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Securing Development with PMD

Teaching an Old Dog New Tricks

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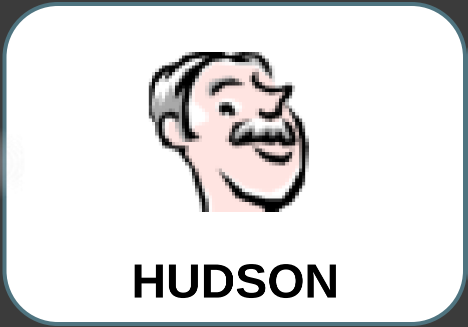
Well, this trick has been around for five years now, so we might be able to learn it...

Integrating Security with Developer Tooling



Key Objectives

- Learn about PMD
- Understand how to extend PMD
- Think about enhancements to similar tools

What Is PMD?

- Open source static analysis tool
- Scans Java source code for potential problems
  - Possible bugs
  - Dead code
  - Suboptimal code
  - Overcomplicated expressions
  - Duplicate code

Very little related to security!!

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Bug Finders vs Security Static Analysis

- Bug Finders (i.e. PMD)
  - Target buggy patterns
  - Minimize false positives even if high false negatives

- Security Static Analysis
  - Target insecure patterns
  - Minimize false negatives even if some false positives
  - Context of violation must be investigated

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Why Extend Security to PMD?

- Used extensively by Java developers already
- Highly extensible with Rule and Report API
- Strong documentation and support network
- Integrates with many IDEs and build tools
- PMD internals operate similar to commercial tools

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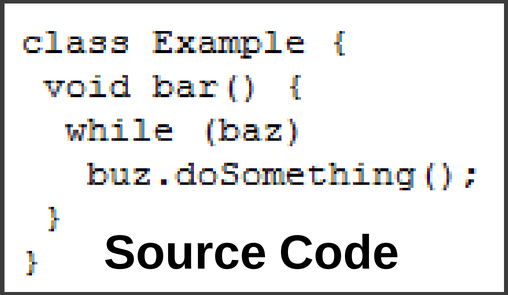
How does PMD work?

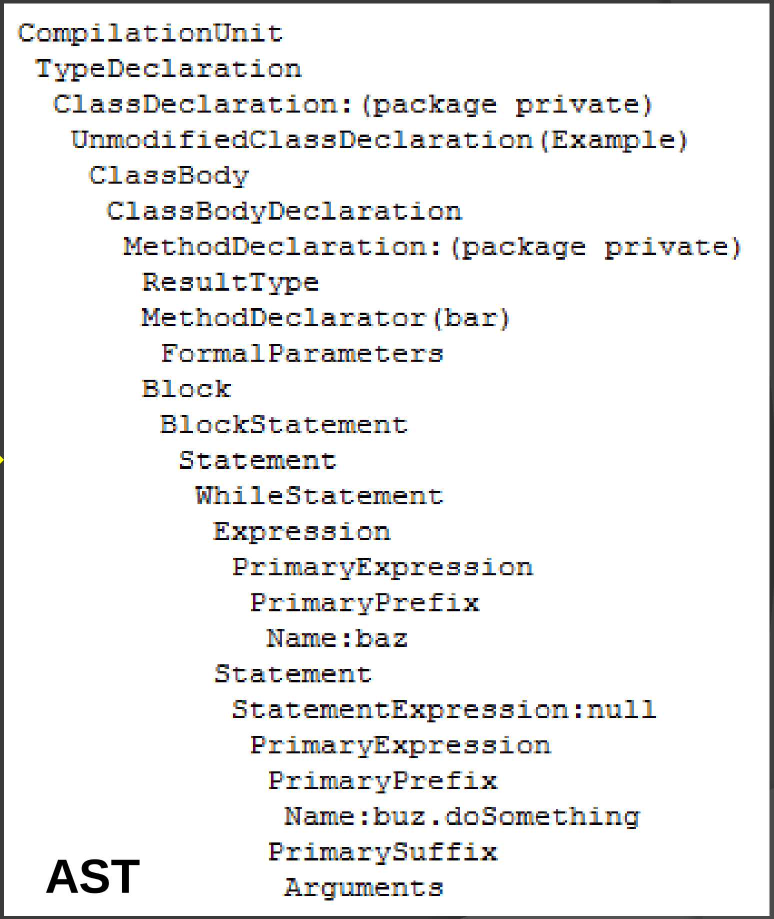
- Run against source file, directory, or archive
- Builds tree-like structure of source code (AST)
- Performs semantic, basic control & data analysis
- Traverses AST looking for patterns (Rules)
- Generates a report of Rule Violations

