Automated Assessment Tools

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CTSC
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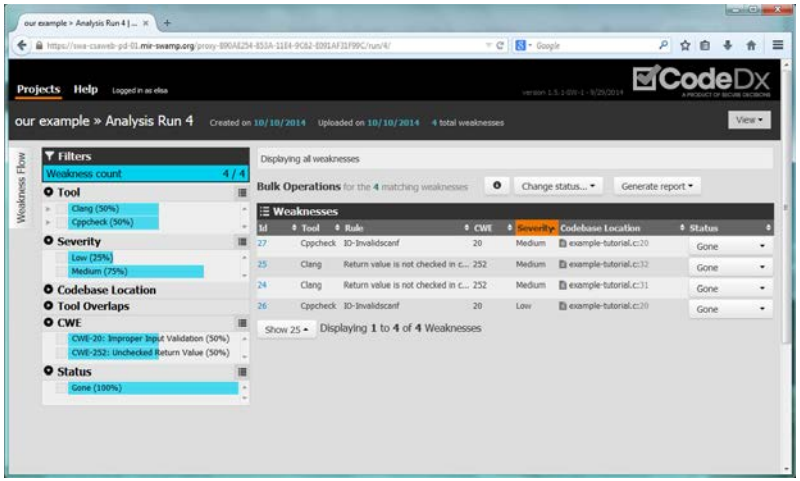
The NSF Cybersecurity Center of Excellence

1. What You Need to Know about How Tools Work

2. The Tools And Their Use

Source Code Analysis Tools

```
p = requesttable;
while (p != (struct table *)0)
{
   if (p->entrytype == PEER_MEET)
   {
      found = (!(strcmp (her, p->me)) &&
               !(strcmp (me, p->her)));
                }
      else if (p->entrytype == PUTSERVR)
      {
         found = !(strcmp (her, p->me));
      }
      if (found)
         return (p);
      else
         p = p->next;
   }
   return ((struct table *) 0);
```



A Bit of History

Compiler warnings

Let the Compiler Help

- Turn on compiler warnings and fix problems
- Easy to do on new code
- Time consuming, but useful on old code
- Use lint, multiple compilers
- **-Wall** is not enough!

  gcc: **-Wall, -W, -O2, -Werror, -Wshadow, -Wpointer-arith, -Wconversion, -Wcast-qual, -Wwrite-strings, -Wunreachable-code** and many more

  – Many useful warning including security related warnings such as format strings and integers

A Bit of History

- Lint (1979)
  - C program checker.
  - Detects suspicious constructs:
    - Variables being used before being set.
    - Division by zero.
    - Conditions that are constant.
    - Calculations whose result is likely to overflow.
- Current automated assessment tools are a sort of “super-Lint”.

Source Code Analysis Tools

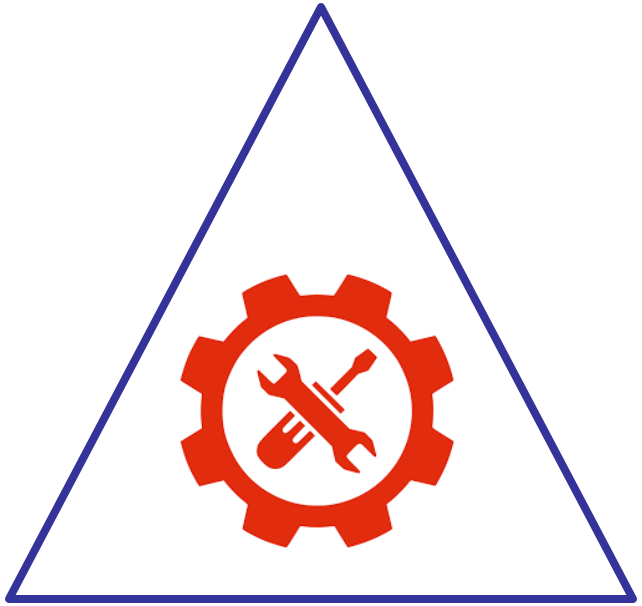
- Designed to analyze source code or binaries to help find security flaws.
- The source code may contain inadvertent or deliberate weaknesses that could lead to security vulnerabilities in the executable versions of the application program.
- Better to use them from the beginning of the software development life cycle.
  - Though commonly applied to legacy code.

Source Code Analysis Tools

- Program that parses and then analyses the source code.
- Doesn't know what the program is supposed to do.
- Looks for violations of good programming practices.
- Looks for specific programming errors.
- Works like a compiler
  - Instead of binaries, it produces an intermediate representation

Source Code Analysis Tools

precision



speed

#checks

You can get 2 out of 3

Courtesy of RedLizards

Source Code Analysis Tools

Different kind of tools:

- Syntax vs. semantics
  - Interprocedural
    - Whole program analysis
      - Local vs. paths
        - Data flow analysis
          - Sound vs. approximate

Implications:

- Scalability
  - Accuracy

Different kind of tools

```
cmd = “/bin/ls”;
execl (cmd, NULL);
```

Pattern (syntax) matching

Will say “always dangerous”.

Semantic analysis

Sometimes definitely no.

Different kind of tools

```
fgets(cmd,MAX,stdin);
execl (cmd, NULL);
```

Pattern (syntax) matching

Will say "always dangerous".

Semantic analysis

Sometimes definitely no.

Sometimes definitely yes.

Different kind of tools

```
cmd=makecmd();
execl (cmd, NULL);
```

Pattern (syntax) matching

- Will say "always dangerous".

Semantic analysis

- Sometimes definitely no.
- Sometimes definitely yes.
- Sometimes undetermined.

Source Code Analysis Tools How do they work

Identify the code to be analyzed.

- Scripts or build systems that build the executable.

The parser interprets the source code in the same way that a compiler does.

Source Code Analysis Tools How do they work

Each invocation of the tool creates a model of the program:

- **Abstract representations of the source**
  - **Control-flow graph**
  - **Call graph**
  - **Information about symbols (variables and type names)**

Source Code Analysis Tools How do they work

Symbolic execution on the model:

- Abstract values for variables.
- Explores paths.
- Based on abstract interpretation and model checking.
- The analysis is path sensitive.
  - The tool can tell the path for the flow to appear.
  - Points along that path where relevant transformations occur and conditions on the data values that must hold.

Source Code Analysis Tools
How do they work

The tool issue a set of warnings.

- List with priority levels.

The user goes through the warning list and labels each warning as:

- True positive.
- False Positive.
- Don't care.

Source Code Analysis Tools
The Output

A tool grades weaknesses according things such as

severity,

potential for exploit, or

certainty that they are vulnerabilities.

Problems:

- False positives.
- False negatives.

Source Code Analysis Tools
The Output

Ultimately people must analyze the tool's report and the code then decide:

- **Which reported items are not true weaknesses.**
- **Which items are acceptable risks and will not be mitigated.**
- **Which items to mitigate, and how to mitigate them.**

Source Code Analysis Tool Limitations

No single tool can find every possible weaknesses:

- **A weakness may result in a vulnerability in one environment but not in another.**
- **No algorithm can correctly decide in every case whether or not a piece of code has a property, such as a weakness.**
- **Practical analysis algorithms have limits because of performance, approximations, and intellectual investment.**
- **And new exploits are invented and new vulnerabilities discovered all the time!**

Source Code Analysis Tools
What can they find

- Stylistic programming rules.
- Type discrepancies.
- Null-pointer dereferences.
- Buffer overflows.
- Race conditions.
- Resource leaks.
- SQL Injection.

Source Code Analysis Tools
What is difficult to find

- Authentication problems.
  - Ex: Use of non-robust passwords.
- Access control issues.
  - Ex: ACL that does not implement the principle of least privilege.
- Insecure use of cryptography.
  - Ex: Use of a weak key.

Source Code Analysis Tools
What is not possible to find

- Incorrect design.
- Code that incorrectly implements the design.
- Configuration issues, since they are not represented in the code.
- Complex weaknesses involving multiple software components.

Code Analysis Basics

Control flow analysis

- Analyze code structure and build a graph representation.
- Basics blocks and branch/call edges.
- Pointers are difficult.

Data flow analysis

- Usage, calculation, and setting of variables.
- Extract symbolic expressions.
- Arrays are annoying.
- Pointers are difficult.

Control Flow Analysis

Control Flow Analysis

Detects control flow dependencies among different instructions.

Control Flow Graph (CFG)

- Abstract representation of the source code.
- Each node represents a basic block.
- Call or jump targets start a basic block.
- Jumps end a basic block.
- Directed edges represent the control flow.

```
void foo() {
  char buf[MAX] = "example";
  int i, j, k;
  char a, b;
  char *p = buf;

  i = 0;
  if (c)
     j = i;
  else
     j = MAX;
  a = buf[i];
  b = buf[j];
  k = 0;
  while (k < MAX) {
     if (buf[k]== 'x')
        print(k);
     if (*p == 'z')
        print(p);
     p++;
     k++;
  }
}
```

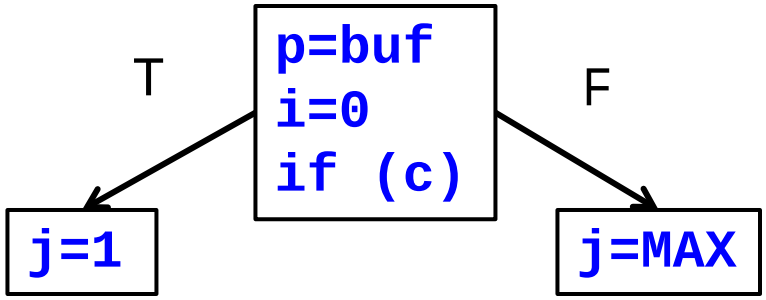
```
void foo() {
   char buf[MAX] = "example";
   int i, j, k;
   char a, b;
   char *p = buf;

   i = 0;
   if (c)
      j = i;
   else
      j = MAX;
   a = buf[i];
   b = buf[j];
   k = 0;
   while (k < MAX) {
      if (buf[k]== 'x')
         print(k);
      if (*p == 'z')
         print(p);
      p++;
      k++;
   }
}
```

```
p=buf
i=0
if (c)
```

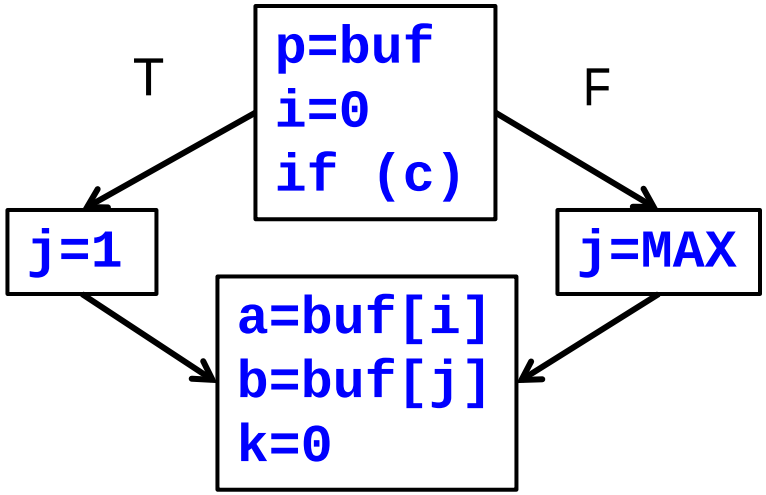
```
void foo() {
   char buf[MAX] = "example";
   int i, j, k;
   char a, b;
   char *p = buf;

   i = 0;
   if (c)
      j = i;
   else
      j = MAX;
   a = buf[i];
   b = buf[j];
   k = 0;
   while (k < MAX) {
      if (buf[k]== 'x')
         print(k);
      if (*p == 'z')
         print(p);
      p++;
      k++;
   }
```



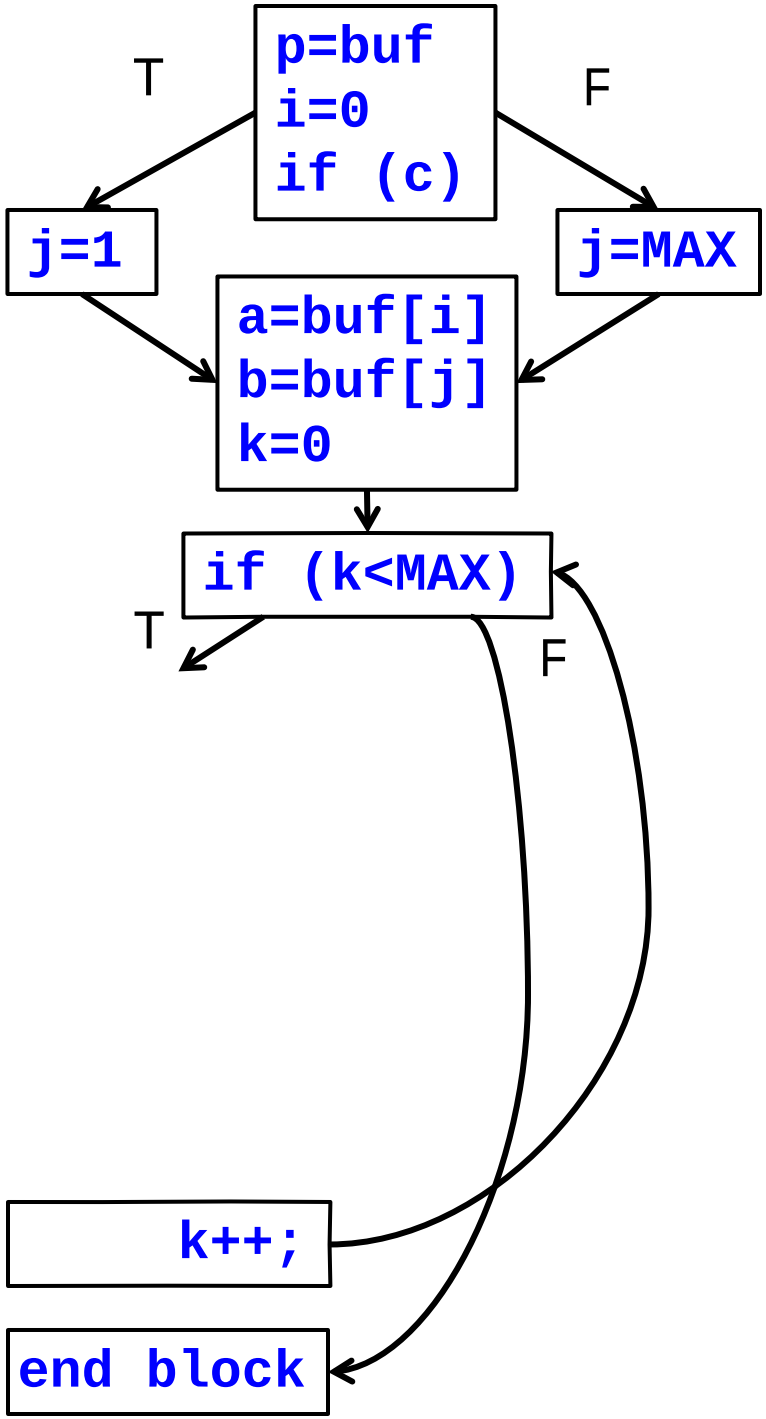
```
void foo() {
   char buf[MAX] = "example";
   int i, j, k;
   char a, b;
   char *p = buf;

   i = 0;
   if (c)
      j = i;
   else
      j = MAX;
   a = buf[i];
   b = buf[j];
   k = 0;
   while (k < MAX) {
      if (buf[k]== 'x')
         print(k);
      if (*p == 'z')
         print(p);
      p++;
      k++;
   }
```



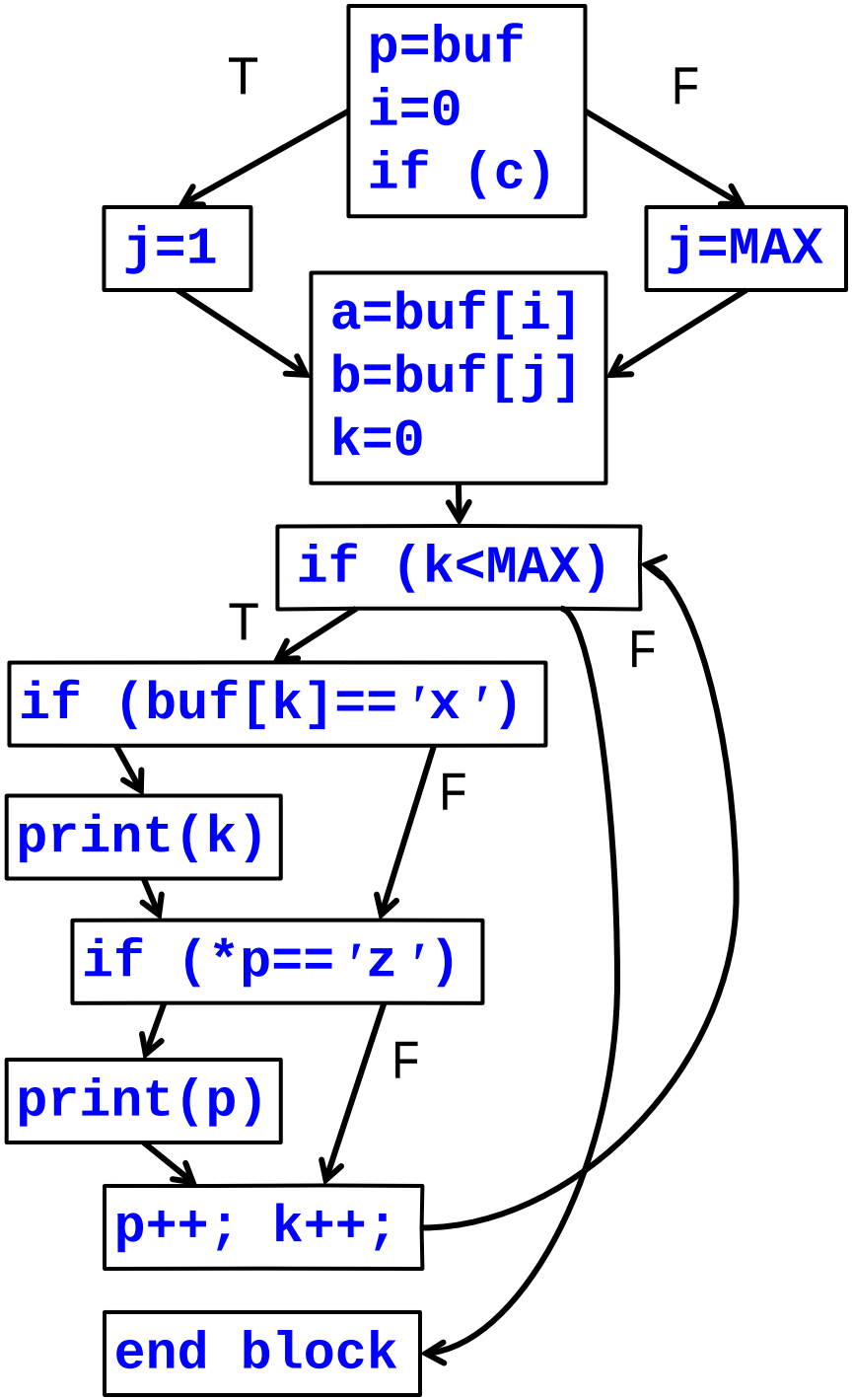
```
void foo() {
  char buf[MAX] = "example";
  int i, j, k;
  char a, b;
  char *p = buf;

  i = 0;
  if (c)
     j = i;
  else
     j = MAX;
  a = buf[i];
  b = buf[j];
  k = 0;
  while (k < MAX) {
     if (buf[k]== 'x')
        print(k);
     if (*p == 'z')
        print(p);
     p++;
     k++;
  }
}
```



```
void foo() {
   char buf[MAX] = "example";
   int i, j, k;
   char a, b;
   char *p = buf;

   i = 0;
   if (c)
      j = i;
   else
      j = MAX;
   a = buf[i];
   b = buf[j];
   k = 0;
   while (k < MAX) {
      if (buf[k]== 'x')
         print(k);
      if (*p == 'z')
         print(p);
      p++;
      k++;
   }
}
```



Data Flow Analysis

Goal: Is this code safe?

