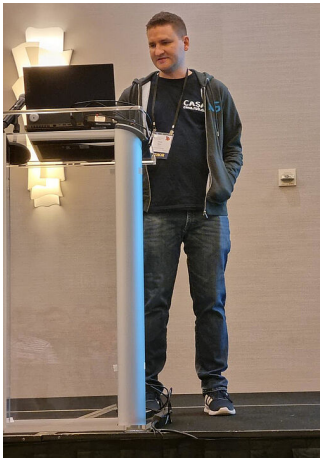

# Parse Me Baby One More Time: Bypassing HTML Sanitizer via Parsing Differentials

Speaker: David Klein

# About Me



- PhD Candidate
- Research interests:
  - Web Security
  - Privacy
  - Application Security

IAS | INSTITUTE FOR APPLICATION SECURITY

CASA
CYBER SECURITY IN THE AGE OF LARGE-SCALE ADVERSARIES

CAROLO-WILHELMINA BRAUNSCHWEIG
Technische Universität Braunschweig

# Cross Site Scripting (XSS)

## Client-Side

```
document.write(location.hash);
```

## Server-Side

```
<?php
echo $_GET["name"];
```

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User Input

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**Such Code Patterns Are Everywhere!**

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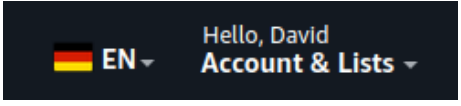
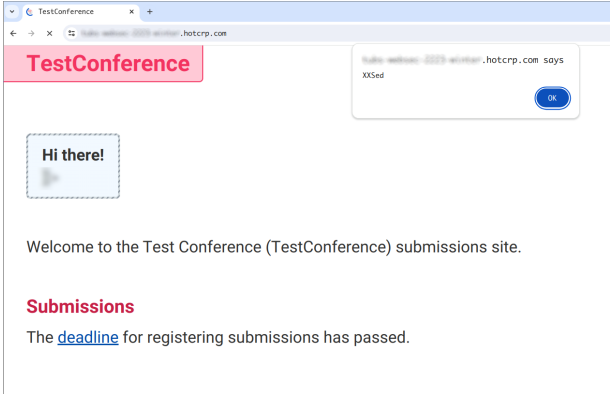


# Everywhere?


TestConference
.hotcrp.com
TestConference
.hotcrp.com says
XXSed
OK
Hi there!
Welcome to the Test Conference (TestConference) submissions site.
Submissions
The deadline for registering submissions has passed.

# Detecting XSS

## Client-Side

- Dynamic Taint Tracking!
  - A taint browser

Project Foxhound

## Server-Side

- Less clear
- SAST? DAST? Linter?

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- This is called **sanitization**

# Sanitization to Prevent XSS

- Simply remove or change dangerous parts from the input
  - Allow formatting tags to pass through, but remove everything dangerous
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- This is called **sanitization**

**Definition: Sanitizer**

Function taking arbitrary input and returns a safe value

- The output shall resemble the input
  - ⇒ I.e., perserve benign parts

# My journey towards this research

- Researching people rolling their own sanitizers
- E.g., trying to filter HTML with regular expressions

```
function f(v) {
  return v.replace(/'/g, "").replace(/\(/g, "")
  .replace(/\)/g, "").replace(/alert/g, "");
```

How not to sanitize HTML

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How not to sanitize HTML

- My takeaway: Use sanitizers relying on a real HTML parser
- I.e., most server-side sanitizers

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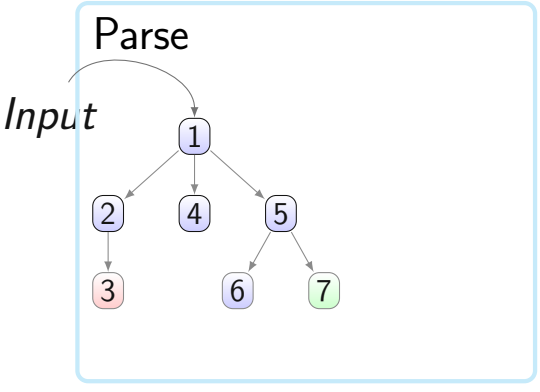
How not to sanitize HTML

- My takeaway: Use sanitizers relying on a real HTML parser
- I.e., most server-side sanitizers
- But does that really help?

