
# Writing robust client-side code using Modern JavaScript

# or

## JavaScript: the Good, the Bad, the Strict and the Secure Parts

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@tvcutsem

# Talk Outline

- This talk is about:
  - The JavaScript language proper
  - Language dialects and features to enable or improve security
- This talk is not about:
  - Security exploits involving JavaScript, or how to avoid specific exploits (e.g. XSS attacks)

# Talk Outline

- Part I: 20 years of JavaScript
- Part II: the Good and the Bad parts
- Part III: ECMAScript 5 and Strict Mode
- Part IV: ECMAScript 6
- Part V: Caja and Secure ECMAScript (SES)

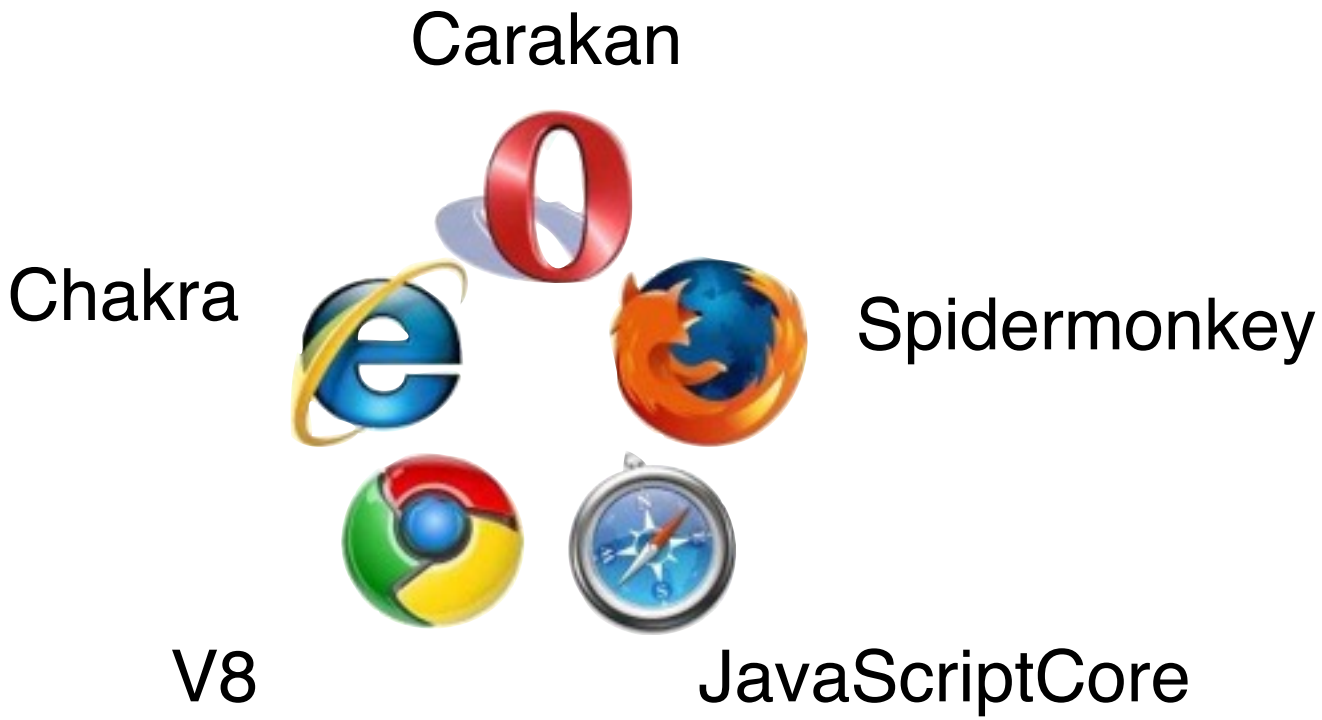
# Part I: 20 years of Javascript

# JavaScript's origins

- Invented by Brendan Eich in 1995, to support client-side scripting in Netscape Navigator
- First called *LiveScript*, then *JavaScript*, then standardized as *ECMAScript*
- Microsoft "copied" JavaScript in IE JScript, "warts and all"