What Does AST Look Like?



```
class Example {
 void bar() {
  while (baz)
   buz.doSomething();
 }
}
```

Source Code



```
CompilationUnit
 TypeDeclaration
  ClassDeclaration:(package private)
   UnmodifiedClassDeclaration(Example)
    ClassBody
     ClassBodyDeclaration
      MethodDeclaration:(package private)
       ResultType
       MethodDeclarator(bar)
        FormalParameters
       Block
        BlockStatement
         Statement
          WhileStatement
           Expression
            PrimaryExpression
             PrimaryPrefix
              Name:baz
           Statement
            StatementExpression:null
             PrimaryExpression
              PrimaryPrefix
               Name:buz.doSomething
              PrimarySuffix
               Arguments
```

AST

Extending PMD with Custom Rules

- Implement as Xpath expression or Java class
- Wire up rules for use by PMD in ruleset file
- Modify behavior by configuring rule properties
- Group rules into rulesets for enforcement

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Xpath and Java Rule Writing Demo

Resources to Help Writing Rules

- PMD Website
  - http://pmd.sourceforge.net/xpathruletutorial.html
  - http://pmd.sourceforge.net/howtowritearule.html (Java)
- PMD source code
  - net.sourceforge.pmd.rules.*
  - net.sourceforge.pmd.dfa.DaaRule
- PMD Applied (Centennial Books Nov 2005)
- PMD test cases & framework (wraps JUnit)
  - test.net.sourceforge.pmd.testframework
  - test.net.sourceforge.pmd.*

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v1.0 Goals For Custom PMD Security Rules

- Add security without modifying PMD itself
- Write rules that identify “low hanging fruit”
- Perform analysis beyond lexing and pattern match

Selecting Rules for Implementation

GDS Assessment Vulnerability	Customer's Secure Coding Guideline(s)	Rule Type	OWASP Top 10
SQL Injection	2.1 – Commands should not be Constructed through String Concatenation	Data Flow, Structural	A1: Injection
Cross-Site Scripting (XSS)	1.1 – All Input Crossing a Trust Boundary Must be Validated 1.2 – Data from External Sources must be Properly Encoded or Escaped	Data Flow	A2: Cross-Site Scripting (XSS)
Arbitrary File Retrieval	1.1 – All Input Crossing a Trust Boundary Must be Validated 3.2 – Callable Code Must Enforce Authorization Requirements	Data Flow	A4: Insecure Direct Object References
Use of Cryptographically Insecure Algorithms	4.1 – Use of Sound Encryption Algorithms 4.2 – Use of Sound Hashing Algorithms	Structural	A7: Insecure Cryptographic Storage
Arbitrary URL Redirection	1.1 – All Input Crossing a Trust Boundary Must be Validated	Data Flow	A10: Un-validated Redirects and Forwards

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Challenges to Writing PMD Security Rules

PMD Analysis Limitations	Impact on Detecting Security Bugs
▪ Analysis limited to single file at a time ▪ Data Flow Analyzer (DFA) limited to single method (intraprocedural) ▪ DFA tracks local variable declarations and references, but does not evaluate expressions	▪ Data often passes through multiple files/classes and tiers ▪ Security bugs often result of mixing data and code in wrong context
▪ Symbols limited to source file, resulting in names and types not fully resolved	▪ Custom code often wraps well-known APIs (Java or Framework)
▪ Only analyzes JSP files that are XHTML-compliant (i.e. JSP Documents / XML syntax)	▪ Standard JSP syntax more common ▪ Often severe web application security bugs in presentation layer

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Rule Writing Challenges – JSP Files

#1 – Overcome XHTML limitation

- Solution: Leverage JSP compiler
- Result: Java implementation of JSP logic in `_jspService` method
- Benefit:
  - Identify security bugs in any JSP
  - Scope of PMD’s analysis increased

Example of JSP to Java Translation

```
<%
String a1 = request.getParameter("y1");
String b1 = a1;
%>
<%=b1 %>
```

