A Language Workbench for Creating Production-Ready Extensions to AspectJ

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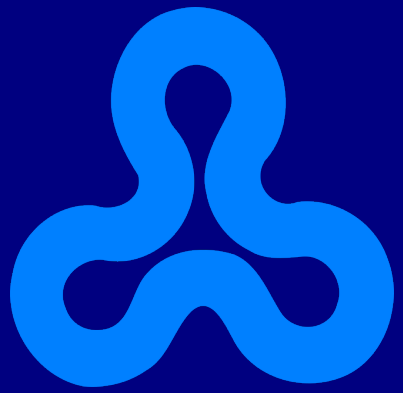


Advisor:
David H. Lorenz

Motivation

“Explicit join points looks interesting, let's evaluate it”

abc? AWESOME? Spoofax? xtext?

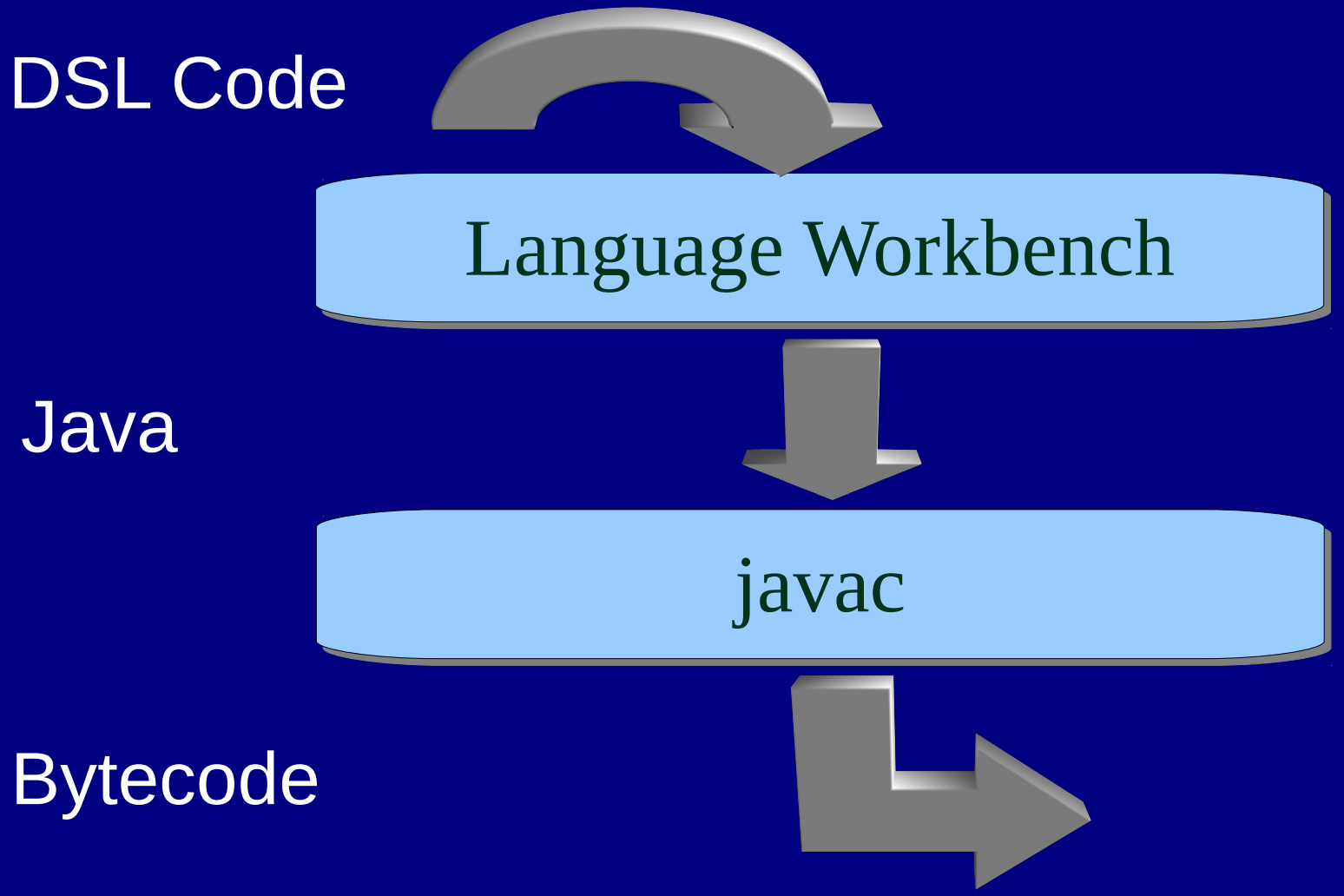
Our Research Goal

- **Tool for the development, evaluation and production of extensions for AspectJ**
  - Like abc
- **Workbench, not a compiler**
  - Provide common editing tools
  - Compatible with AOP development tools
- **Generate production-ready extensions**
  - Work with a commonly used version of AspectJ
  - Proper support for programming in multiple extensions simultaneously

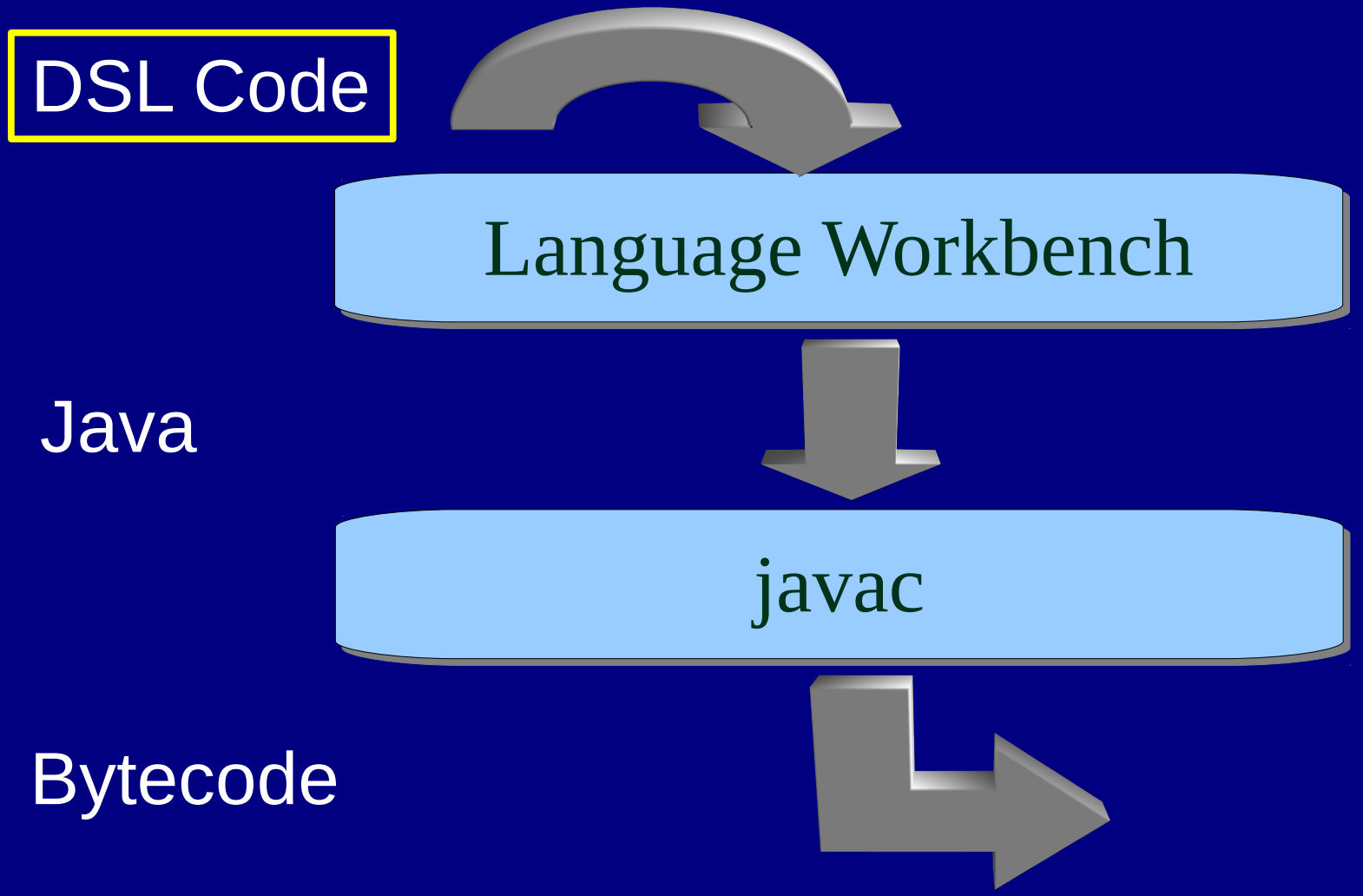
Limitations of the AspectBench Compiler (abc)

- **Used to be the default choice for implementing AspectJ extensions**
- **Not suitable for development of new extensions**
  - Does not work with recent versions of AspectJ
- **Not suitable for evaluation of new extensions**
  - Does not provide development tools
  - No support for advanced weaving semantics