*Brendan Eich,*
*Inventor of JavaScript*

# ECMAScript: “Standard” JavaScript



# ECMAScript: “Standard” JavaScript

~~Carakan~~ V8

Chakra

Spidermonkey

V8

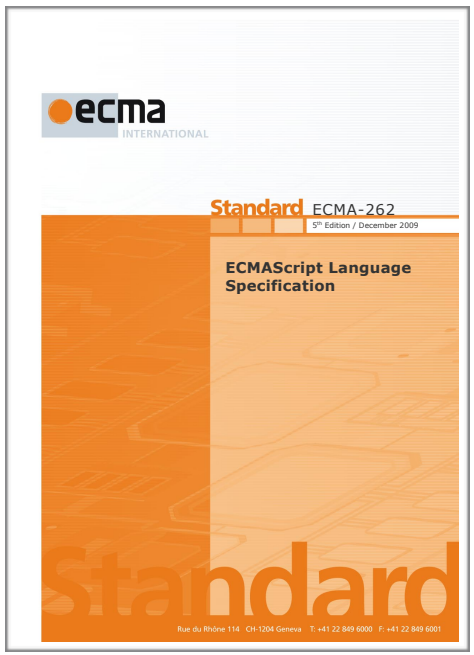
JavaScriptCore

*(170.000+ npm packages!)*

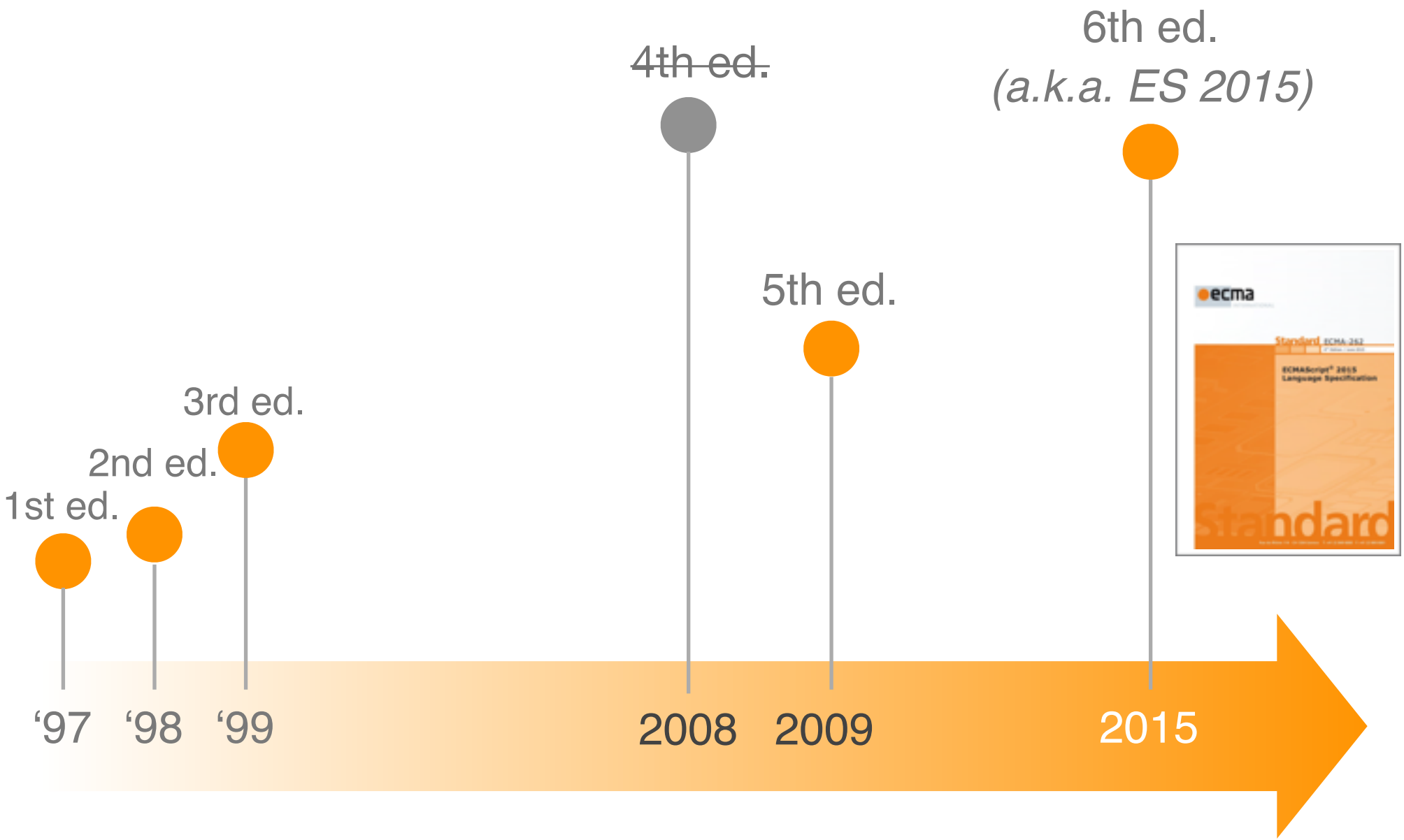
# TC39: the JavaScript “standardisation committee”

- Representatives from major Internet companies, browser vendors, web organisations, popular JS libraries and academia. Meets bi-monthly.
- Maintains the ECMA-262 specification.
- The spec is a handbook mainly intended for language implementors.


*Allen Wirfs-Brock,*
*ECMA-262 5th & 6th ed. editor*



# A brief history of the ECMAScript spec



# Part II: the **Good** and the **Bad** parts

# The world's most misunderstood language


*Douglas Crockford,*
*Inventor of JSON*

See also: "JavaScript: The World's Most Misunderstood Programming Language" by Doug Crockford at http://www.crockford.com/javascript/javascript.html

# Good Parts: Functions

- Functions are first-class, may capture lexical variables (closures)

```
var add = function(a,b) {
  return a+b;
}

add(2,3); // 5
```

```
function accumulator(s) {
  return function(n) {
    return s += n;
  }
}

var a = accumulator(0);
a(1); // 1
a(2); // 3
```

```
button.addEventListener('click', function (event) { … });
```

# Good Parts: Objects

- No class declaration needed, literal syntax, arbitrary nesting

```
var bob = {
  name: “Bob”,
  dob: {
    day: 15,
    month: 03,
    year: 1980
  },
  address: {
    street: “Main St.”,
    number: 5,
    zip: 94040,
    country: “USA”
  }
};
```

# Good Parts: combining objects and functions

- Functions can act as object constructors and methods

```
function makePoint(i,j) {
  return {
    x: i,
    y: j,
    toString: function() {
      return '('+ this.x +','+ this.y +')';
    }
  };
}

var p = makePoint(2,3);
var x = p.x;
var s = p.toString();
```

# The Good Parts


- Functions as first-class objects
- Dynamic objects with prototype-based inheritance
- Object literals
- Array literals

# The Bad Parts


- Global variables (no modules)
- `with` statement (breaks lexical scoping)
- Implicit type coercion (‘’ == 0)
- No integers (all numbers are IEEE 754 double-precision floats)
- “var hoisting”: variables *appear* block-scoped but are really function-scoped
- …

# Part III: ECMAScript 5 and **Strict** Mode

# ECMAScript 5 Themes

- Support for more robust programming
    - Tamper-proof objects
    - Strict mode

# ECMAScript 5 Themes

- Support for more robust programming
  - **Tamper-proof objects**
  - Strict mode