JSP Scriptlet Code

```
public void _jspService(HttpServletRequest request,
   HttpServletResponse response)
        throws java.io.IOException, ServletException {
..snip..
 PageContext pageContext = null;
..snip..
 out = pageContext.getOut();
..snip..
 String a1 = request.getParameter("y1");
 String b1 = a1;
 out.print(b1 );
```

Translated Java code equivalent

Rule Writing Challenges – Reporting

#2 – Report JSP security violations meaningful to developer

- Solution:
  - Wrote custom Source Map Format (SMAP) translator (JSR-045)
  - Implemented *net.sourceforge.pmd.IRuleViolation*
- Result: Report findings in terms of JSP line numbers
- Benefit:
  - JSP developers remediate bugs in JSP
  - Security violations understood by PMD built-in renders

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SMAP Example

```
SMAP
index7_jsp.java
JSP
```

Header (SMAP, generated filename, default stratum)

```
*S JSP
```

Stratum Section

```
*F
+ 0 index7.jsp
index7.jsp
```

File Section (contains translated filenames and path)

```
*L
2,10:53,0
12,3:55
14:58,0
15:60
16,3:61,0
```

Line Section (associates line numbers in input source with output source)

```
*E
```

End Section

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Rule Writing Challenges – DFA w/PMD

#3 – Despite PMD limitations, perform data flow analysis

- Solution: Use PMD DFA and Symbol Table
- Result:
  - Determine if variable assignments assigned *source*
  - Track those *tainted variables* down each data flow
  - Report security violations if tainted variable passed to *sink*
- Benefit: Automated, accurate tracing from source to sink

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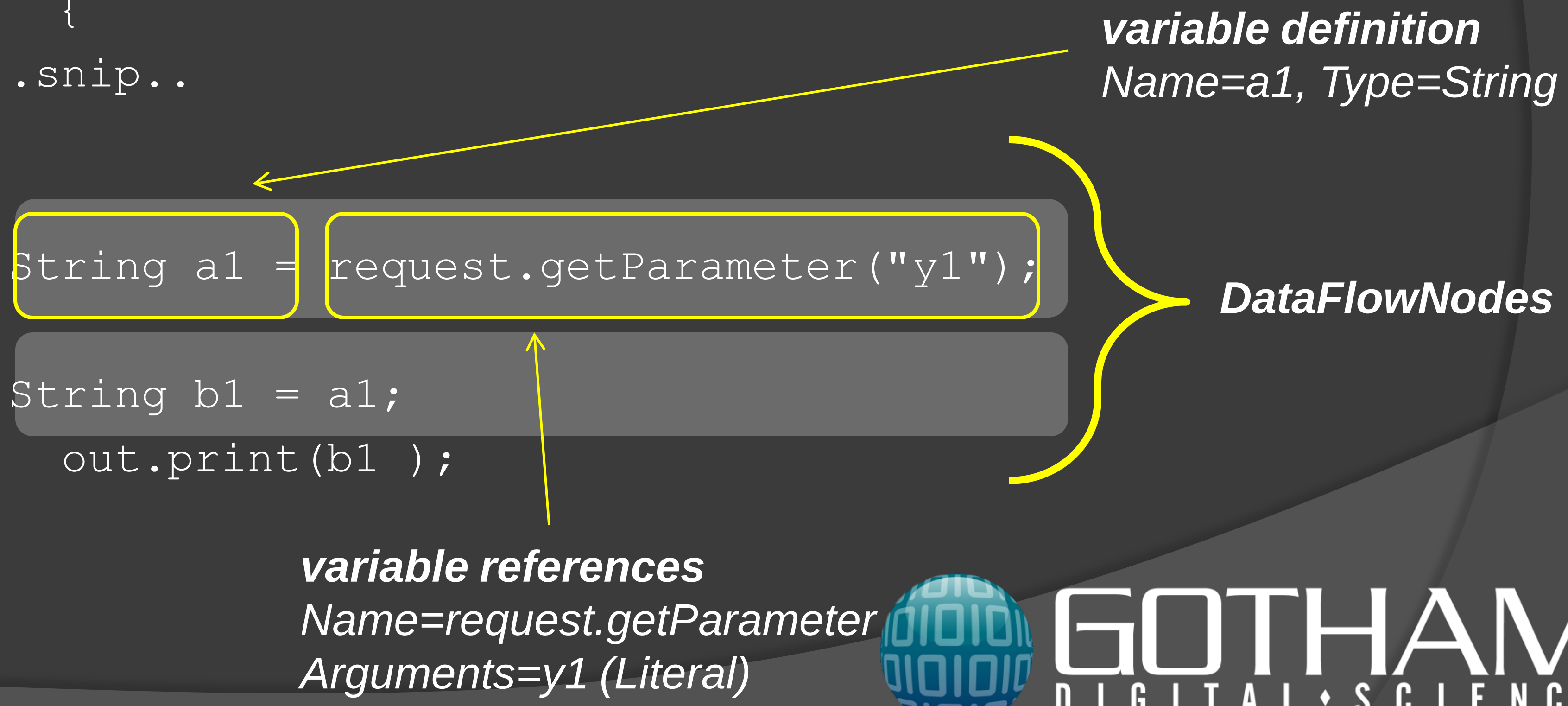
PMD Data Flow Analysis



```
public void _jspService(HttpServletRequest request,
   HttpServletResponse response)
        throws java.io.IOException, ServletException
   {
..snip..

 String a1 = request.getParameter("y1");

 String b1 = a1;
   out.print(b1 );
```

