Riding out DOMsday:

Toward Detecting and Preventing DOM Cross-Site Scripting

William Melicher
Anupam Das
Mahmood Sharif
Lujo Bauer
Limin Jia

Carnegie Mellon University

XSS vulnerabilities account for 25% of web vulnerabilities

```
document.write('<a href="' +
   document.location + '">Link</a>');
```

```
url.com/page#"></a><script>ATTACK</script>
```

Attacker

Craft exploit

Browser executes attacker code

User

Visit page

Return exploited page

Website with vulnerability

DOM XSS: vulnerability is inside JavaScript run on client

Current client-side defenses are still inadequate

Example: CSP is often not configured properly

Example: Web application firewall filters easily bypassable

More promising solution: Detect bugs ahead of time

State of the art: taint tracking and recognize vulnerable flows [1]

[1] Lekies et al. 25 million flows later - large scale detection of DOM XSS. CSS ‘13.

Our contributions

1. Improved methodology for detecting DOM XSS
2. Studied prevalence of DOM XSS in real world
3. Examined whether static analysis tools help

What are vulnerable flows?

Sources: document.location, cross-origin messages, referrer, ...

```
var the_url = document.location.href;
var markup = '<a href="' + the_url + '">Link</a>';
document.write(markup);
```

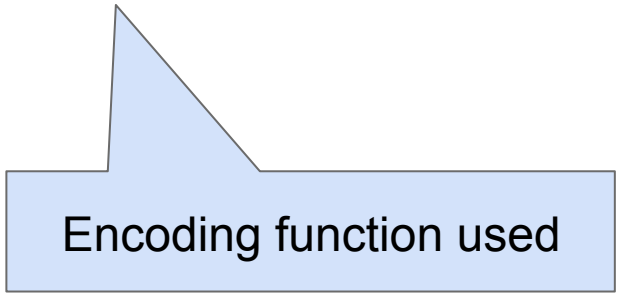
Sinks: document.write, innerHTML, eval, ...

What are vulnerable flows?

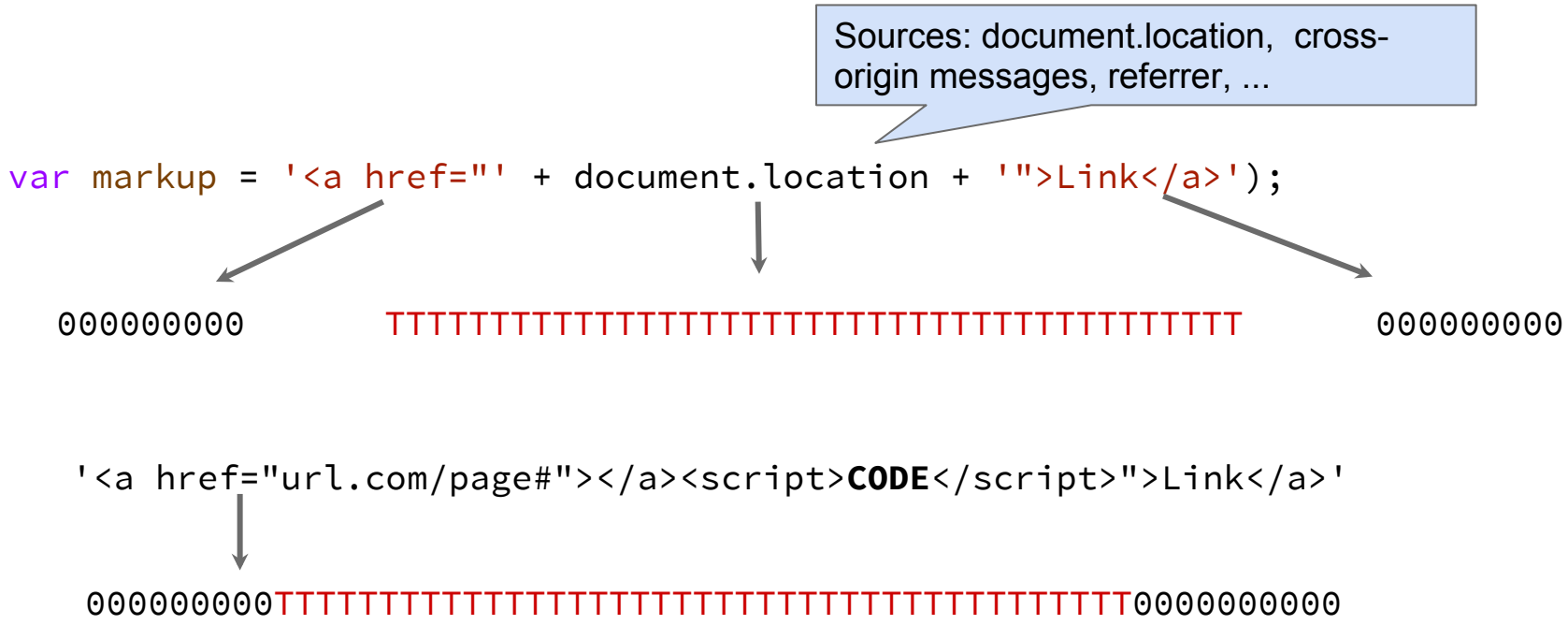
```
var the_url = document.location.href;
var markup = '<a href="' + encodeURI(the_url) + '">Link</a>';
document.write(markup);
```