# Tamper-proof Objects: motivation

- Objects are *mutable* bags of properties
- Cannot protect an object from modifications by its clients
- Client code may *monkey-patch* shared objects
  - Powerful: allows to fix bugs or extend objects with new features
  - Brittle: easily leads to conflicting updates
  - Insecure: third-party scripts can deliberately modify shared objects

# Tamper-proof Objects

```
var point =
  { x: 0,
    y: 0  };


Object.preventExtensions(point);
point.z = 0; // error: can't add new properties


Object.seal(point);
delete point.x; // error: can't delete properties


Object.freeze(point);
point.x = 7; // error: can't assign properties
```

# ECMAScript 5 Themes

- Support for more robust programming
  - Tamper-proof objects
  - **Strict mode**

# Ecmascript 5 Strict mode

- Safer, more robust, subset of the language
- Why?
  - No silent errors
  - True static scoping rules
  - No global object leakage

# Ecmascript 5 Strict: no silent errors

- Runtime changes (fail silently outside of strict mode, throw an exception in strict mode)

```
function f() {
  "use strict";
  var xfoo;
  xFoo = 1;  // error: assigning to an undeclared variable
}
```

```
"use strict";
var p = Object.freeze({x:0,y:0});
delete p.x; // error: deleting a property from a frozen object
```

# Ecmascript 5 Strict: true static scoping

- ECMAScript 5 non-strict is not statically scoped
- Four violations, all fixed in strict mode:
  - `with (obj) { x }` statement
  - `delete x;` // may delete a statically visible var
  - `eval('var x = 8');` // may add a statically visible var
  - Assigning to a non-existent variable creates a new global variable

    ```
    function f() { var xfoo; xFoo = 1; }
    ```

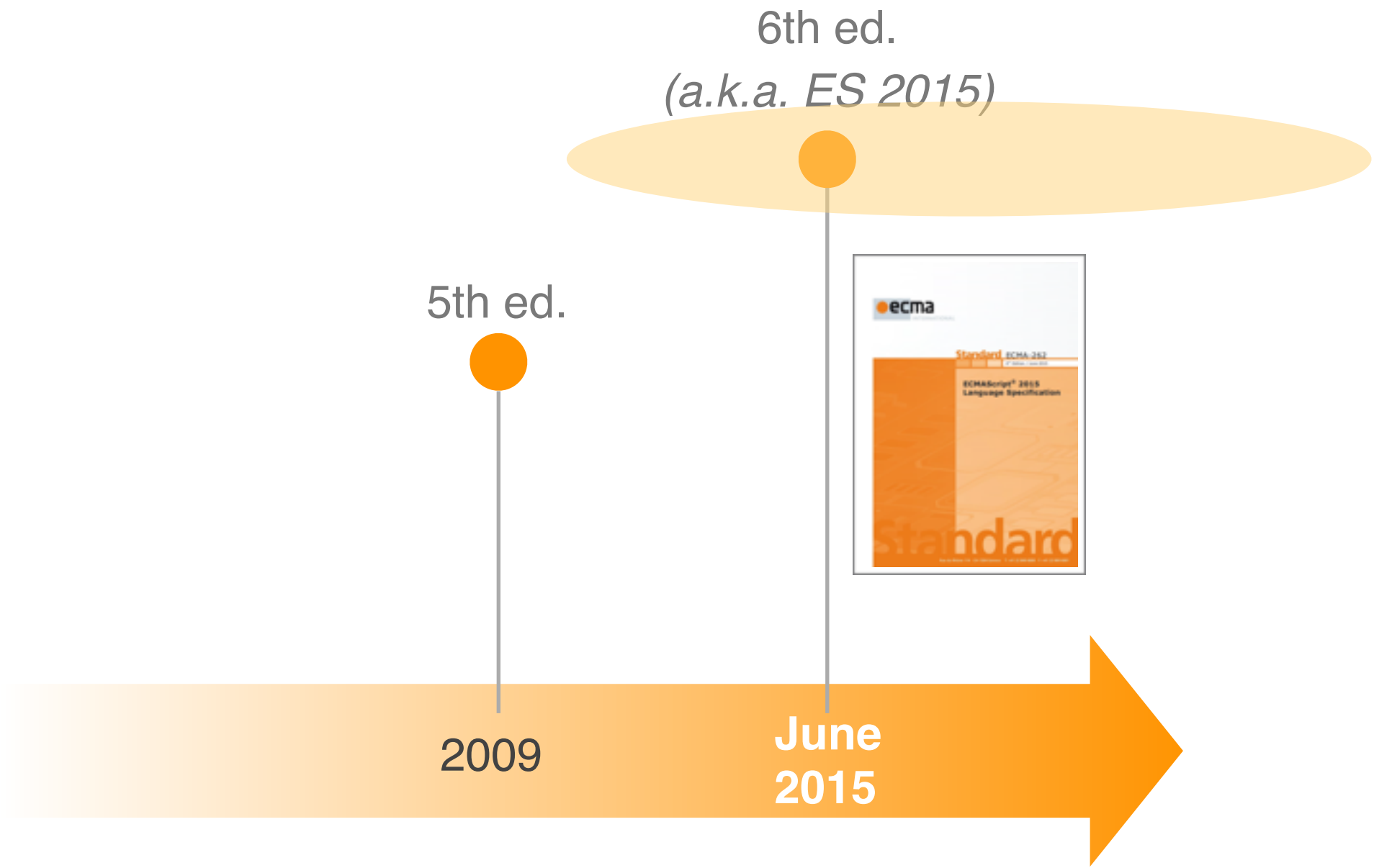
# Part IV: ECMAScript 6

# ECMAScript 6

- Many new additions (too many to list here *). Big-ticket items:
  - Modules
  - Classes
  - Control flow abstractions (iterators, generators, promises)
  - Proper block scoping (let)
  - …

