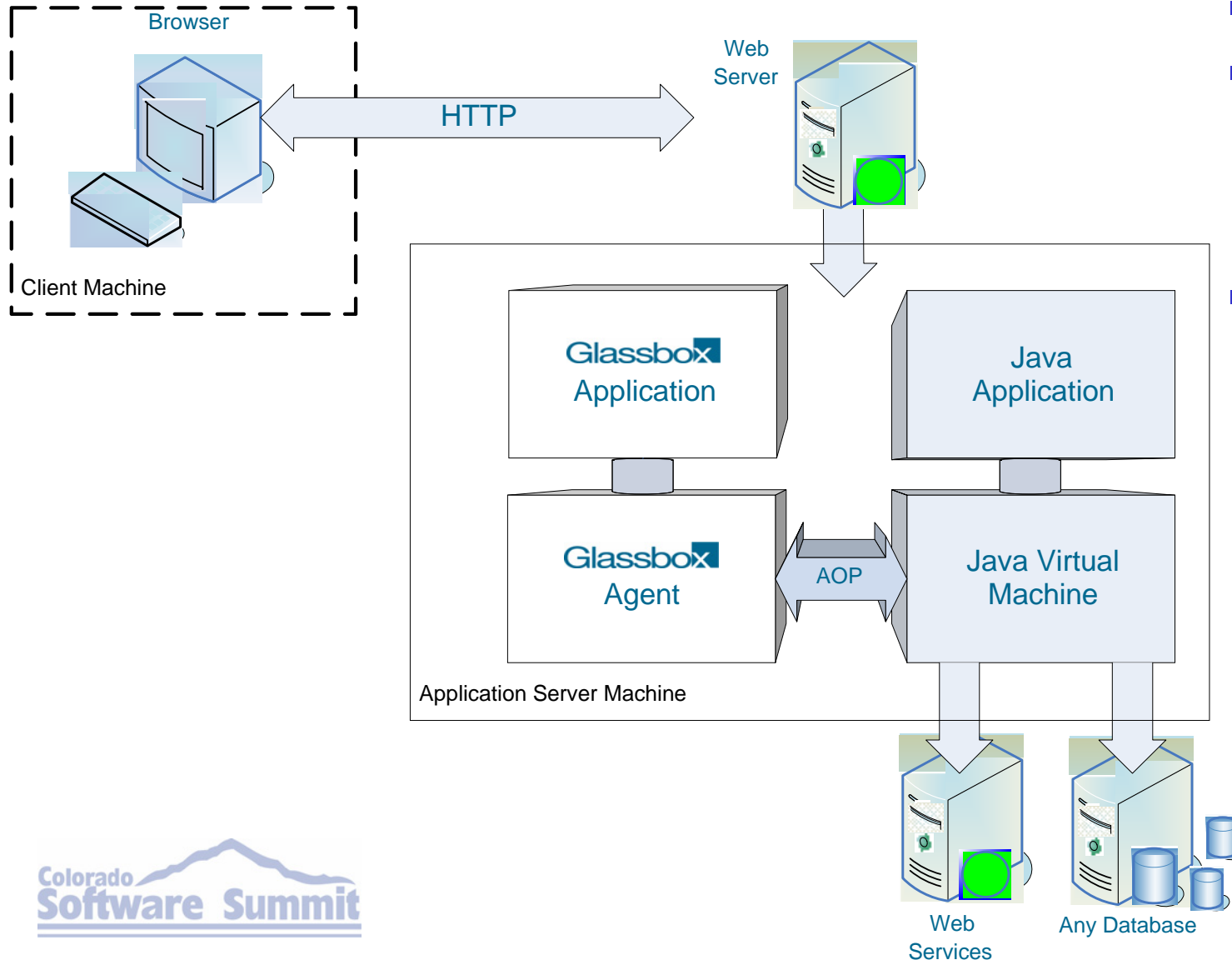
```
public class Layering extends Architecture {  
    @DeclareError("scope() && modelCall() && inDataAccess()")  
    static final String callingModelFromDataAccess =  
        "Don't call the model from the data access tier directly";  
  
    @DeclareError("scope() && persistenceCall() && !inDataAccess()")  
    static final String callingPersistenceNotFromDataAccess =  
        "Don't call the persistence tier from outside data access";  
}
```




