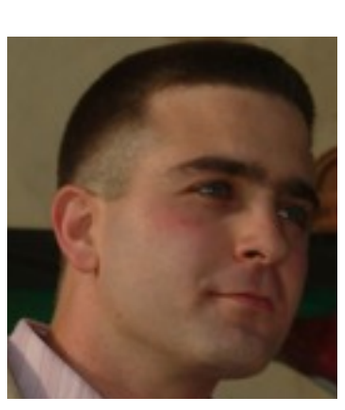
F4F: Taint Analysis of Framework-based Web Applications





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OOPSLA 2011

Web Application Security

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T.J. maxx®

Security on msnbc.com

T.J. Maxx theft believed largest hack ever

Sony Pictures hacked by Lulz Security, 1,000,000 passwords claimed stolen (update)

PBS Website Hacked With Fake News

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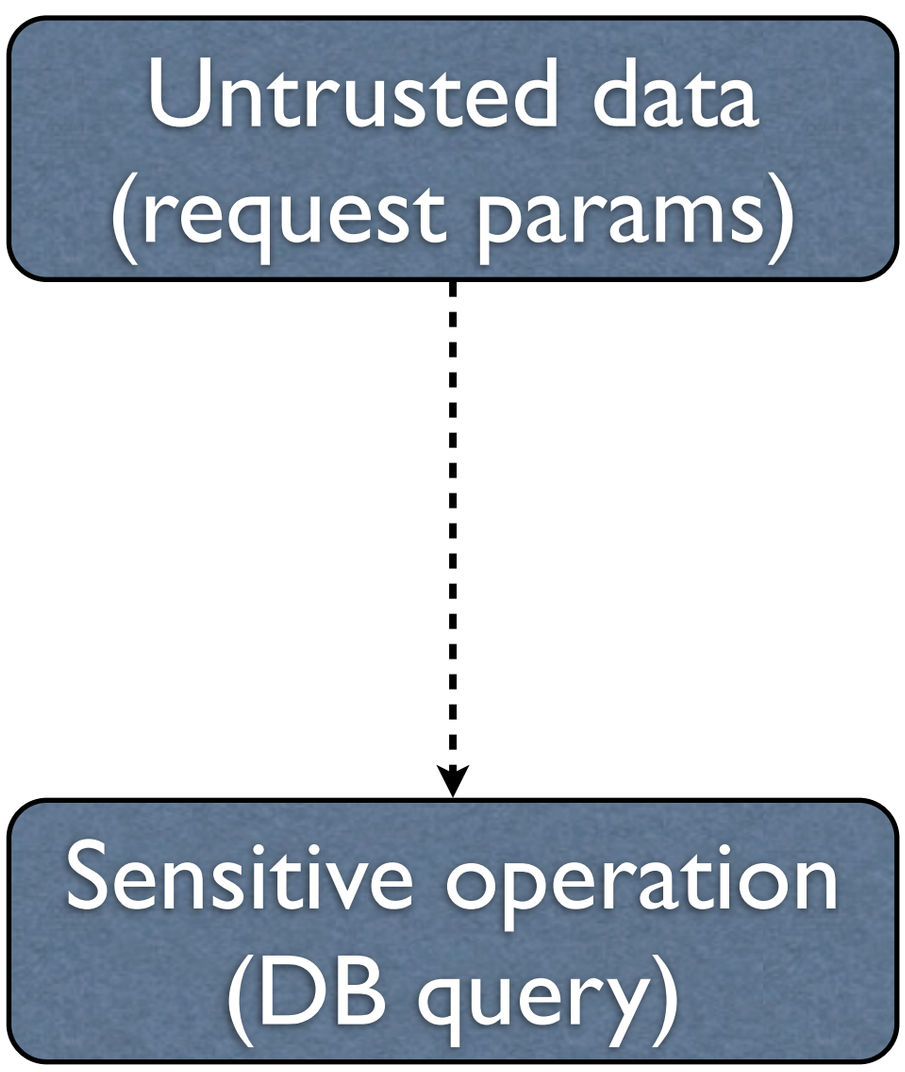
Lady Gaga's website hacked by SwagSec cyber attackers

Taint Analysis for Security



Key: accurate tracking of data flow

Web Application Frameworks

Web Application Frameworks

- **Bad for taint analysis!**
  - Data flow via reflection, "interpreting" config files

Existing Approaches

- Only analyzing the code not effective
  - Analyze reflection: many false positives
    - Can't see config info!
  - Ignore reflection: miss many issues
- Baked-in framework support doesn't scale
  - Tens of frameworks for Java alone
  - Different versions, customizations, ...