* see https://github.com/lukehoban/es6features for an overview of ES6 features

# ECMAScript 6: timeline

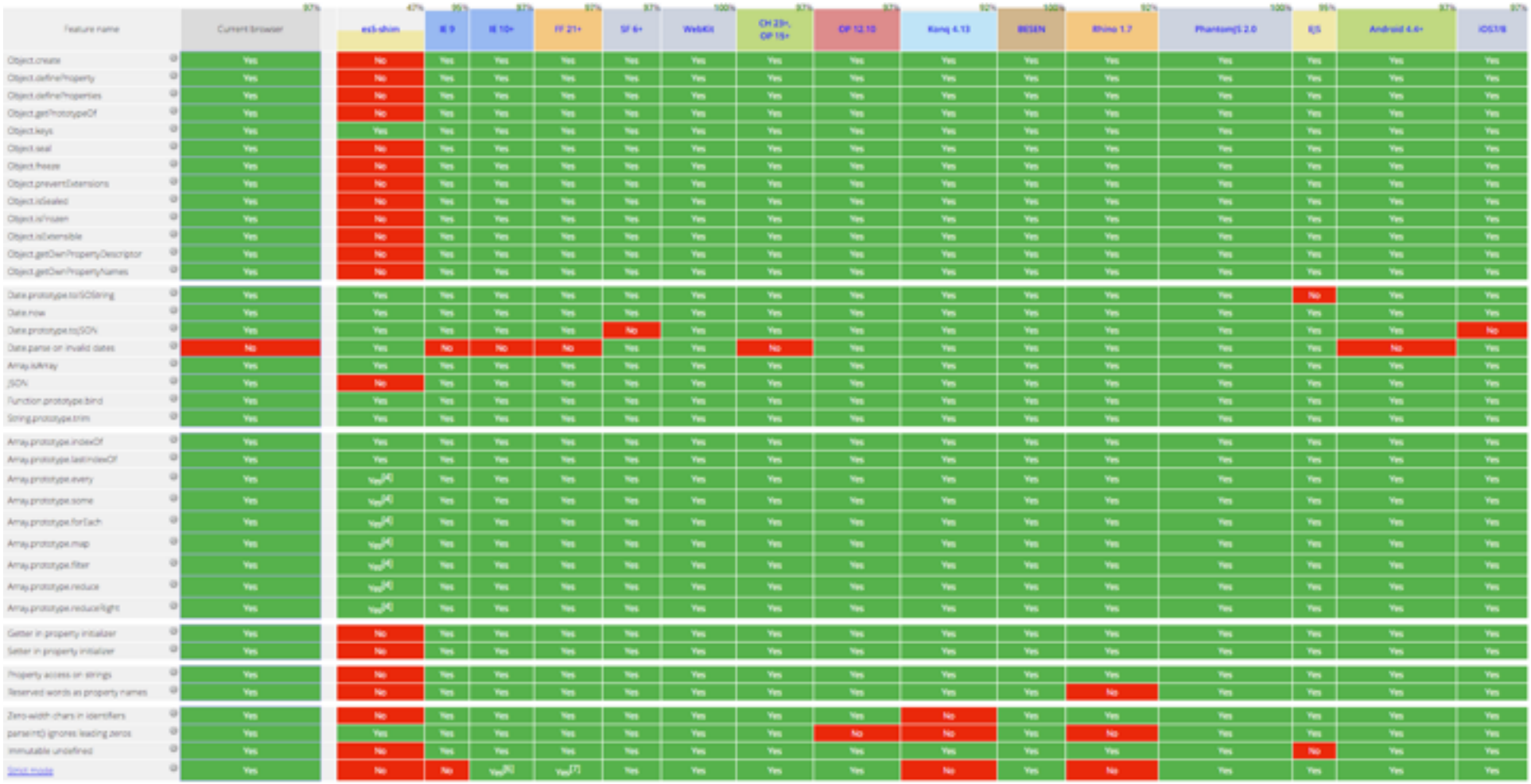


# ECMAScript 6 support (february 2016)

| Feature name | Current browser | Traceur | Babel + core-js[1] | Closure | TypeScript + core-js | es6-shim | IE 11 | Edge 12[3] | Edge 13[3] | FF 38 ESR | FF 44 | FF 45 | CH 48, OP 35[2] | CH 49, OP 36[2] | CH 50, OP 37[2] | SF 6.1, SF 7 | SF 7.1, SF 8 | SF 9 | WK | KQ 4.14[4] | PJS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Optimisation** | | | | | | | | | | | | | | | | | | | | | |
| proper tail calls (tail call optimisation) | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 2/2 | 0/2 | 0/2 |
| **Syntax** | | | | | | | | | | | | | | | | | | | | | |
| default function parameters | 6/7 | 4/7 | 4/7 | 4/7 | 4/7 | 0/7 | 0/7 | 0/7 | 0/7 | 3/7 | 4/7 | 4/7 | 0/7 | 7/7 | 7/7 | 0/7 | 0/7 | 0/7 | 7/7 | 0/7 | 0/7 |
| rest parameters | 5/5 | 4/5 | 3/5 | 2/5 | 3/5 | 0/5 | 0/5 | 5/5 | 5/5 | 4/5 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 0/5 | 0/5 | 0/5 | 5/5 | 0/5 | 0/5 |
| spread (...) operator | 15/15 | 15/15 | 13/15 | 12/15 | 4/15 | 0/15 | 0/15 | 12/15 | 15/15 | 15/15 | 15/15 | 15/15 | 15/15 | 15/15 | 15/15 | 0/15 | 5/15 | 9/15 | 10/15 | 0/15 | 0/15 |
| object literal extensions | 6/6 | 6/6 | 6/6 | 4/6 | 6/6 | 0/6 | 0/6 | 6/6 | 6/6 | 6/6 | 6/6 | 6/6 | 6/6 | 6/6 | 6/6 | 0/6 | 1/6 | 5/6 | 6/6 | 0/6 | 0/6 |
| for..of loops | 7/9 | 9/9 | 9/9 | 6/9 | 3/9 | 0/9 | 0/9 | 6/9 | 7/9 | 7/9 | 7/9 | 7/9 | 7/9 | 7/9 | 7/9 | 0/9 | 2/9 | 8/9 | 9/9 | 0/9 | 0/9 |
| octal and binary literals | 4/4 | 2/4 | 4/4 | 2/4 | 4/4 | 2/4 | 0/4 | 4/4 | 4/4 | 4/4 | 4/4 | 4/4 | 4/4 | 4/4 | 4/4 | 0/4 | 0/4 | 4/4 | 4/4 | 0/4 | 0/4 |
| template strings | 5/5 | 4/5 | 4/5 | 3/5 | 3/5 | 0/5 | 0/5 | 4/5 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 0/5 | 0/5 | 5/5 | 5/5 | 0/5 | 0/5 |
| RegExp 'y' and 'u' flags | 2/4 | 2/4 | 2/4 | 0/4 | 0/4 | 0/4 | 0/4 | 2/4 | 4/4 | 2/4 | 2/4 | 2/4 | 0/4 | 2/4 | 2/4 | 0/4 | 0/4 | 0/4 | 0/4 | 0/4 | 0/4 |
| destructuring, declarations | 21/22 | 20/22 | 21/22 | 18/22 | 14/22 | 0/22 | 0/22 | 0/22 | 0/22 | 19/22 | 19/22 | 19/22 | 0/22 | 21/22 | 21/22 | 0/22 | 9/22 | 19/22 | 22/22 | 0/22 | 0/22 |
| destructuring, assignment | 0/24 | 23/24 | 24/24 | 15/24 | 18/24 | 0/24 | 0/24 | 0/24 | 0/24 | 20/24 | 21/24 | 21/24 | 0/24 | 23/24 | 23/24 | 0/24 | 12/24 | 21/24 | 24/24 | 0/24 | 0/24 |