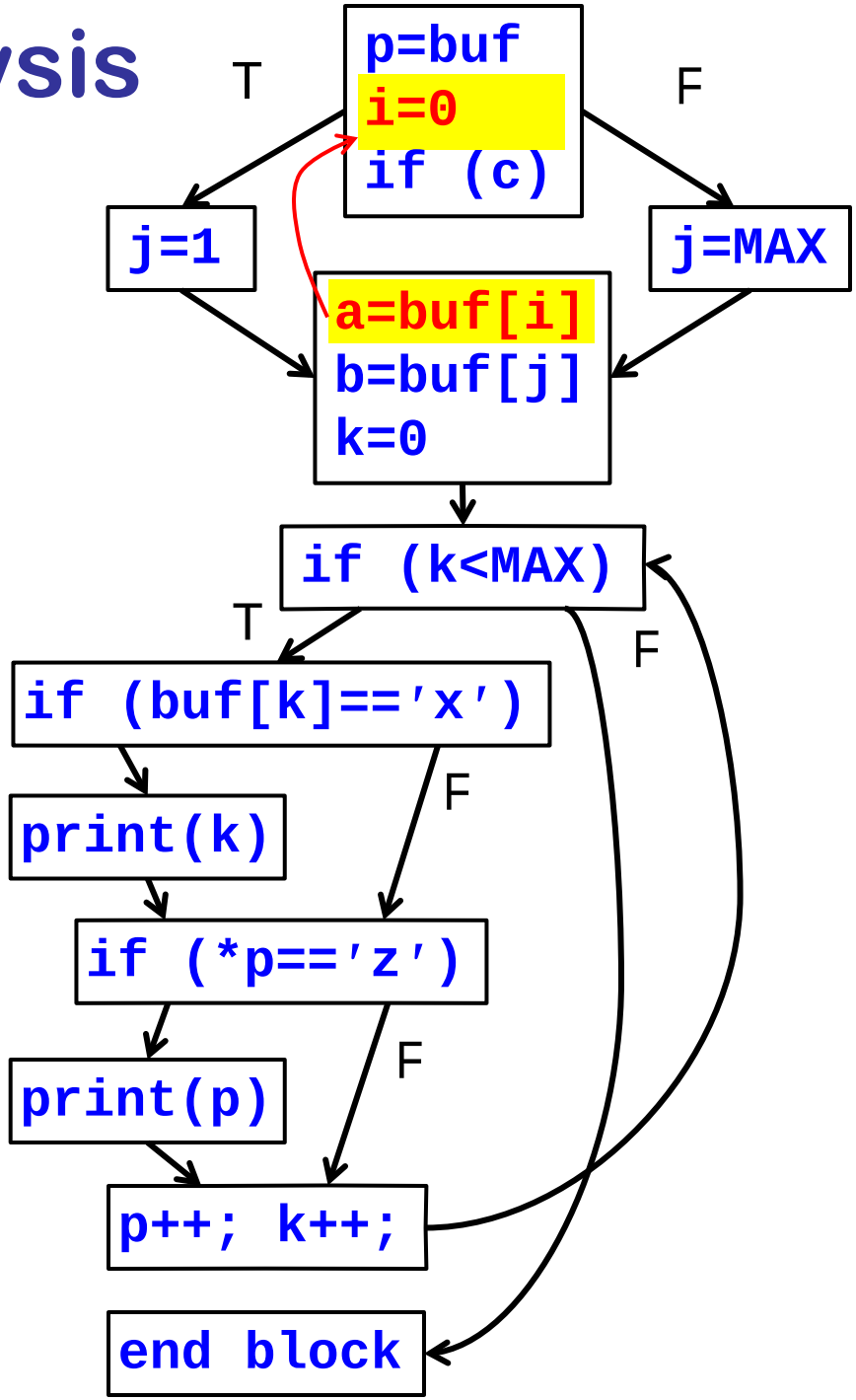
Subgoal:

Do we ever violate the borders of `buf`?