A Framework for Frameworks (F4F)

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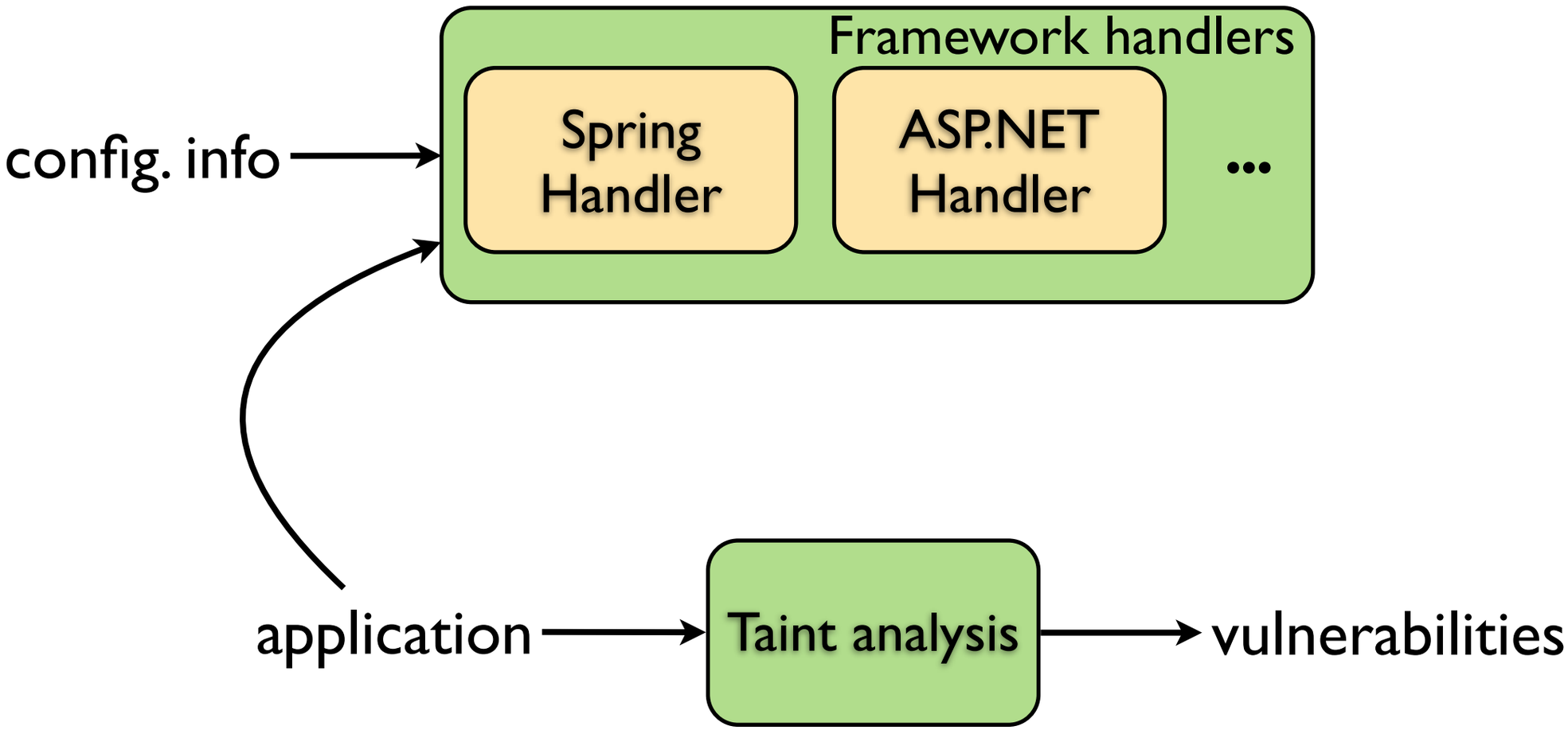