| destructuring, parameters | 22/23 | 19/23 | 20/23 | 17/23 | 14/23 | 0/23 | 0/23 | 0/23 | 0/23 | 18/23 | 18/23 | 18/23 | 0/23 | 22/23 | 22/23 | 0/23 | 10/23 | 18/23 | 22/23 | 0/23 | 0/23 |
| Unicode code point escapes | 2/2 | 1/2 | 1/2 | 1/2 | 1/2 | 0/2 | 0/2 | 2/2 | 2/2 | 0/2 | 1/2 | 1/2 | 2/2 | 2/2 | 2/2 | 0/2 | 0/2 | 2/2 | 2/2 | 0/2 | 0/2 |
| new.target | 2/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 0/2 | 1/2 | 0/2 | 2/2 | 2/2 | 2/2 | 2/2 | 2/2 | 0/2 | 0/2 | 0/2 | 1/2 | 0/2 | 0/2 |
| **Bindings** | | | | | | | | | | | | | | | | | | | | | |
| const | 8/8 | 6/8 | 6/8 | 6/8 | 6/8 | 0/8 | 8/8 | 8/8 | 8/8 | 8/8 | 8/8 | 8/8 | 5/8 | 8/8 | 8/8 | 1/8 | 1/8 | 1/8 | 8/8 | 2/8 | 1/8 |
| let | 10/10 | 8/10 | 8/10 | 8/10 | 7/10 | 0/10 | 8/10 | 8/10 | 8/10 | 0/10 | 8/10 | 8/10 | 5/10 | 10/10 | 10/10 | 0/10 | 0/10 | 0/10 | 10/10 | 0/10 | 0/10 |
| block-level function declaration[12] | Yes | Yes | Yes | Yes | No | No | Yes | Yes | Yes | No | No | No | Yes | Yes | Yes | No | No | No | No | No | No |
| **Functions** | | | | | | | | | | | | | | | | | | | | | |
| arrow functions | 13/13 | 11/13 | 9/13 | 11/13 | 9/13 | 0/13 | 0/13 | 9/13 | 13/13 | 8/13 | 11/13 | 13/13 | 11/13 | 13/13 | 13/13 | 0/13 | 0/13 | 0/13 | 13/13 | 0/13 | 0/13 |
| class | 23/23 | 16/23 | 18/23 | 8/23 | 16/23 | 0/23 | 0/23 | 0/23 | 23/23 | 0/23 | 0/23 | 23/23 | 0/23 | 23/23 | 23/23 | 0/23 | 0/23 | 15/23 | 23/23 | 0/23 | 0/23 |
| super | 8/8 | 7/8 | 4/8 | 4/8 | 7/8 | 0/8 | 0/8 | 0/8 | 8/8 | 0/8 | 0/8 | 8/8 | 0/8 | 8/8 | 8/8 | 0/8 | 0/8 | 6/8 | 8/8 | 0/8 | 0/8 |
| generators | 21/25 | 23/25 | 22/25 | 16/25 | 0/25 | 0/25 | 0/25 | 0/25 | 25/25 | 20/25 | 21/25 | 23/25 | 19/25 | 21/25 | 22/25 | 0/25 | 0/25 | 0/25 | 25/25 | 0/25 | 0/25 |
| **Built-ins** | | | | | | | | | | | | | | | | | | | | | |
| typed arrays | 43/46 | 0/46 | 45/46 | 0/46 | 45/46 | 0/46 | 16/46 | 42/46 | 44/46 | 41/46 | 42/46 | 42/46 | 43/46 | 44/46 | 44/46 | 18/46 | 18/46 | 18/46 | 44/46 | 8/46 | 18/46 |
| Map | 16/18 | 13/18 | 18/18 | 0/18 | 18/18 | 14/18 | 7/18 | 15/18 | 17/18 | 14/18 | 16/18 | 17/18 | 16/18 | 16/18 | 16/18 | 0/18 | 10/18 | 17/18 | 18/18 | 0/18 | 0/18 |
| Set | 16/18 | 13/18 | 18/18 | 0/18 | 18/18 | 14/18 | 7/18 | 15/18 | 17/18 | 14/18 | 16/18 | 17/18 | 16/18 | 16/18 | 16/18 | 0/18 | 10/18 | 17/18 | 18/18 | 0/18 | 0/18 |
| WeakMap | 9/10 | 5/10 | 10/10 | 0/10 | 10/10 | 0/10 | 4/10 | 9/10 | 9/10 | 7/10 | 8/10 | 8/10 | 9/10 | 9/10 | 9/10 | 0/10 | 5/10 | 10/10 | 10/10 | 0/10 | 0/10 |