Language Workbench (LW) for Java

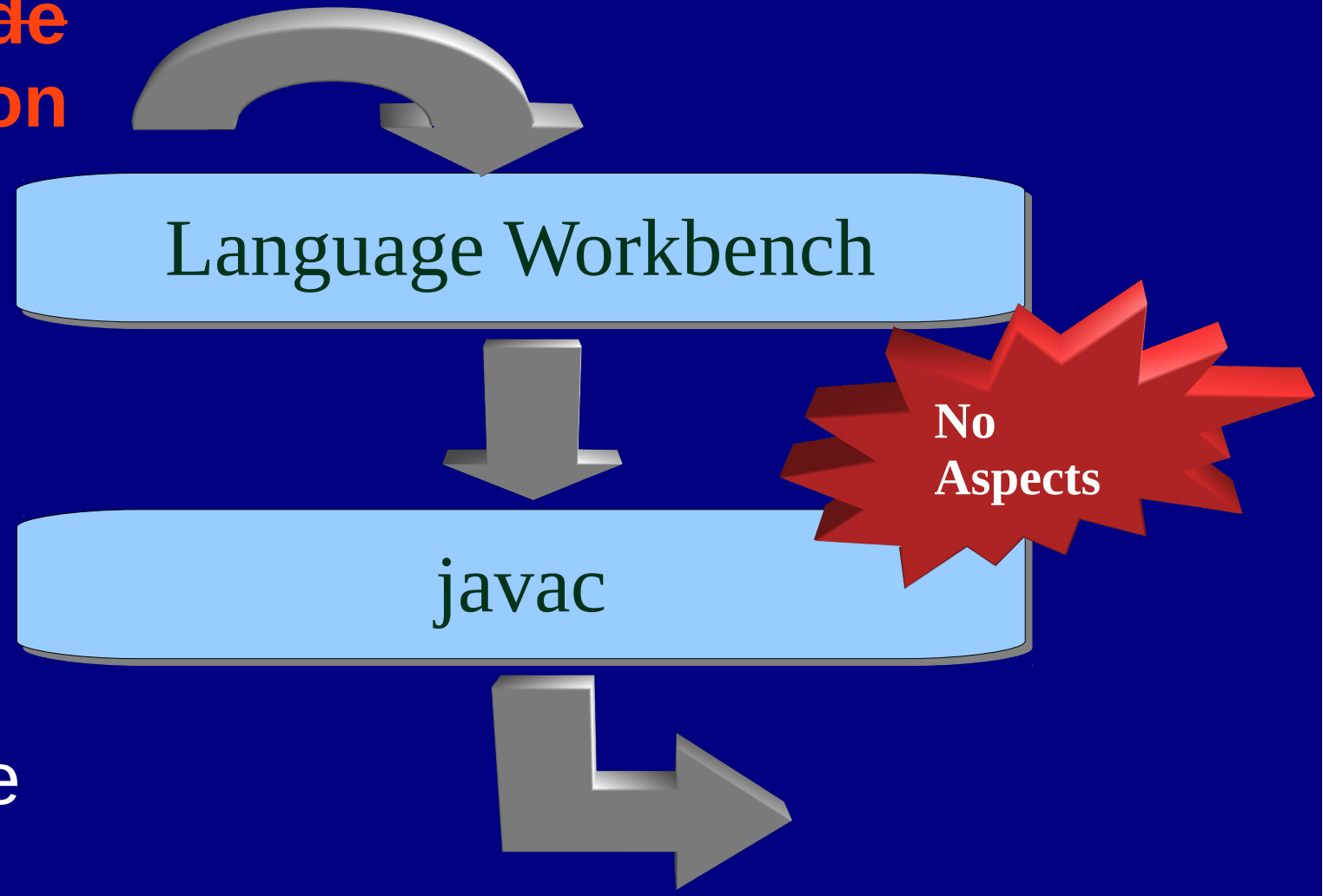


Language Workbench (LW) for Java



Will It Work for AspectJ?

~~DSL Code~~
Extension Code

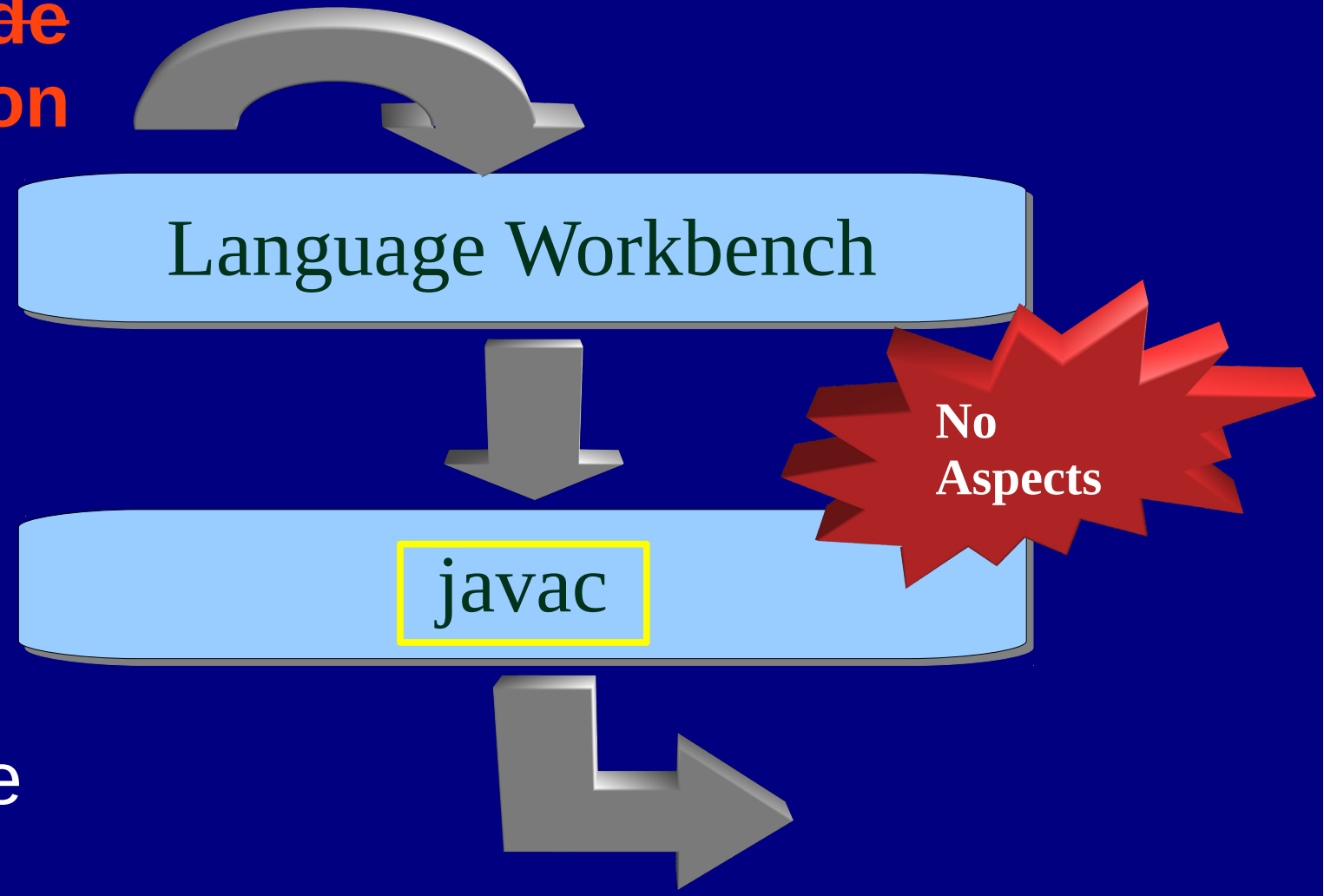


Java

Bytecode

Will It Work for AspectJ?

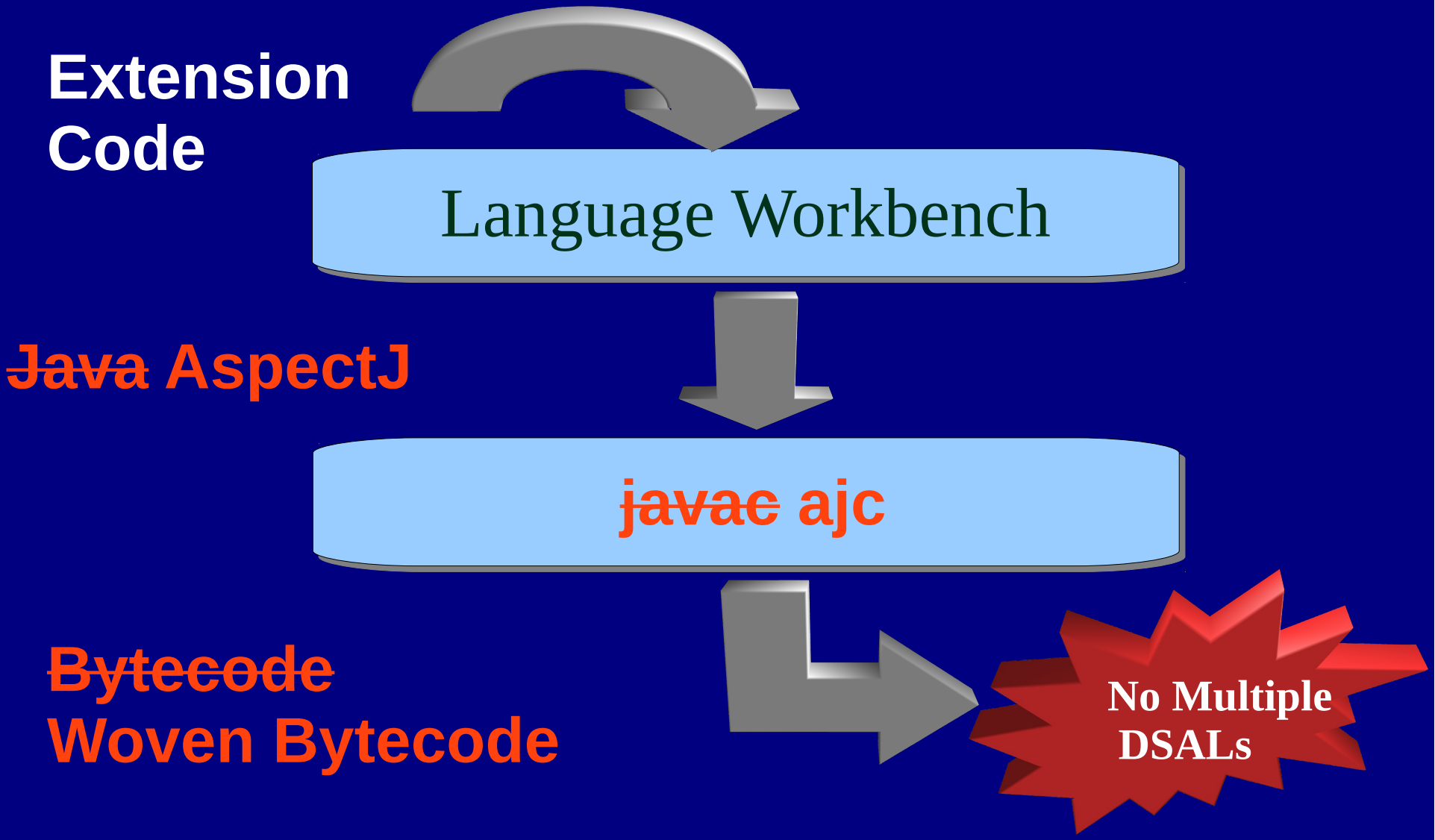
~~DSL Code~~
Extension
Code



Java

Bytecode

Replacing javac with ajc



AOP Composition Framework (CF)