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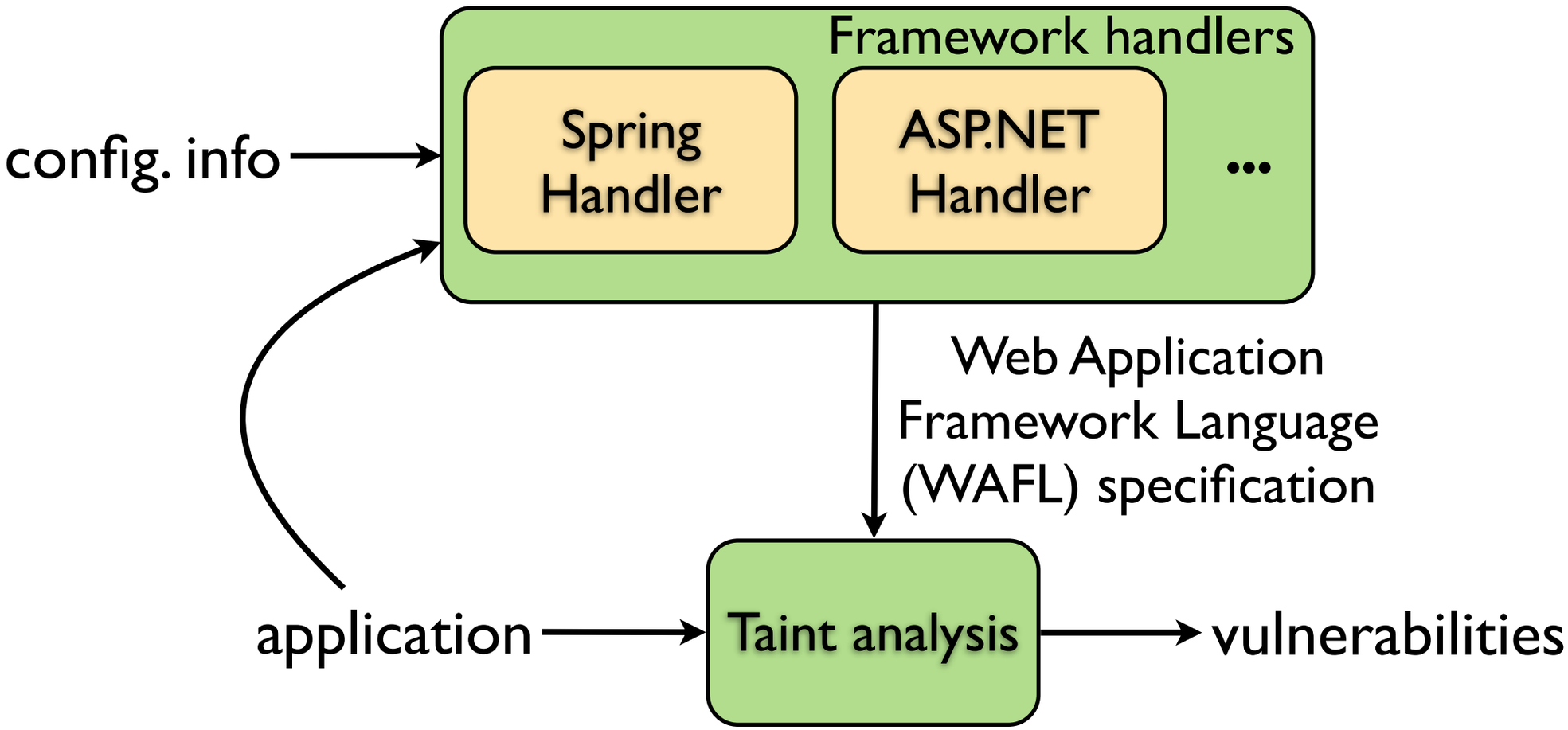