- Simple dependence
- Flow insensitive
- Loops
- Pointers
- Aliasing

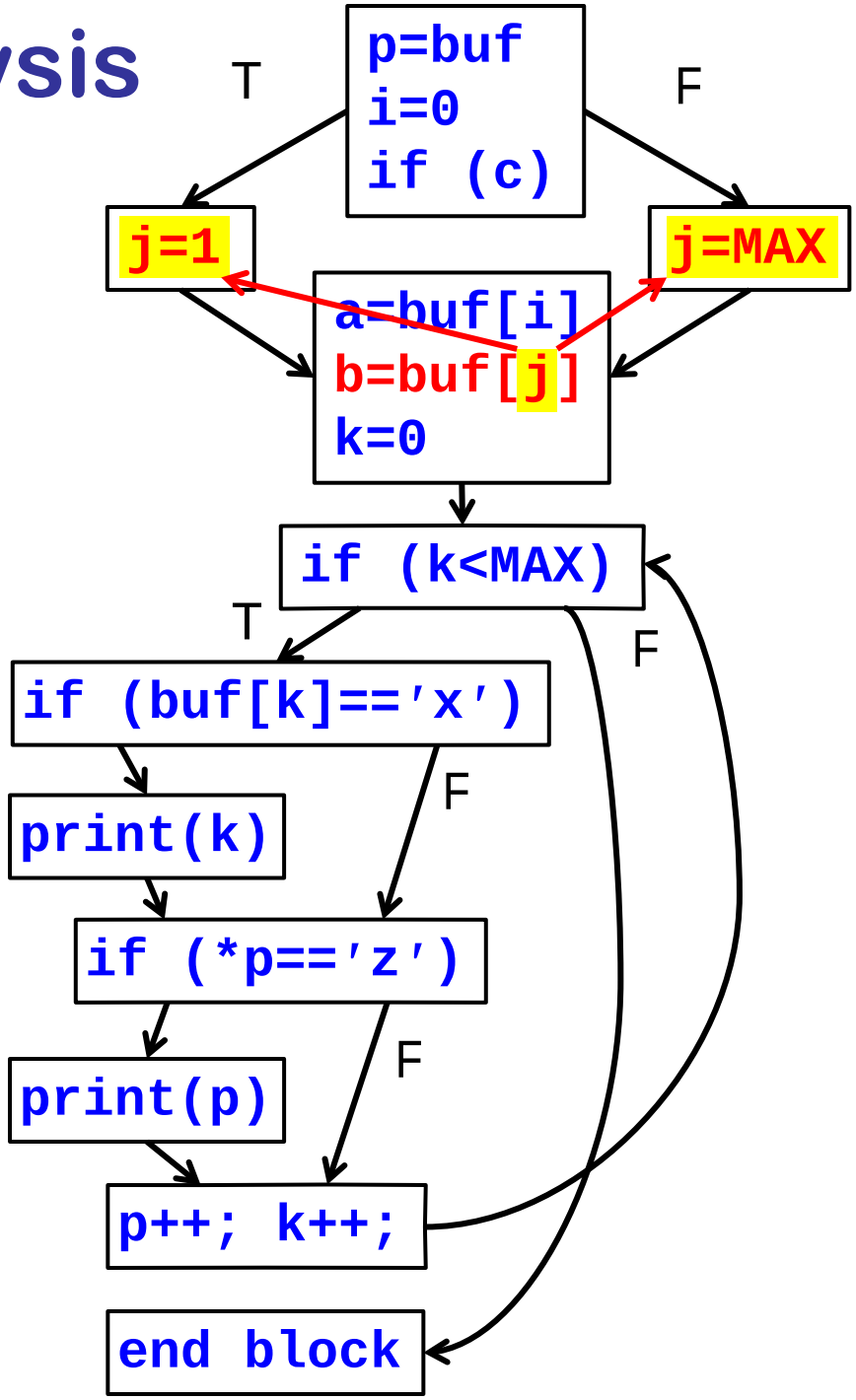
Data Flow Analysis

- **Simple dependence**



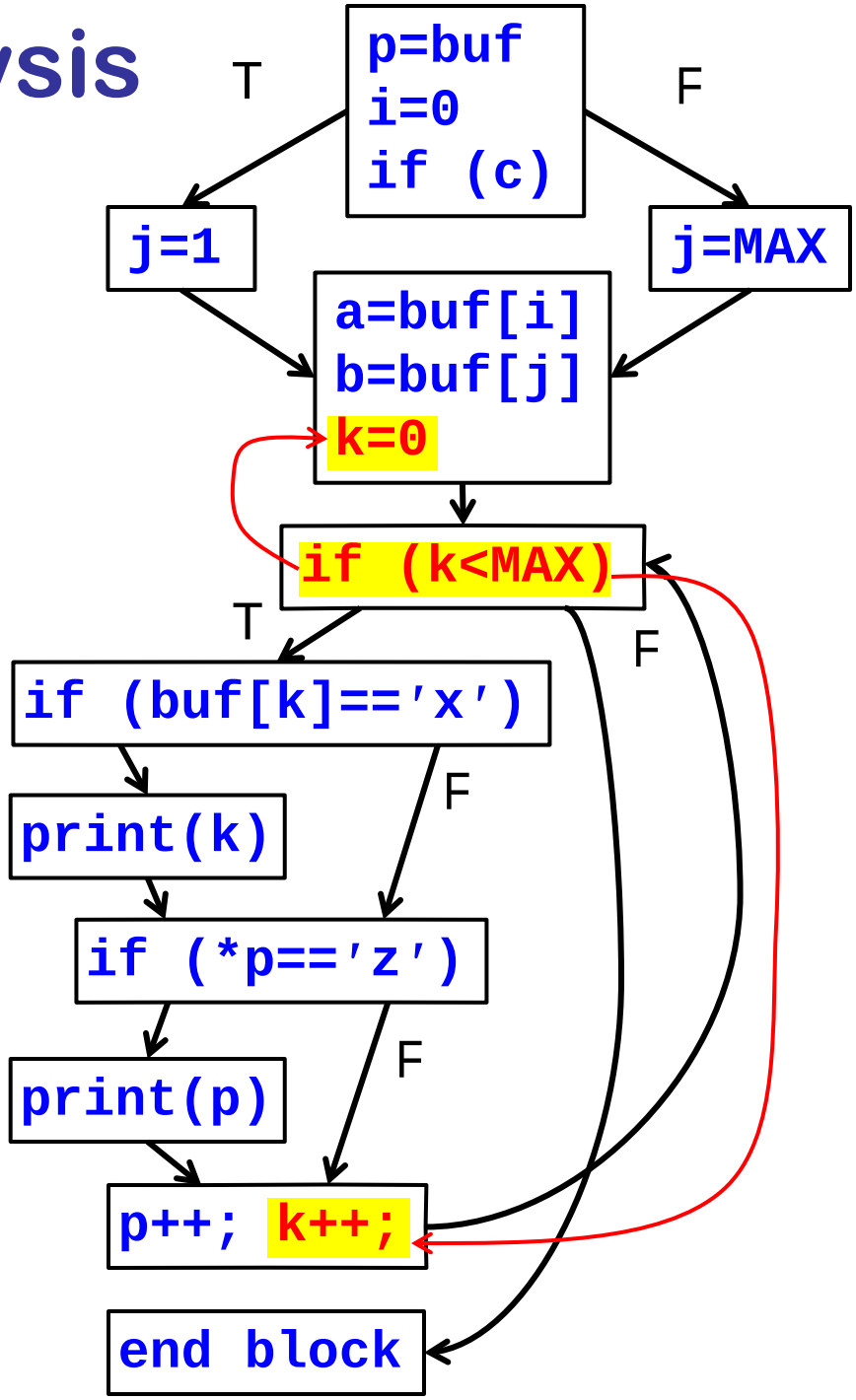
Data Flow Analysis

- Flow insensitive



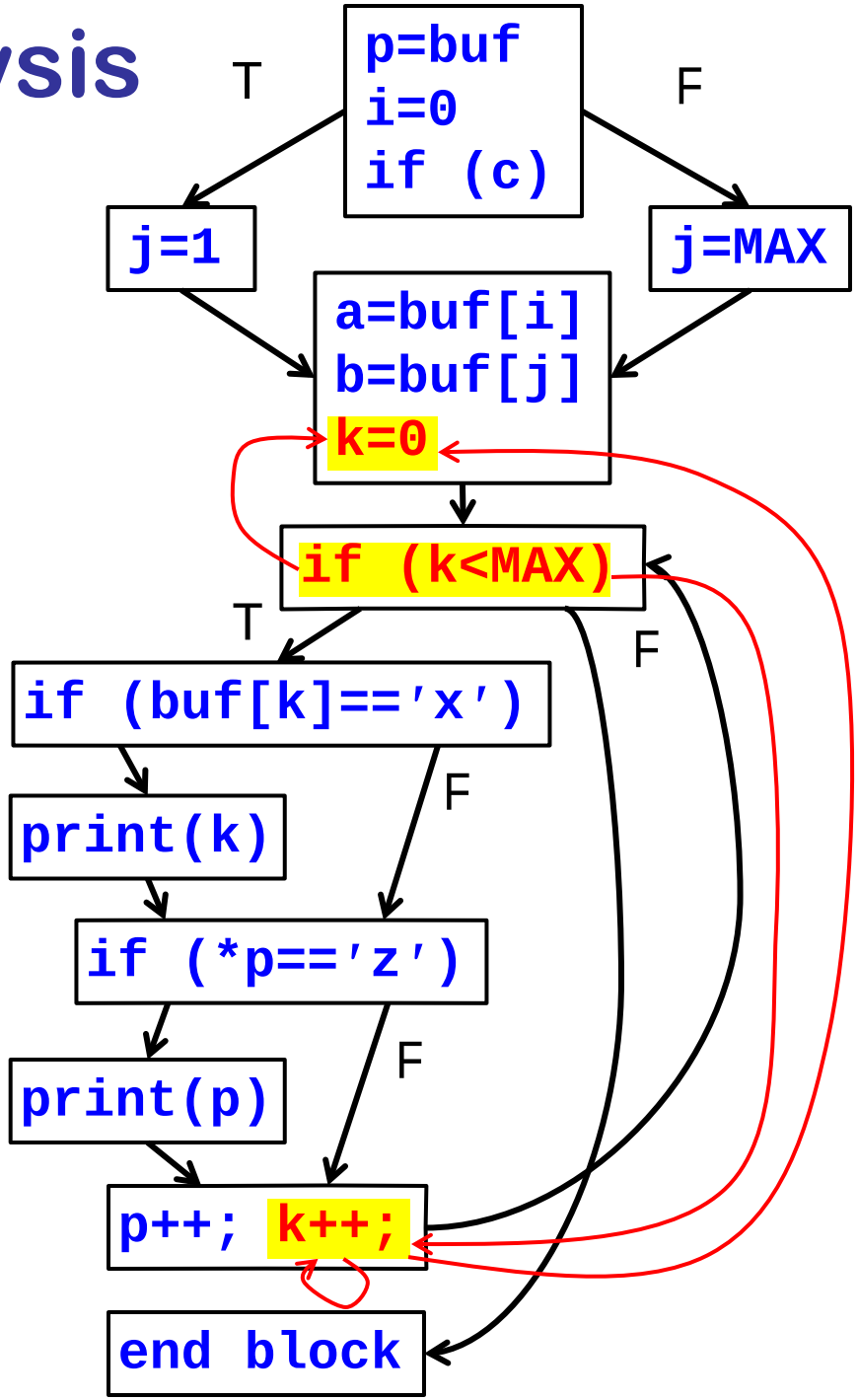
Data Flow Analysis

- Loops



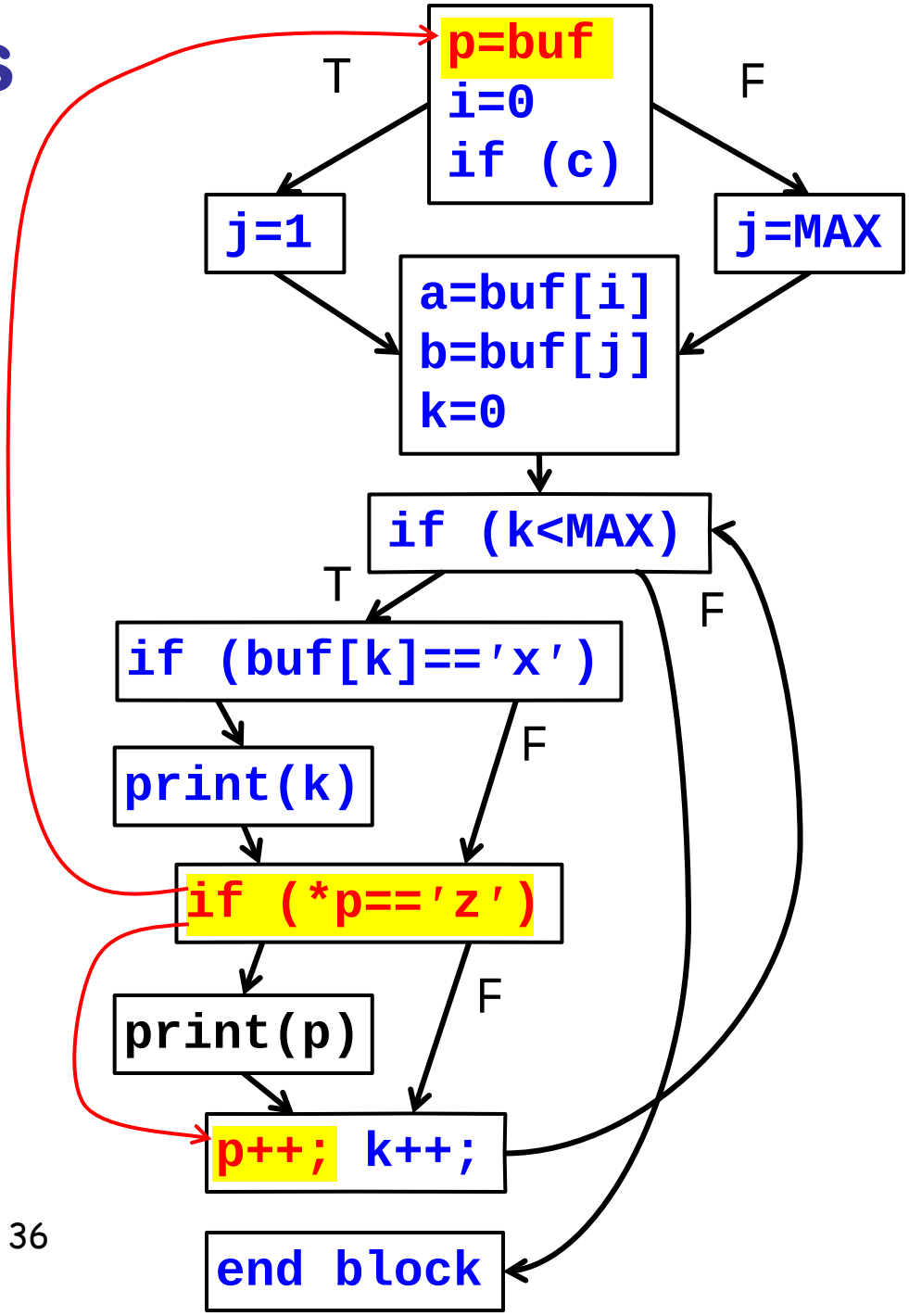
Data Flow Analysis

- Loops



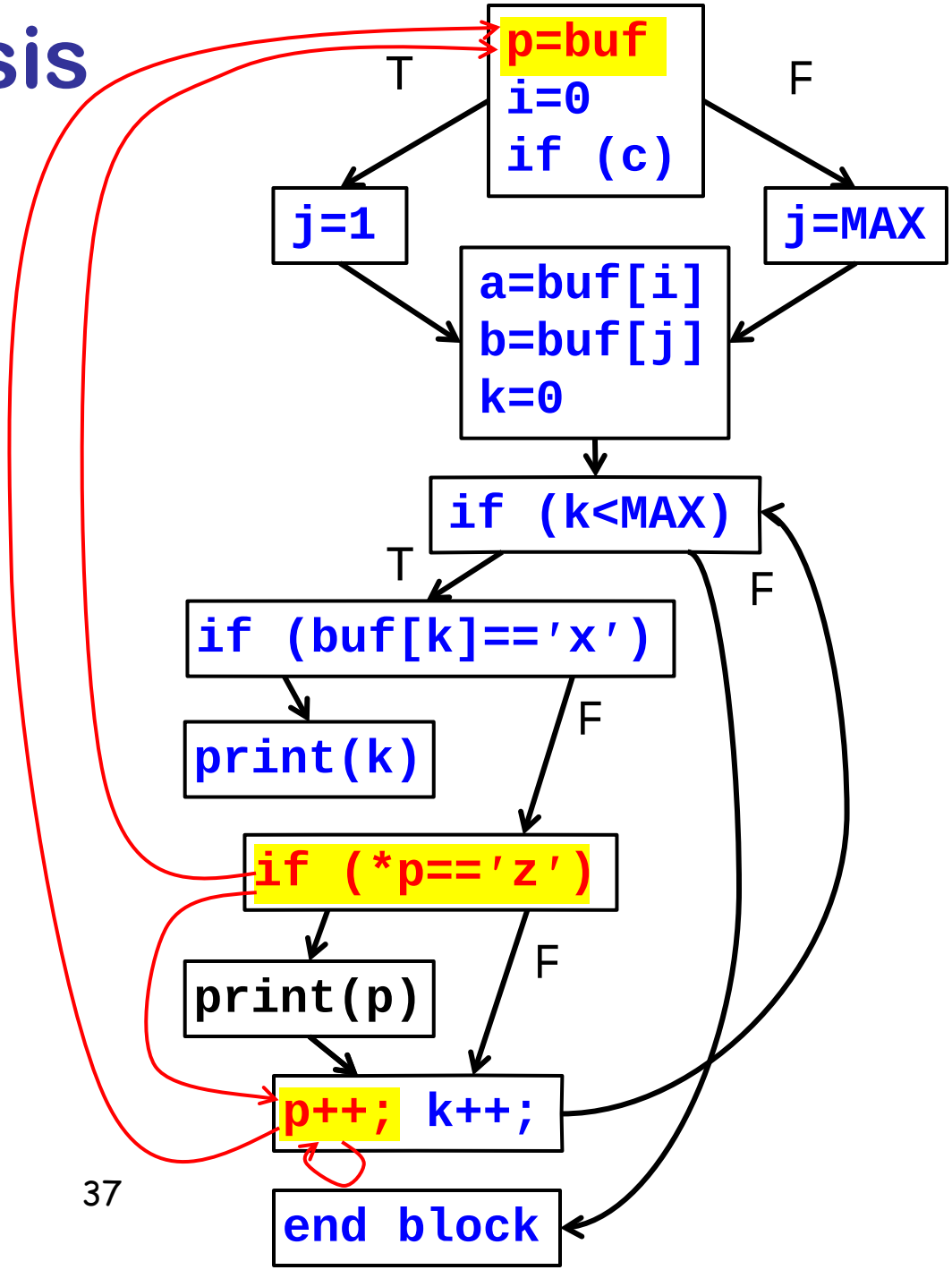
Data Flow Analysis

- **Pointers**



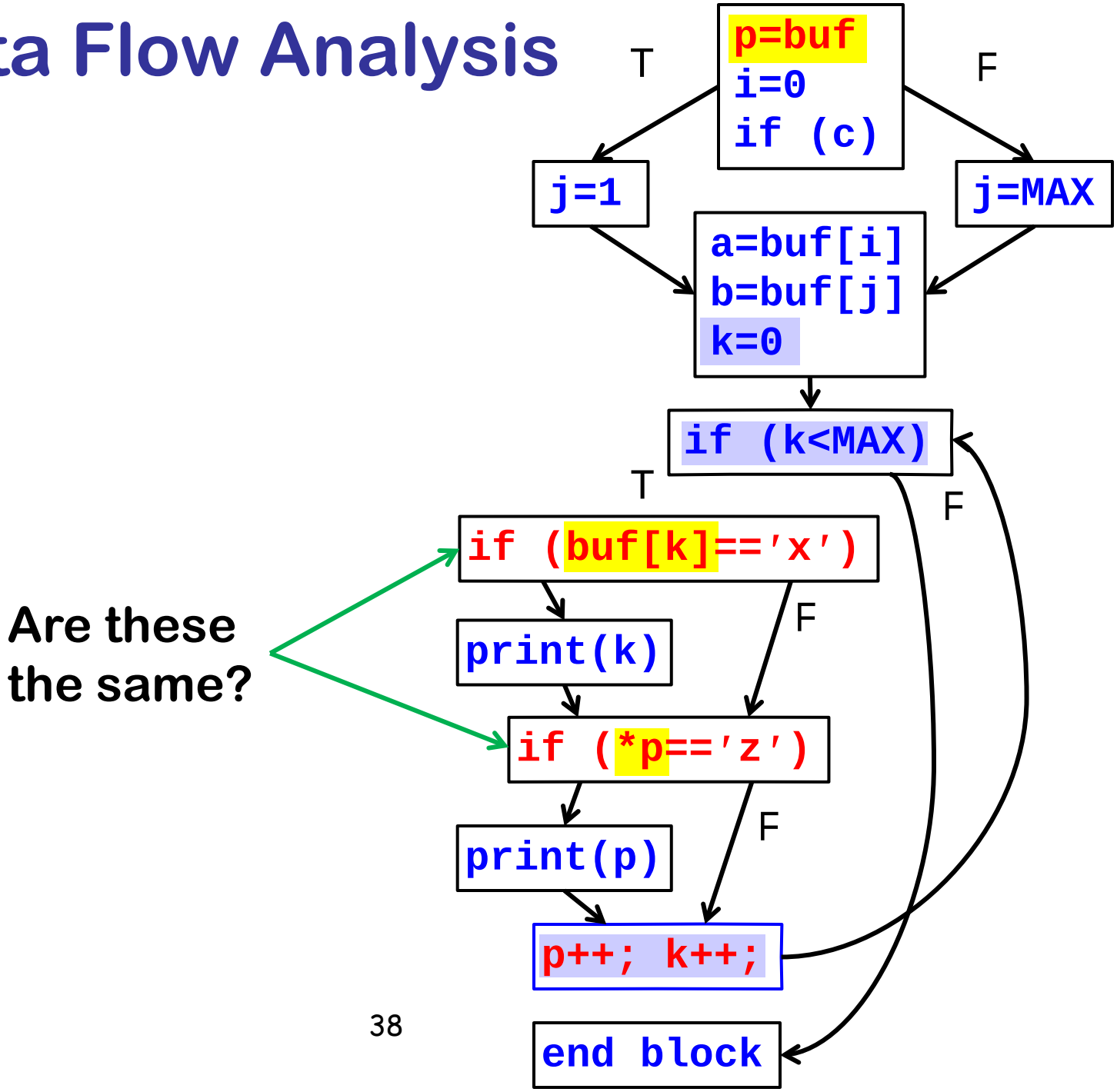
Data Flow Analysis

- **Pointers**



Data Flow Analysis

- Aliasing

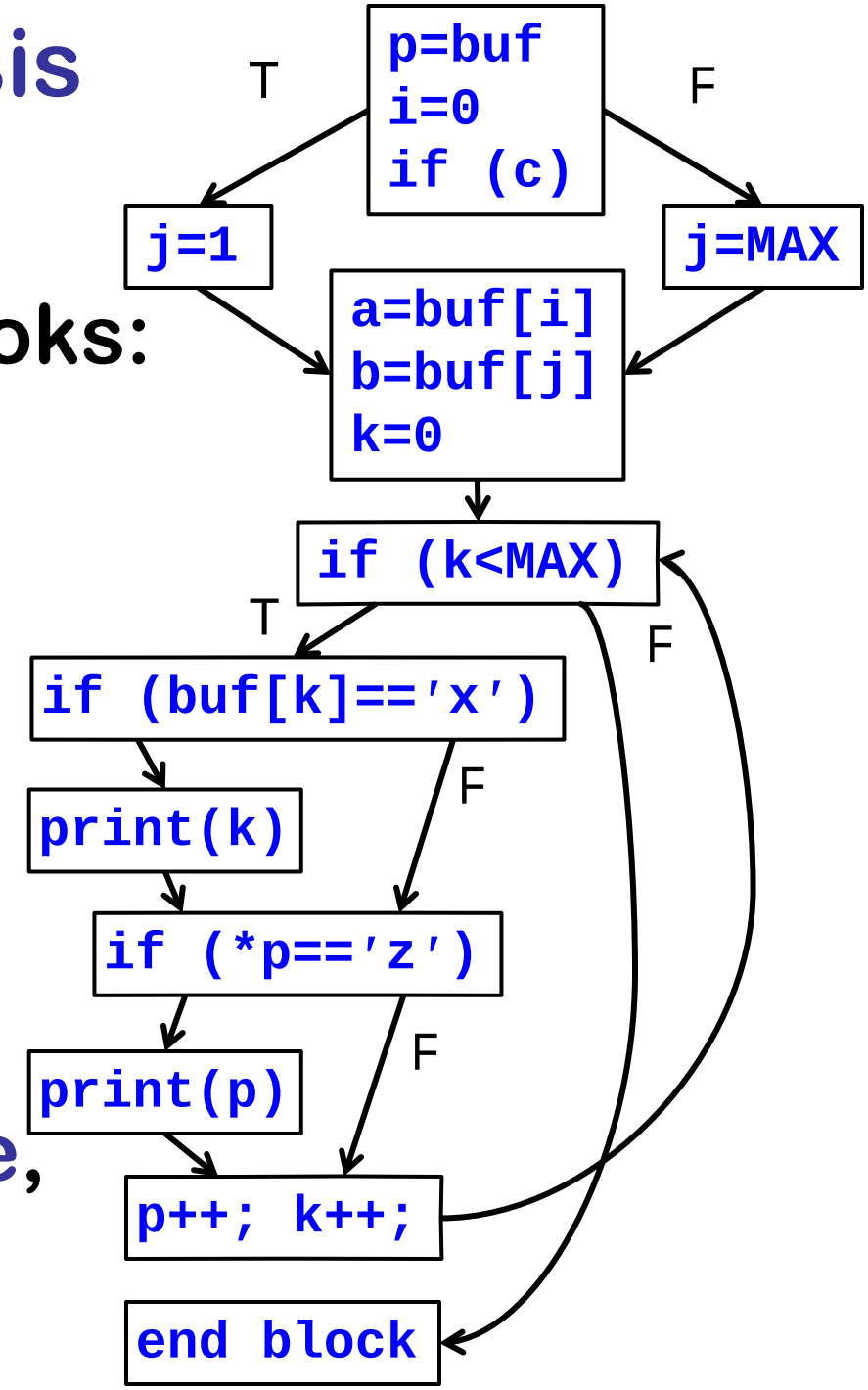


Semantic Analysis

But it's harder than it looks:

- Pointers to functions
- Virtual functions
- Interprocedural analysis
- Context sensitivity

These make program analysis slow, imprecise, or both.



Source Code Analysis Tools. What is expensive to find

It's difficult for a tool to explore all the paths.

- Loops handled considering a small fixed number of iterations.
- Most tools ignore concurrency.
- Many tools ignore recursive calls.
- Many tools struggle with calls made through function pointers.

Common Weakness Enumeration (CWE)

- "CWE provides a unified, measurable set of software weaknesses".
- "Allows a more effective use of software security tools".
- 719 weaknesses in 244 categories.
- Id, description, consequences, examples, relationship, taxonomy mapping.

http://cwe.mitre.org/

Common Weakness Scoring System (CWSS)

- It "provides a mechanism for prioritizing software weaknesses in a consistent, flexible, open manner".
- Based on three metric groups:
  - Base finding metric group.
  - Attack surface metric group.
  - Environmental metric group.

1. What You Need to Know about How Tools Work

2. The Tools And Their Use

Roadmap

- Motivation
- Source code examples
- Tools for C/C++ applied to the source code
- Tools for Java applied to the source code
- The SWAMP

What and Why

- Learn about different automated tools for vulnerability assessment.
- Start with small programs with weaknesses.
- Apply different tools to the programs.
- Understand the output, and strong and weak points of using specific tools.

CWE 78: OS Command Injection

```
1.  void CWE78_OS_Command_Injection__char_console_execl_41_bad(){
2.      char *data; char dataBuffer[100] = "";
3.      data = dataBuffer;
4.      /* Read input from the console */
5.      size_t dataLen = strlen(data);
6.      /* If there is room in data, read into it from the cons */
7.      if (100-dataLen > 1)  {
8.      /* POTENTIAL FLAW: Read data from the console */
9.        if (fgets(data+dataLen,(int)(100-dataLen),stdin)!= NULL)
10.       {
11.           /* Remove the carriage return from the string */
12.           dataLen = strlen(data);
13.           if (dataLen > 0 && data[dataLen-1] == '\n')
14.                data[dataLen-1] = '\0';
15.           else {
16.                printf("fgets() failed\n");
17.                data[dataLen] = '\0';
18.           }
19.           /* POTENTIAL FLAW: Execute command without
                 validating */
20.           system (data);
21.       }
22. }
```

How to Describe a Weakness

Descriptive name of weakness (CWE XX)

An intuitive summary of the weakness.

- Attack point: How does the attacker affect the program.
- Impact point: Where in the program does the bad thing actually happen.
- Mitigation: A version of the program that does not contain the weakness.

(CWEXX_Long_Detailed_File_Name_Containg_The_Code_yy.cpp)

OS Command Injection (CWE 78)

User supplied data is used to create a string that will be interpreted by a command shell.

- **Attack Point:** Input read from the console.
- **Impact Point:** Executing command with `system()`.
- **Mitigation:** Don't execute user provided input; instead use a fixed string.

CWE78_OS_Command_Injection__char_console_execl_41.c
(Highly modified to compensate for errors.)

Tools for C/C++

- Goanna (RedLizards)
- Coverity analyze

Goanna (RedLizards)

Goanna

goanna

- Commercial tool by Red Lizard Software available at redlizards.com
- The Goanna suite of static analysis tools pinpoints defects and vulnerabilities in C/C++ programs.
  - Access violations
  - Memory leaks
  - Array and string overruns
  - Division by zero
  - Unspecified, non-portable, and/or dangerous constructs
  - Security vulnerabilities

Goanna

1. Download Goanna Central
2. Activate the license and install the software

   ```
   ./install-goanna
   ```

3. Include in **PATH** the location of **goanna/bin**.
4. Initialize goanna for the project

   ```
   goanna-init
   ```

3. Enable the security package:

   ```
   goanna-package --enable-pkg security
   ```

4. Goanna Dashboard is the web interface to navigate and interact with analysis results.

   ```
   $goreporter start-server &
   ```

Goanna

Three-step process:

- Run a full build of your program using the Goanna build integration utility to capture settings of the build.

```
$goanna-trace make
```

- Use this information from full build to run analysis.

```
$goanna-analyze
```

- Produce an analysis report

```
$goanna-report
```

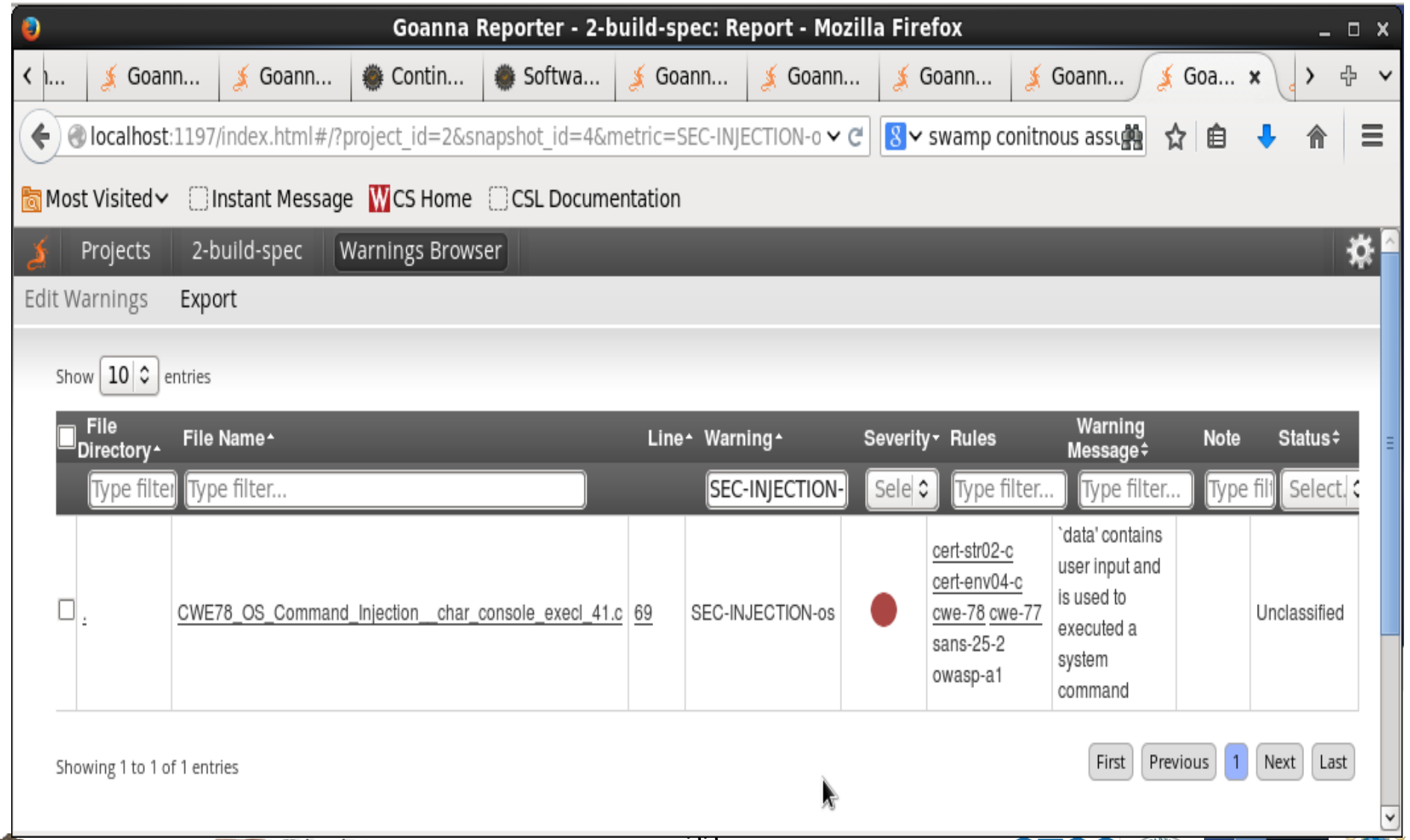
- Read and interact with the analysis results.
  - After goreporter is running, load the provided URL in a web browser.