- **To work with multiple AspectJ extensions simultaneously, one will need to define:**
  - Weaving semantics for co-advising
  - Weaving semantics for foreign advising
- **CF Allows to define the required semantics**
  - As opposed to ajc
- **CF does not provide editing tools**

LW vs CF

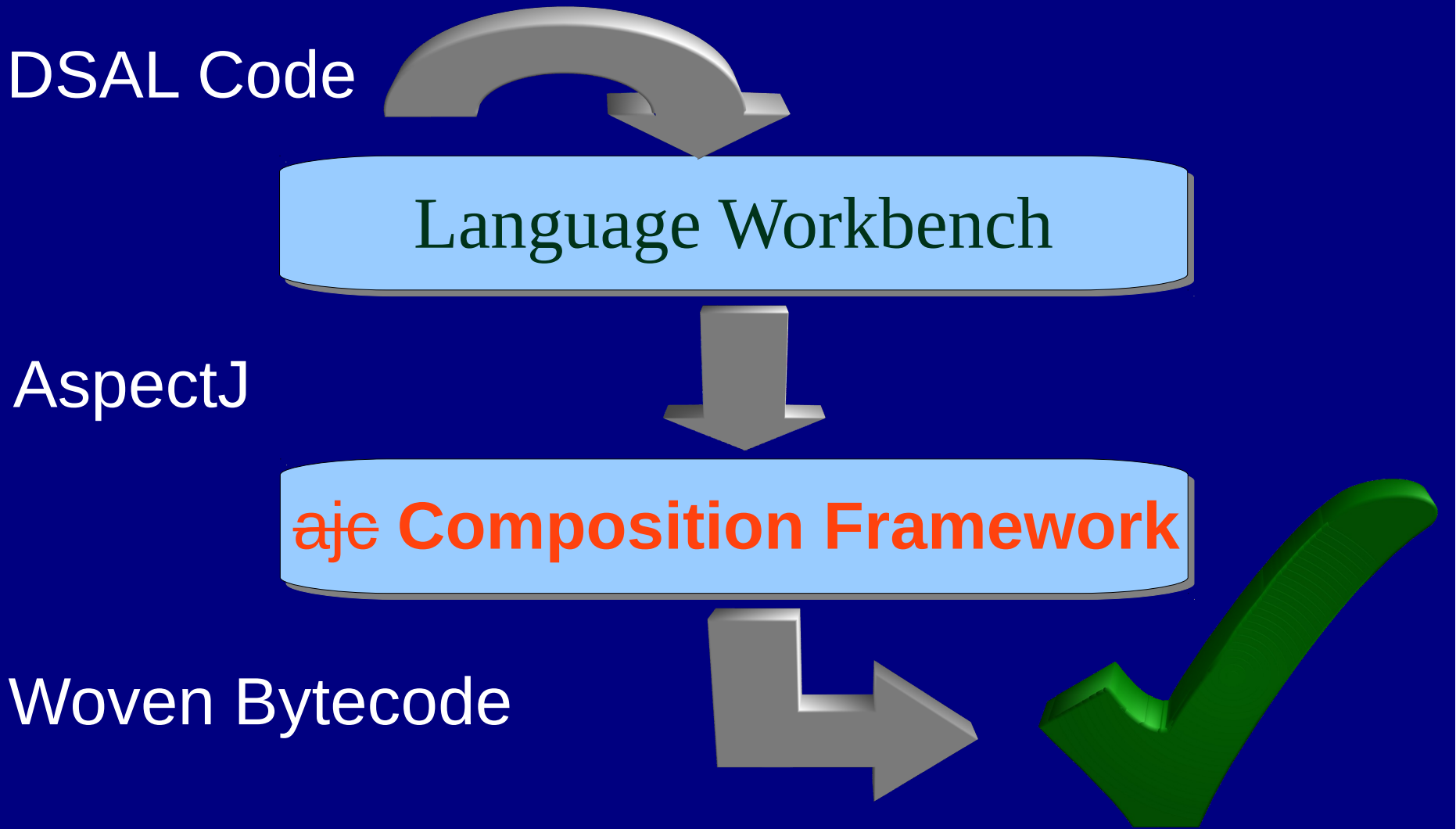
	Language Workbench	AOP Composition Framework
Tools for creation & usage of languages	☺	☹
Defining weaving semantics needed for DSALs	☹	☺

Can We Enjoy Both Worlds?

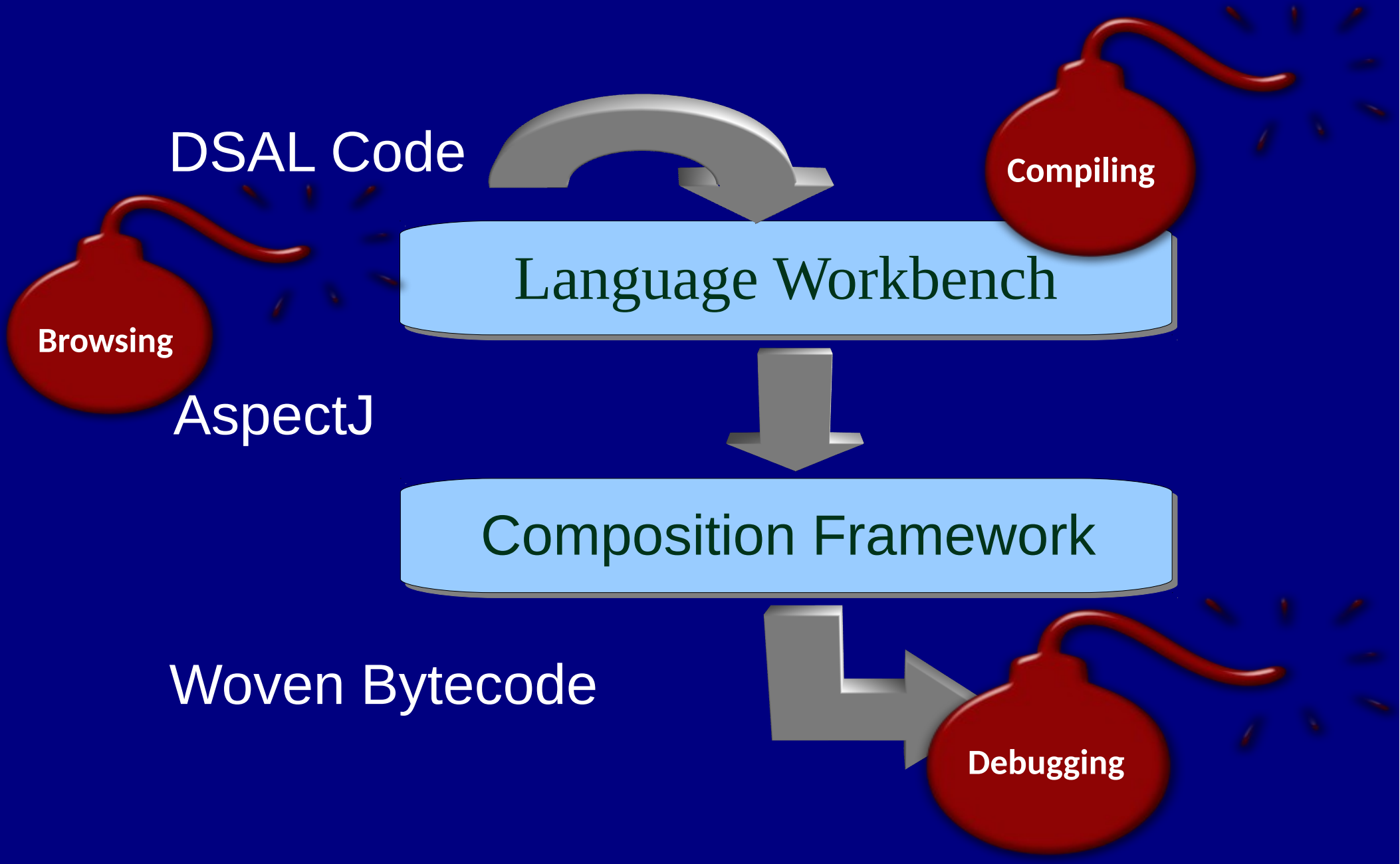
	Language Workbench	AOP Composition Framework	?
Tools for creation & usage of languages	☺	☹	☺
Defining weaving semantics needed for DSALs	☹	☺	☺

Will a naive combination of the two be a proper solution?