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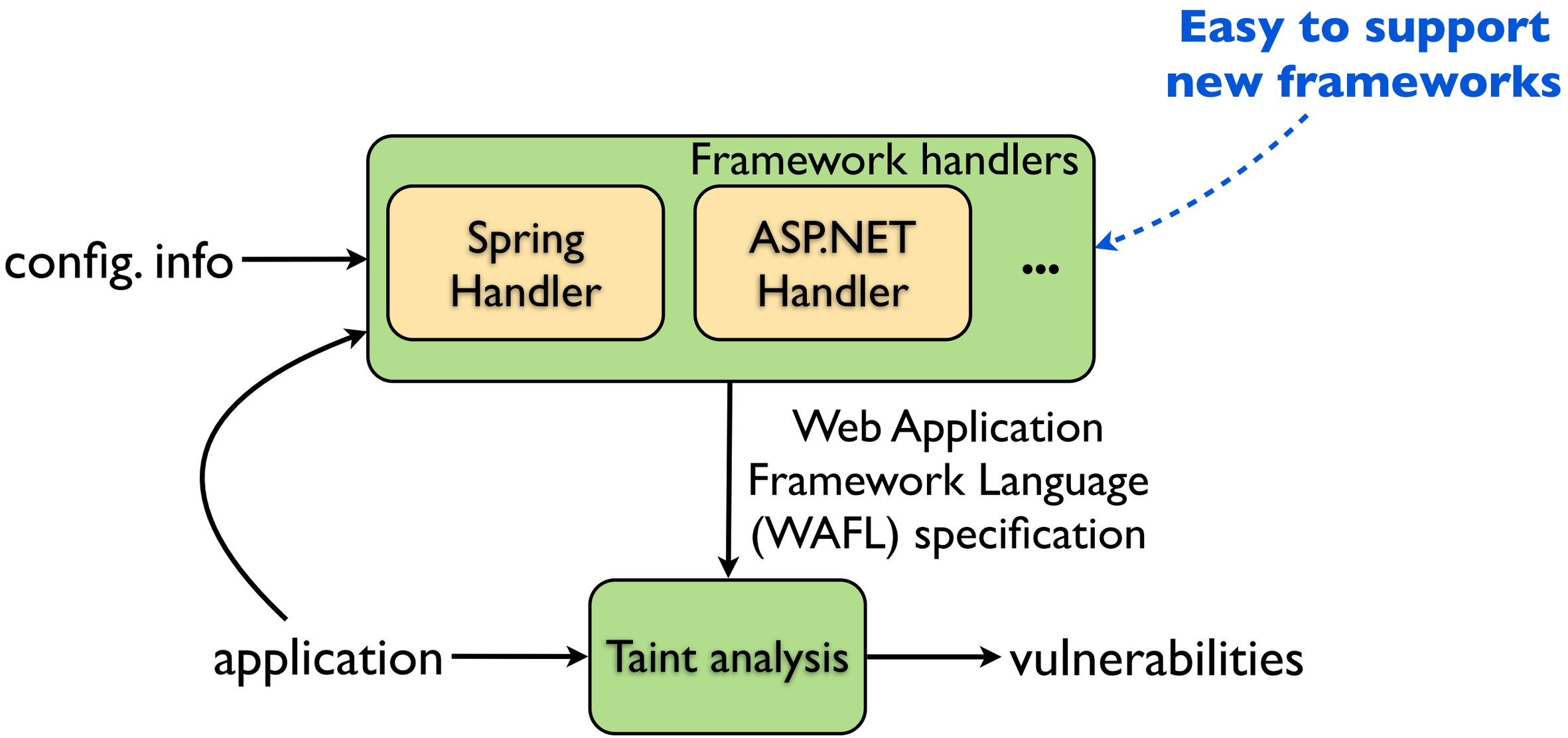

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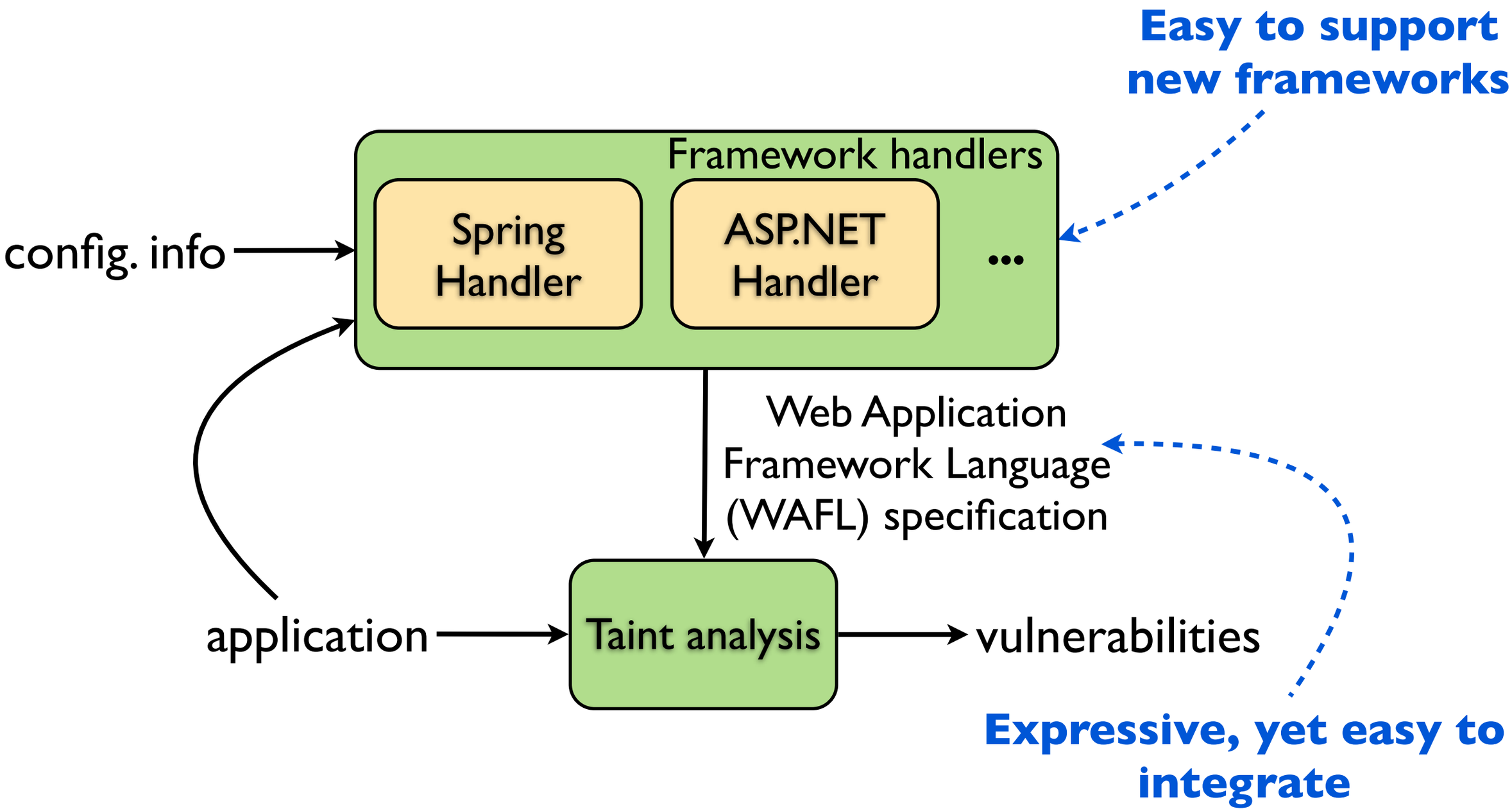