Goanna. OS Command Injection

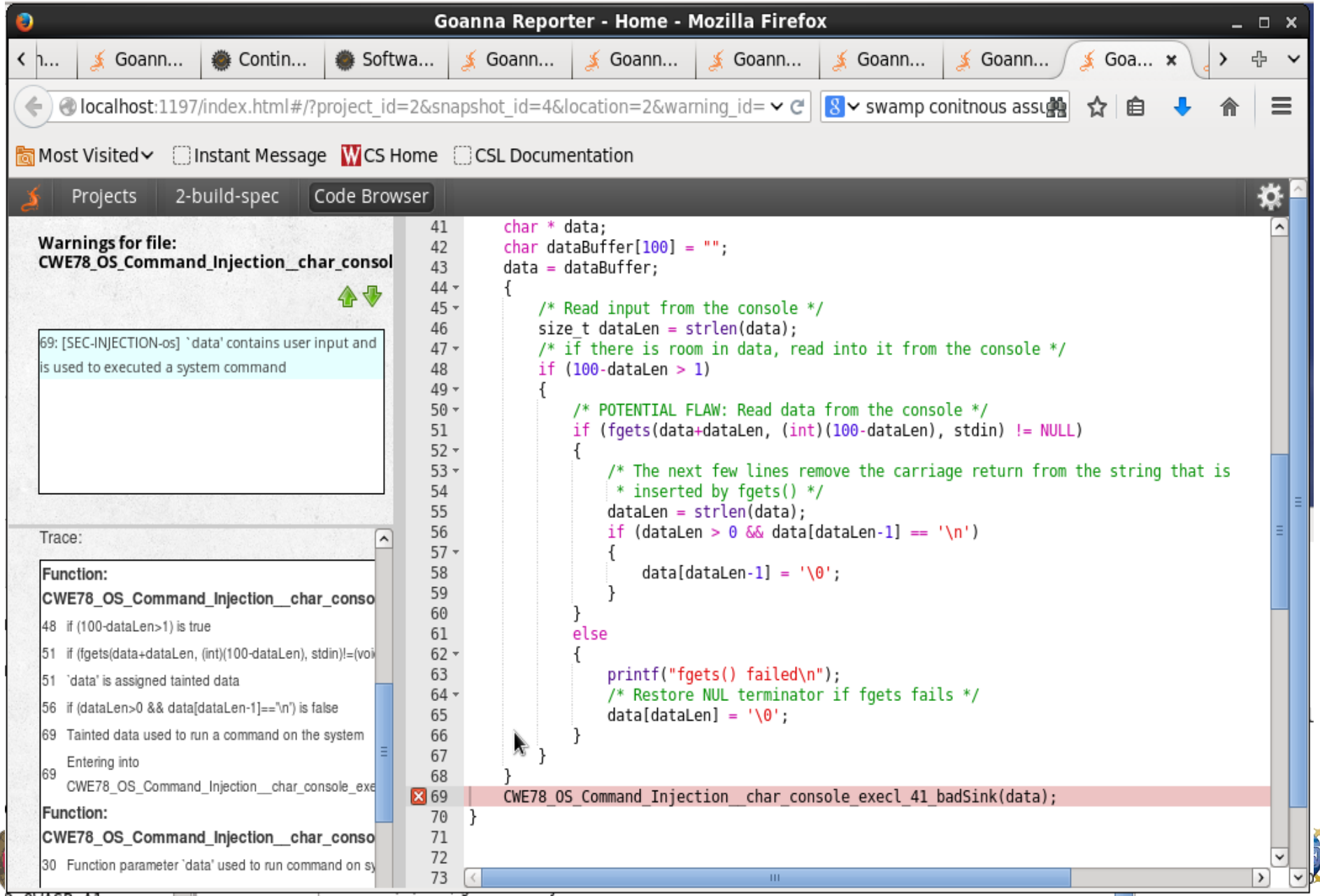
```
$ goanna-trace make
$ goanna-analyze
$ goanna-report
```

- 0 false positive.
- 0 false negative.
- 1 true positive: It detects the command injection.

Goanna. OS Command Injection



Goanna. OS Command Injection



Coverity Analyze

Coverity

- Commercial tool. Available at http://www.coverity.com/
- Starting Point: Accurate Compilation.
- Depth and Accuracy of Analysis
  - Interprocedural Dataflow Analysis.
  - False Path Pruning.
  - Design Pattern Intelligence.
  - Enterprise Framework Analyzer.
  - White Box Fuzzer.
- Scalable.

Coverity

1. **Download the license and the software:** `https://coverity.secure.force.com/apex/LicenseManagement2`
2. **Run the installation script:** `cov-analysis-linux64-7.6.0.sh`
3. **Include in PATH the location of** `~elisa/cov-analysis-linux64-7.6.0/bin`
4. **Command line and graphic interface.**

Coverity

Steps:

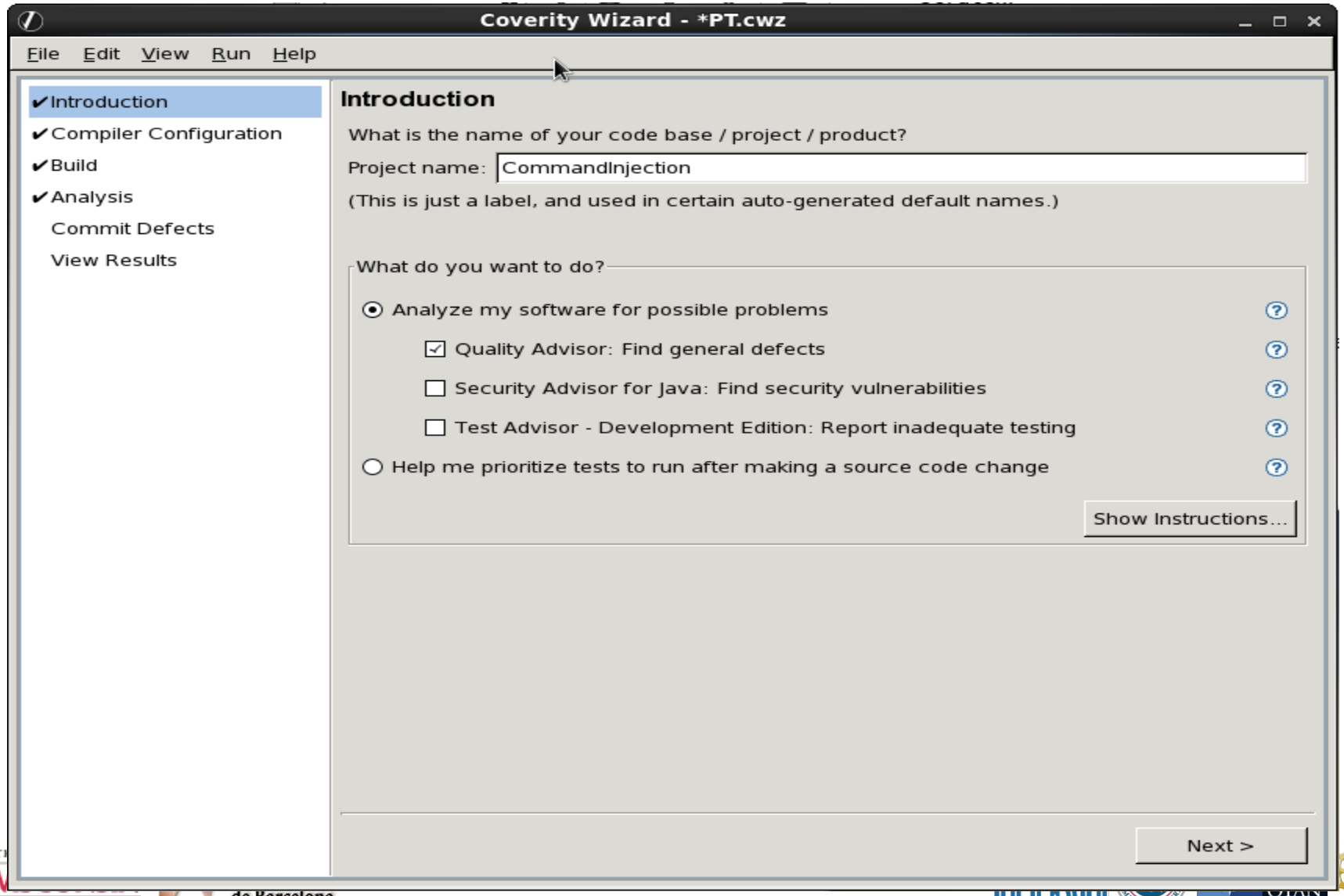
- Generate a configuration for the compiler:
  `cov-configure --gcc`
- Build the intermediate representation of the source code:
  `cov-build --dir <intermediate-dir> make`
- `cov-analyze --dir <intermediate-dir>`
- Check the checkers included by `cov-analize`:
  `cov-analyze --list-checkers`
- Read and interact with the analysis results.
- Graphic mode: `cov-wizard`

Coverity. OS Command Injection

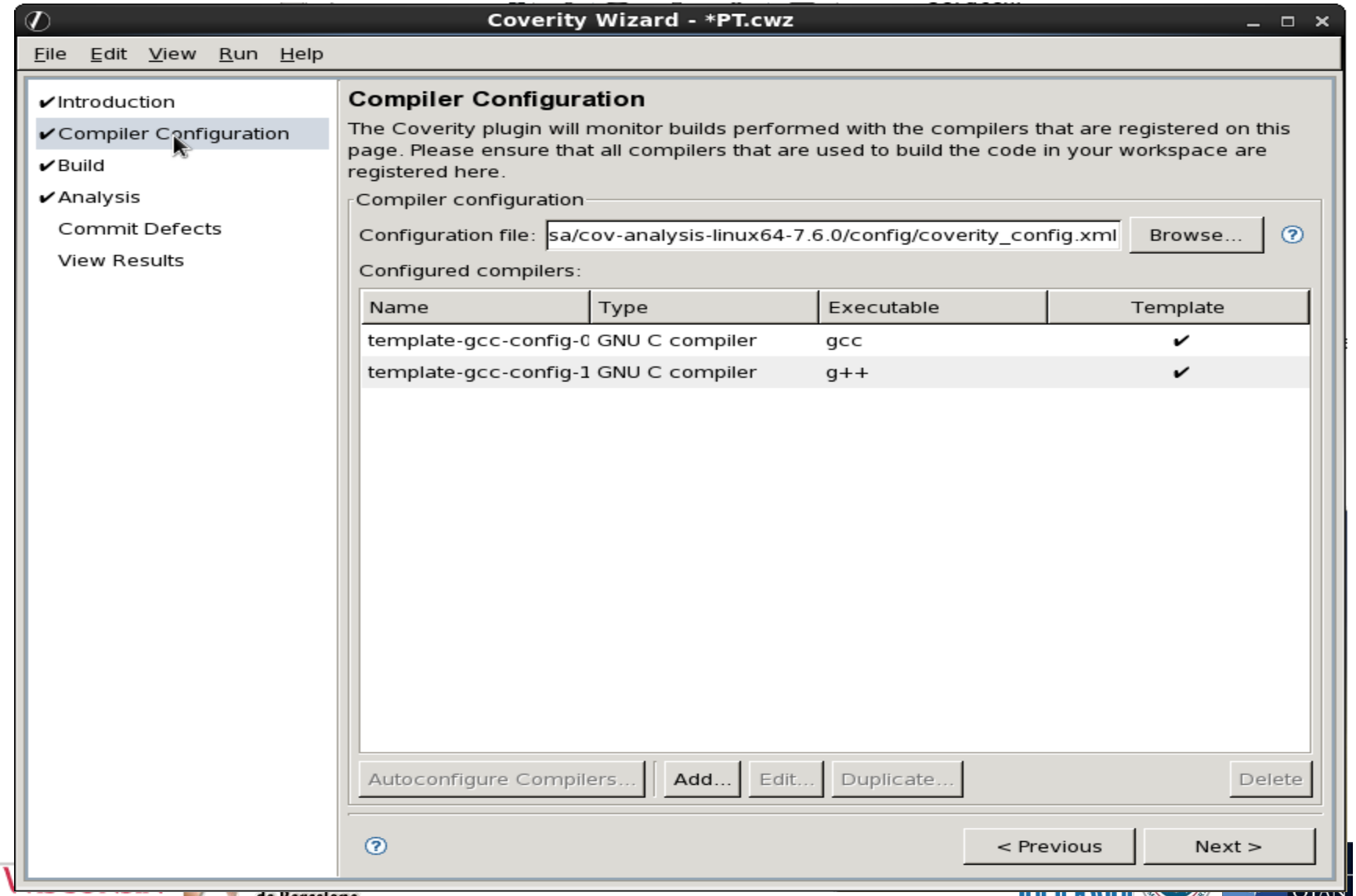
```
$ cov-build --dir cov-comm-injection make
$ cov-analyze --dir cov-comm-injection
              --security
```

- 1 defect found.
- 1 true positive: It detects the command injection.

Coverity. OS Command Injection



Coverity. OS Command Injection



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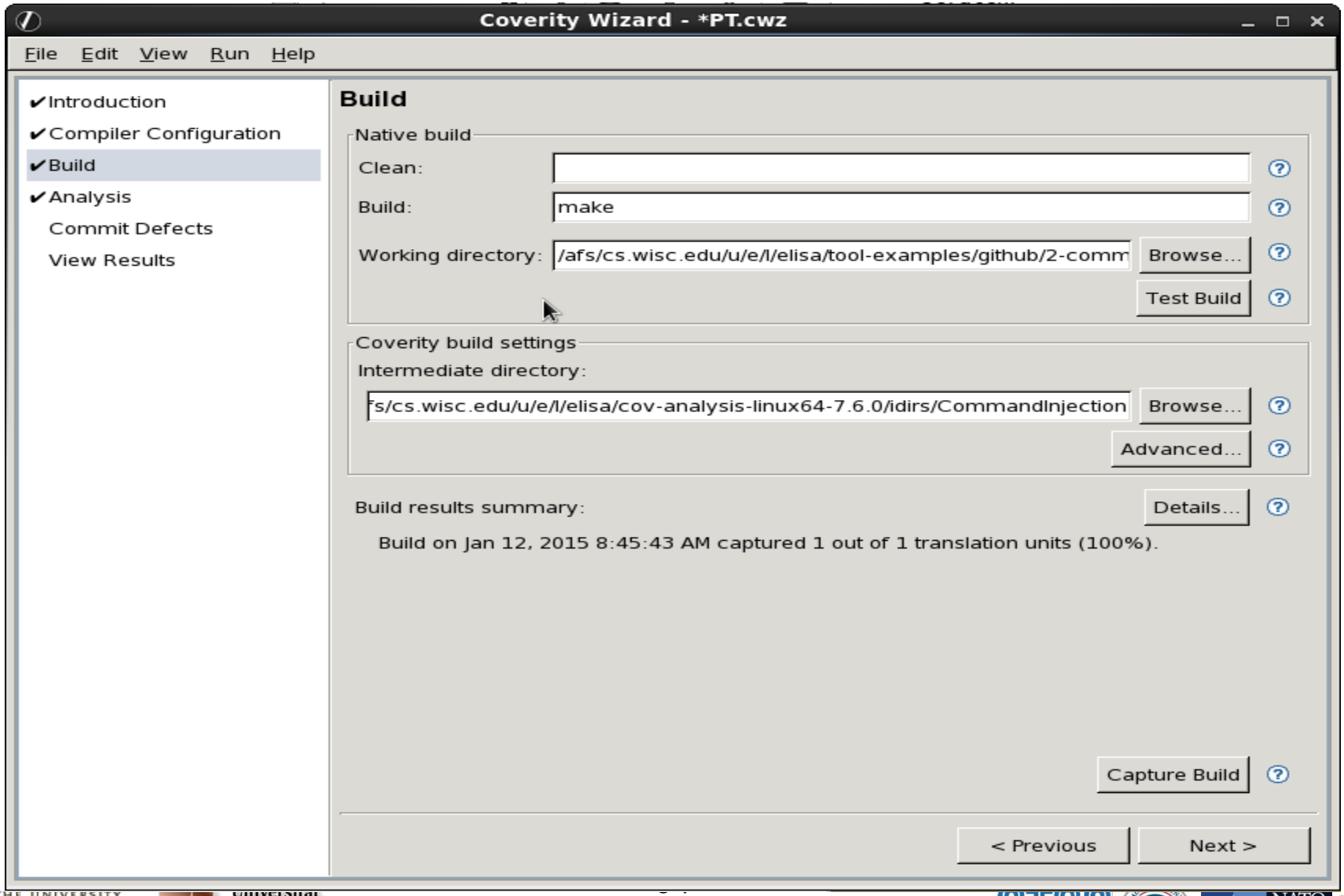

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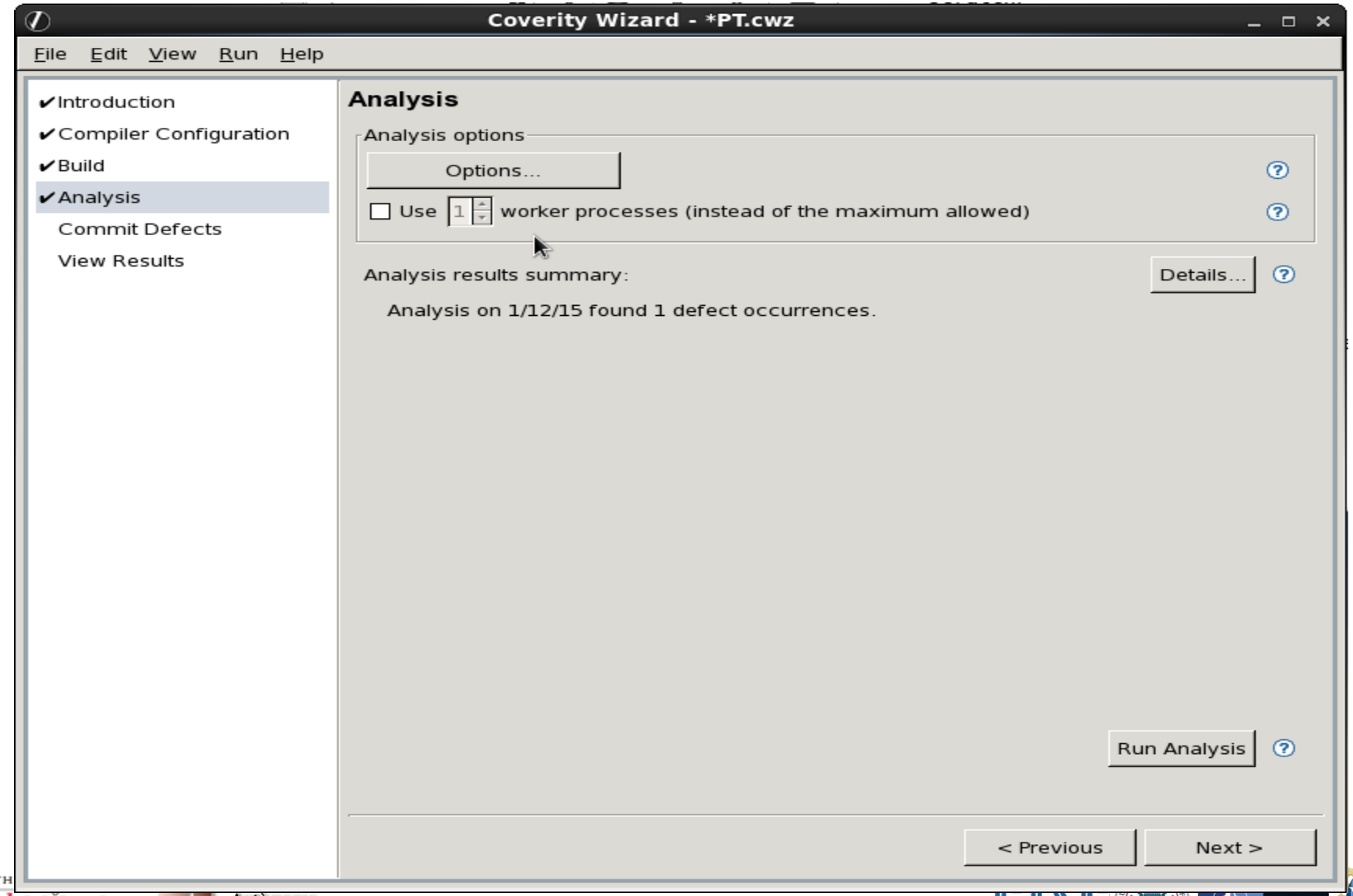