Glassbox Open Source

- Non-invasive data capture
 - Captures data with AOP, Java 5 and server JMX data
 - Exposes detailed data through JMX consoles
- Automated analysis: Glassbox Troubleshooter
 - Automatically diagnoses common problems
 - Correlates, compares, analyzes data from data capture & summary
 - Exposed through an AJAX Web client
- Focus on the 80% of common problems
 - Database issues (connections, slow query, death by 1000 cuts)
 - Remote service calls (failures, chattiness, slow response)
 - Java contention, failures
- Open Source LGPL License
- Supports Java 1.4 and later

Glassbox Architecture



- Load-time weaving
- Discovers and tracks high-level operations as they execute
- Efficiently detects common problems, *e.g.*
 - Slow queries
 - Excessive service calls
 - Connection failures
 - Java bottlenecks



Extending Glassbox with XML

```
<aspectj >
  <aspects>
    <concrete-aspect name="com. myco. moni tor. Servi ceMoni tor"
                    extends="gl assbox. moni tor. AbstractMoni tor" >
      <poi ntcut name="scope" val ue="wi thi n(com. myco. servi ce. . *)" />
    </concrete-aspect>
  </aspects>
</aspectj >
```

- This illustrates AspectJ XML-defined aspects
- Defined inside a load-time weaving configuration file: META-INF/aop.xml



Spring @AspectJ with Glassbox

@Aspect

```
public class PlayableMonitor extends AbstractMonitor {  
    @Pointcut("music.metering.MeteringPolicy.useTitle(key)")  
    public void monitorPoint(Object key) {  
    }  
}
```



Schema AOP with Glassbox

```
public class PlayableMonitor {
    private ResponseFactory responseFactory =
        AbstractMonitor.getResponseFactory();

    public void setResponseFactory(ResponseFactory factory) {
        this.responseFactory = factory;
    }
    public ResponseFactory getResponseFactory() {
        return factory;
    }

    public void beforeUseTitle(Playable playable) {
        Response response =
            responseFactory.getResponse(playable.getName());
        response.setLayer("streaming");
        response.start();
    }
}
```



Schema AOP with Glassbox

```
...  
public void afterExceptionTitle(Playable playable) {  
    Response response = responseFactory.getLastResponse();  
    FailureDescription =  
        fdFactory.getFailureDescription(t);  
    response.set(Response.FAILURE_DATA, description);  
    response.complete();  
}  
  
public void afterUseTitle(Playable playable) {  
    responseFactory.getLastResponse().complete();  
}  
}
```



Schema AOP with Glassbox

```
<aop: config>
  <aop: pointcut id="useTitle" expression="execution..." />
  <aop: aspect id="playableMonitorAspect"
    ref="playableMonitor">
    <aop: before pointcut-ref="useTitle"
      method="beforeUseTitle" />
    <aop: after-throwing pointcut-ref="useTitle"
      method="afterExceptionUseTitle" />
    <aop: after-returning pointcut-ref="useTitle"
      method="afterUseTitle" />
  </aop: aspect>

  <aop: aspect id="meteringPolicyAspect">...</aop: aspect>
</aop: config>

<bean id="playableMonitor" class="music.PlayableMonitor" />
```



Part III: Conclusion ...