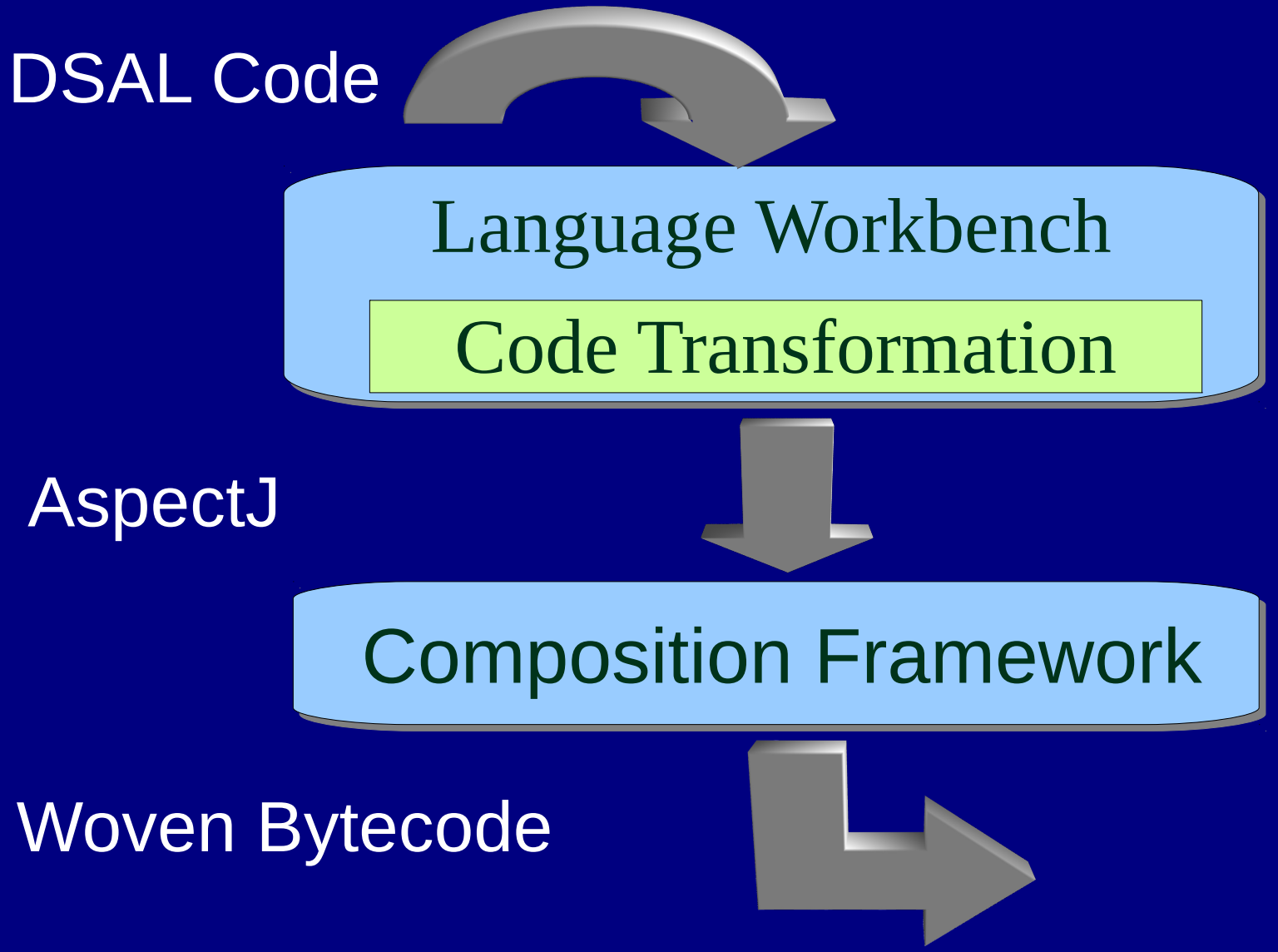
Naive Combination of LW and CF



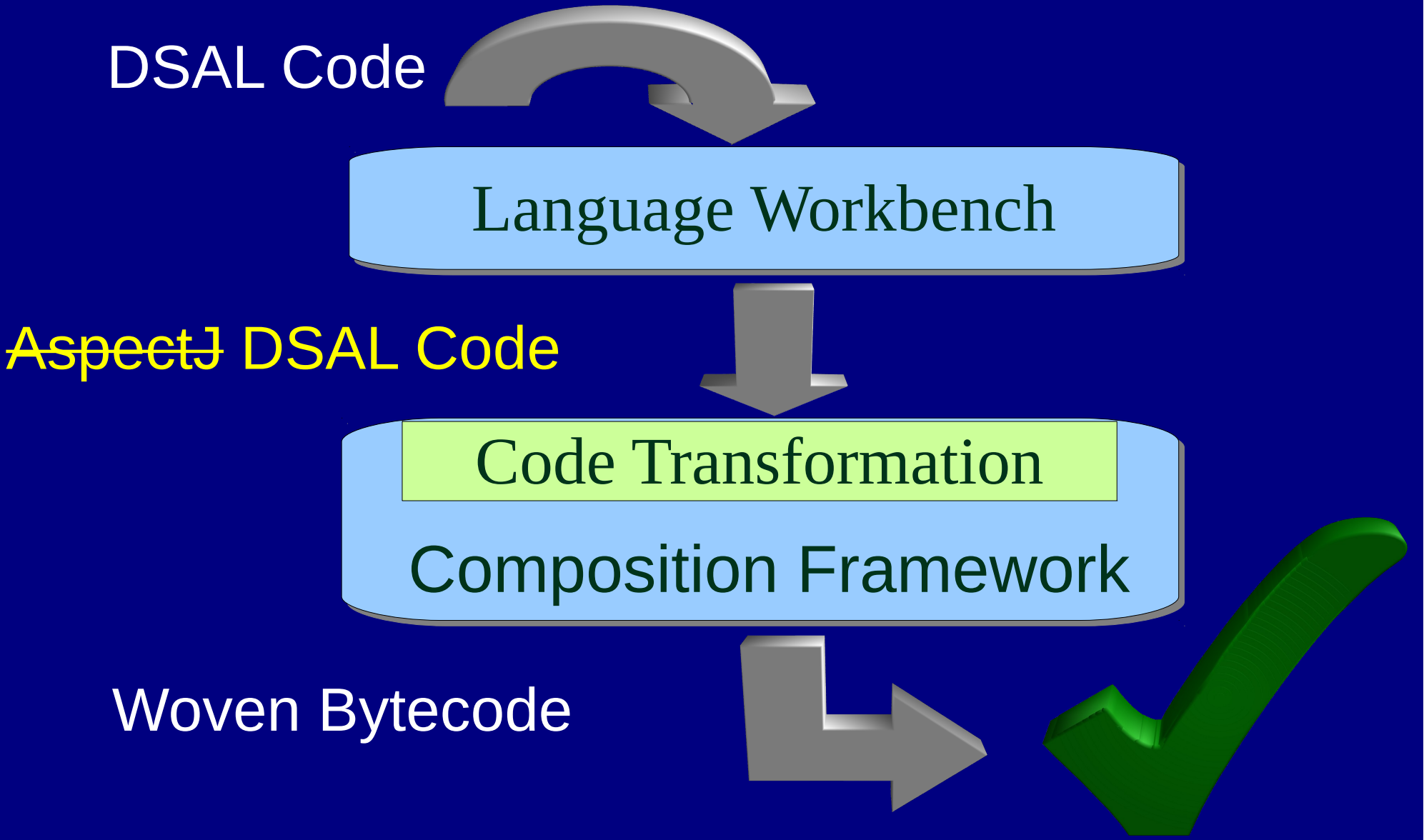
But We Still Lack AOP Tools..