# Sanitization: Workflow

*Input*

# Sanitization: Workflow



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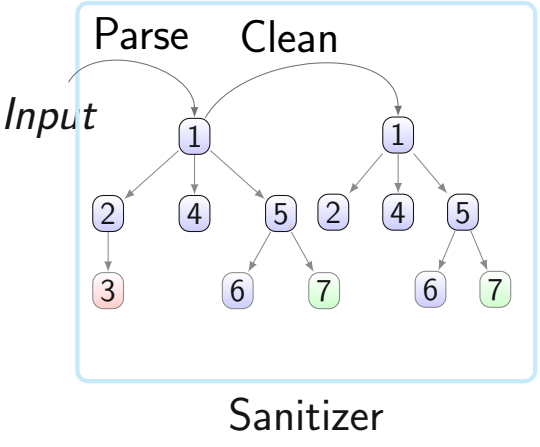

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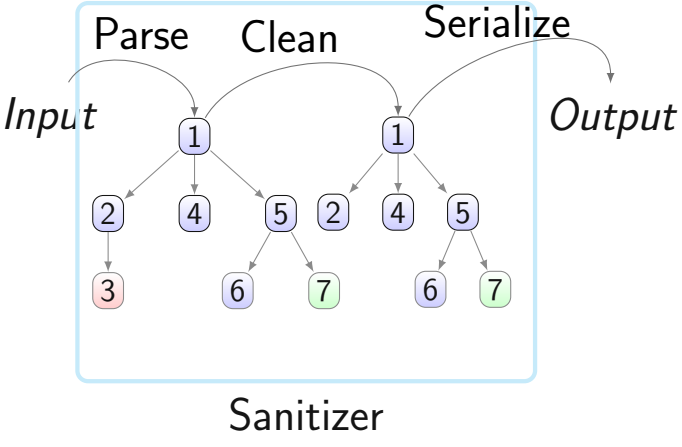

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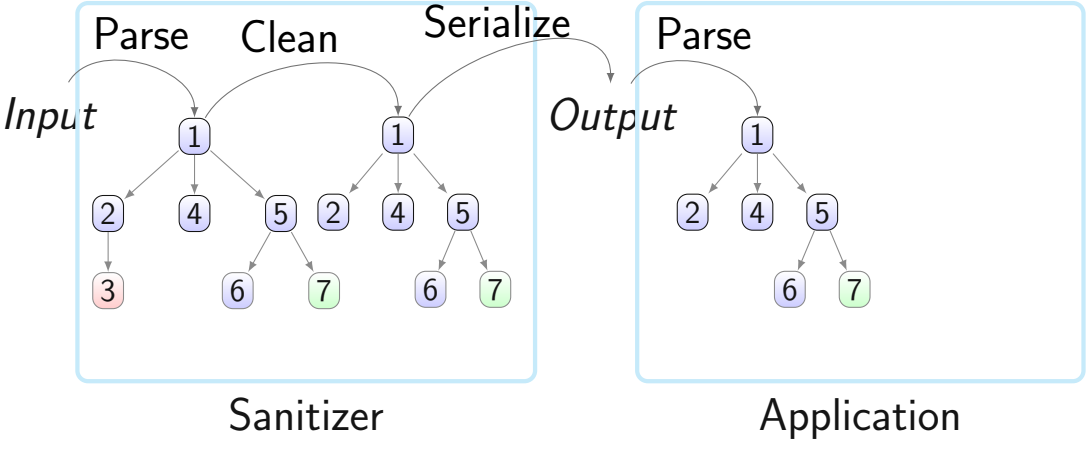