- The state of AOP
- Adoption strategy



The State of AOP

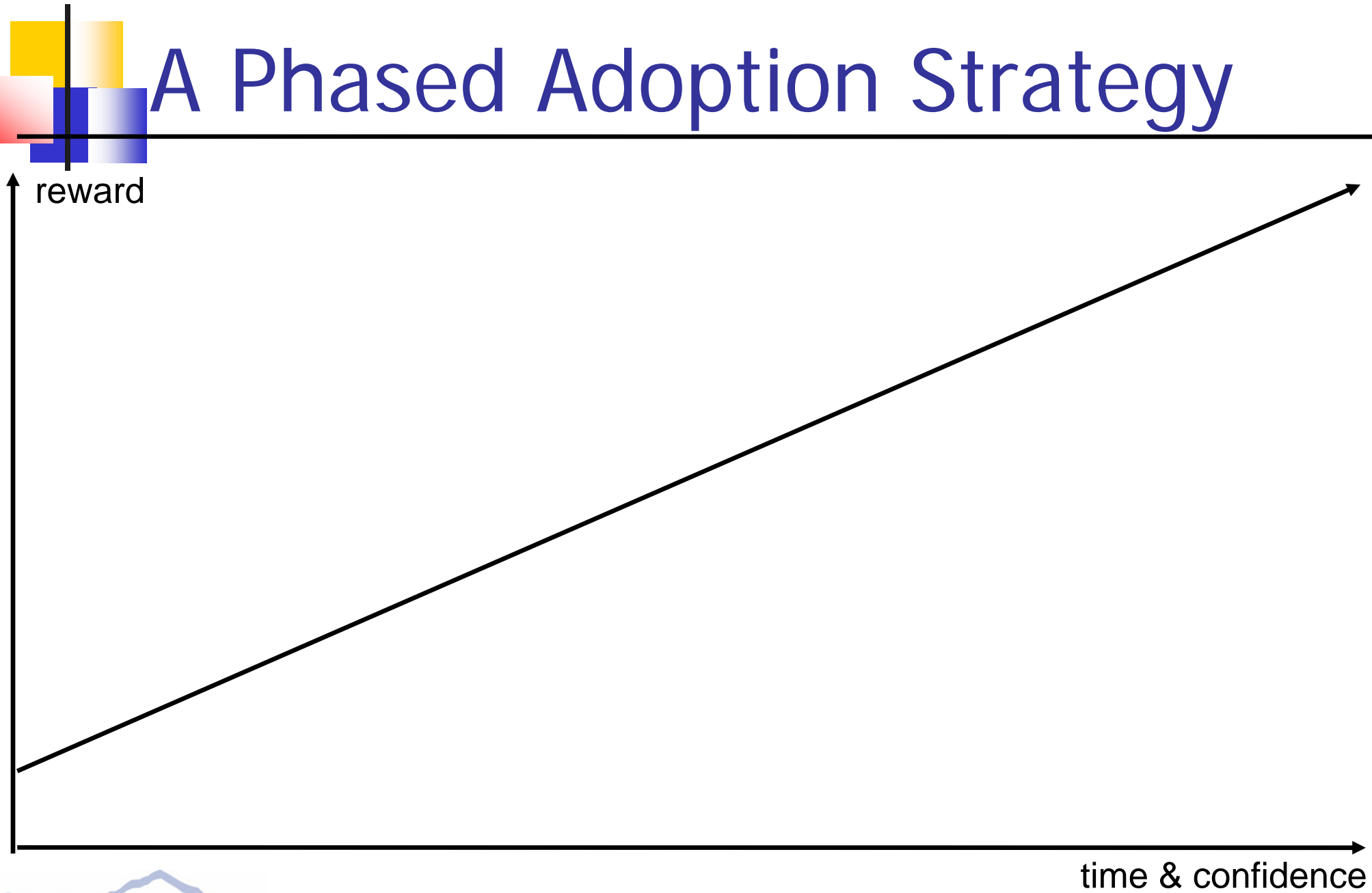
- AspectJ 5:
 - The pure play
 - Powerful, complete, more to learn
 - Tools support
- Spring 2.0
 - Built-in AOP + AspectJ integration
- JBoss AOP
 - Integrated aspects:
Core to EJB3 implementation, POJO Cache, ...
- Emerging for .NET, PHP, Ruby ...
 - *e.g.*, Spring.NET aspects