*(Source: Juriy Zaytsev (kangax)*
*http://kangax.github.io/es5-compat-table/es6 )*

# ECMAScript 5 support (october 2015)



*(Source: Juriy Zaytsev (kangax)*
*http://kangax.github.io/es5-compat-table/es5 )*

# ECMAScript 6 compilers

- Compile ECMAScript 6 to ECMAScript 5
- **Babel**: focus on producing readable (as-if hand-written) ES5 code. Supports JSX as well.


- Microsoft **TypeScript**: technically not ES6 but roughly a superset of ES6. Bonus: type inference and optional static typing.

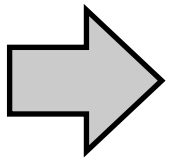
# ECMAScript 6: modules

- Prior to ES6: scripts depend on global variables for linkage

## Bad

```
<script>
var x = 0; // global
var myLib = {
  inc: function() {
    return ++x;
  }
};
</script>


<script>
var res = myLib.inc();
</script>
```



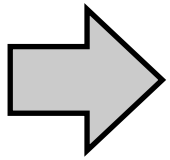
## Better

```
<script>
var myLib = (function(){
  var x = 0; // local
  return {
    inc: function() {
      return ++x;
    }
  };
}());
</script>
```

# ECMAScript 6: modules

- All code inside a module is implicitly opted into strict mode!

```
<script>
var x = 0; // global
var myLib = {
  inc: function() {
    return ++x;
  }
};
</script>
```



```
<script type="module"
        name="myLib">
var x = 0; // local!
export function inc() {
  return ++x;
}
</script>
```

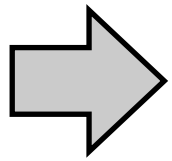
```
<script>
var res = myLib.inc();
</script>
```

```
<script type="module">
import { inc } from 'myLib';
var res = inc();
</script>
```

# ECMAScript 6: modules

- All code inside a module is implicitly opted into strict mode!

```
<script>
var x = 0; // global
var myLib = {
  inc: function() {
    return ++x;
  }
};
</script>
```



```
<script type="module"
        name="myLib">
var x = 0; // local!
export function inc() {
  return ++x;
}
</script>
```

```
<script>
var res = myLib.inc();
</script>
```

```
<script type="module">
import { inc } from 'myLib';
var res = inc();
</script>
```

# ECMAScript 6: modules

- Dynamic module loader API (WHATWG Draft Spec *)

```
System.import("lib/math").then(function(m) {
  alert("2π = " + m.sum(m.pi, m.pi));
});
```

```
// create a sandboxed environment
var loader = new Loader({
  global: wrap(window) // replace ‘console.log’
});
loader.eval("console.log(\"hello world!\");");
```

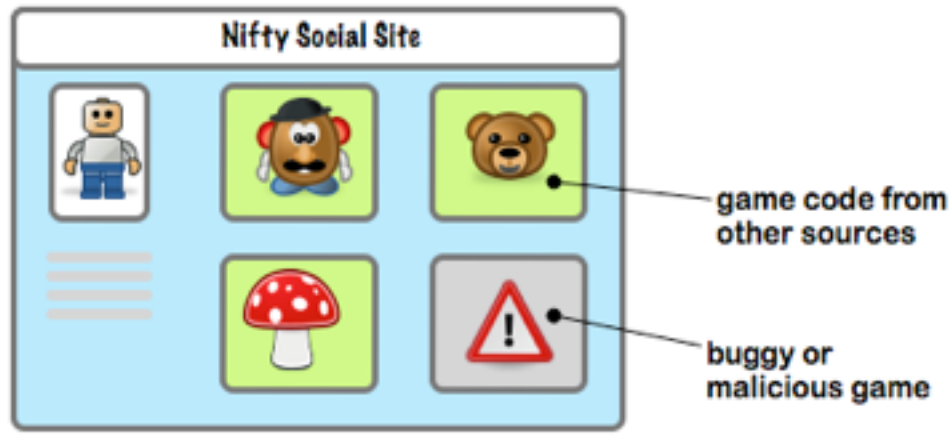
*(Source: https://babeljs.io/docs/learn-es2015/)*

* See http://whatwg.github.io/loader/

# Part V: Caja and **Secure** ECMAScript (SES)

# Caja

- Caja enables the safe embedding of third-party active content inside a single web page
- Secures Google Earth Engine, Google Sites, Google Apps Scripts
- More generally: Gadgets, Mashups:



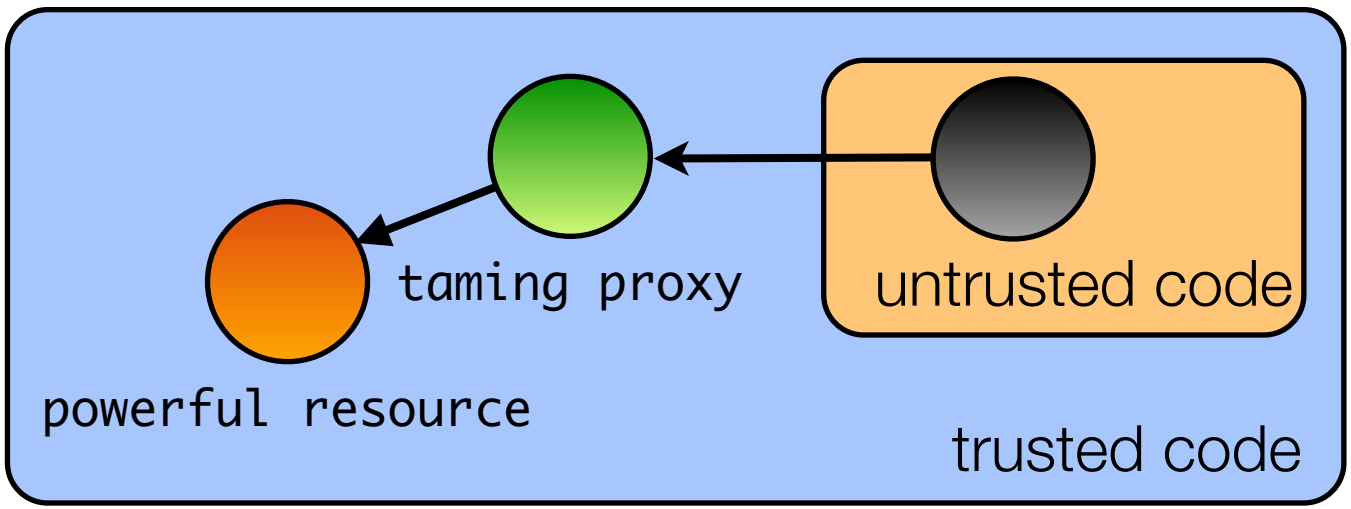

https://developers.google.com/caja/docs/about/

# Caja 

- Caja consists of:
  - A HTML and CSS sanitizer (sandbox scripts embedded in HTML/CSS)
  - A capability-secure JavaScript subset (SES)
  - A safe DOM wrapper
- SES is the portion of Caja responsible for securing JavaScript

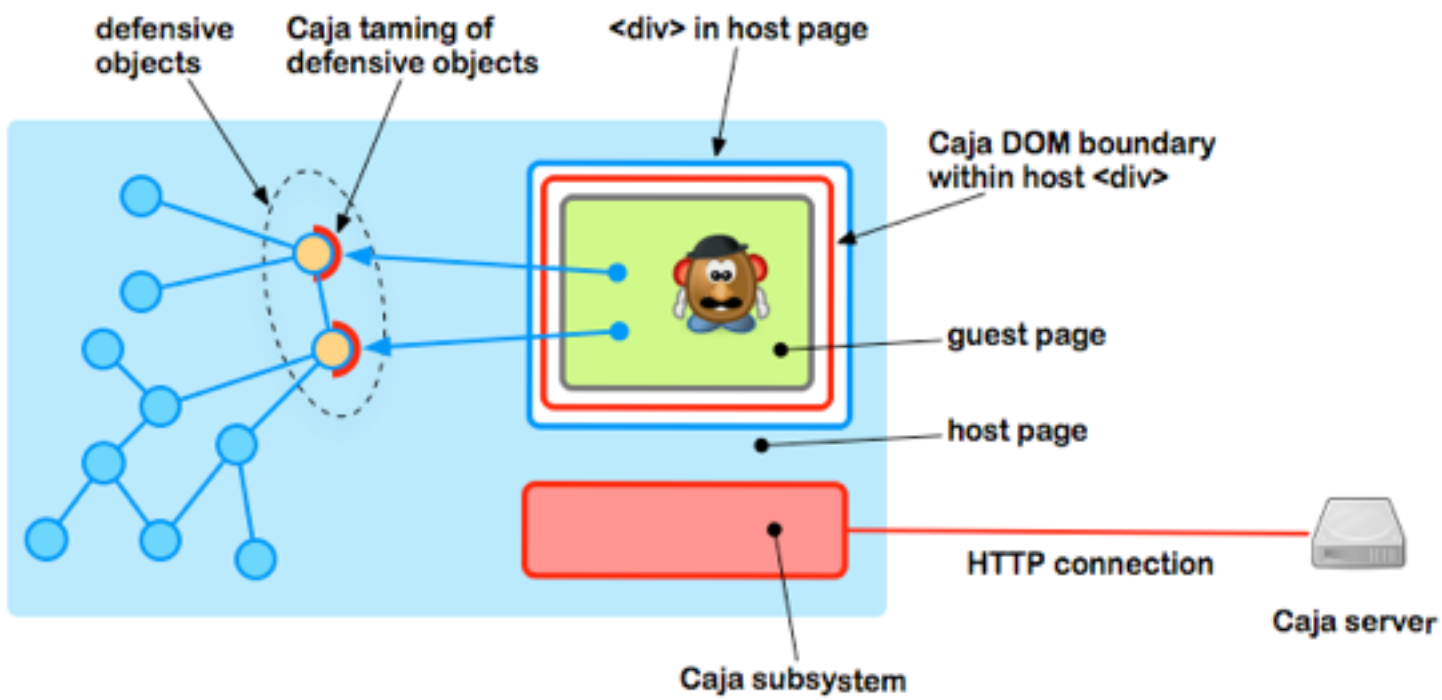
# Capability-based security

- Caja uses object capabilities to express security policies
- In the object-capability paradigm, an object is powerless unless given a reference to other (more) powerful objects
- Common to wrap powerful objects with restrictive proxies (“taming”)