What are vulnerable flows?

```
var the_url = document.location.href;
var markup = '<a href="' + encodeURI(the_url) + '">Link</a>';
document.write(markup);
```



Detecting vulnerable flows using taint tracking



Taint tracking inside Chromium

```
document.write(markup);
```

```
document.write('<a href="url.com/page#"></a><script>CODE</script>">Link</a>');
               ↓
               000000000TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT000000000
```

Log tainted call:

- Code location
- Value of tainted argument
- Taint information
- ...

Vulnerability confirmation: at-end injection

Original URL:

`url.com/path?param=test&a=b`

Our confirmation URL:

`url.com/path?param=test&a=b#INJECT`

```
document.write('<a href="' + document.location + '">Link</a>');
```

```
document.write('<a href="url.com/path?param=test&a=b">Link</a>');
```

```
document.write('<a href="url.com/path?param=test&a=b#INJECT">Link</a>');
```

Vulnerability confirmation: in-parameter injection

Original URL:

```
url.com/path?link=test&a=b
```

Our confirmation URL:

```
url.com/path?a=b#&link=INJECT&a=b
```

```
var data = getQueryParameter('link');
document.write('<a href="../' + data + '">Link</a>');
```

```
document.write('<a href="../test">Link</a>')
```

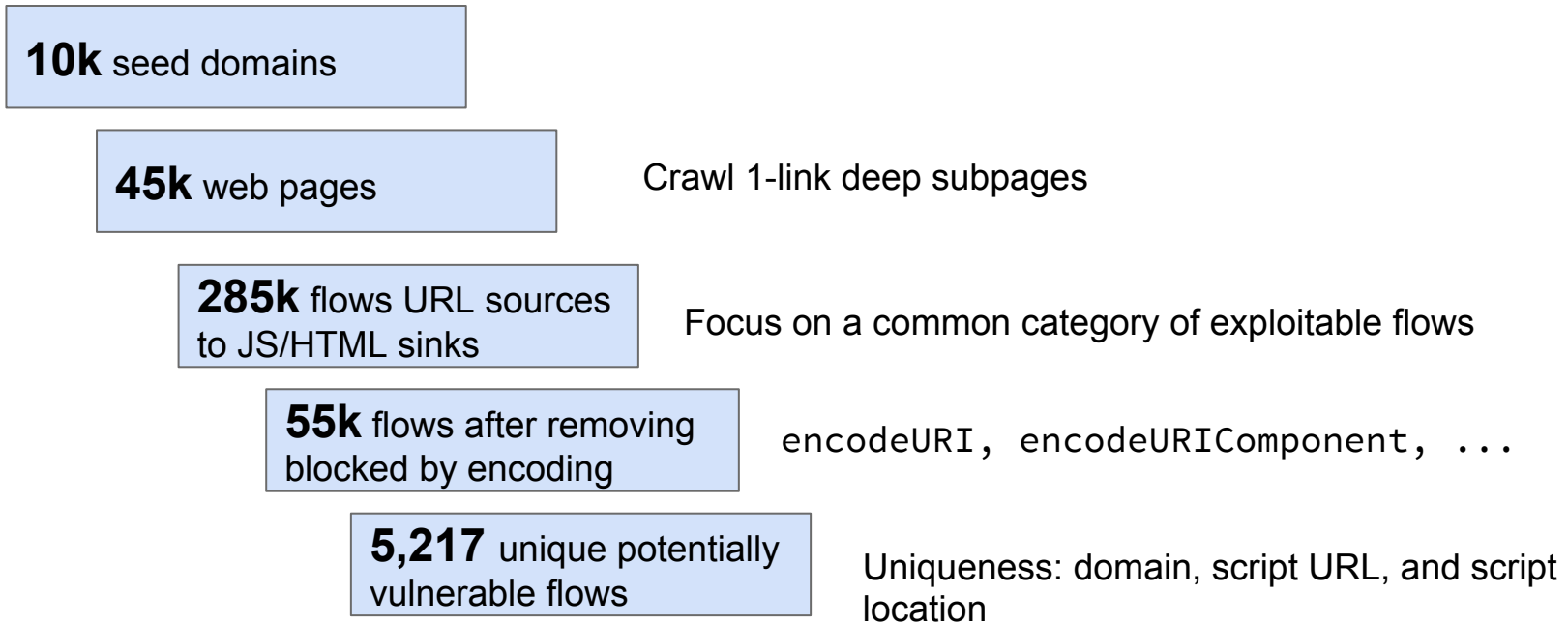
```
document.write('<a href="../INJECT">Link</a>')
```