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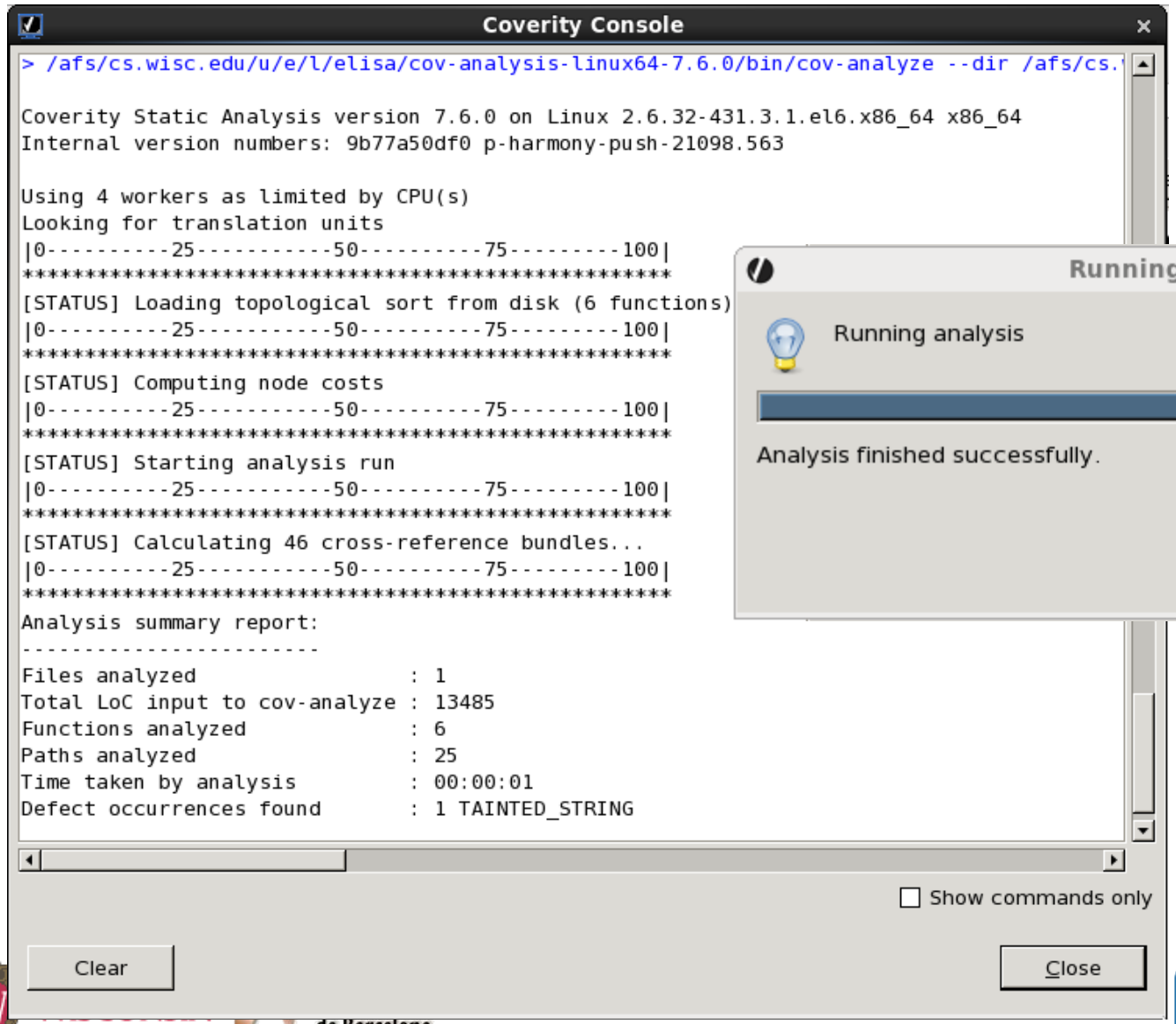

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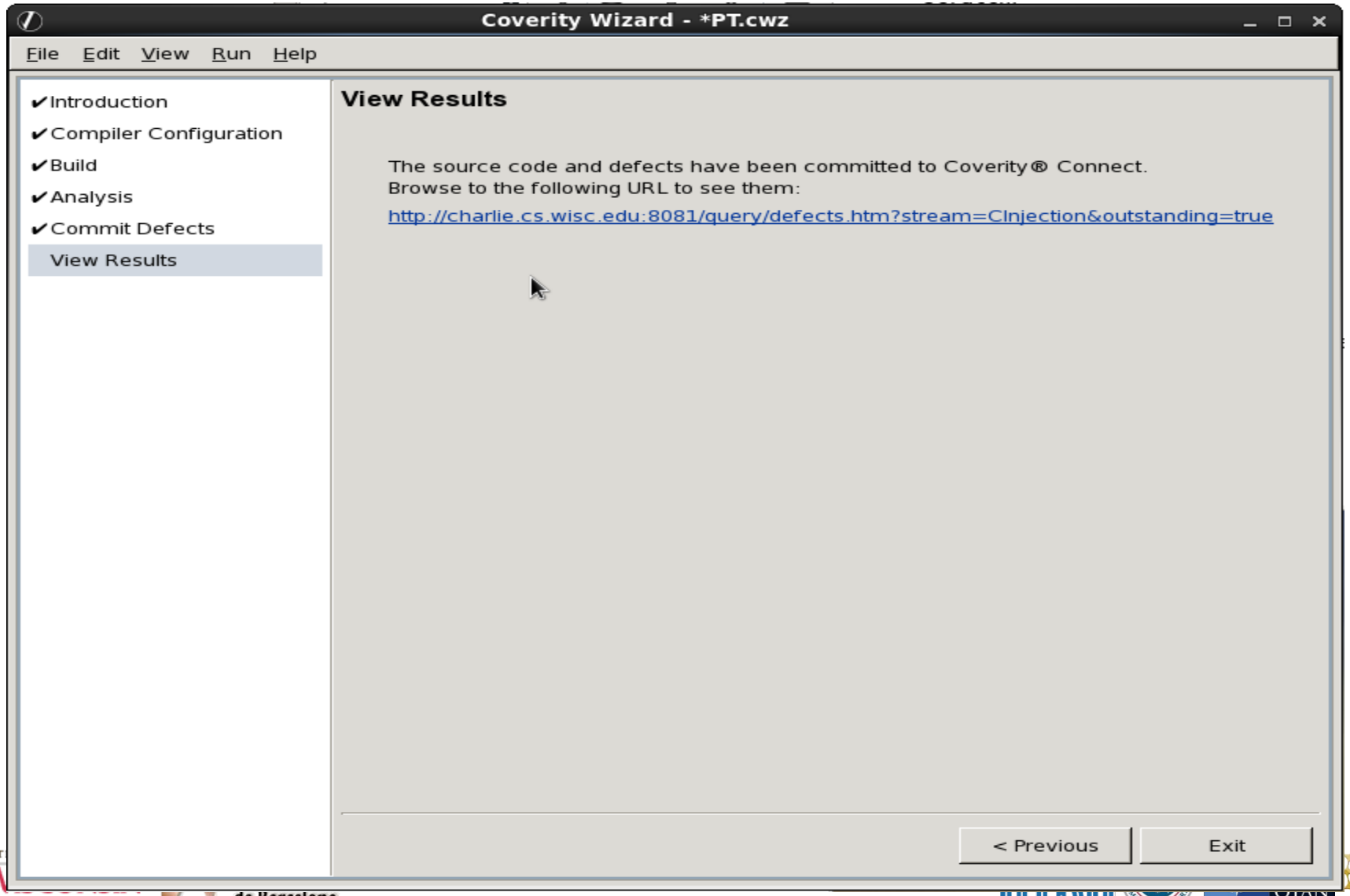

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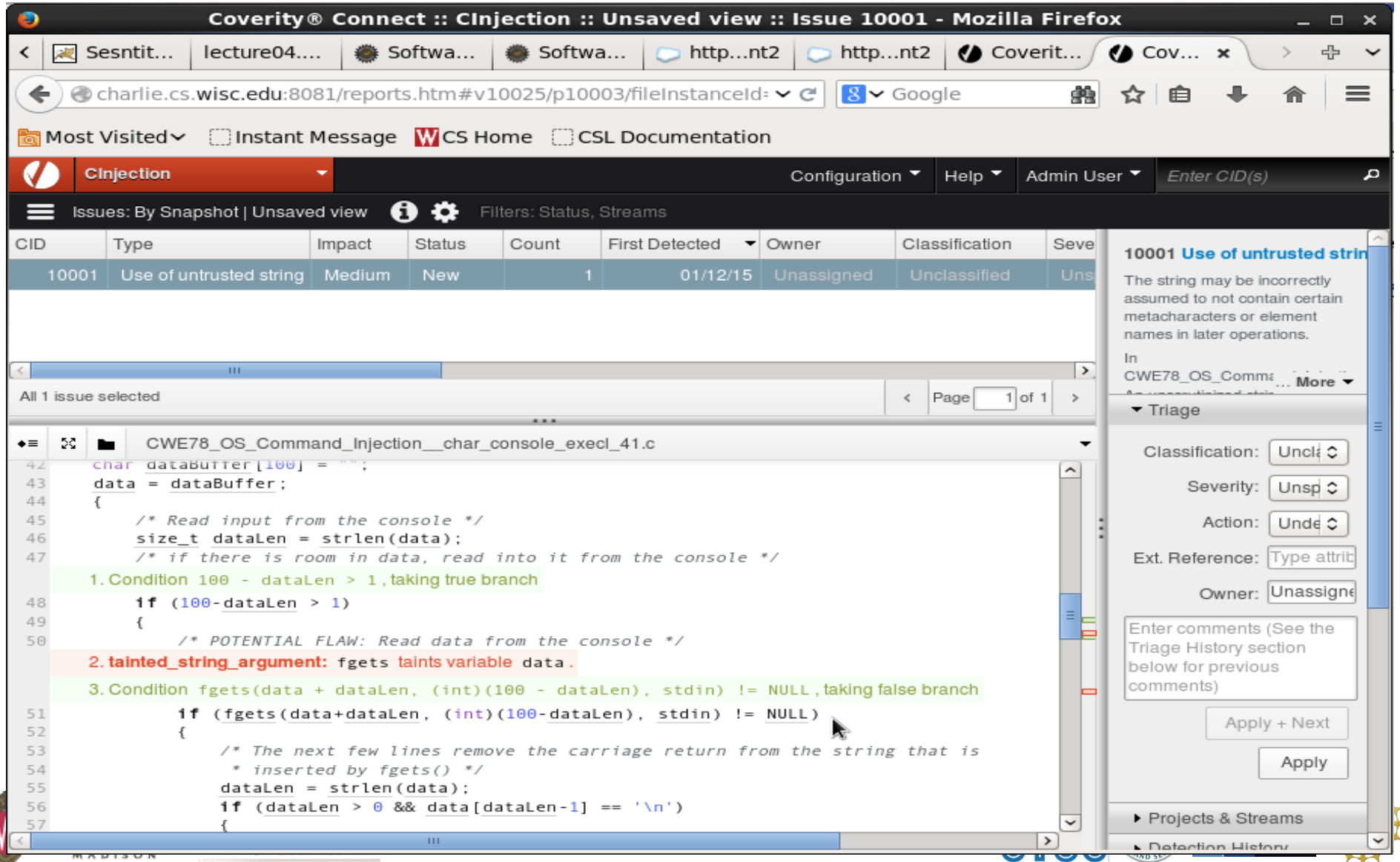

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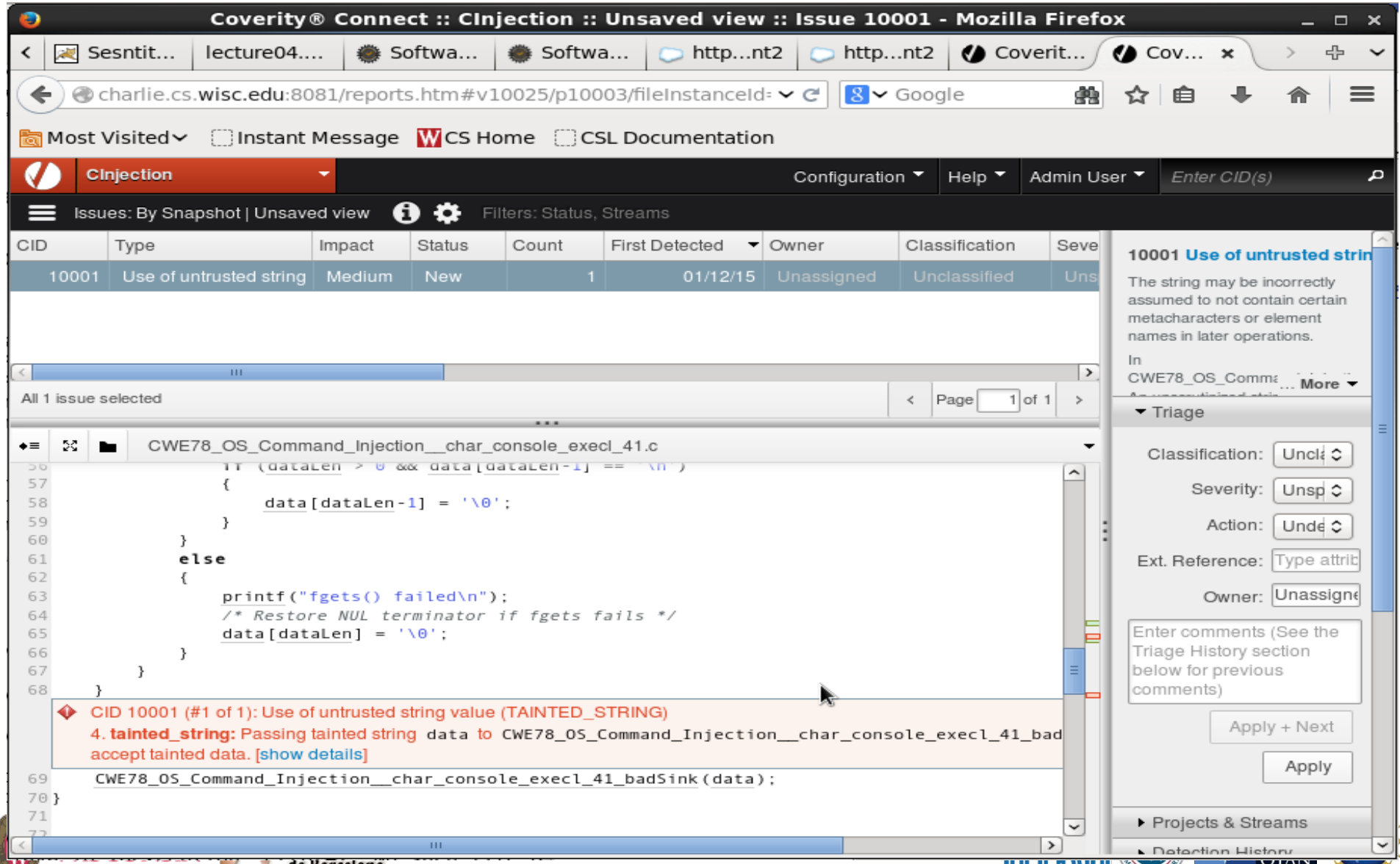



```
57                {
58                    data[dataLen-1] = '\0';
59                }
60            }
61            else
62            {
63                printf("fgets() failed\n");
64                /* Restore NUL terminator if fgets fails */
65                data[dataLen] = '\0';
66            }
67        }
68    }
69    CWE78_OS_Command_Injection__char_console_execl_41_badSink(data);
70}
```

Java

CWE 601: Open Redirect

```
   public void doGet(HttpServletRequest request,
1.                           HttpServletResponse response)
2.                          throws ServletException, IOException {
3.     response.setContentType("text/html");
4.     PrintWriter returnHTML = response.getWriter();
5.     returnHTML.println("<html><head><title>");
6.     returnHTML.println("Open Redirect");
7.     returnHTML.println("</title></head><body>");
8.
9.     String data;
10.    data = ""; // initialize data in case there are no cookies.
11.    // Read data from cookies.
12.    Cookie cookieSources[] = request.getCookies();
13.    if (cookieSources != null)
14.    // POTENTIAL FLAW: Read data from the first cookie value.
15.          data = cookieSources[0].getValue();
16.    if (data != null) {
17.          URI uri;
18.          uri = new URI(data);
19.          // POTENTIAL FLAW: redirect is sent verbatim.
20.          response.sendRedirect(data);
21.          return;
22.     }
23.
```

Open Redirect (CWE 601)

Web app redirects user to malicious site chosen by an attacker.

- Attack Point: Reading data from the first cookie using `getCookies()`.
- Impact Point: `SendRedirect()` uses user supplied data.
- GoodSource: Use a hard-coded string.

CWE601_Open_Redirect__Servlet_getCookies_Servlet_01.java

It's a Servlet

Tools for Java

- FindBugs
- Parasoft Jtest

FindBugs

FindBugs

- Open source tool available at findbugs.sourceforge.net/downloads.html
- Uses static analysis to look for bugs in Java code.
- Need to be used with the FindSecurityBugs plugin.
- Installation: Easy and fast.

FindBugs

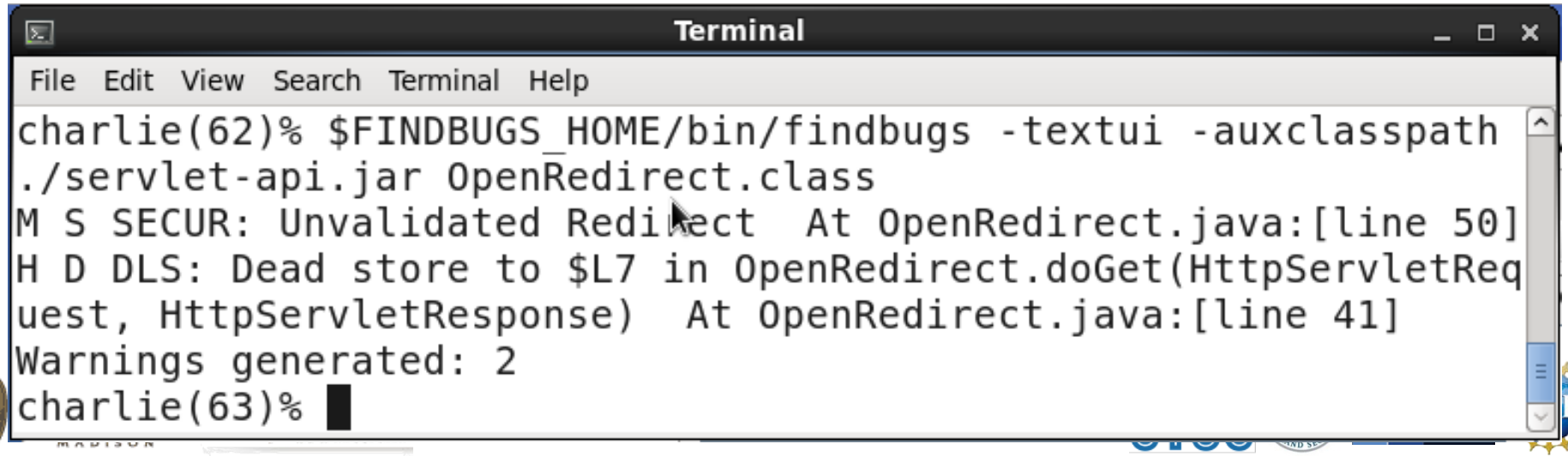
1. Define FINDBUGS_HOME in the environment.
2. Install the Find Security Bugs plugin.
3. Learn the command line instructions and also use the graphical interface.
4. Command line interface:

```
$FINDBUGS_HOME/bin/findbugs -textui
-javahome $JAVA_HOME
RelativePathTRaversal.java
```