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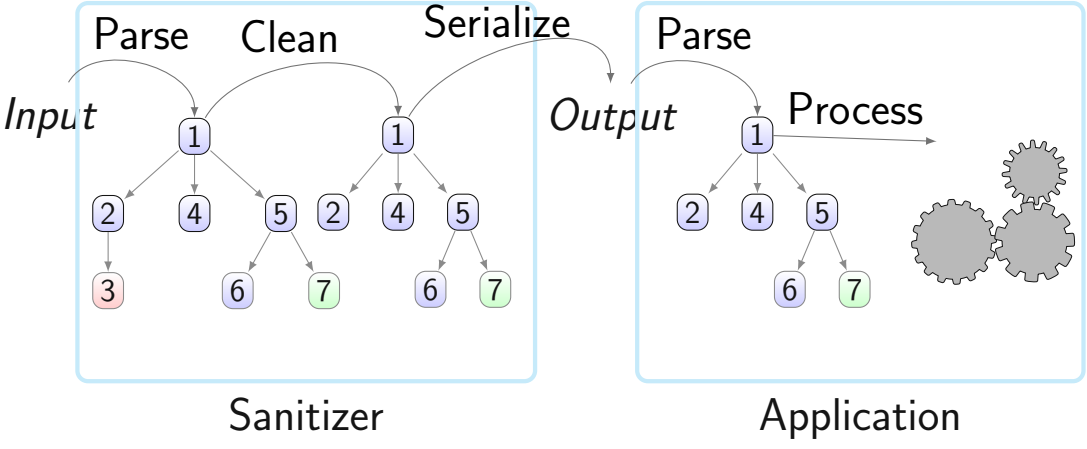
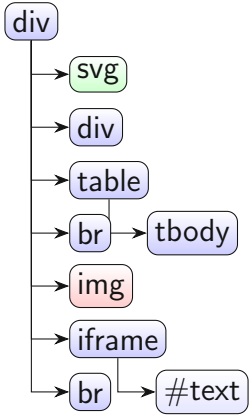


# HTML Parsing Complexities

**HTML Code** → Parsed into → **DOM Tree**

```
<div>
  <svg>...</svg>
  <table>
    <div>
      <tbody></tbody>
    </div>
  </table>
  <br>
    <img src=x onerror=f()>
    <style>
      Te</div>xt
    </style>
  </br>
</div>
```



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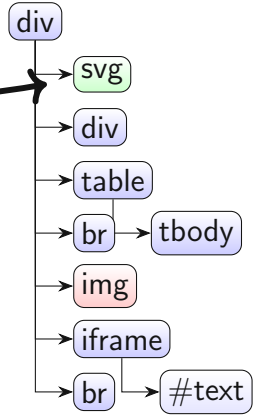
Change to SVG parser



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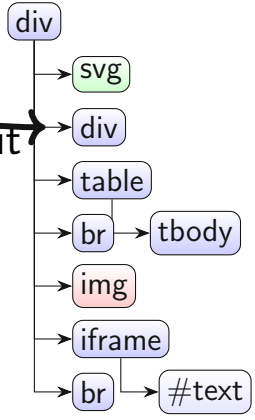
Repair broken input



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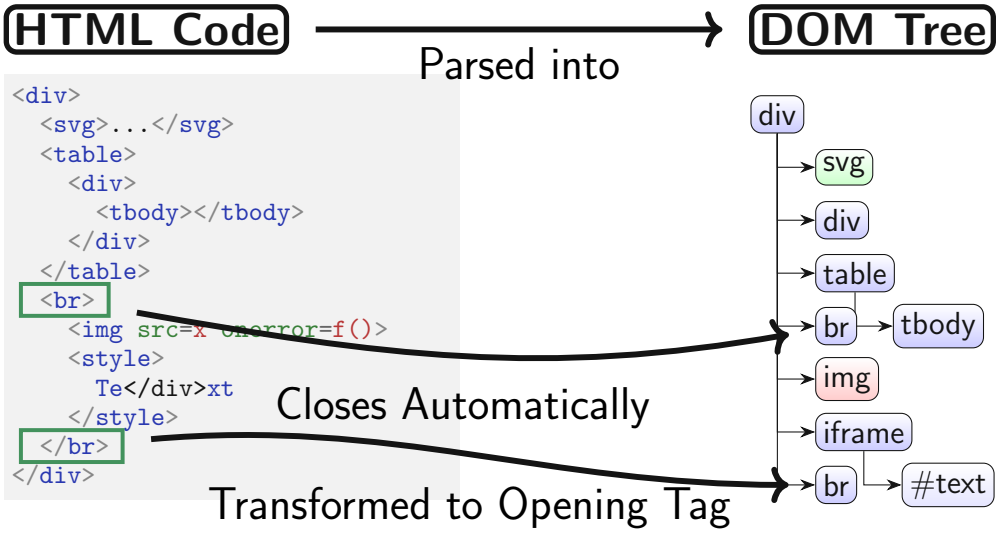