variable definition
Name=a1, Type=String

DataFlowNodes

variable references
Name=request.getParameter
Arguments=y1 (Literal)

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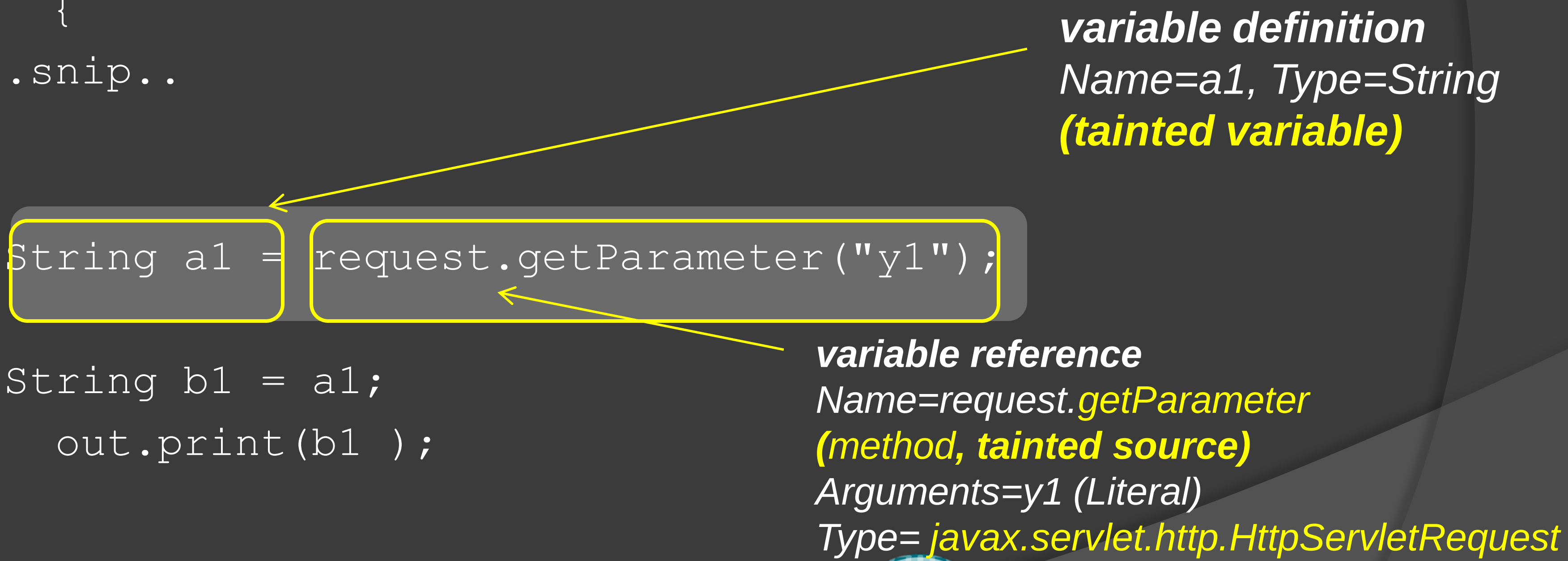
PMD Data Flow Analysis Extended (XSS)

```
public void _jspService(HttpServletRequest request,
   HttpServletResponse response)
        throws java.io.IOException, ServletException
   {
..snip..
```



```
 String a1 = request.getParameter("y1");

 String b1 = a1;
   out.print(b1 );
```

variable definition

Name=a1, Type=String

(tainted variable)

variable reference

Name=request.getParameter

*(method, **tainted source)***

Arguments=y1 (Literal)