Results

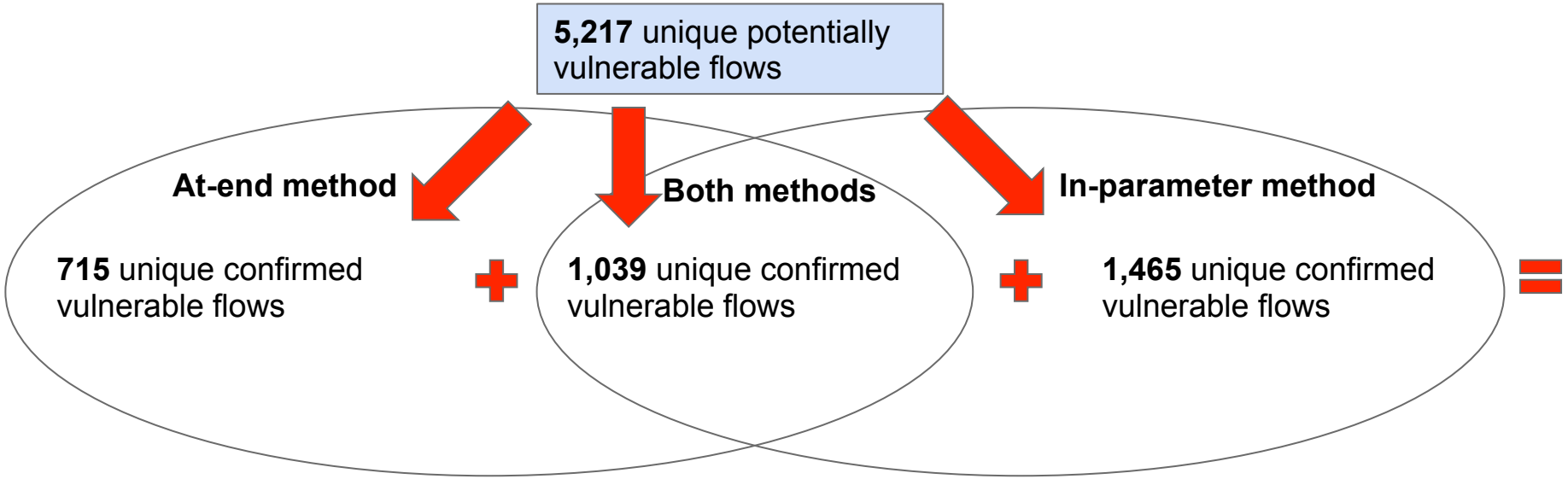
Our contributions

1. Improved methodology for detecting DOM XSS
2. **Studied prevalence of DOM XSS in real world**
3. Examined whether static analysis tools help