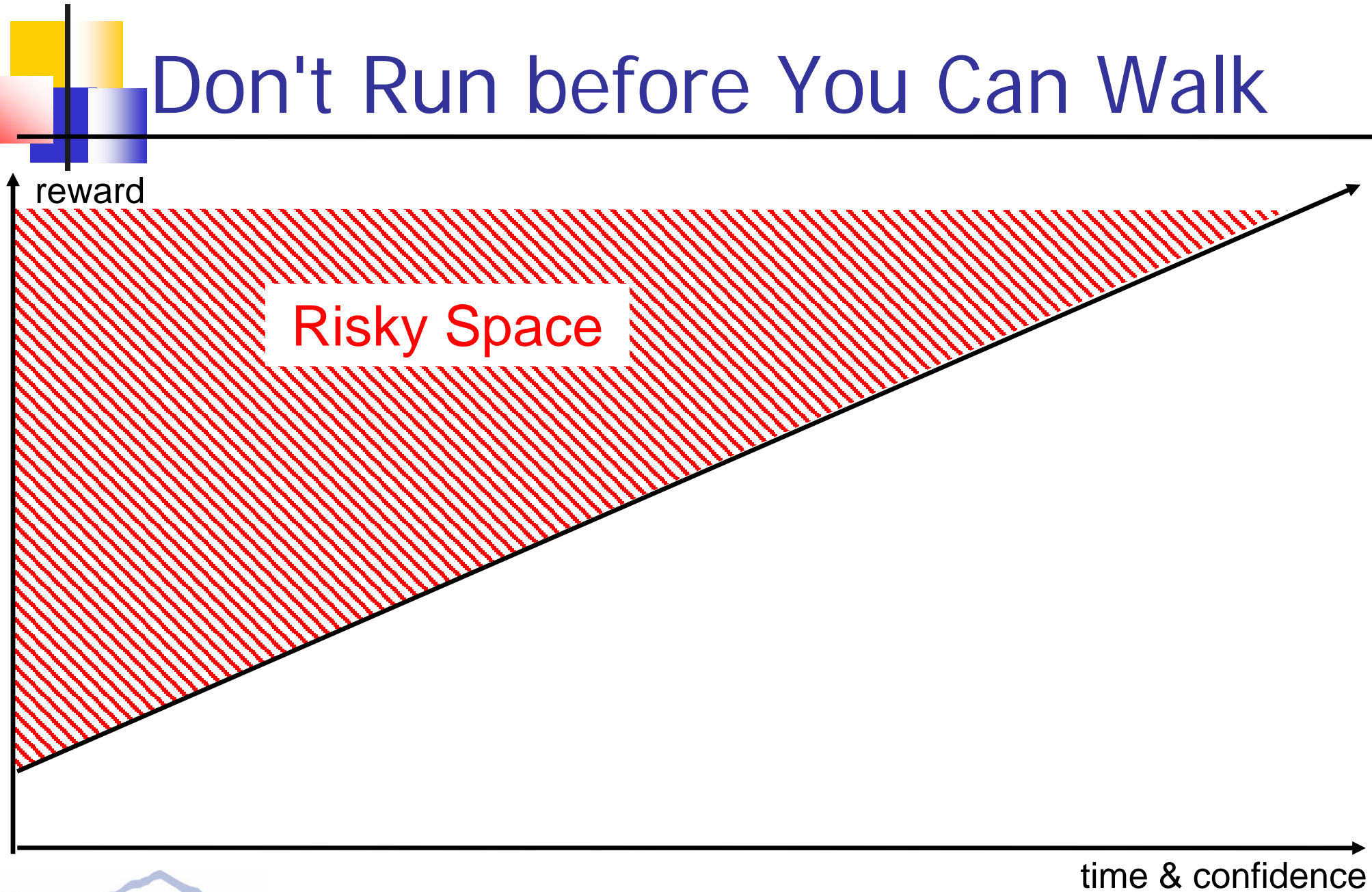
Aspect-Oriented Development

- Good OOD & good AOD work together
- Use UML extension with stereotypes
- Analysis aspects from crosscutting concepts
- **ARC**: Aspect, Responsibilities, Collaborators
- Pointcut design should use stable properties
- Aspects let you unit test & integration test crosscutting requirements