Type= javax.servlet.http.HttpServletRequest

PMD Data Flow Analysis Extended (XSS)

```
public void _jspService(HttpServletRequest request,
   HttpServletResponse response)
        throws java.io.IOException, ServletException
   {
..snip..


 String a1 = request.getParameter("y1");

 String b1 = a1;
   out.print(b1 );
```

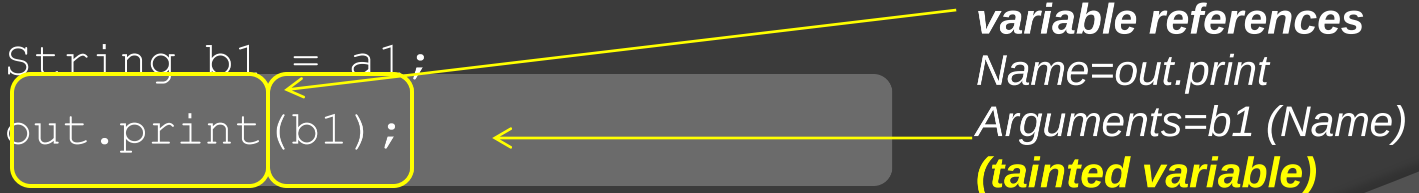
variable definition
Name=b1, Type=String
(tainted variable)

variable reference
Name=a1 ***(tainted variable)***

PMD Data Flow Analysis Extended (XSS)

```
public void _jspService(HttpServletRequest request,
   HttpServletResponse response)
        throws java.io.IOException, ServletException
   {
..snip..


 String a1 = request.getParameter("y1");
```



```
 String b1 = a1;
 out.print(b1);
```

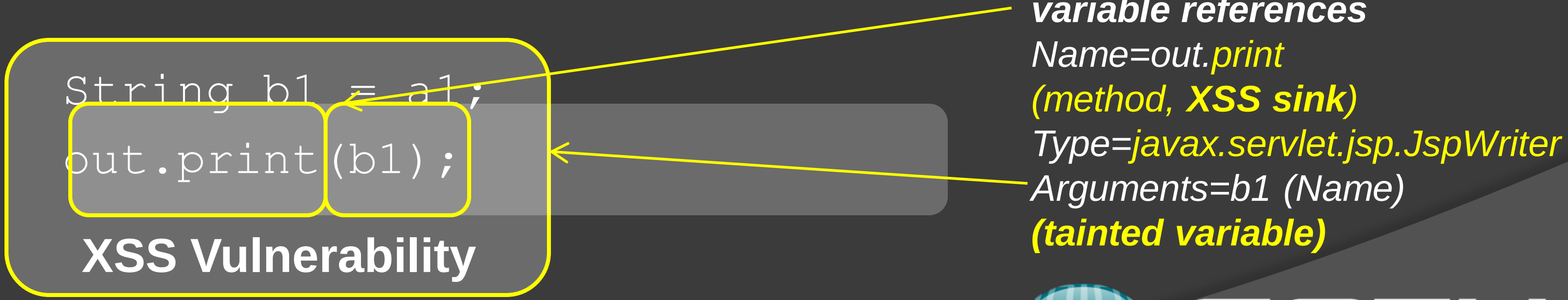
variable references
Name=out.print
Arguments=b1 (Name)
(tainted variable)

PMD Data Flow Analysis Extended (XSS)

```
public void _jspService(HttpServletRequest request,
   HttpServletResponse response)
        throws java.io.IOException, ServletException
   {
..snip..


 String a1 = request.getParameter("y1");

 String b1 = a1;
 out.print(b1);
```



XSS Vulnerability

variable references
Name=out.print
*(method, **XSS sink**)*
Type=javax.servlet.jsp.JspWriter
Arguments=b1 (Name)
(tainted variable)