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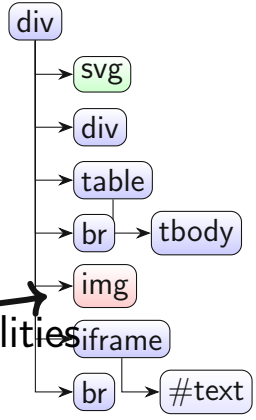
```

Script execution capabilities



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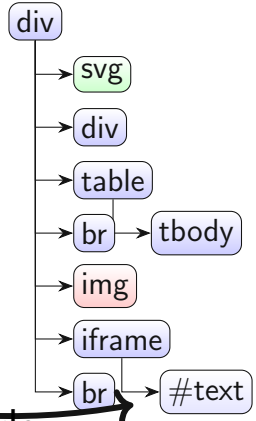
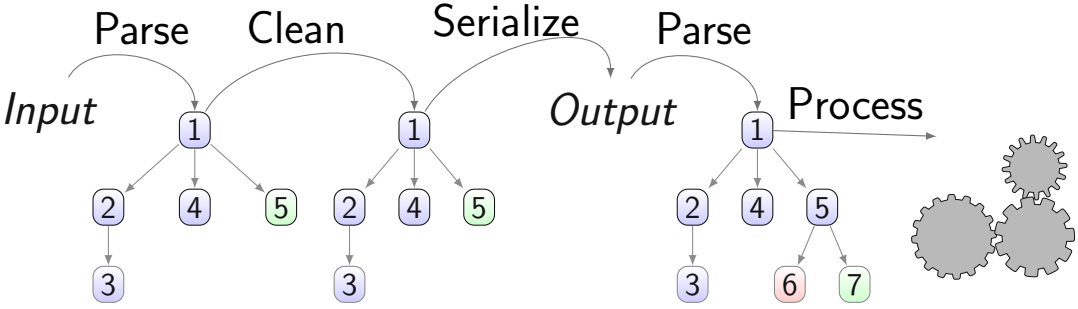



Different Parsing Mode

# Sanitization: Parsing Differential



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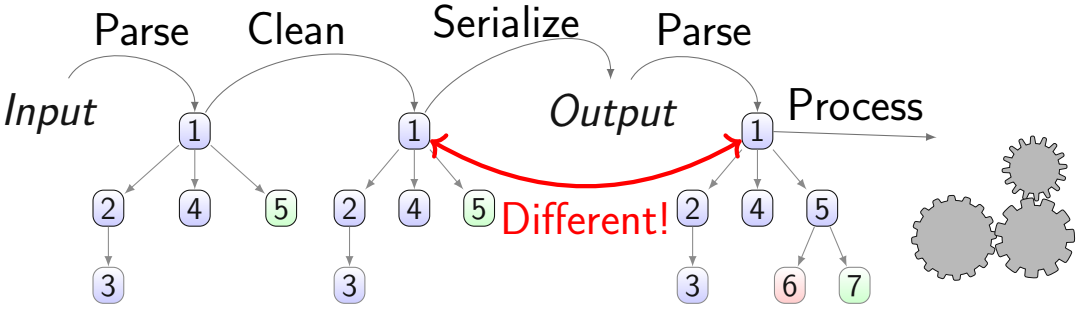

# Parsing Differential to XSS

Payload: `<select><iframe><script>payload()</script>`

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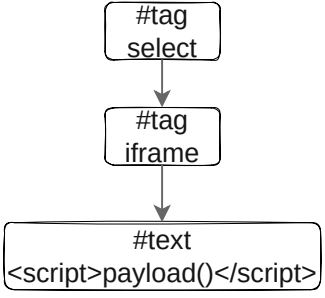
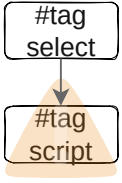
## Parsed by Caja




## Parsed by Chrome



# Root Cause

### 4.8.5 The `iframe` element

**Categories:**

Flow content.
Phrasing content.
Embedded content.
Interactive content.
Palpable content.

**Contexts in which this element can be used:**

Where embedded content is expected.

**Content model:**

Nothing.

# Root Cause

**The "nothing" content model:**

. . . the element must contain no Text nodes (other than inter-element whitespace) and no element nodes.

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- However, the parsing specification disagrees: content of `iframe` shall be parsed as text!

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⇒ Inconsistency in the spec! One parsing quirk we identified

# Root Cause

**The "nothing" content model:**

...the element must contain no Text nodes (other than inter-element whitespace) and no element nodes.

Results in `iframe` element with payload as textual content. No code execution!