DOM XSS vulnerabilities on the Internet



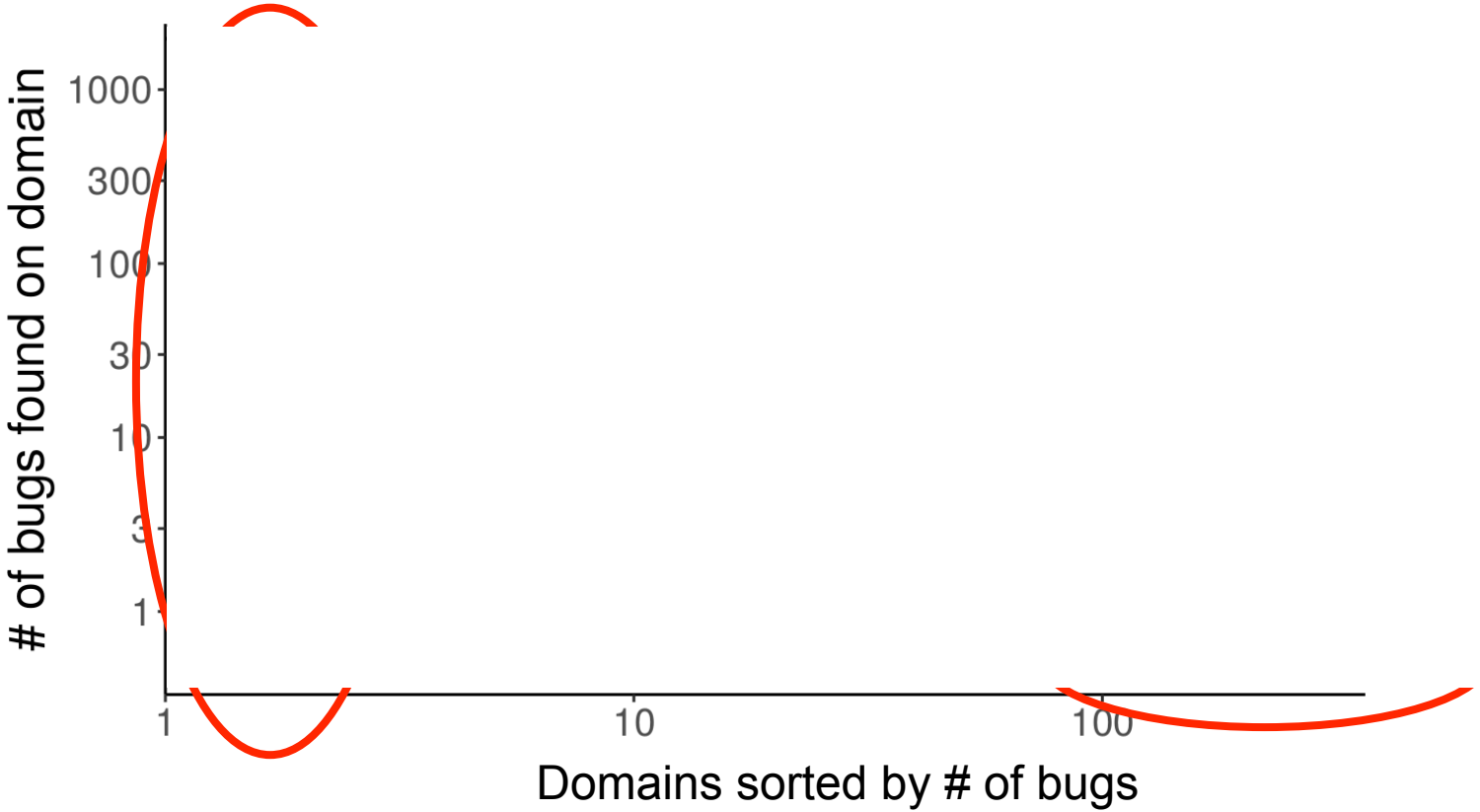
How we confirm potentially vulnerable flows