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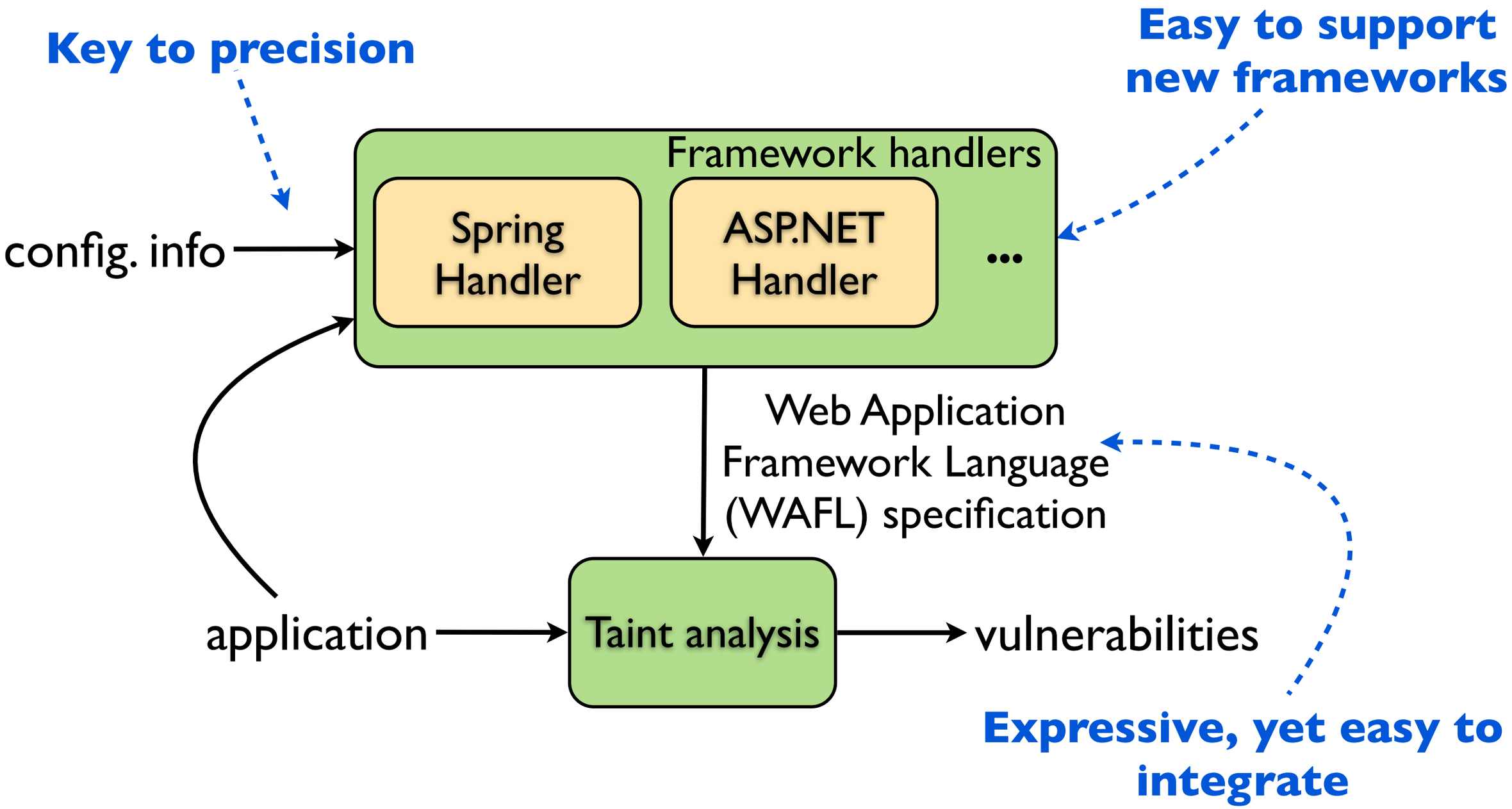