```
div.innerHTML = `<iframe><img src=x onerror=alert(1)>`;
```

# Root Cause

**The "nothing" content model:**

> ...the element must contain no Text nodes (other than inter-element whitespace) and no element nodes.

- However, the parsing specification disagrees:

⇒ Inconsistency in the spec! One parsing quirk we identified

- So the sanitizer is actually correct, but...

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- However, the parsing specification disagrees:

⇒ Inconsistency in the spec! One parsing quirk we identified

- So the sanitizer is actually correct, but...

? Where has the `iframe` gone?

# The Missing iframe

Recall the payload:

```
<select><iframe><script>payload()</script>
```

# The Missing `iframe`

Recall the payload:

```
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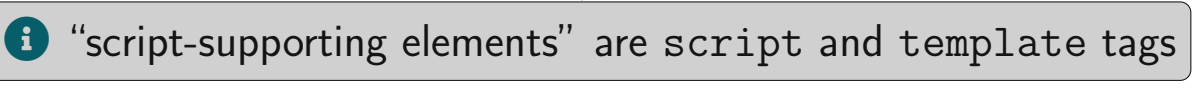
**The `select` Element**

**Content model:**

*Zero or more `option`, `optgroup`, and script-supporting elements.*



# The Missing `iframe`

Recall the payload:

```
<select><iframe><script>payload()</script>
```

**The `select` Element**

**Content model:**

*Zero or more `option`, `optgroup`, and script-supporting elements.*

⇒ An `iframe` can't be a child of `select`!

- So Chrome simply drops it

# Who Uses Google Caja?

- Google has deprecated Caja 5y+ ago
- That does not stop others from using it, however
- 

- 

# MutaGen

- Goal: Find Parsing Differentials to bypass HTML sanitizers

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**MutaGen: HTML payload generator**

Generate HTML that is difficult to parse

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Generate HTML that is difficult to parse

$\Rightarrow$ It *mutates* during parsing

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- Goal: Find Parsing Differentials to bypass HTML sanitizers

**MutaGen: HTML payload generator**

Generate HTML that is difficult to parse

⇒ It *mutates* during parsing

- Important to keep in mind: HTML parsing never fails!

⇒ Garbage in, DOM out

Simplified Payload Generation and Serialization.

**Generation**

**Serialization**

Simplified Payload Generation and Serialization.

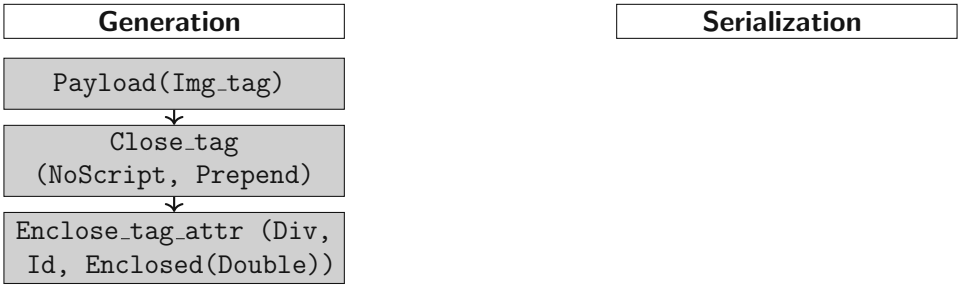
**Generation**

```
Payload(Img_tag)
```

**Serialization**

Simplified Payload Generation and Serialization.

Simplified Payload Generation and Serialization.