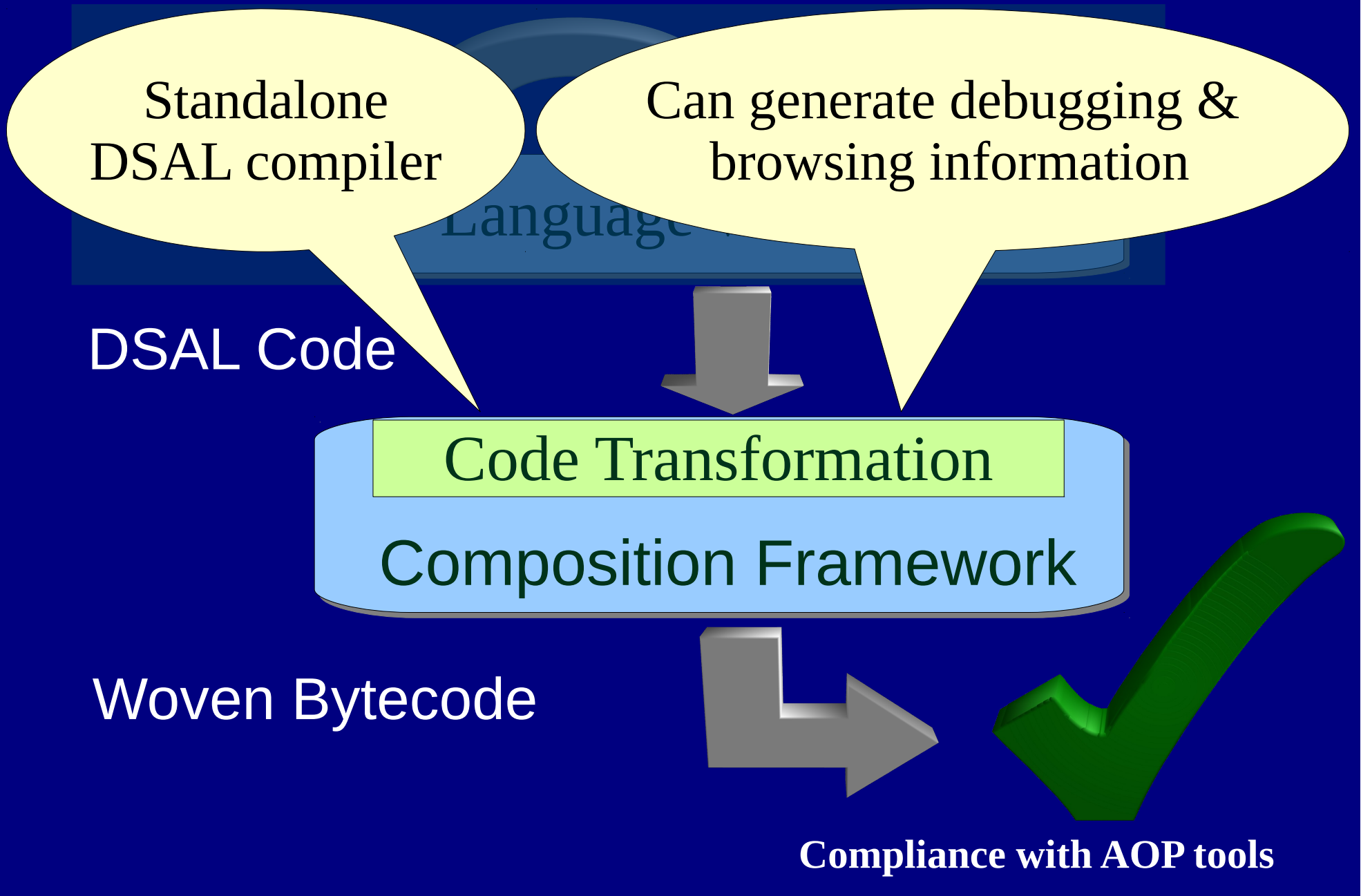
Traditional LW Architecture



Our Workbench Architecture



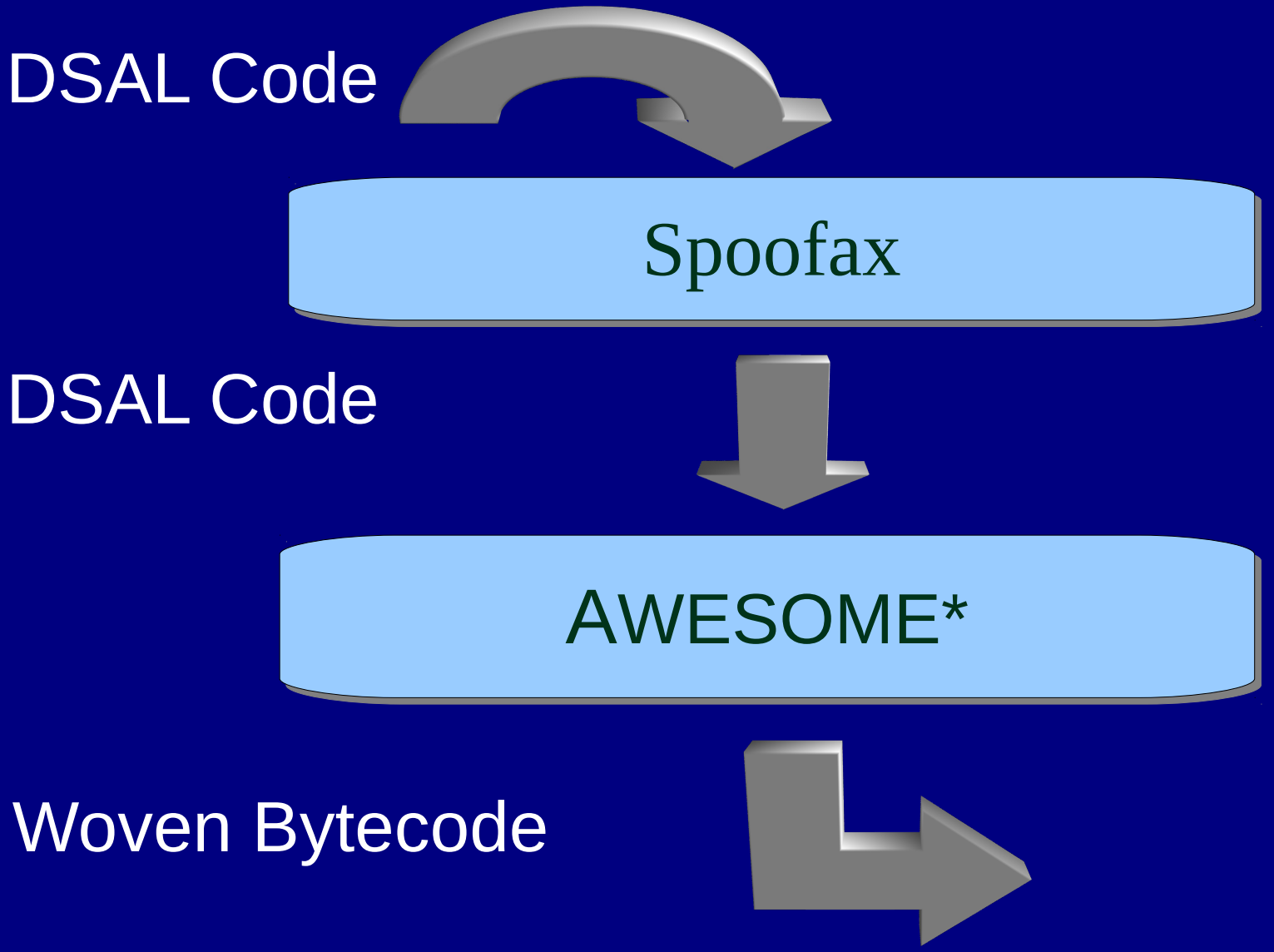
Our Workbench Architecture



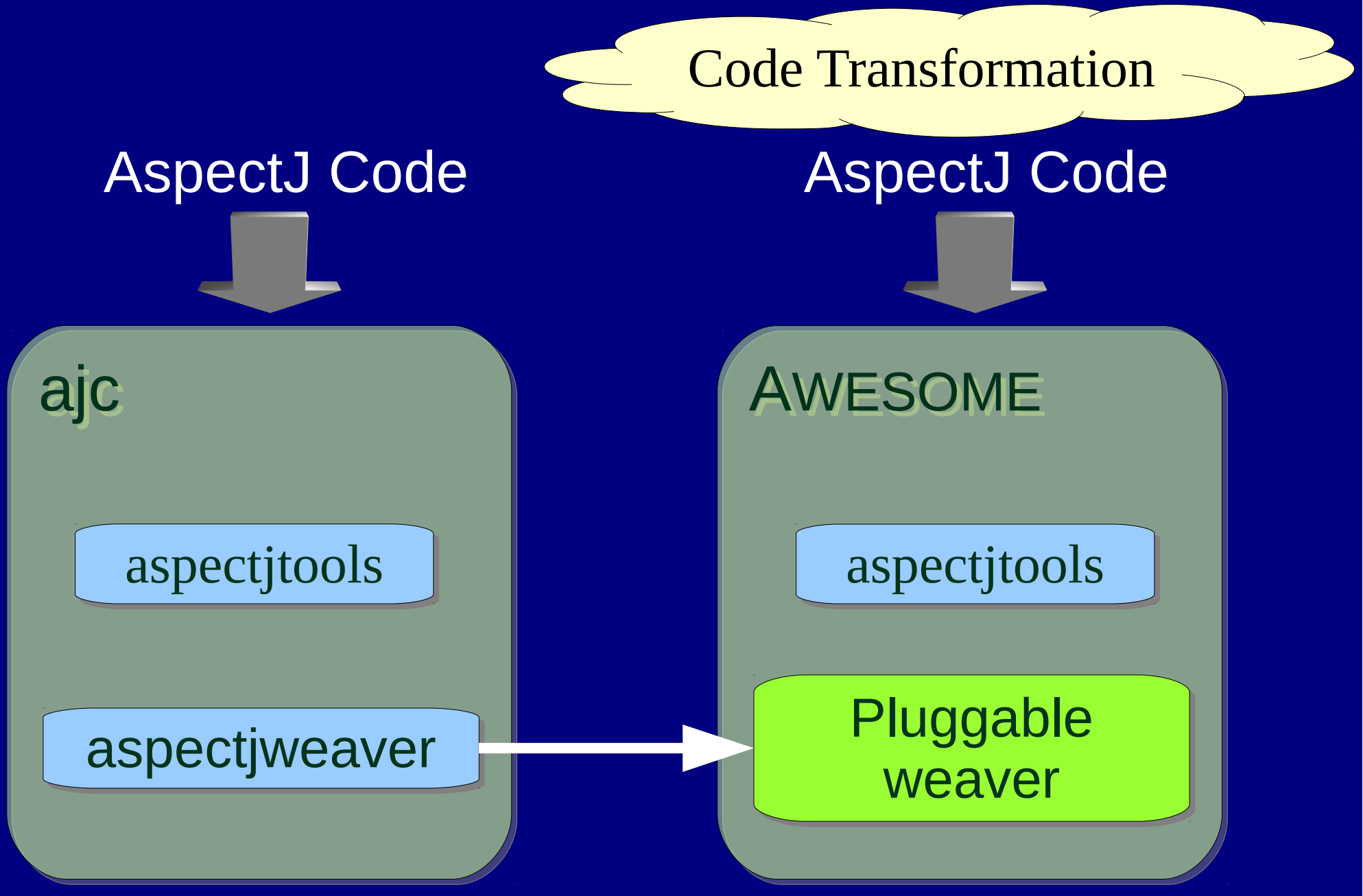
Validation

- **We implemented a workbench**
- **We Implemented third-party extensions that were proposed to AspectJ**
  - COOL
  - Closure Join Points (CJP)
  - Explicit Join Points (EJP)
- **Available as an open source**
  - https://github.com/OpenUniversity