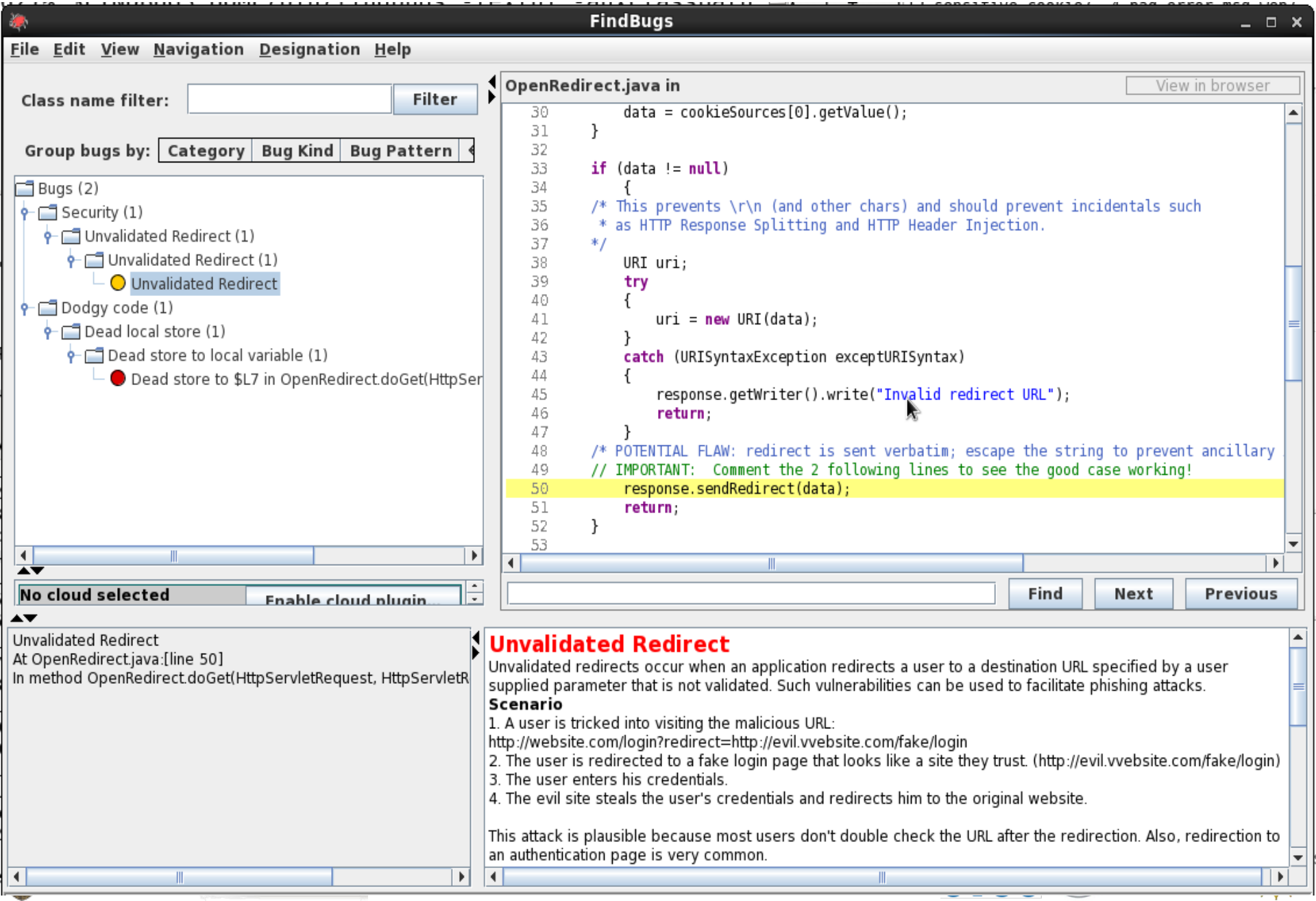
5. Graphic Interface: `java -jar $FINDBUGS_HOME/lib/findbugs.jar -gui`

FindBugs. Open Redirect

- **FindBugs**
  - `$FINDBUGS_HOME/bin/findbugs -textui -auxclasspath ./servlet-api.jar OpenRedirect.class`
    - **1 irrelevant warning.**
    - **1 true positive: It detects the Open Redirect vulnerability.**



FindBugs. Open Redirect



Parasoft Jtest

Jtest

PARASOFT

- Commercial tool available at http://www.parasoft.com/product/jtest/
- Automates a broad range of practices proven to improve development team productivity and software quality.
- Standalone Linux 9.5 version used.
  - gui mode and command line mode.
- Installation process: Slow download & easy installation.

Jtest

1. Include `/u/e/l/elisa/Jtest/9.5` in `path`.
2. Include the license.
3. Learn the command line instructions and also use the graphical interface.

Jtest

1. Command line interface: `$jtestcli <options>`
2. Graphic Interface: `jtest&`
3. Create a project and copy the `.java` files to the `project/src` directory.
4. Different tests available. We chose `Security->CWE Top 25`.

Jtest. Open Redirect

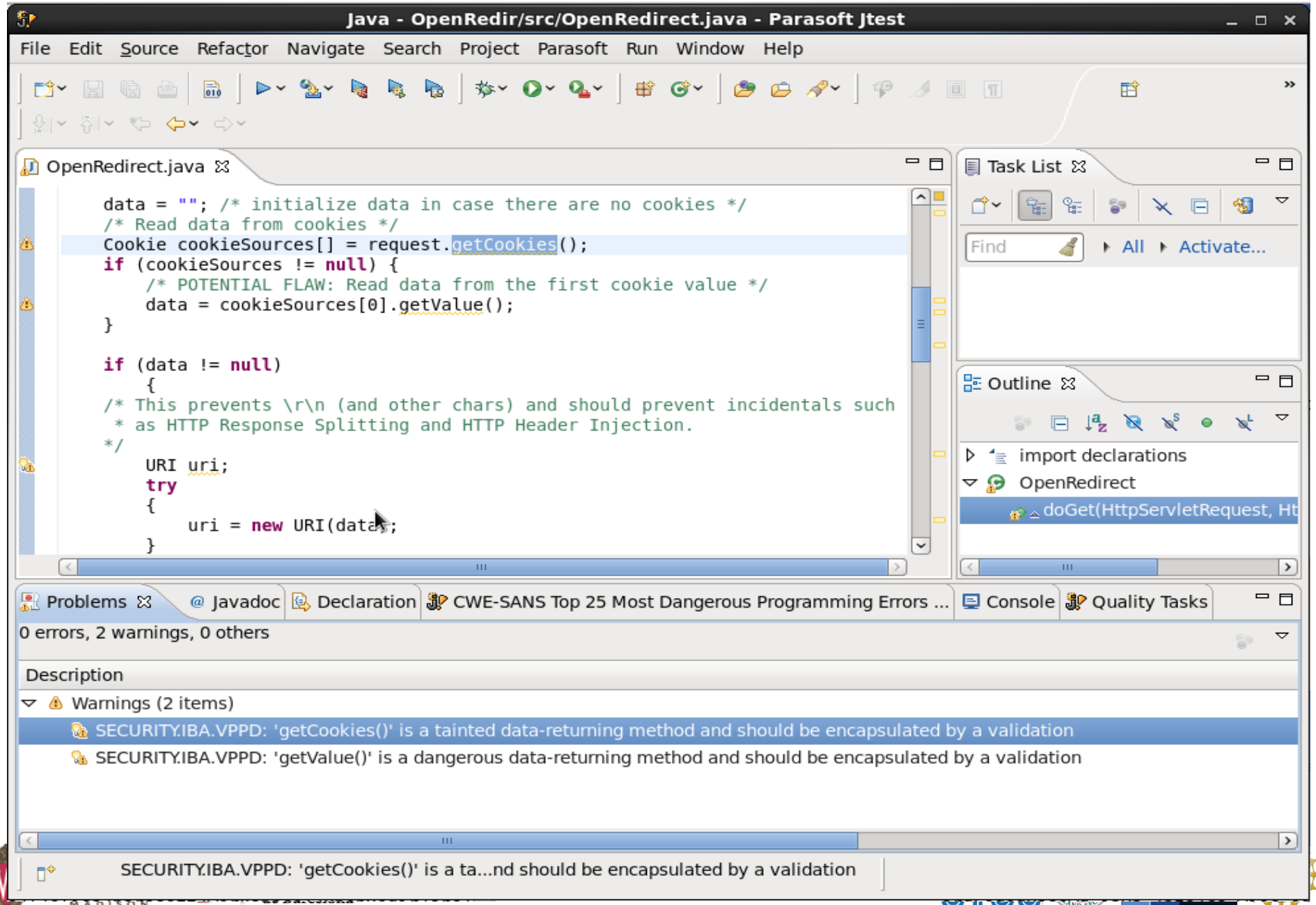
Create the OpenRedir project.

Include servlet-api.jar in the OpenRedir project.

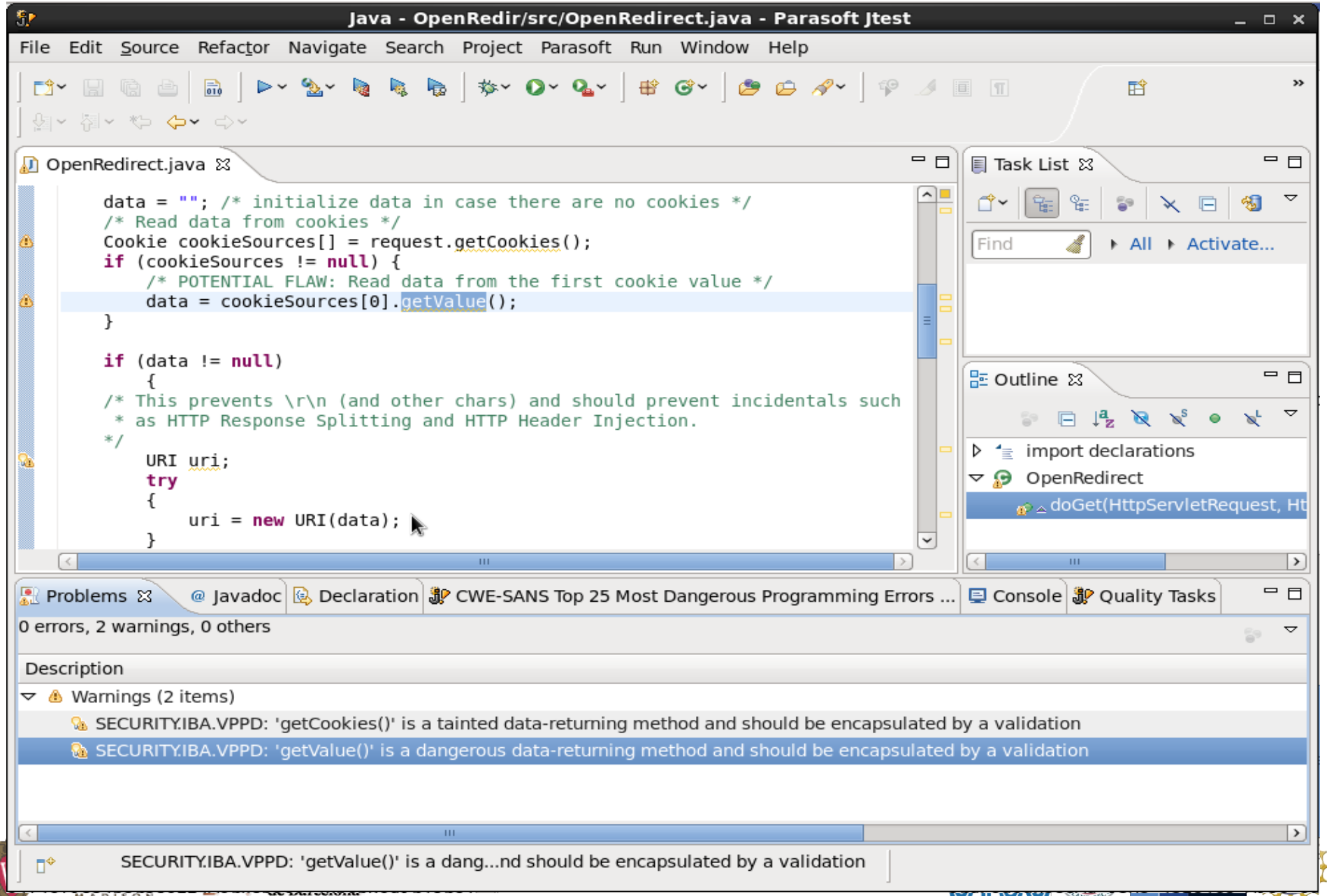
```
cp OpenRedirect.java
~elisa/parasoft/workspace1/OpenRedir/src
```

- **4 issues detected:**
  - `getCookies()` **returns tainted data.**
  - `cookieSources[0].getValue()` **should be validated.**
  - **2 Open Redirect detected.**
- **It detects the Open Redirect for both the good and bad cases.**

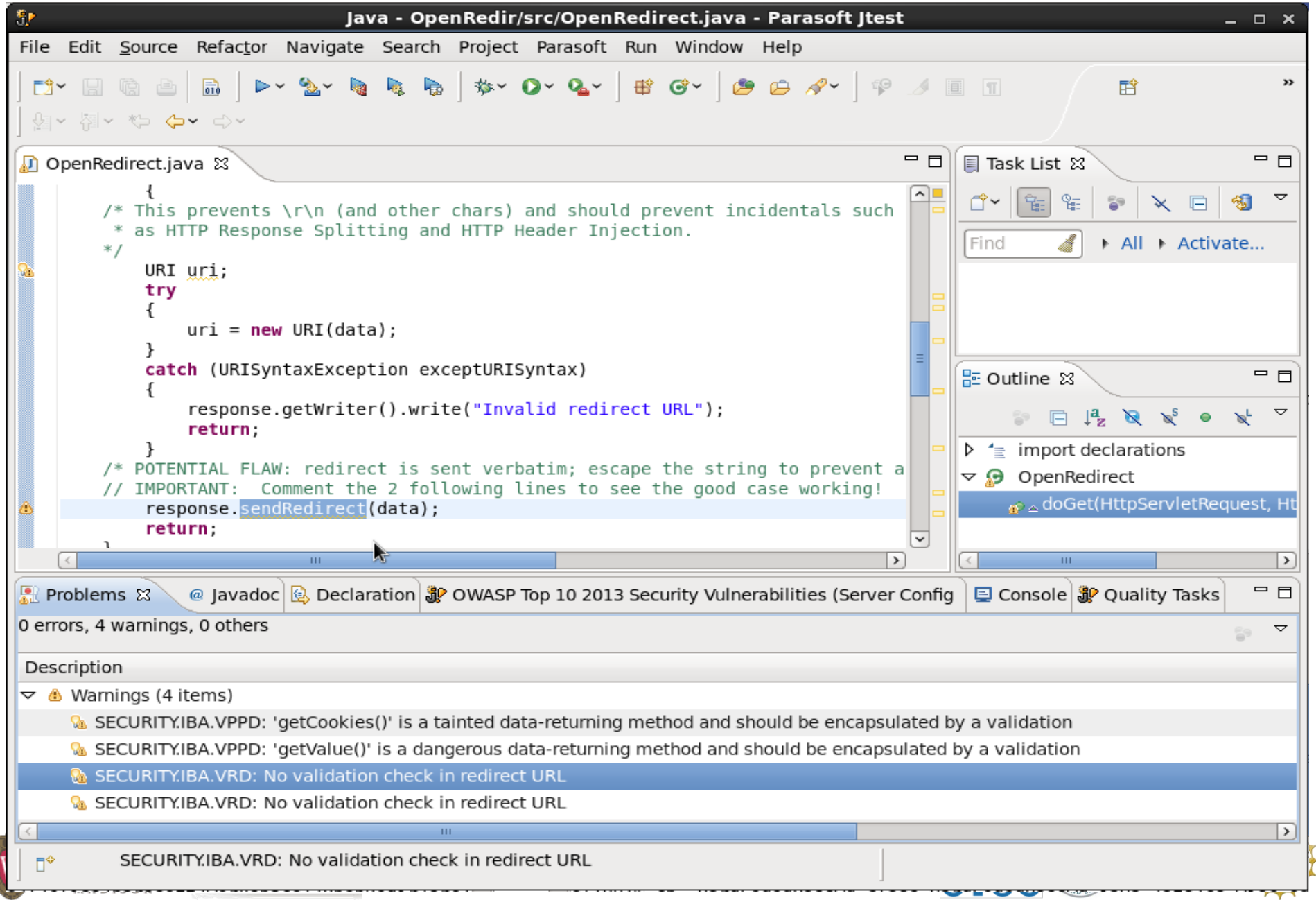
Jtest. Open Redirect



Jtest. Open Redirect



Jtest. Open Redirect



Roadmap

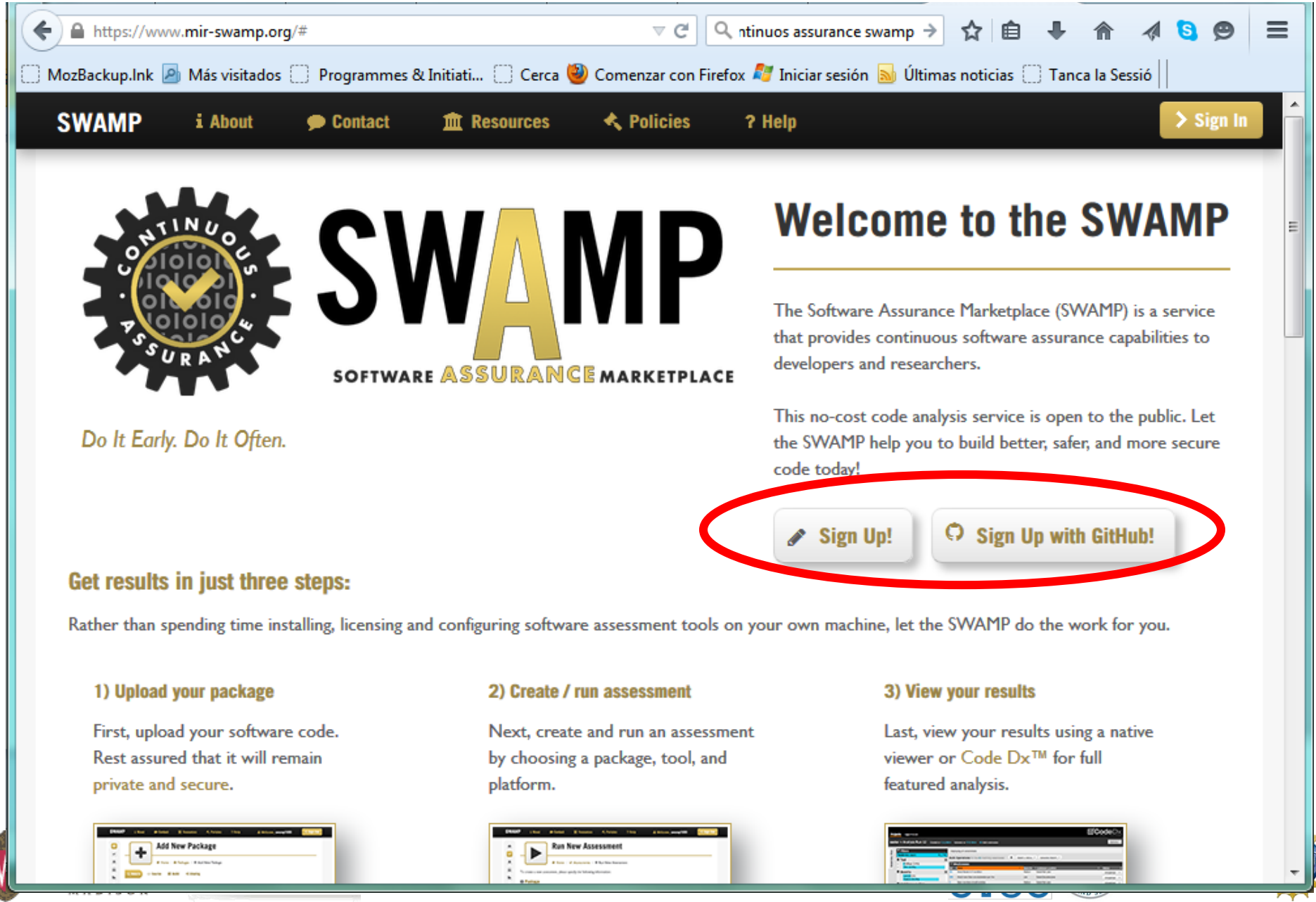
- What is the SWAMP?
- Using the SWAMP
  - Register
  - Create a project
  - Upload your software package
  - Run your assessment
  - View the results
    - Java
    - C/C++