DFA Security Rule Usage Notes

- Violations need to be manually investigated for proper escaping/validation

- Configurable sources and sinks via properties
  - URL Redirection
    - *javax.servlet.http.HttpServletResponse.sendRedirect*
  - SQL Injection
    - *java.sql.execute*

- Effective source/sink same method / “reflected” variants

PMD Structural Rule Example – SQLi

- DFA susceptible to false negatives
  - Data traverse multiple files between source and sink

- Supplement with structural rule
  - Investigates AST AdditiveExpression nodes
  - Performs following analysis
    - Is string a SQL command?
    - Is concatenated data of type String?
    - Is concatenated data a method argument?

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Using PMD Security Rules

Basic Usage Steps

- Configure `CLASSPATH`
  - Add *`pmd-gds-1.0.jar`*
  - Add jars/classes used when building (for type resolution)
- Configure PMD to use */rulesets/GDS/SecureCodingRuleset.xml*
- Run PMD and audit results

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PMD ANT Task Example - CLASSPATH

```
<path id="pmd.classpath">
 <fileset dir="${pmd.dir.home}\lib">
  <include name="pmd-${pmd.version}.jar" />
  ..snip..
 </fileset>
 <pathelement location="lib\${gds.jar}" />
 <pathelement location="${app1.src}\build\classes\"/>
 <fileset dir="C:\tomcat\apache-tomcat-6.0.29\lib">
    <include name="servlet-api.jar" />
 </fileset>
</path>

<target name="pmd" description="Runs PMD">
 <taskdef name="pmd" classname="net.sourceforge.pmd.ant.PMDTask"
    classpathref="pmd.classpath" />
 <pmd rulesetfiles="rulesets/GDS/SecureCodingRuleset.xml" shortFilenames="false"
  <formatter type="text" toConsole="true" />
  <fileset dir="${app1.src}"><include name="**/*.java" /></fileset>
 </pmd>
</target>
```

PMD ANT Task Example – Rules Config

```
<path id="pmd.classpath">
 <fileset dir="${pmd.dir.home}\lib">
  <include name="pmd-${pmd.version}.jar" />
  ..snip..
 </fileset>
 <pathelement location="lib\${gds.jar}" />
 <pathelement location="${app1.src}\build\classes\"/>
 <fileset dir="C:\tomcat\apache-tomcat-6.0.29\lib">
    <include name="servlet-api.jar" />
 </fileset>
</path>

<target name="pmd" description="Runs PMD">
 <taskdef name="pmd" classname="net.sourceforge.pmd.ant.PMDTask"
    classpathref="pmd.classpath" />
 <pmd rulesetfiles="rulesets/GDS/SecureCodingRuleset.xml" shortFilenames="false"
  <formatter type="text" toConsole="true" />
  <fileset dir="${app1.src}"><include name="**/*.java" /></fileset>
 </pmd>
</target>
```

Configuring JSP to Java Translation

- Add JSP compiler task to build tool (build.xml)
- Configure *smapSuppressed* to *false* and *smapDump* to *true*

```
<jasper2 validateXml="false" uriroot="C:\Code\web.war"
    webXmlFragment="${jspBuildDir}/WEB-
    INF/generated_web.xml" outputDir="${jspBuildDir}/WEB-
    INF/src" smapSuppressed="false"  smapDumped="true"/>
```

- Add extra clean task to remove .smap files before production deployment

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Custom Rules with PMD Eclipse Plug-in

- Plug-in only supports xpath rules out of box
- Put custom rules on plug-in `CLASSPATH`
  - Requires modification of PMD Eclipse plugin jars
  - Add rules to PMD Eclipse plugin source and compile
  - Wrap PMD Eclipse plugin with custom plugin

Current and Future Development

- Publish version 1.0 of Secure Coding Ruleset @ https://github.com/GDSSecurity
- Integrate NIST Juliet Test cases
- Contribute to PMD project (need to pass tests first!)
- Extend rules beyond Java with PMD 5
- Write PMD 5.0 Rules
- Enhance PMD feature set

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Conclusion

- Learned about PMD and extensibility
- Discussed approach for rule writing & deployment
- Use, add and improve SecureCodingRuleset on GitHub
- Look for other developer tools where it would be practical to add security

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References

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