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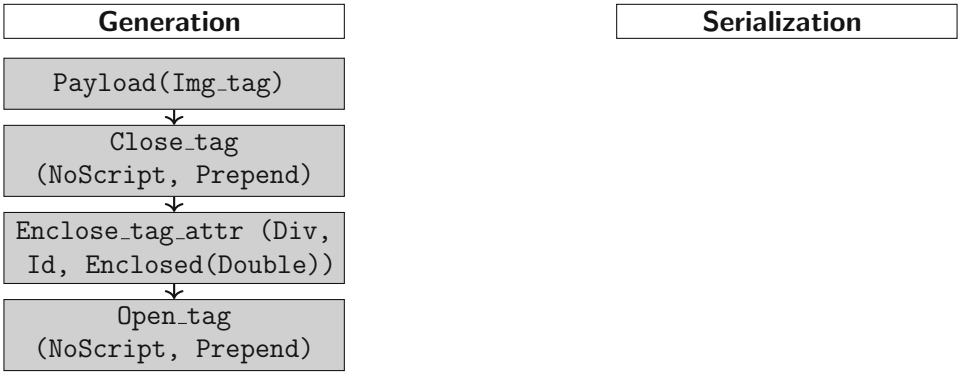

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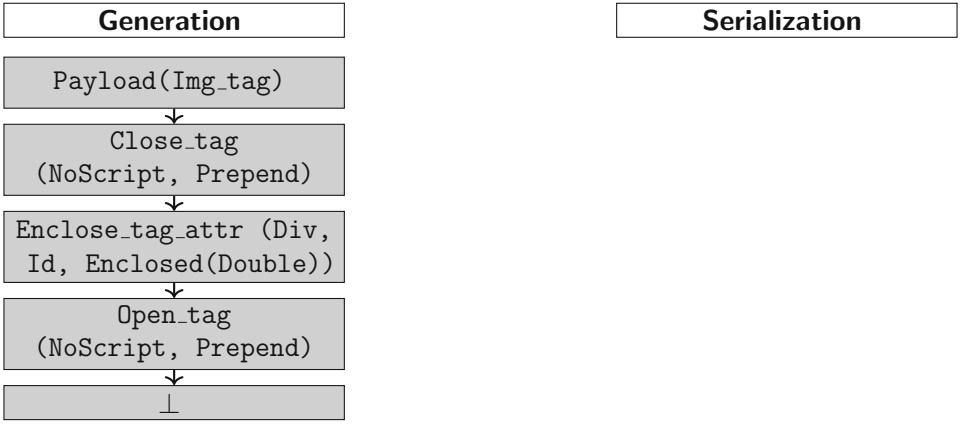

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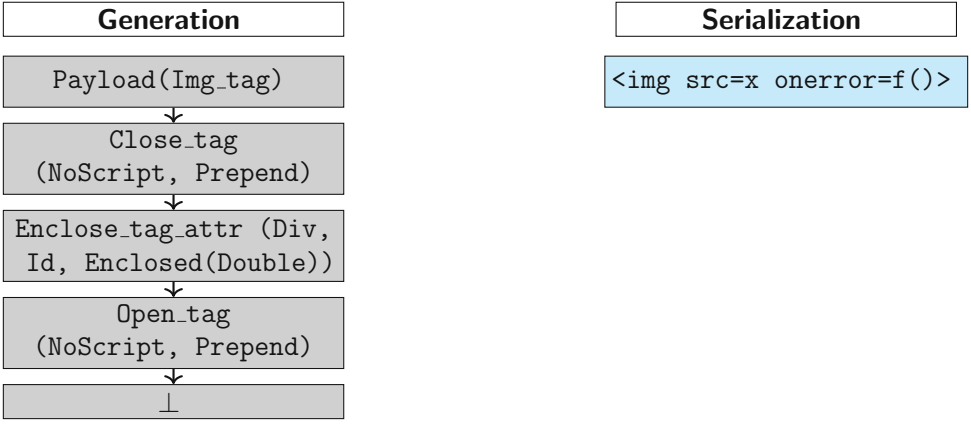