https://continuousassurance.org/swamp/SWAMP-User-Manual.pdf

Getting Started with the SWAMP

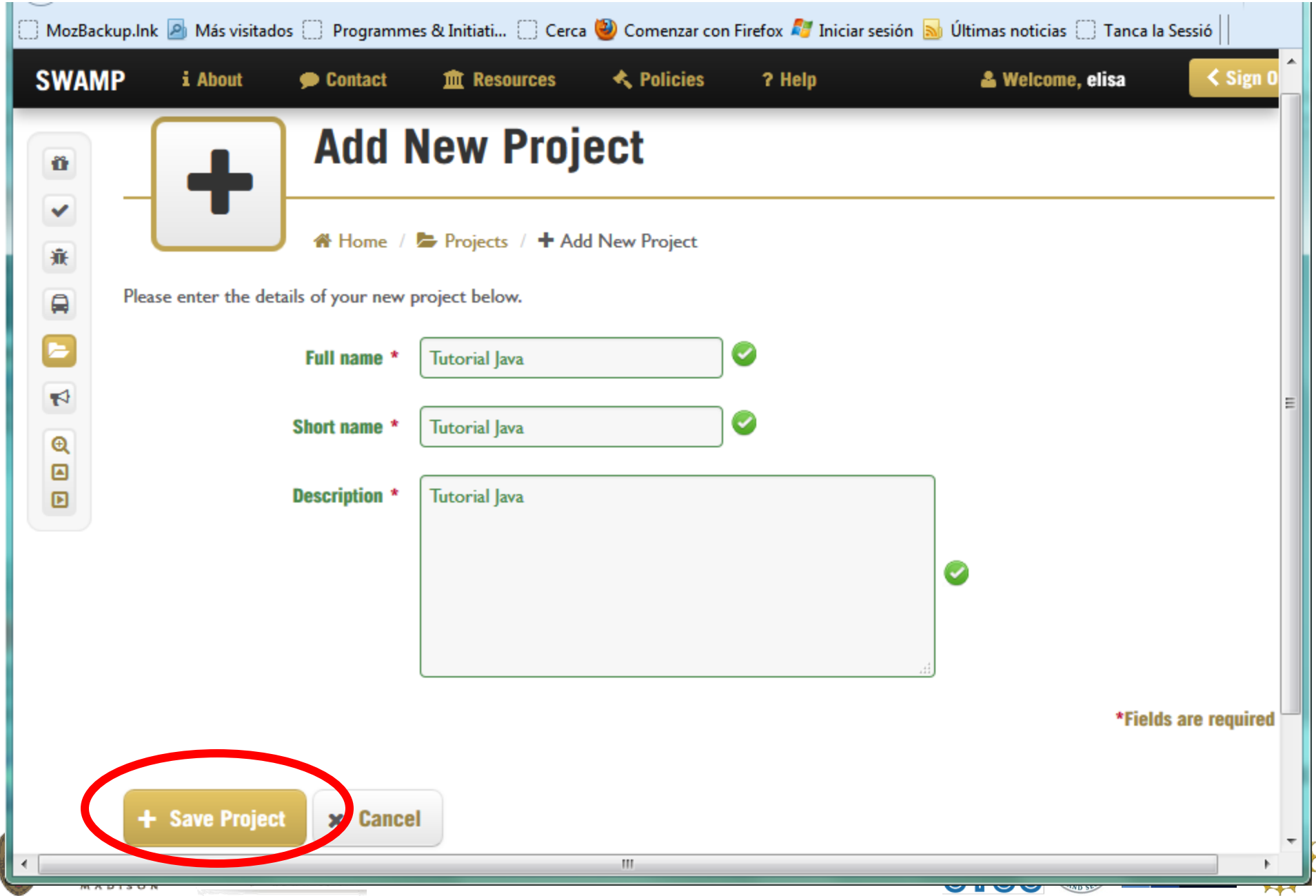
- Software Assurance Market Place.
- Objective: Automate and simplify the use of (multiple) tools.
- A national, no-cost resource for software assurance (SwA) technologies used across research institutions, non-governmental organizations, and civilian agencies and their communities as both a research platform and a core component of the software development life cycle.

Register to use the SWAMP

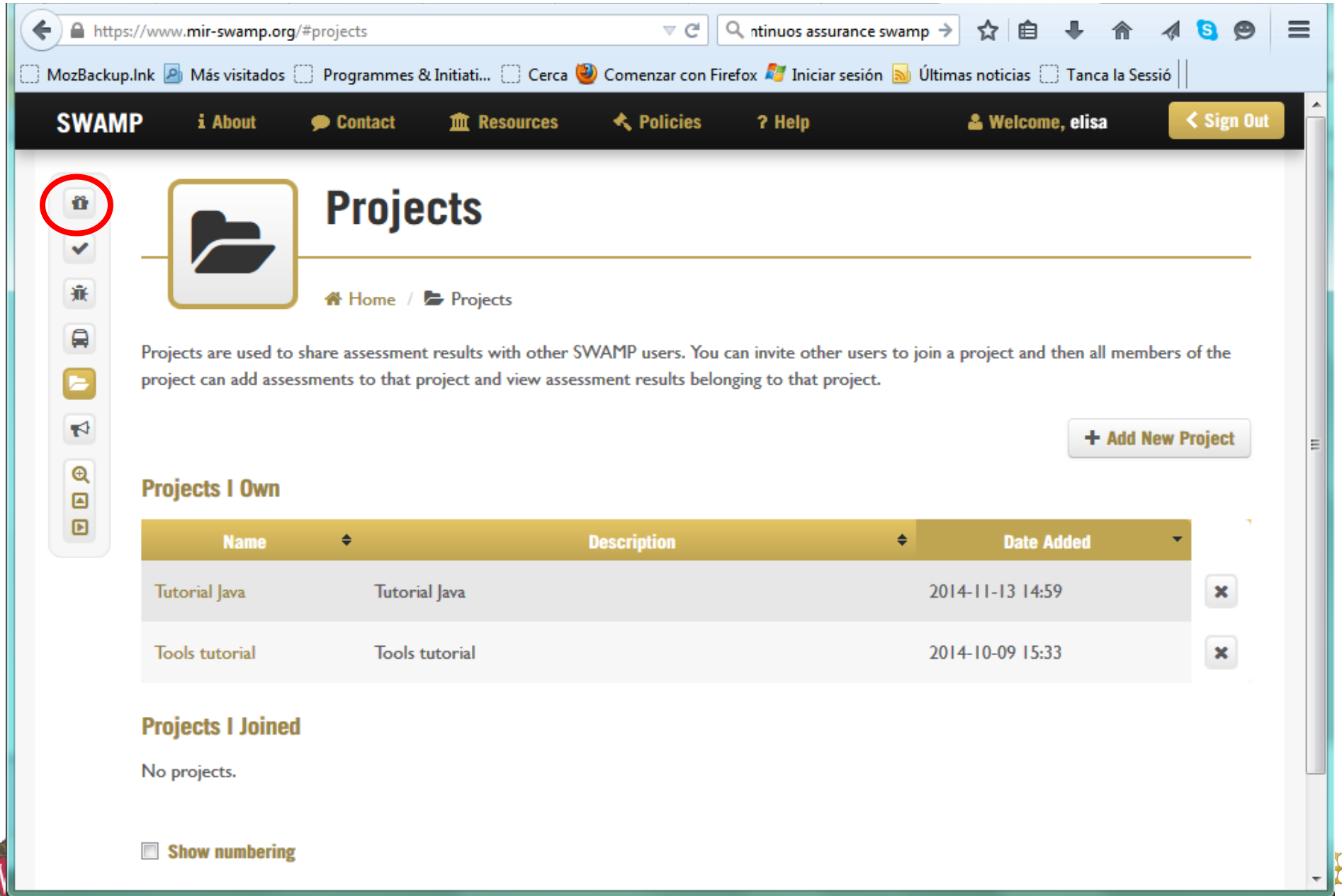


What can I do in the SWAMP?

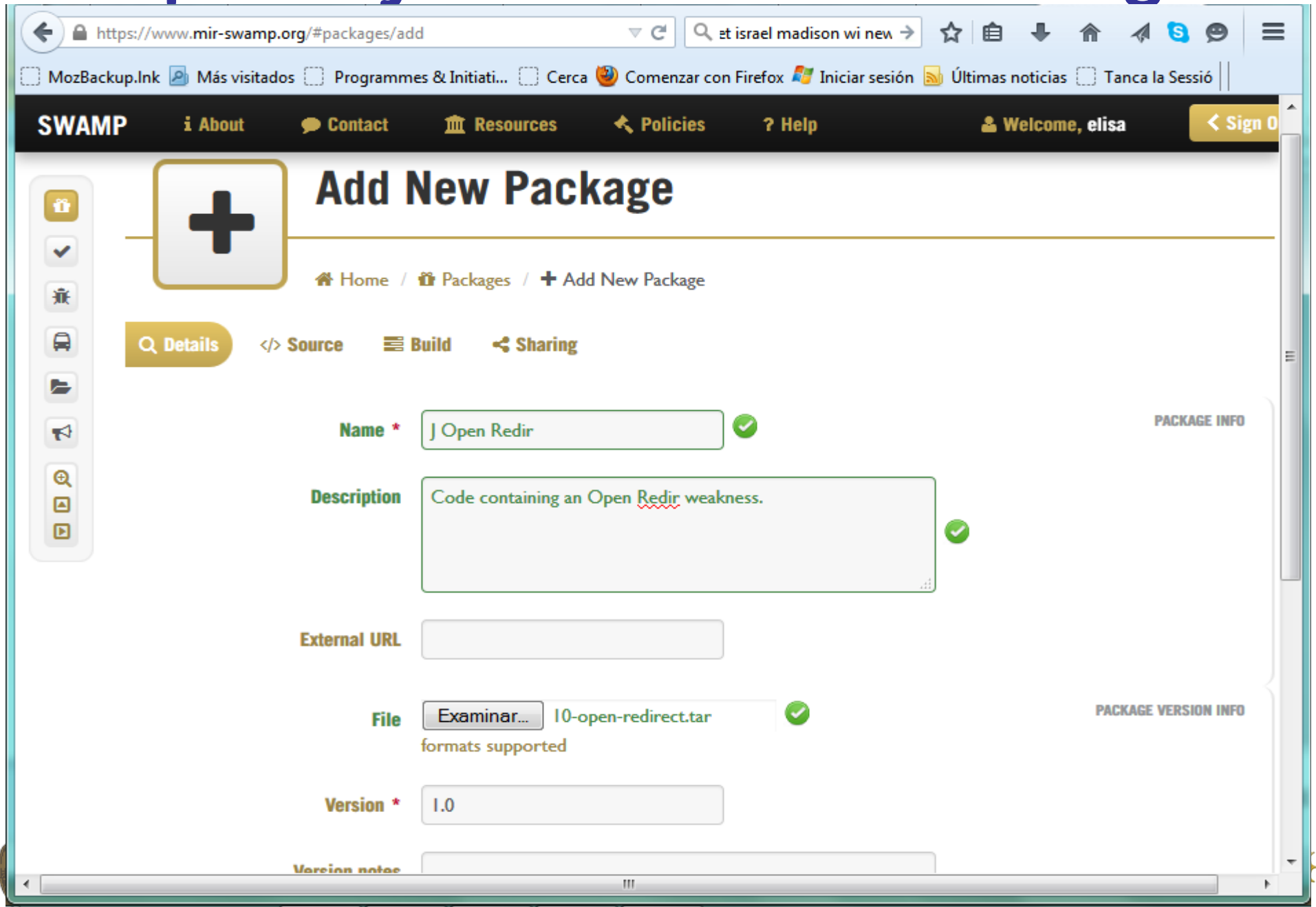
Create a Project



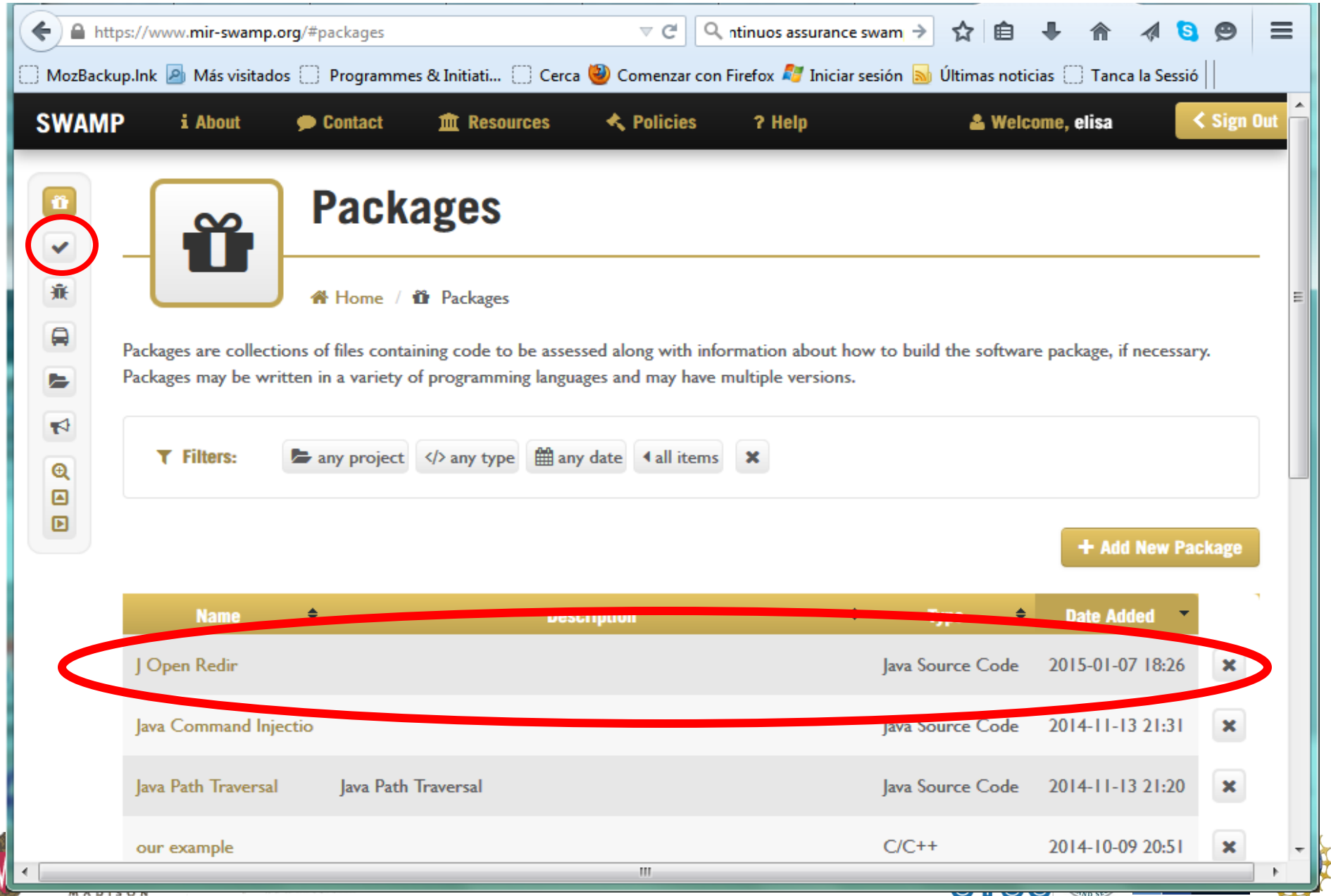
My Projects


https://www.mir-swamp.org/#projects
ntinuos assurance swamp
MozBackup.lnk
Más visitados
Programmes & Initiati...
Cerca
Comenzar con Firefox
Iniciar sesión
Últimas noticias
Tanca la Sessió
SWAMP
About
Contact
Resources
Policies
Help
Welcome, elisa
Sign Out
Projects
Home / Projects
Projects are used to share assessment results with other SWAMP users. You can invite other users to join a project and then all members of the project can add assessments to that project and view assessment results belonging to that project.
+ Add New Project
Projects I Own
Name
Description
Date Added
Tutorial Java
Tutorial Java
2014-11-13 14:59
Tools tutorial
Tools tutorial
2014-10-09 15:33
Projects I Joined
No projects.
Show numbering