Example: edit profile

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Code

Configuration

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Code

```
// for user data
class UserForm {
  String firstName,lastName;
  // getters and setters...
}
```

Configuration

Example: edit profile

Code

```
// for user data
class UserForm {
  String firstName,lastName;
  // getters and setters...
}

// updates profile
class UserAction
  implements IAction {
  String exec(HttpRequest req,
              Object form) {
    UserForm uf = (UserForm) form;
    updateDB(uf);
    ...
  }
}
```

Configuration

Example: edit profile

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// for user data
class UserForm {
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// updates profile
class UserAction
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    ...
  }
}
```

Configuration

```
<action url="/edit"
        type="UserAction"
        formtype="UserForm">
</action>
```

In English: When "/edit" is visited, create a UserForm object (reflection), set its fields using request data (reflection), and pass it to UserAction.exec() (reflection).

WAFL: synthetic methods

```
fun entrypoint UserAction_entry(request) {
  UserForm f = new UserForm();
  f.setFirstName(request.getParam(“firstName”));
  f.setLastName(request.getParam(“lastName”));
  (new UserAction()).exec(request, f);
}
```

WAFL: synthetic methods

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  (new UserAction()).exec(request, f);
}
```

- Simple structure: no branches, loops, etc.
  - Eases integration with analysis engine
  - Taint analysis usually flow insensitive anyway
- Based on both app code and config info

Example: show profile

Code

Configuration

Example: show profile

Code

```
class UserAction {
  String exec(HttpRequest req,
              Object form) {
    UserForm uf = (UserForm) form;
    updateDB(uf);
    // store for use by view
    req.setAttribute(“user”,uf);
    // return view name
    return “showuser”;
  }
}
```

Configuration

Example: show profile

Code

```
class UserAction {
  String exec(HttpRequest req,
              Object form) {
    UserForm uf = (UserForm) form;
    updateDB(uf);
    // store for use by view
    req.setAttribute(“user”,uf);
    // return view name
    return “showuser”;
  }
}
// view code in ShowUser.jsp
<% UserForm uf =
    (UserForm)req.getAttribute(“user”); %>
<p><%= uf.getLastName(); %>,
   <%= uf.getFirstName(); %></p>
```

Configuration

Example: show profile

Code

```
class UserAction {
  String exec(HttpRequest req,
              Object form) {
    UserForm uf = (UserForm) form;
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// view code in ShowUser.jsp
<% UserForm uf =
    (UserForm)req.getAttribute(“user”); %>
<p><%= uf.getLastName(); %>,
   <%= uf.getFirstName(); %></p>
```

Configuration

```
<forward name="showuser"
         path="/ShowUser.jsp" />
```

In English: If exec() method returns “showuser”, display “/ShowUser.jsp” (reflection).

WAFL: call replacements and globals

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```
// model flow through “user” request attribute
global request_user;
replaceCall ‘req.setAttribute(“user”,uf)’ in exec() {
  request_user = uf;
}
replaceCall ‘uf = req.getAttribute(“user”)’ in ShowUser.jsp {
  uf = request_user;
}
```

WAFL: call replacements and globals

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// model flow through “user” request attribute
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fun entrypoint UserAction_entry(request) { ...
  // model forward to (compiled) ShowUser.jsp
  ShowUser_jsp.render(request);
}
```

WAFL: call replacements and globals

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```

- Globals help modeling flows across disparate modules
- Only replace calls
  - expressive enough in our experience
  - significantly eases integration

Building WAFL generators

```
genSynthMethod(<action> a, SynthMethod m):
  type := a.attr(“type”), formtype := a.attr(“formtype”)
  // populate form object
  m.addLocal(“f”, formtype)
  for each setter method setProp() in formtype:
    m.add(‘f.setProp(request.getParam(“prop”))’)
// invoke action
m.addLocal(“a”, type)
m.add(‘a.exec(request,f)’)
// handle forwards to views
for each string s returned by type.exec():
  f := <forward> element with name s
  url := f.attr(“path”)
  m.add(invokeURLEntry(url))
```