# Caja : Taming the DOM

- Caja proxies the DOM. Untrusted content interacts with a virtual DOM, never with the real DOM.




https://developers.google.com/caja/docs/about/

# Secure ECMAScript

- Implemented as a library on top of ES5/strict
- Include as first script, before any other JavaScript code runs:

```
<script src="startSES.js"></script>
```

# Secure ECMAScript

```
<script src="startSES.js"></script>
```

- Deep-frozen global environment (incl. frozen global object)
  - Can't update properties of `Object`, `Array`, `Function`, `Math`, `JSON`, etc.
- Whitelisted global environment
  - No "powerful" non-standard globals
    (e.g. `document`, `window`, `XMLHttpRequest`, ...)
  - Code that spawns an SES environment may provide selective access to these
- Patches `eval` and `Function` to accept only ES5/strict code that can only name global variables on the whitelist

# Secure ECMAScript

- Problem with SES as a library: slow initial page load due to transitive freezing of all standard library objects
- Draft proposal available to standardise SES as part of ES7
- One new API call: `Reflect.confine(src, globals)`
  evals `src` in a new SES “realm”, with access only to standard library + its own global object containing the parameter-passed `globals`

```
Reflect.confine(“x + y”, {x:1, y:2}) => 3
```

SES enables safe mobile code!

# Wrap-up

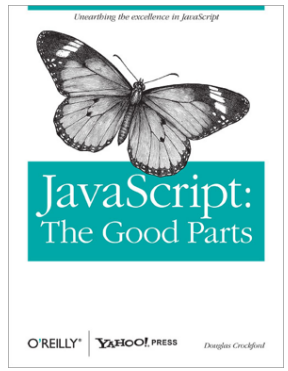
# Wrap-up

ES3

ES5

ES5/strict

SES




JavaScript:

the Good,
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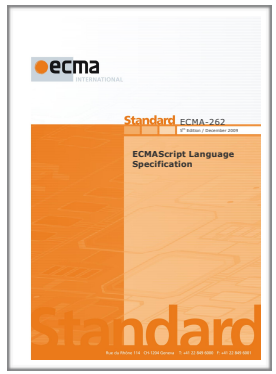



the Strict,

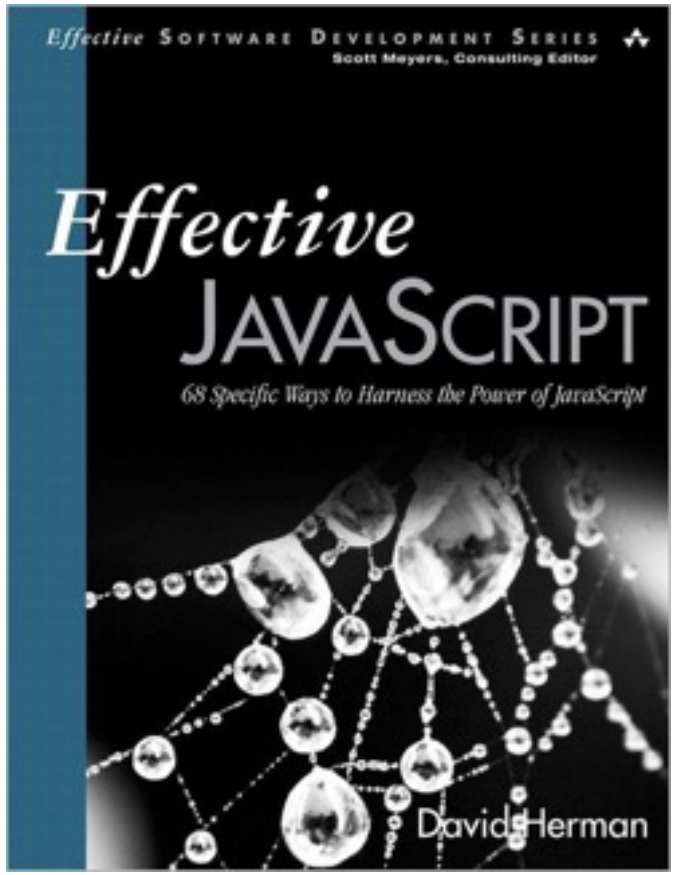
and
the Secure parts.

# Take-home messages

- Strict mode: a saner JavaScript (opt-in in ES5)
- ES6 builds on strict mode (classes and modules)
- Secure ECMAScript (SES) builds on strict mode
- SES enables safe mobile code

# References

- Warmly recommended: Doug Crockford on JavaScript http://goo.gl/FGxmM (YouTube playlist)

# References

- ECMAScript 5:
  - “Changes to JavaScript Part 1: EcmaScript 5” (Mark S. Miller, Waldemar Horwat, Mike Samuel), Google Tech Talk (May 2009)
  - “Secure Mashups in ECMAScript 5” (Mark S. Miller), QCon 2012 Talk http://www.infoq.com/presentations/Secure-Mashups-in-ECMAScript-5
- Caja: https://developers.google.com/caja
- SES: https://github.com/FUDCo/ses-realm and https://github.com/google/caja/wiki/SES
- HTML templating with template strings: http://www.2ality.com/2015/01/template-strings-html.html
- ES6 latest developments: https://github.com/tc39 and the es-discuss@mozilla.org mailing list.
  ES6 Modules: http://www.2ality.com/2014/09/es6-modules-final.html https://github.com/ModuleLoader/es6-module-loader and http://jsmodules.io/
  ES6 Proxies: http://www.2ality.com/2014/12/es6-proxies.html
  R. Mark Volkmann: “Using ES6 Today!”: http://sett.ociweb.com/sett/settApr2014.html


Thanks for listening!

# Writing robust client-side code using Modern JavaScript

# or

## JavaScript: the Good, the Bad, the Strict and the Secure Parts

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