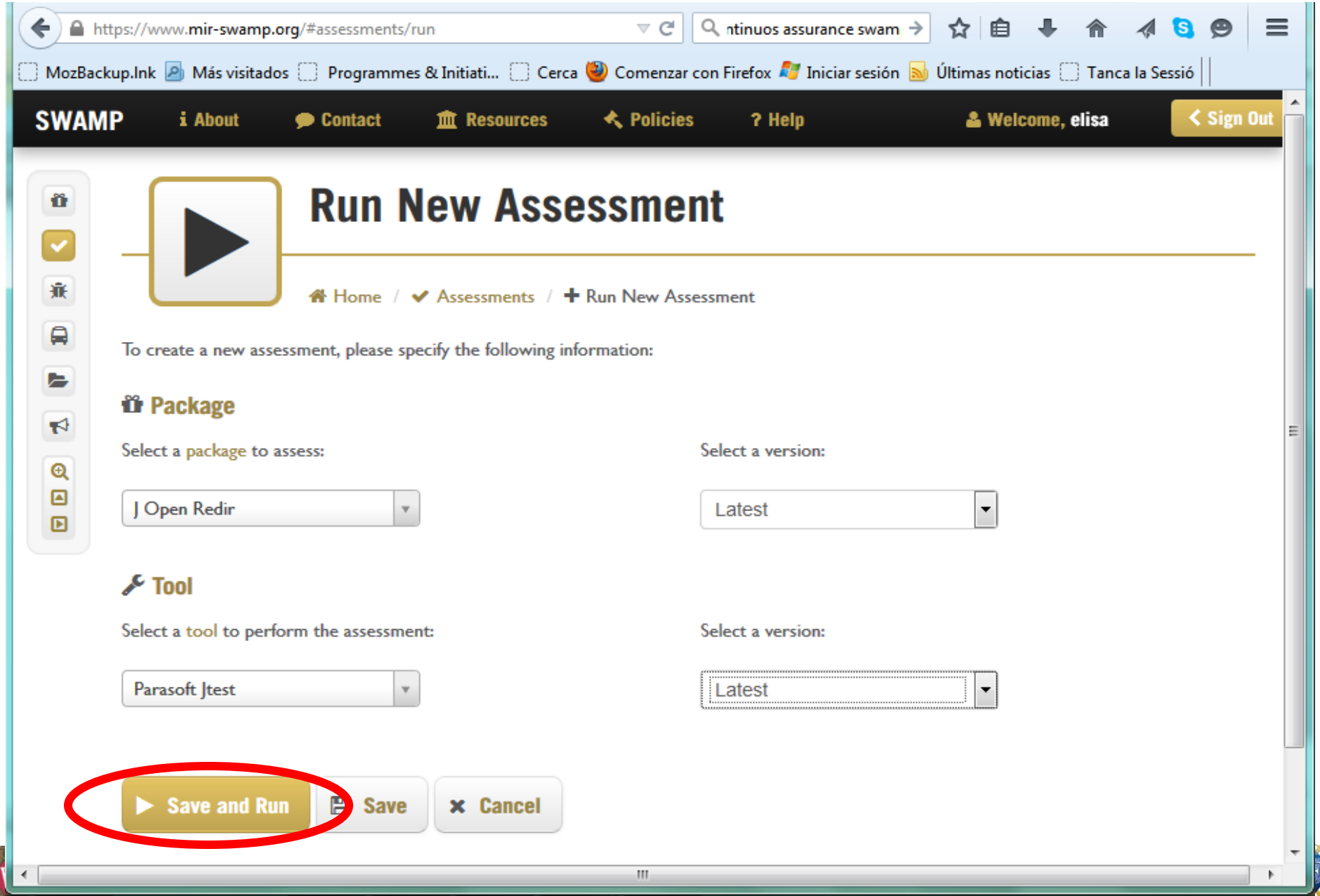
Upload your Software Package



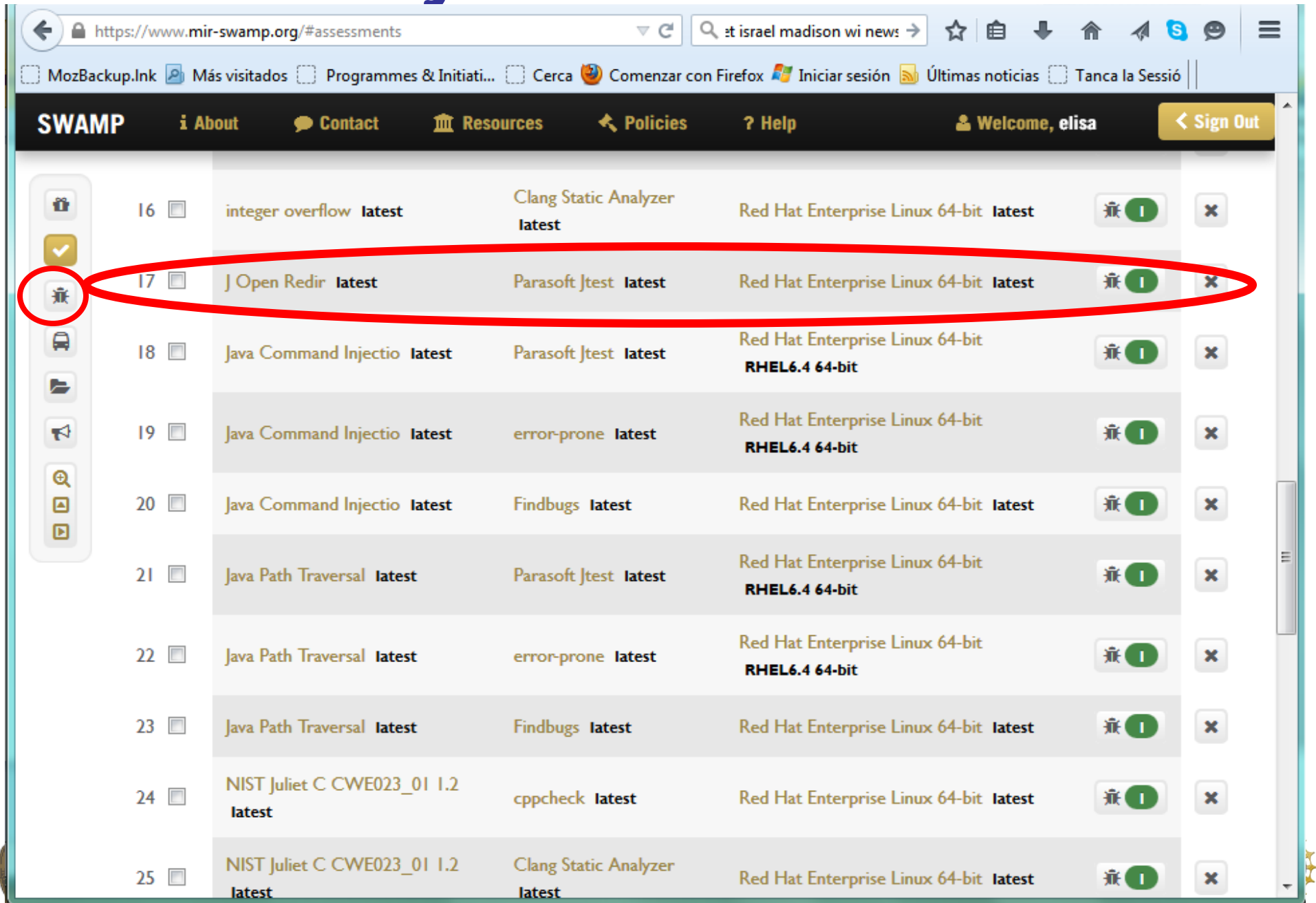
My software Packages



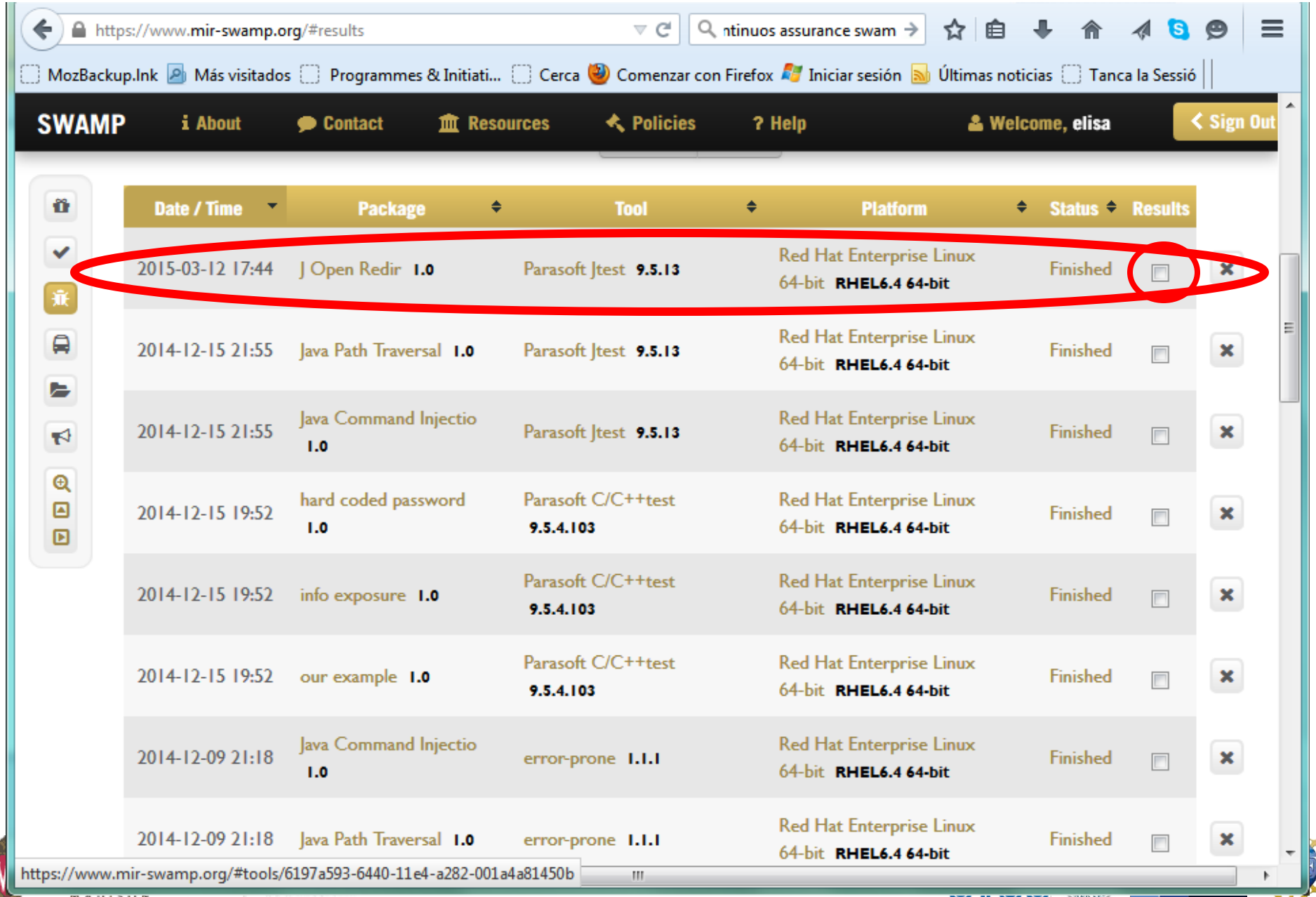
Run your Assessments



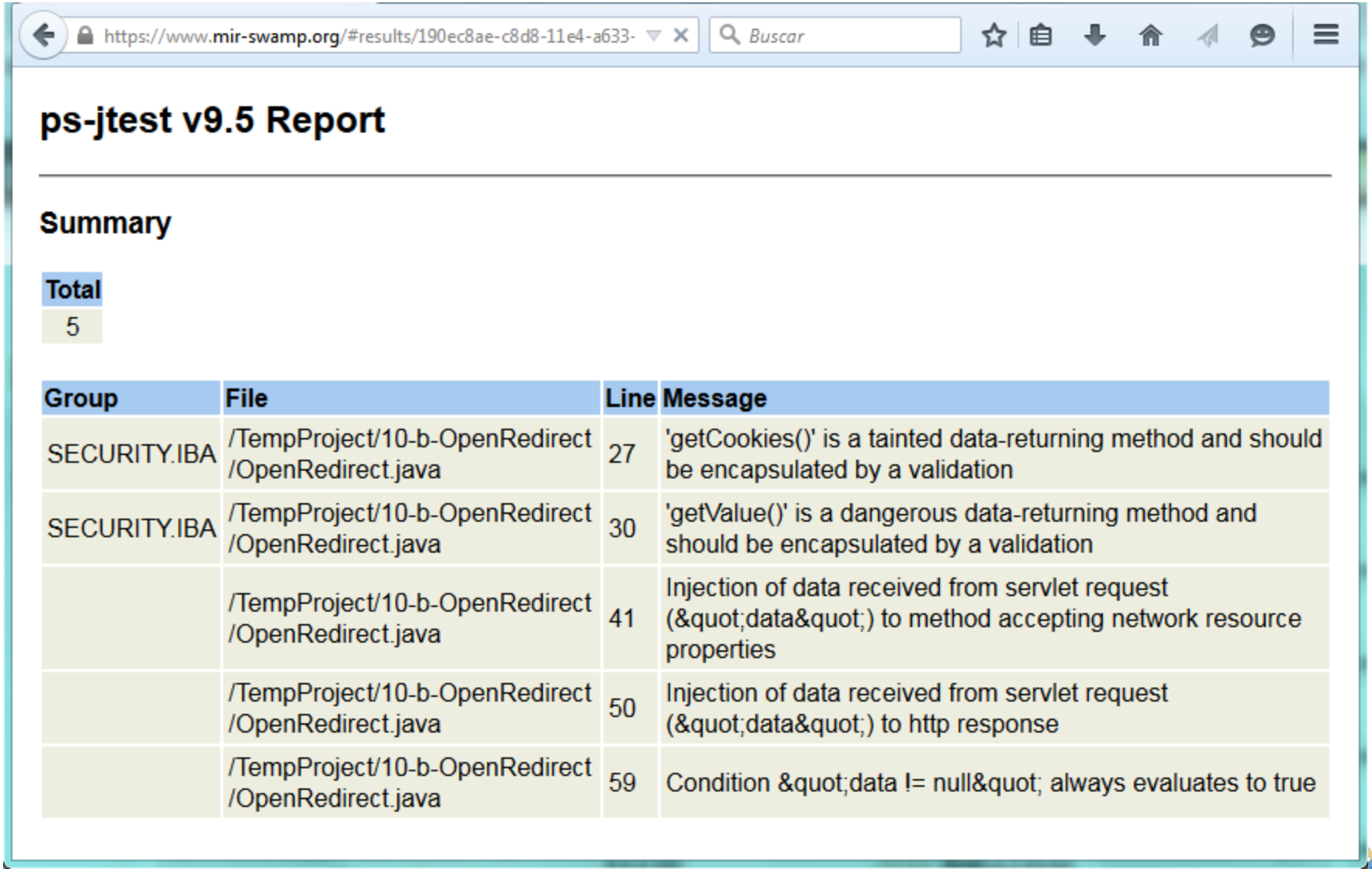
My Assessments



View your Results



My Results for Java: Jtest – J Open Redir - Native



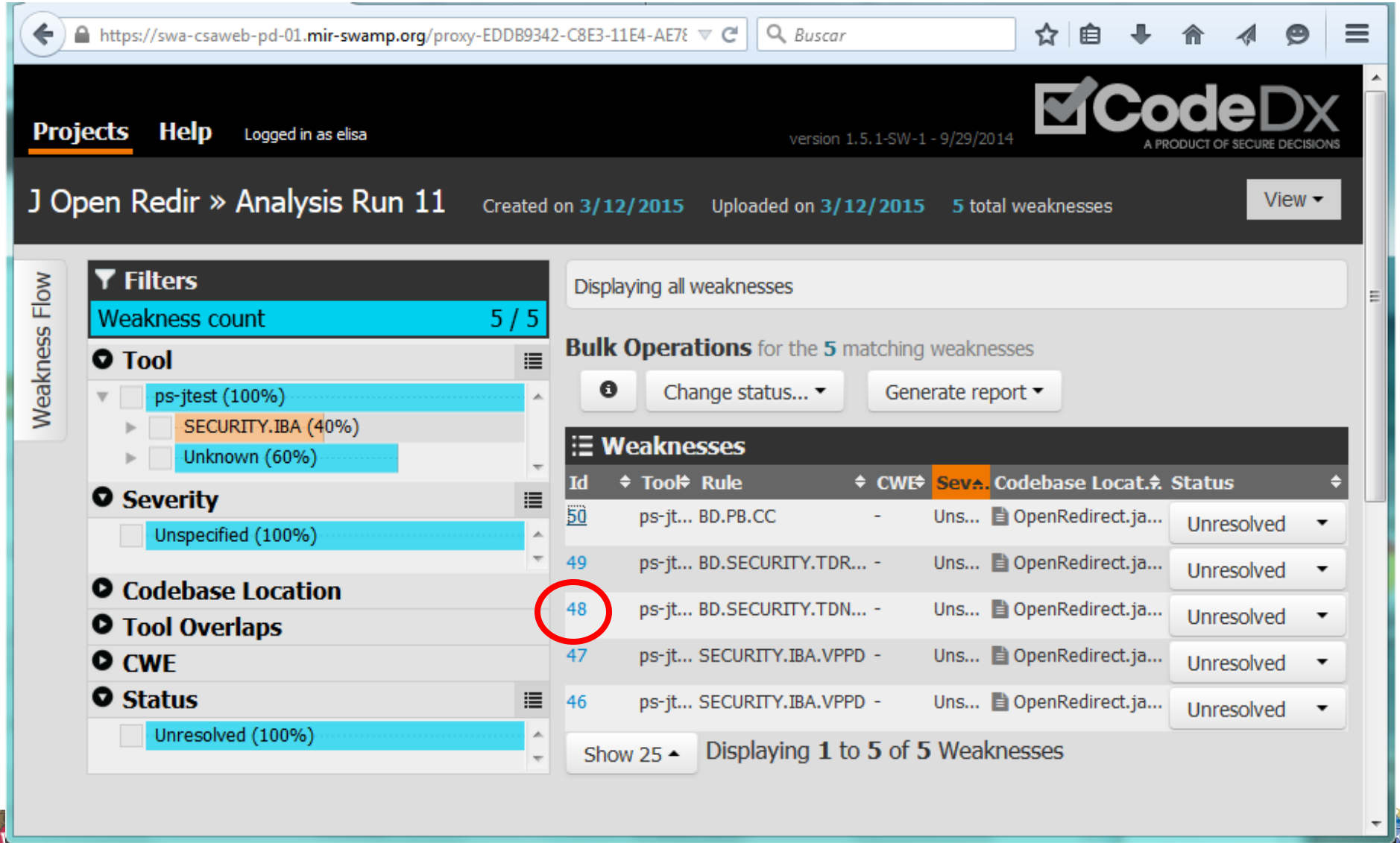
ps-jtest v9.5 Report

Summary

Total
5

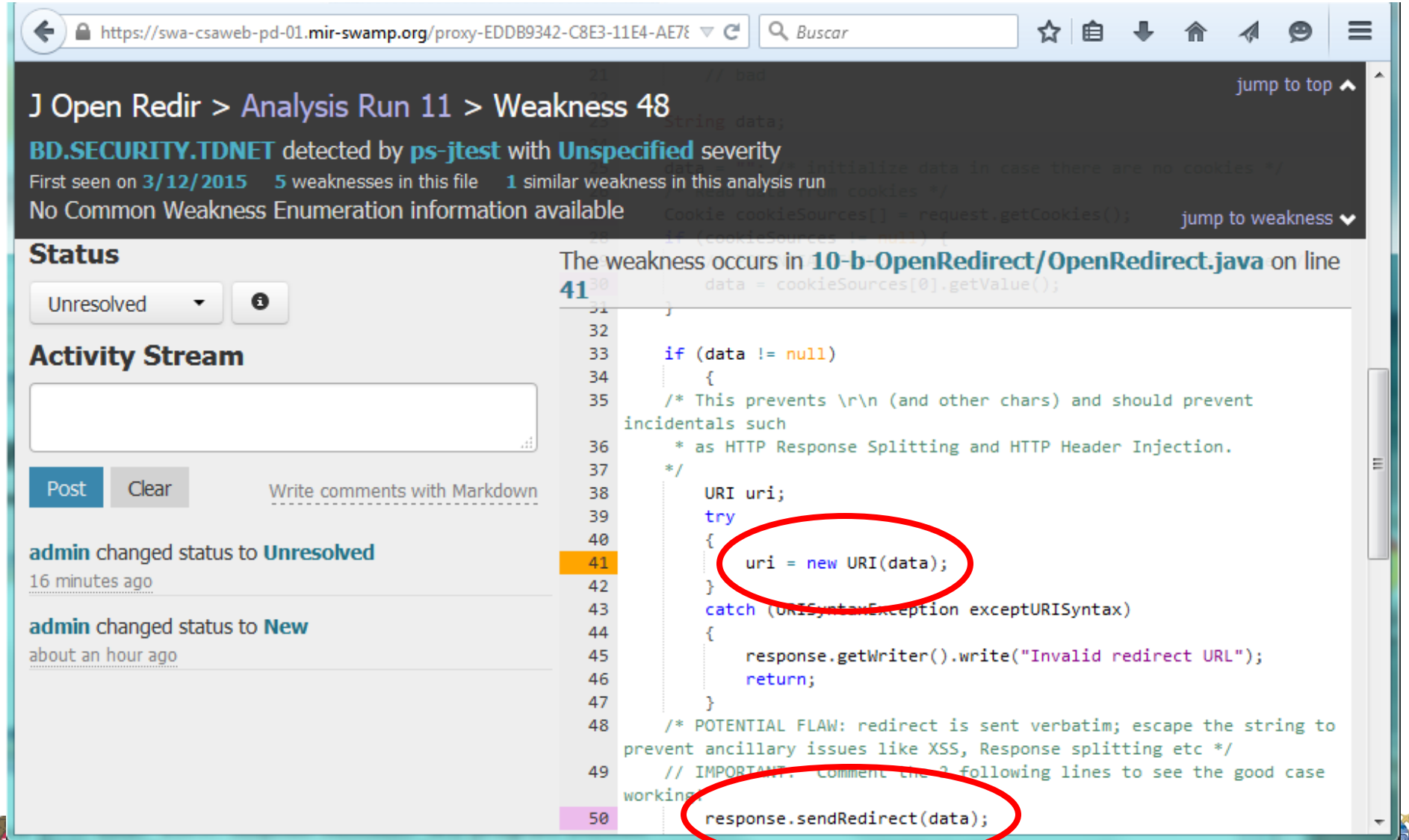
Group	File	Line	Message
SECURITY.IBA	/TempProject/10-b-OpenRedirect /OpenRedirect.java	27	'getCookies()' is a tainted data-returning method and should be encapsulated by a validation
SECURITY.IBA	/TempProject/10-b-OpenRedirect /OpenRedirect.java	30	'getValue()' is a dangerous data-returning method and should be encapsulated by a validation
	/TempProject/10-b-OpenRedirect /OpenRedirect.java	41	Injection of data received from servlet request ("data") to method accepting network resource properties
	/TempProject/10-b-OpenRedirect /OpenRedirect.java	50	Injection of data received from servlet request ("data") to http response
	/TempProject/10-b-OpenRedirect /OpenRedirect.java	59	Condition "data != null" always evaluates to true

My Results for Java: Jtest – J Open Redir - CodeDx



My Results for Java: Jtest – J Open Redir - CodeDx

My Results for Java: Jtest – J Open Redir - CodeDx



Questions?

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