Building WAFL generators

- Only lightweight analysis needed
  - class hierarchy, local data-flow analysis
    - little redundancy with taint analysis
- Others can build generators!
  - Sales engineer built EJB handler using API

Taint Analysis Integration

- Generate code for synthetic methods
  - Pass on entrypoint list
- Call replacements via modified dispatch

```
replaceCall 'req.setAttribute("user",uf)' in exec() {
  request_user = uf;
}
```

Method matching signature

```
static void repl1(Request r,
                  String s,
                  UserForm uf) {
  request_user = uf;
}
```

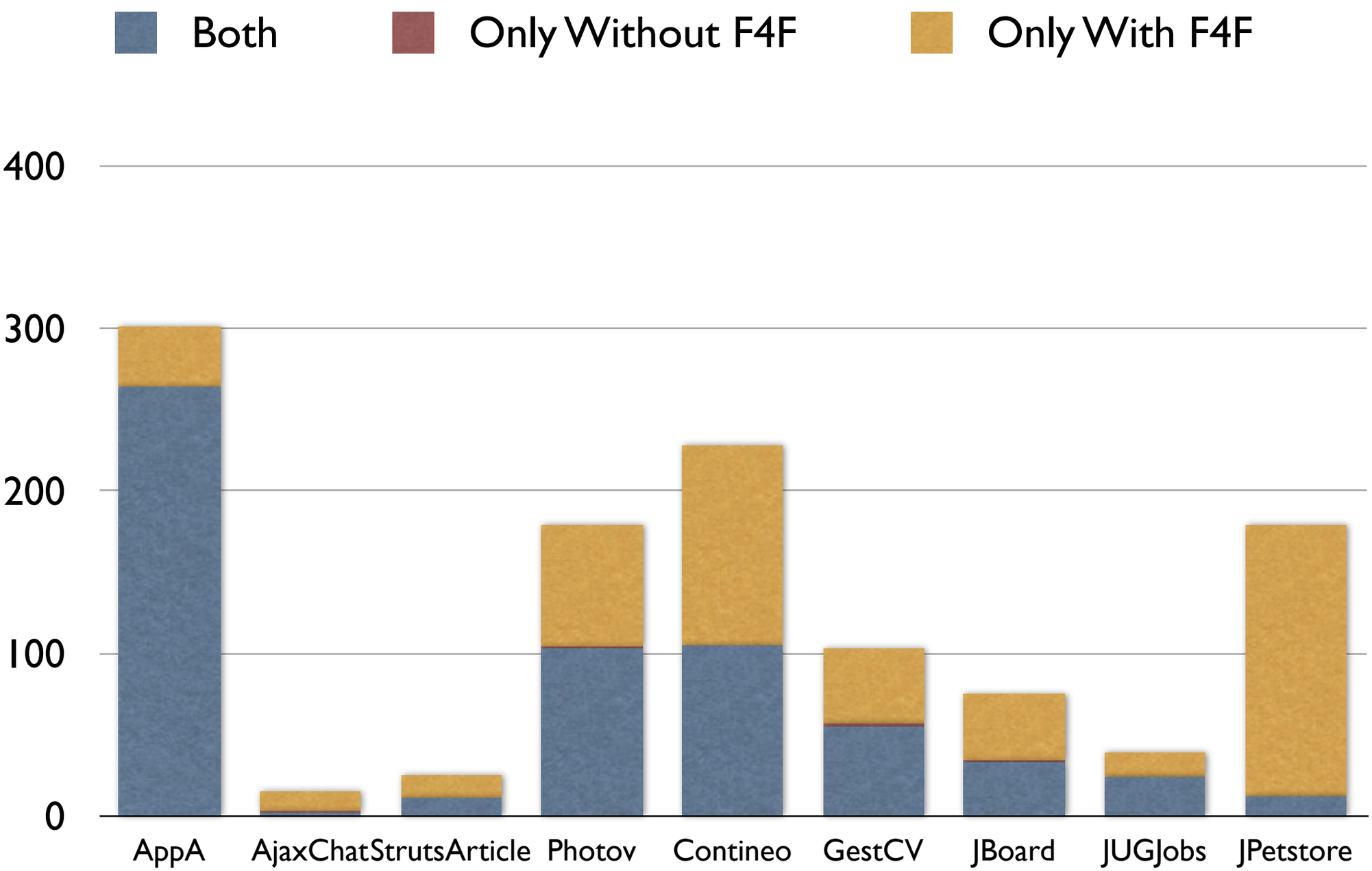
Replacement info

dispatch 'req.setAttribute("user", uf)' in exec() to repl1()