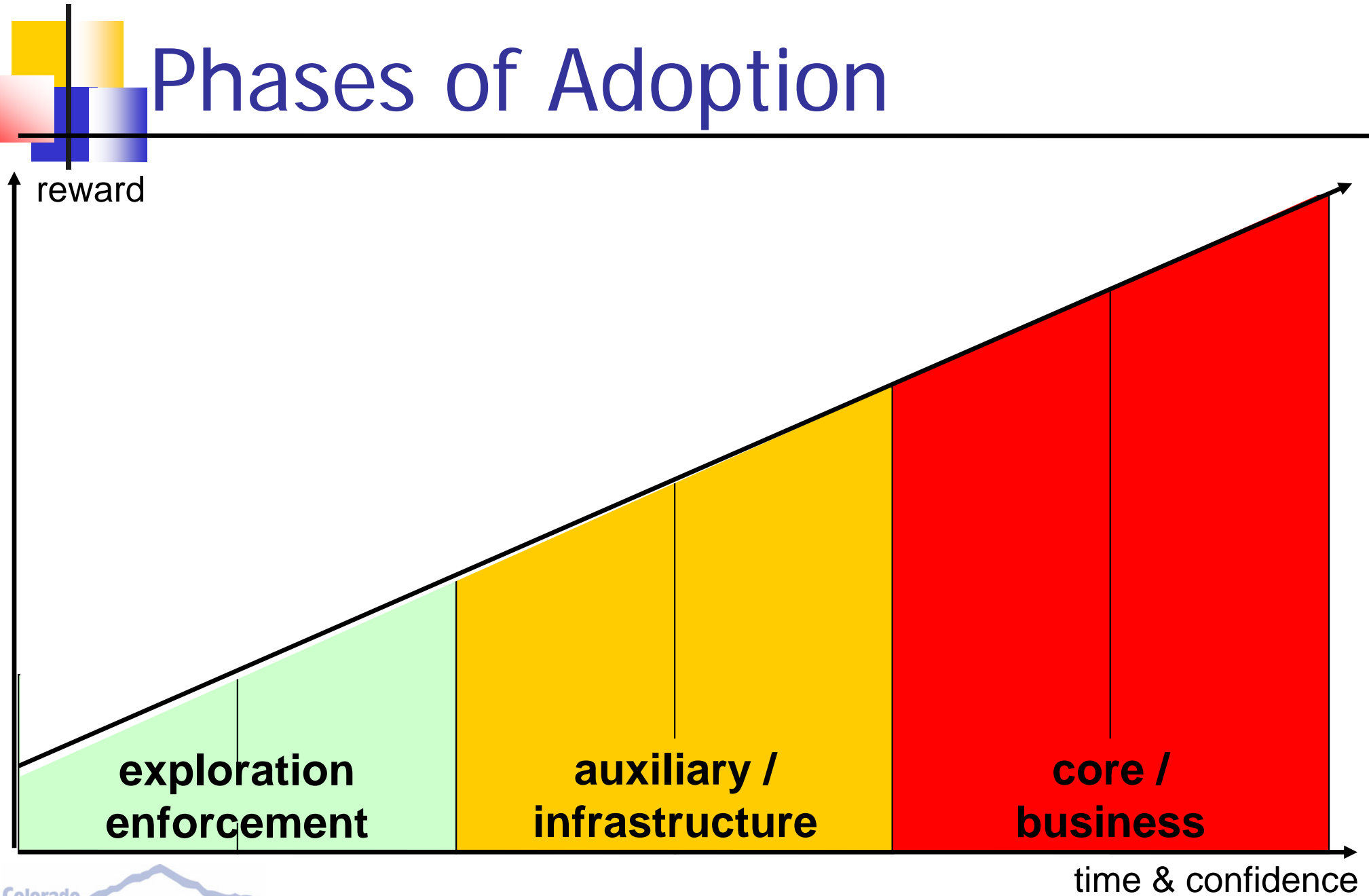
A Phased Adoption Strategy



Don't Run before You Can Walk



Phases of Adoption



Conclusion

- Spring *and* AOP are rapidly gaining adoption in the enterprise



- Incremental adoption works best
 - Coarse-grained Spring aspects
 - Fine-grained AspectJ aspects
- Training, consulting, and support available





Thank You

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New Aspects of Software

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