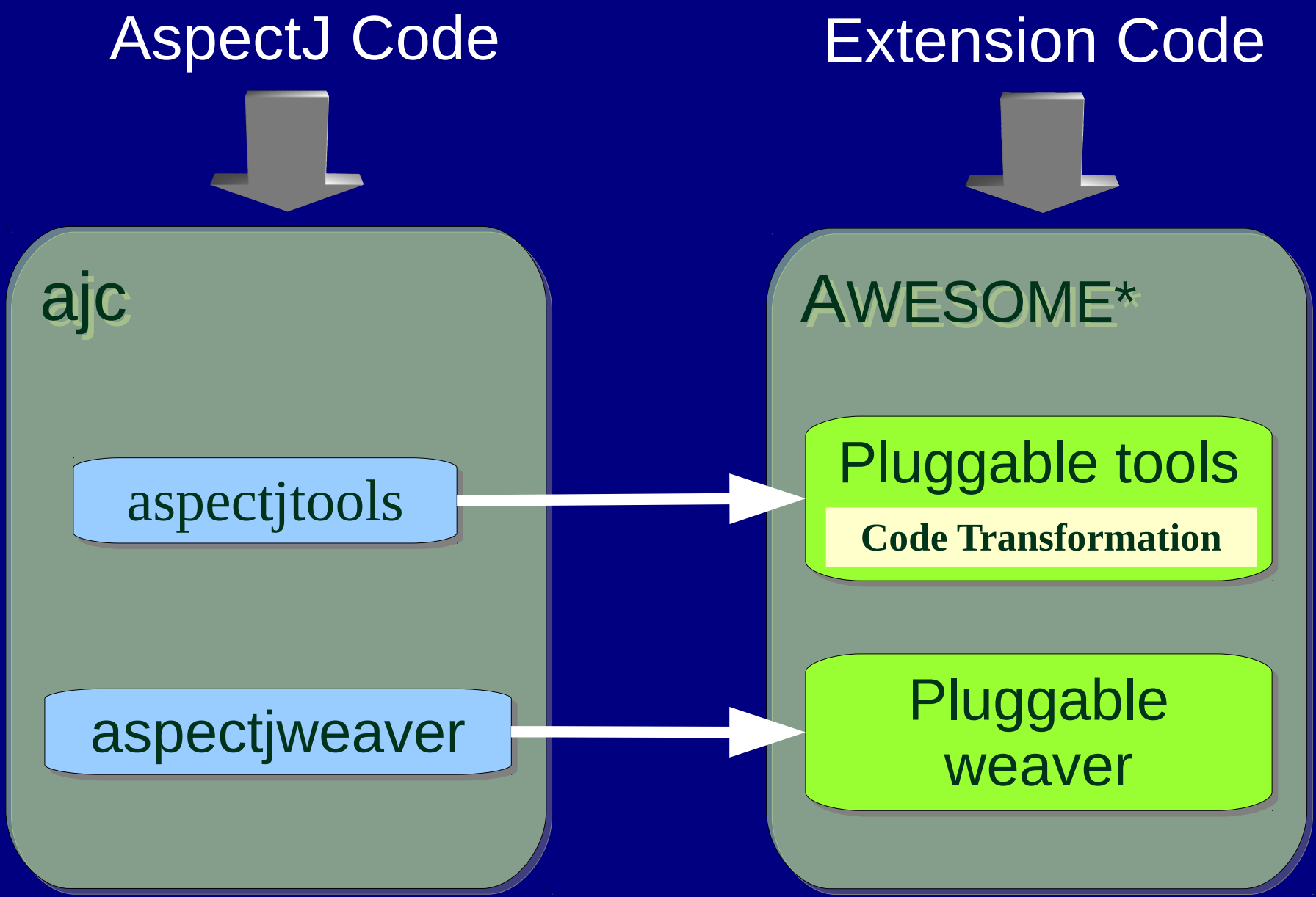
Our Workbench Implementation



AWESOME


Code Transformation
AspectJ Code
AspectJ Code
ajc
aspectjtools
aspectjweaver
AWESOME
aspectjtools
Pluggable weaver

Enhancing AWESOME



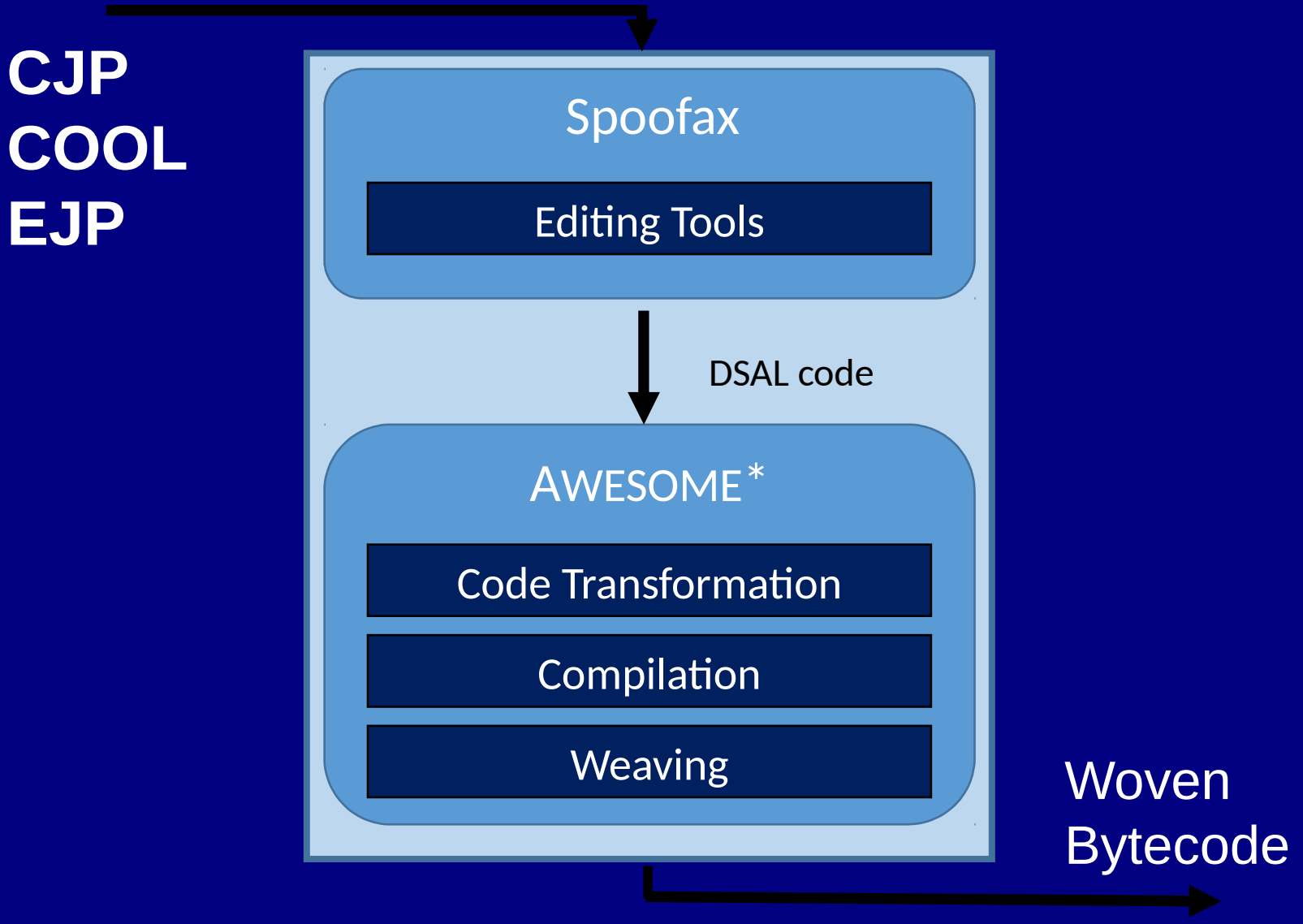
AWESOME's Weaving Model

```
List<BcelShadow> around(MultiMechanism mm, LazyClassGen clazz):
    reifyClass(mm,clazz) { ... }

public List<IEffect> match(BcelShadow shadow) { ... }

public List<IEffect> order(BcelShadow shadow, List<IEffect> effects) { ... }

void around(MultiMechanism mm, List effects, BcelShadow shadow):
    execution(void MultiMechanism.mix(List, BcelShadow)) { ... }
```

Extended Weaving Model

```
List<BcelShadow> around(MultiMechanism mm, LazyClassGen clazz):
    reifyClass(mm,clazz) { ... }

public List<IEffect> match(BcelShadow shadow) { ... }

public List<IEffect> order(BcelShadow shadow, List<IEffect> effects) { ... }

void around(MultiMechanism mm, List effects, BcelShadow shadow):
    execution(void MultiMechanism.mix(List, BcelShadow)) { ... }

public void preweave(List<ResolvedType> types) { ... }
```

So I've been asked to implement EJP...



CJP – Grammar Definition

Expr ::= ... | *ClosureJoinpoint*.

StmtExpr ::= ... | *ClosureJoinpoint*.

ClosureJoinpoint ::=
  "**exhibit**" *ID* "(" [*ParamList*] ")" *Block*
    "(" [*ArgList*] ")" |

  "**exhibit**" *ID Block*.

AspectMember ::= ... | *JoinpointDecl*.

JoinpointDecl ::=
  "**joinpoint**" *Type ID* "(" [*ParamList*] ")" [*ThrowsList*].

AdviceDecl ::= ... | *CJPAdviceDecl*.

CJPAdviceDecl ::=
  [*Modifiers*] *CJPAdviceSpec* [*ThrowsList*] *Block*.

CJPAdviceSpec ::=
  Type "**before**" *ID* "(" [*ParamList*] ")" |
  Type "**after**" *ID* "(" [*ParamList*] ")" |
  Type "**after**" *ID* "(" [*ParamList*] ")"
    "**returning**" ["(" [*Param*] ")"] |
  Type "**after**" *ID* "(" [*ParamList*] ")"
    "**throwing**" ["(" [*Param*] ")"] |
  Type "**around**" *ID* "(" [*ParamList*] ")".