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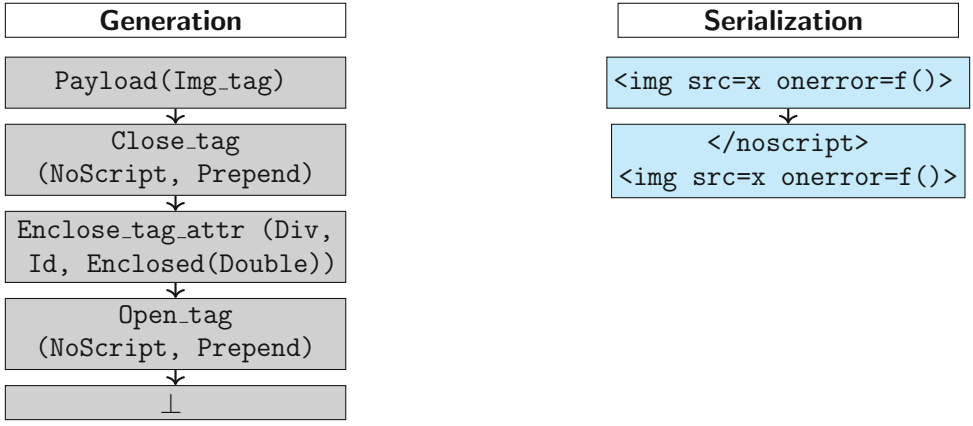

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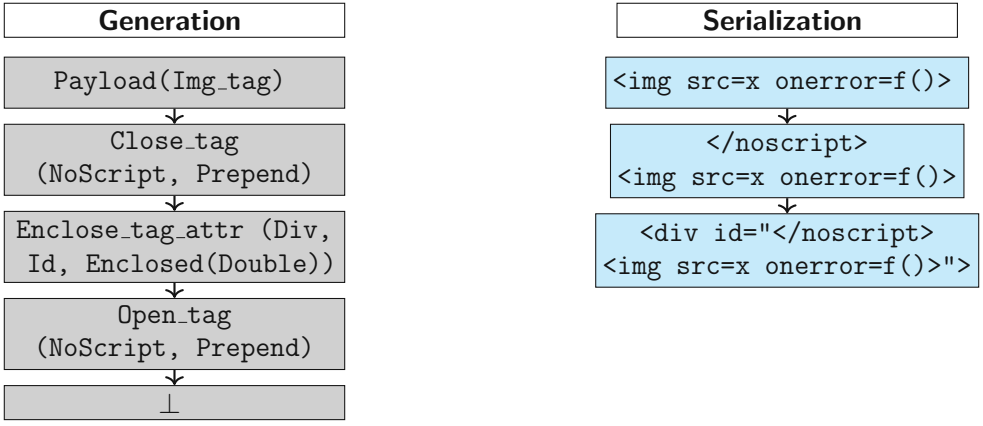

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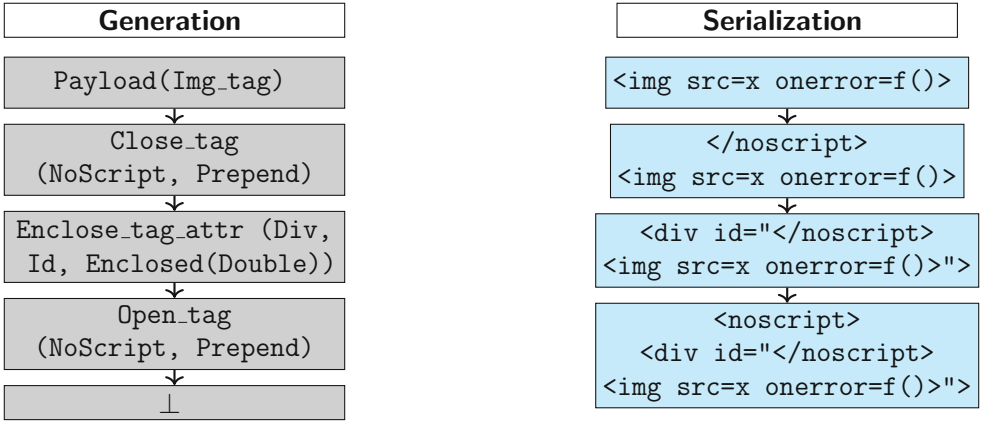

# Parsing Differential in the Wild

⇒ 11 sanitizers across five programming languages.