Evaluation

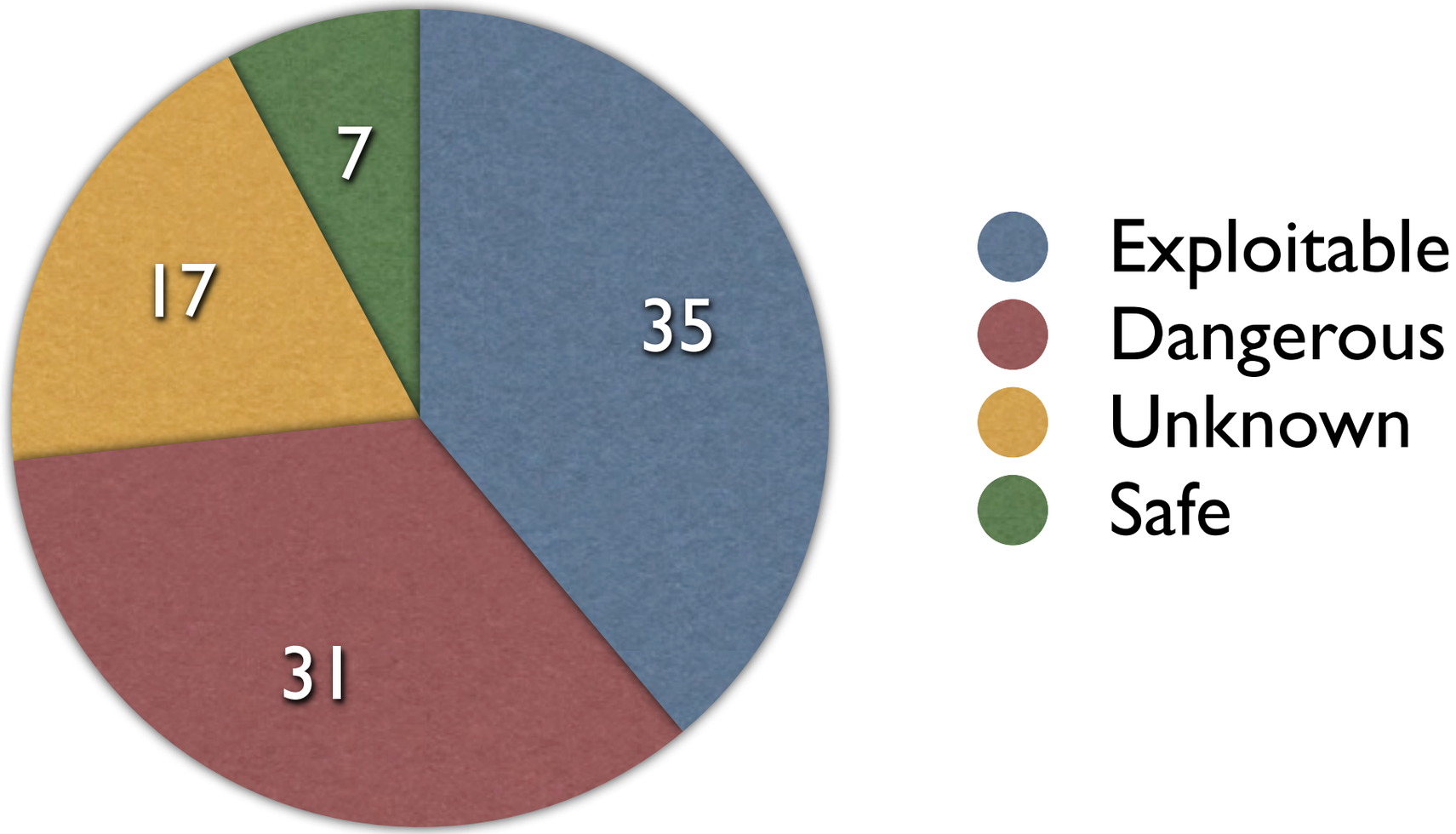
- Nine framework-based web apps
  - Frameworks: Struts, Spring, Tiles, EL
  - See http://bit.ly/F4Fbenchmarks for generated WAFL specs
- Ran state-of-the-art taint analysis with and without F4F

Issues reported



2.10X (1.1X-14.9X) more issues with F4F

Exploitability



Most issues require inspection

Related Work

- Spec languages for "environment", e.g.
  - effects of Java native methods
    - how OS kernel invokes drivers
- MERLIN (Livshits et al., PLDI'09)
- TAJ (Tripp et al., PLDI'09)

Conclusions

- F4F helps to tame web frameworks
  - Separate framework handlers, analyzing config files
  - Expressive, consumable spec language (WAFL)
    - Future work: apply to other domains, DSL for WAFL generators

Rational. software

AppScan Source Edition 8.0

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