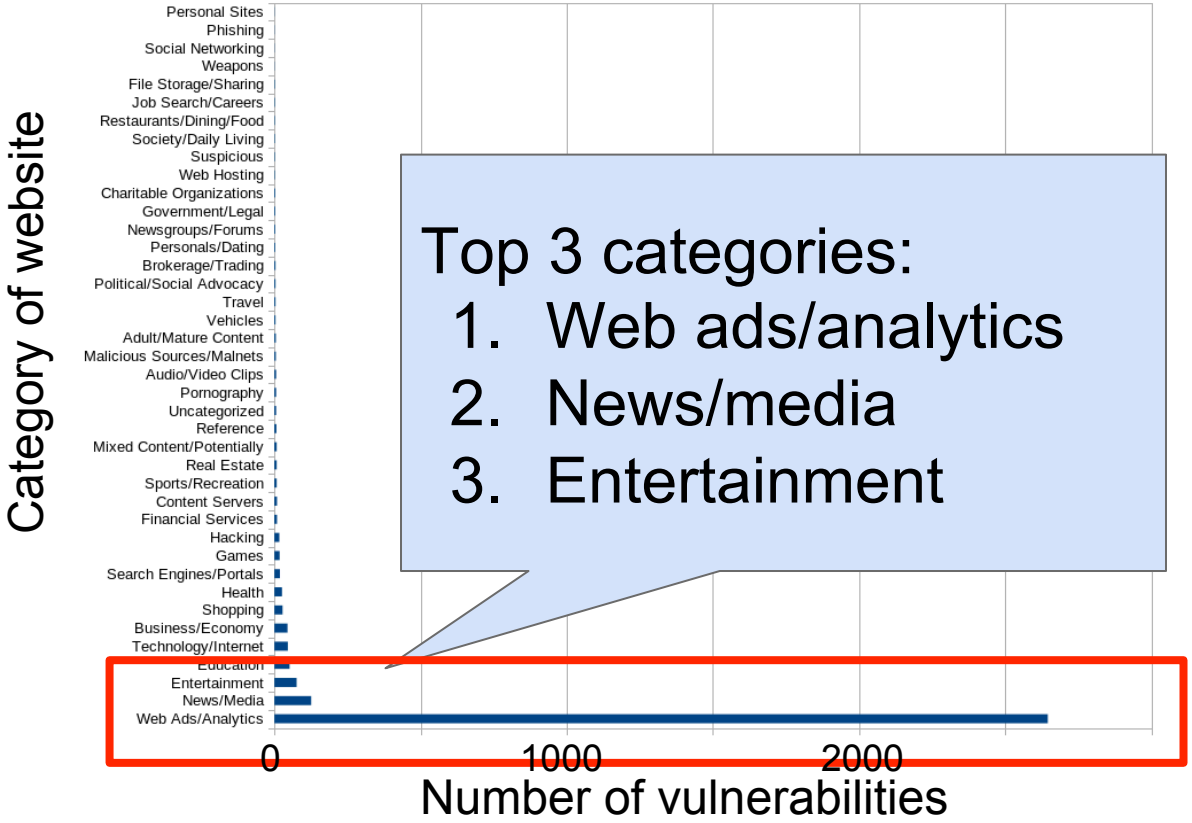
Total: **3,219** unique confirmed vulnerable flows

83% more confirmed vulnerabilities using new in-parameter method

How are vulnerabilities distributed across domains?



How are vulnerabilities distributed by category?



What is causing the vulnerabilities?

- Simple concatenation without effort to sanitize data

```
document.write('<a href="' + document.location + '">Link</a>');
```

- Custom HTML templating code

```
'<a href="%s">Link</a>'
```

- Ad-hoc sanitization

```
if (markup.indexOf("<script>") != -1) ...
```

Have things changed over time?

- Using same methodology as past experiment
- More flows per page: 92.6 vs. 48.5
- Larger ratio of vulnerabilities per page: 0.039 vs. 0.012
- Larger fraction of flows vulnerable: 0.04% vs. 0.03%

Prior work 5 years ago [1]

Trend towards more DOM XSS vulnerabilities

[1] Lekies et al. 25 million flows later - large scale detection of DOM XSS. CSS ‘13.

Our contributions

1. Improved methodology for detecting DOM XSS
2. Studied prevalence of DOM XSS in real world
3. **Examined whether static analysis tools help**

Can static analysis tools help?

What we did:

- Sampled confirmed vulnerabilities
- Checked if they are found by some off-the-shelf tools

No tool found more than 10% of vulnerabilities we tested

- Burp Suite found 10% and had 0% false positives, and found other bugs
- Other tools had high FP rate (95%)

Toward Detecting and Preventing DOM Cross-Site Scripting

- Improved measurement methodology for DOM XSS vulnerabilities
- Gained insight into causes and distribution of vulnerabilities
- Found that DOM XSS vulnerabilities may be increasing
- Showed that static analysis tools likely do not find many vulnerabilities

`github.com/wrmelicher/ChromiumTaintTracking`

William Melicher, Anupam Das, Mahmood Sharif, Lujo Bauer, Limin Jia
{billy, anupamd, msharif, lbauer, liminjia}@cmu.edu

Carnegie Mellon University