Figure 9: Syntax for Closure Joinpoints, as a syntactic extension to AspectJ (shown in gray)

```
sorts JoinpointDeclaration
   context-free syntax
      "exhibit" MethodName "(" {FormalParam ","}* ")" Block
           "("  {Expr ","}* ")" ->
            Expr{cons("ClosureJoinpoints")}
      "exhibit" MethodName Block ->
        Expr {cons("ShortClosureJoinpoints")}

      JoinpointDeclaration -> AspectBodyDec
      "joinpoint" ResultType Id "(" {FormalParam ","}* ")"
          Throws? ";" ->
          JoinpointDeclaration{cons("JoinpointDeclaration")}
      (Anno | MethodMod)* CJPAdviceSpec Throws? Block ->
        AdviceDec {cons("CJPAdvice")}
      "before" Id "(" {FormalParam ","}* ")" ->
        CJPAdviceSpec {cons("CJPBefore")}
      "after" Id "(" {FormalParam ","}* ")" ->
        CJPAdviceSpec {cons("CJPAfter")}
      "after" Id "(" {FormalParam ","}* ")" "returning"
           CJPSingleParam?
        ->CJPAdviceSpec {cons("CJPAfterReturning")}
      "after" Id "(" {FormalParam ","}* ")" "throwing"
            CJPSingleParam?
        -> CJPAdviceSpec {cons("CJPAfterThrowing")}
      "(" FormalParam? ")" -> CJPSingleParam
        {cons("CJPSingleParam")}
        ResultType "around" Id "(" {FormalParam ","}* ")"
        -> CJPAdviceSpec {cons("CJPAround")}

   lexical syntax
      "exhibit" -> Keyword
      "joinpoint" -> PseudoKeyword
```

CJP – Grammar Definition

Expr ::= ... | *ClosureJoinpoint*.

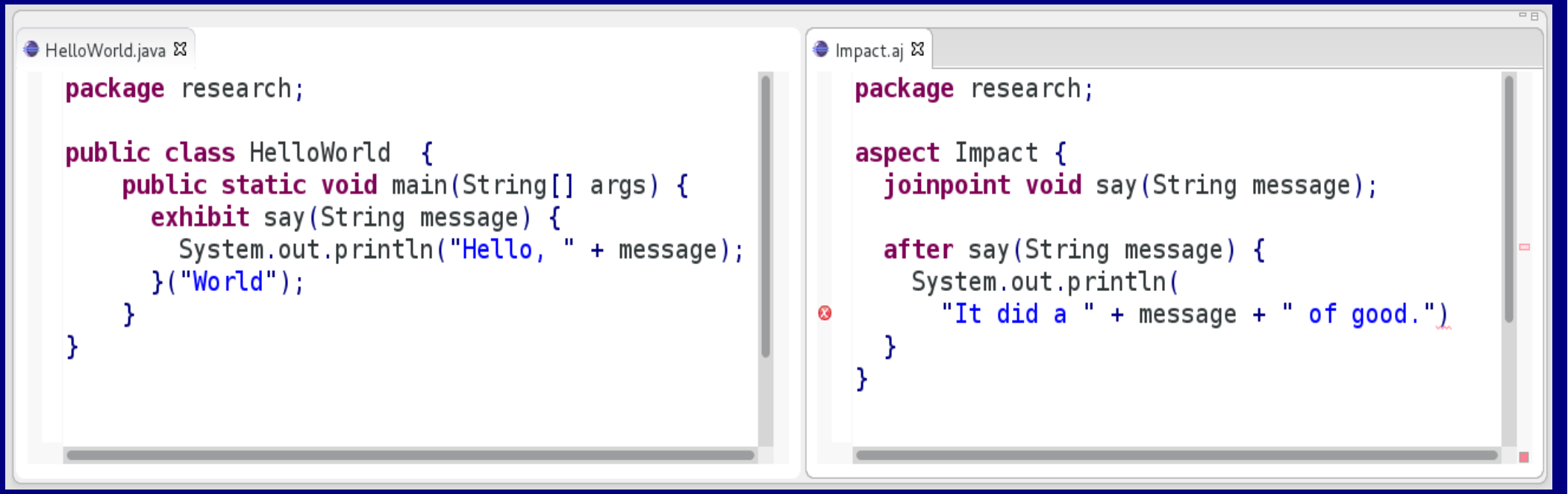
StmtExpr ::= ... | *ClosureJoinpoint*.

ClosureJoinpoint ::=
"**exhibit**" *ID* "(" [*ParamList*] ")" *Block*
"(" [*ArgList*] ")" |

"**exhibit**" *ID Block*.

```
"exhibit" MethodName "(" {FormalParam ","}* ")" Block "("  {Expr ","}* ")"
     -> Expr{cons("ClosureJoinpoints")}

"exhibit" MethodName Block -> Expr {cons("ShortClosureJoinpoints")}
```

Programming in CJP with Eclipse



But It Will Not Compile..

HelloWorld.java

```
package research;

public class HelloWorld  {
    public static void main(String[] args) {
      exhibit say(String message) {
        System.out.println("Hello, " + message);
      }("World");
    }
}
```

Impact.aj

```
package research;

aspect Impact {
  joinpoint void say(String message);

  after say(String message) {
    System.out.println(
      "It did a " + message + " of good.");
  }
}
```

Problems | Javadoc | Declaration | Console

6 errors, 0 warnings, 0 others

Description	Resource	Path	Location	Type
Errors (6 items)				
exhibit cannot be resolved to a type	HelloWorld.jav	/helloworld/src/research	line 5	Java Problem
Syntax error on token "(", ; expected	HelloWorld.jav	/helloworld/src/research	line 5	Java Problem
Syntax error on token ")", ; expected	HelloWorld.jav	/helloworld/src/research	line 5	Java Problem
Syntax error on token "after", delete this toke	Impact.aj	/helloworld/src/research	line 4	Java Problem
Syntax error on token "void", delete this toke	Impact.aj	/helloworld/src/research	line 4	Java Problem
Syntax error, insert "AssignmentOperator Exp	HelloWorld.jav	/helloworld/src/research	line 7	Java Problem

CJP – Code Transformation

java-converter.str

```
            )
          , exprs*
          )

  closure-to-java-impl =
      ?ShortClosureJoinpoints(<or(?MethodName(Id(jp_name)), ?MethodName(_, Id(jp_name)))>, block);
      !Invoke(
        Method(
          NewInstance(
            None()
          , ClassOrInterfaceType(TypeName(Id("JoinpointWrapper")), None())
          , []
          , Some(
              ClassBody(
                [ MethodDec(
                    MethodDecHead(
                      [MarkerAnno(TypeName(Id("Closure"))), Public()]
                    , None()
                    , Void()
                    , Id(jp_name)
                    , []
                    , None()
                    )
                  , block
                  )
                ]
              )
            )
          )
        , None()
        , Id(jp_name)
        )
      , []
      )
```

CJP – Replacing ajc with AWESOME*

HelloWorld.java

```
package research;

public class HelloWorld  {
    public static void main(String[] args) {
      exhibit say(String message) {
        System.out.println("Hello, " + message);
      }("World");
    }
}
```

Impact.aj

```
package research;

aspect Impact {
  joinpoint void say(String message);

  after say(String message) {
    System.out.println(
      "It did a " + message + " of good.");
  }
}
```

Problems @ Javadoc Declaration Console

```
Hello, World
It did a World of good.
```

CJP – Behind the Scenes

Original Code

HelloWorld.java

```
package research;

public class HelloWorld  {
    public static void main(String[] args) {
      exhibit say(String message) {
        System.out.println("Hello, " + message);
      }("World");
    }
}
```

Transformed Code

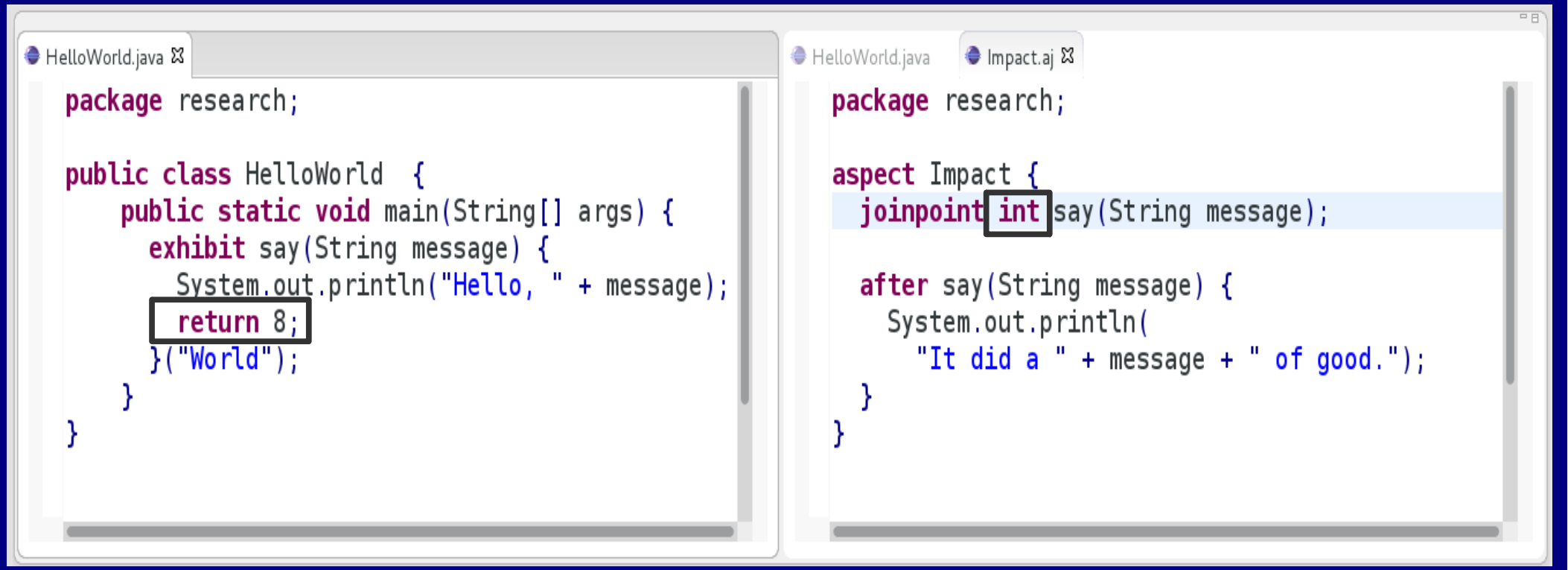
HelloWorld.java

```
package research;

import closures.runtime.*;
import org.aspectj.lang.annotation.*;
import org.aspectj.lang.*;

public class HelloWorld
{
  public static void main(String[] args)
  {
    new JoinpointWrapper()
    {
      @Closure public void say(String message)
      {
        System.out.println("Hello, " + message);
      }
    }.say("World");
  }
}
```