- Java, JavaScript, PHP, Ruby, and .NET

# Parsing Differential in the Wild

| Name | Total Downloads | Language | Vulns. |
|---|---|---|---|
| DOMPurify | 399 001 216 | JavaScript | **2** |
| google caja | 41 305 997 | | † |
| sanitize-html | 276 882 692 | | **0** |
| HtmlSanitizer | 19 800 000 | .NET | **2** |
| HtmlRuleSanitizer | 306 100 | | **2** |
| Typo3 html-sanitizer | 1 950 185 | PHP | **4** |
| rgrove/sanitize | 60 928 006 | Ruby | **1** |
| loofah | 396 621 861 | | **0** |
| AntiSamy | No data available | Java | **3** |
| JSoup | | | **2** |
| Total | Over 1 Billion | | **16** |

# Running MutaGen

During the first test, after like 10s, I was greeted by:

```
PHP Warning: Uninitialized string offset
26 in html5/src/HTML5/Parser/Scanner.php
on line 108
```

A target nobody has fuzzed before, i.e., good target!

# Parsing Differential in the Wild

⇒ 11 sanitizers across five programming languages.

- Java, JavaScript, PHP, Ruby, and .NET
- **All** have functional deficiencies
  - Average parsing similarty compared to browsers is below 60%
  - Even if secure, sanitizers mangle input by parsing incorrectly
- 16 new bypass vectors across 9 of them
  - And one bypass vector in a sanitizer not directly tested by us

# Parsing Accuracy #2

What parser processes the output? Fragment or Document?

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I.e., `innerHTML` assignment or `document.write`

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What parser processes the output? Fragment or Document?

I.e., `innerHTML` assignment or `document.write`

Which browser is the result displayed in?

# Browser Parsing Differentials

Payload:

```
<svg><embed><iframe><desc><img src=x onerror=f()>
```

# Browser Parsing Differentials

Payload:

```
<svg><embed><iframe><desc><img src=x onerror=f()>
```

**Does this execute code?**

# Browser Parsing Differentials

Payload:

```
<svg><embed><iframe><desc><img src=x onerror=f()>
```

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Payload:

```
<svg><embed><iframe><desc><img src=x onerror=f()>
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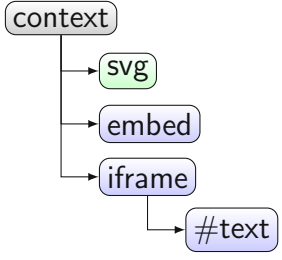


(a) Chrome parsing result

# Browser Parsing Differentials

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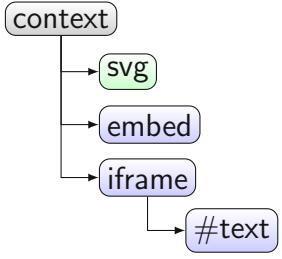
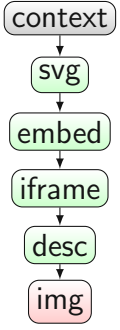



(a) Chrome parsing result




(b) Firefox parsing result

⇒ Perfectly accurate sanitizer is impossible

# DOMPurify to Aid Exploitation

Input: `<svg><style>&lt;img src=x onerror=f()&gt;<keygen>`

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⇒ Sanitizers can help to bypass other security measures!

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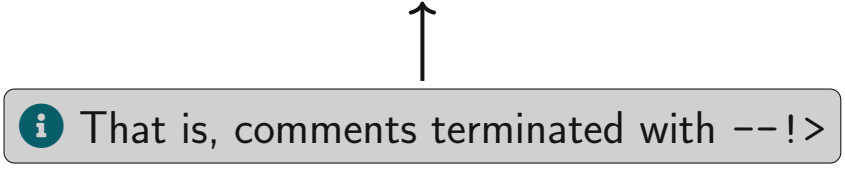

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Sanitizing inputs containing `noscript` impossible!

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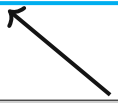

Not correctly switching between different parsers.
Recall the Firefox bug shown earlier!

# Common Problems

- Handling comments is surprisingly error prone...
  - Three sanitizers do not detect *closing bang comments*
- `noscript` is impossible to get right: four bypasses
  - Parsing depends on browser internal state, not exposed to sanitizers
- Namespace confusion bugs are common
- Some fundamental parsing bugs too!

# Thank you!

## If you want to chat Web Security please get in touch!

### Contact

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leinea
twitter.com/ncd_leen

# Black Hat Sound Bytes

**Server-Side HTML Sanitization is Insecure, Broken or Both**

**Parse $\rightarrow$ Serialize $\rightarrow$ Parse is always prone to parsing differentials**

**A New Vision of Sanitization is Required to Get us Out of This Mess**