CJP Implementation

- **Passed all tests from original prototype**
  - Few invalid tests were fixed
- **CJP programs runnable in Eclipse**
  - Looks like regular AspectJ project
- **Non trivial extension**
  - Used context-aware code transformations

Context-aware Code Transformation



Context-aware Code Transformation

HelloWorld.java

```
package research;

public class HelloWorld  {
    public static void main(String[] args) {
      exhibit say(String message) {
        System.out.println("Hello, " + message);
        return 8;
      }("World");
    }
}
```

HelloWorld.java | Impact.aj

```
package research;

import closures.runtime.*;
import org.aspectj.lang.annotation.*;
import org.aspectj.lang.*;

public class HelloWorld
{
  public static void main(String[] args)
  {
    new JoinpointWrapper()
    {
      @Closure public int say(String message)
      {
        System.out.println("Hello, " + message);
        return 8;
      }
    }.say("World");
  }
}
```

Need to know about the joinpoint declaration when transforming the base code!

Another example: COOL

BoundedStack.java

```
package base;

public class BoundedStack implements Stack {

    protected Object[] buffer;

    private int usedSlots = 0;

    public BoundedStack(int capacity) {
        this.buffer = new Object[capacity];
    }

    public Object pop() {
        Object result = buffer[usedSlots - 1];
        usedSlots--;
        buffer[usedSlots] = null;
        return result;
    }

    public void push(Object obj) {
```

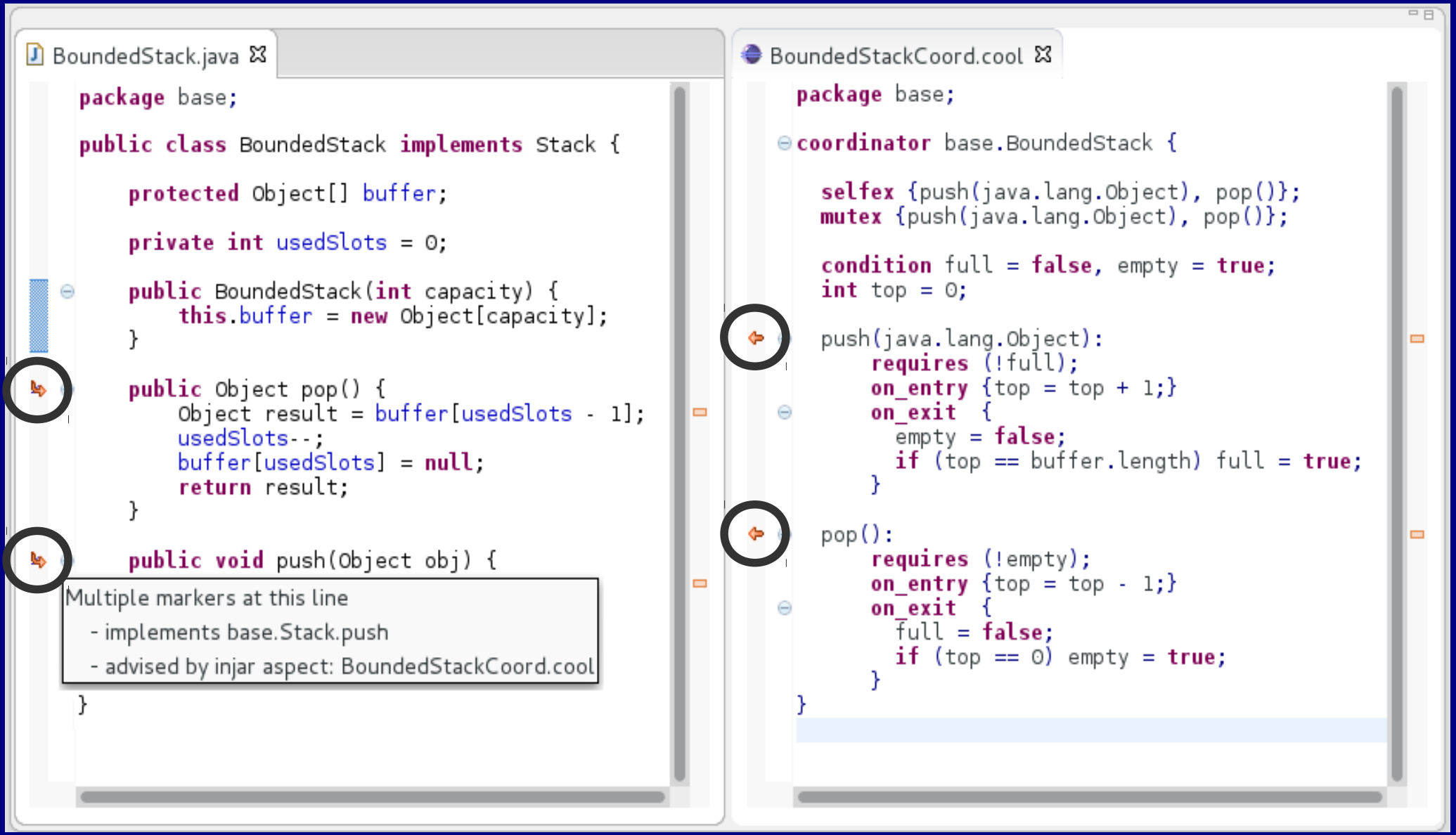
Multiple markers at this line
- implements base.Stack.push
- advised by injar aspect: BoundedStackCoord.cool

```
}
```

BoundedStackCoord.cool

```
package base;

coordinator base.BoundedStack {

  selfex {push(java.lang.Object), pop()};
  mutex {push(java.lang.Object), pop()};

  condition full = false, empty = true;
  int top = 0;

  push(java.lang.Object):
      requires (!full);
      on_entry {top = top + 1;}
      on_exit  {
        empty = false;
        if (top == buffer.length) full = true;
      }

  pop():
      requires (!empty);
      on_entry {top = top - 1;}
      on_exit  {
        full = false;
        if (top == 0) empty = true;
      }
}
```

AJDT Markers for COOL



Another example: EJP

- **Implemented features that were omitted in original prototype**
  - Pointcut arguments
  - Policy enforcement
- **Used the 'preweave' extension in the AWESOME's weaving model**

Using the preweave phase

Main.java

```
package ex_pointcutargs;

public class Main {

  public static void main(String[] args) {
    new Main().foo();
  }

  public void foo() {
    System.out.println("at foo");
    ex_pointcutargs.Aspect.jp()
        pointcutargs mm():call(* goo(..));
    goo();
  }

  public void goo() {
    System.out.println("at goo");
  }
}
```

Aspect.aj

```
package ex_pointcutargs;

aspect Aspect {
 public joinpoint void jp() pointcutargs mm();

 before(): jp.mm() {
   System.out.println("calling " +
    "something that was added to aa.mm");
 }
}
```

Empty pointcut

Extending pointcut in base code

Related Work

- **Language Workbenches**
  - [**Fowler, 2005**] Language workbenches: The killer-app for domain specific languages.
  - [**Kats and Visser, 2010**] The Spoofax language workbench: Rules for declarative specification of languages and IDEs.
- **The AspectBench Compiler**
  - [**P.A, A.S.C, L.H, S.K, J.L, O.L, O.M, D.S, G.S, and J.T, 2005**] abc: an extensible AspectJ compiler.
- **AOP Composition Frameworks**
  - [**Lorenz and Kojarski, 2007**] Understanding aspect interaction, co-advising and foreign advising.
  - [**Kojarski and Lorenz, 2007**] Awesome: An aspect co-weaving system for composing multiple aspect-oriented extensions.

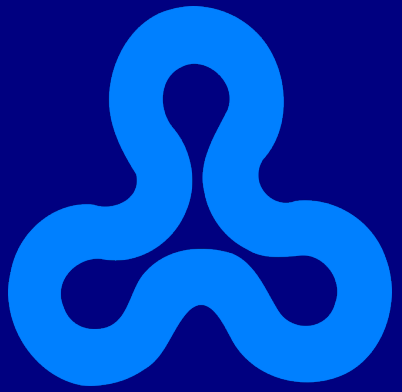
Tools Comparison

	abc	AWESOME	Spoofax	Workbench
Tools for custom syntax definition				
Extensible Java/AspectJ syntax				
Tools for code transformation				
Editing tools for end-programmers				
Ability to define the weaving semantics required for DSAL				
Works with a recent version of AspectJ				
Compliance with AJDT				

Conclusion

- **A novel design for a workbench that produces first-class AspectJ extensions**
  - A modern alternative to abc
  - AOP composition framework used as a back-end to achieve first-class DSL
  - DSAL code passed to the back-end to achieve first-class AOP language
- **Validation**
  - Prototype comprising Spoofax and AWESOME*
  - Plug-ins for COOL, EJP and CJP
- **Future Work**
  - Evaluate AspectJ extensions in real-world cases

Thank You!



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