KU LEUVEN

DistriNet

Designing “least-authority” JavaScript apps

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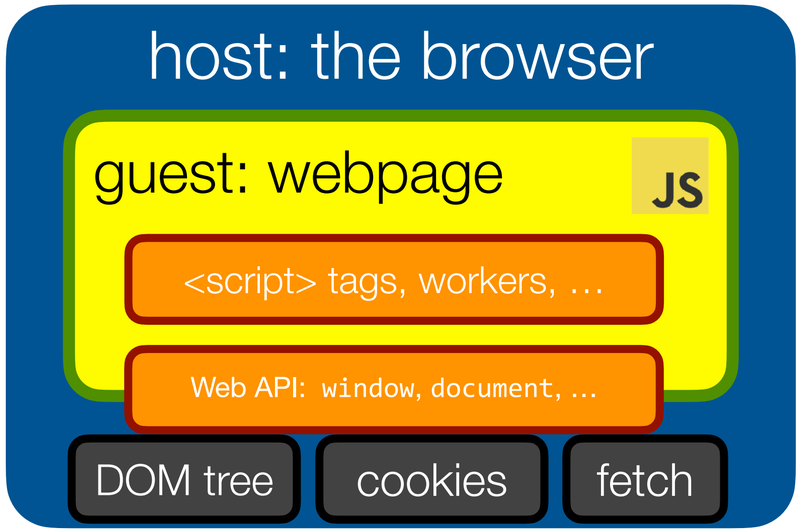
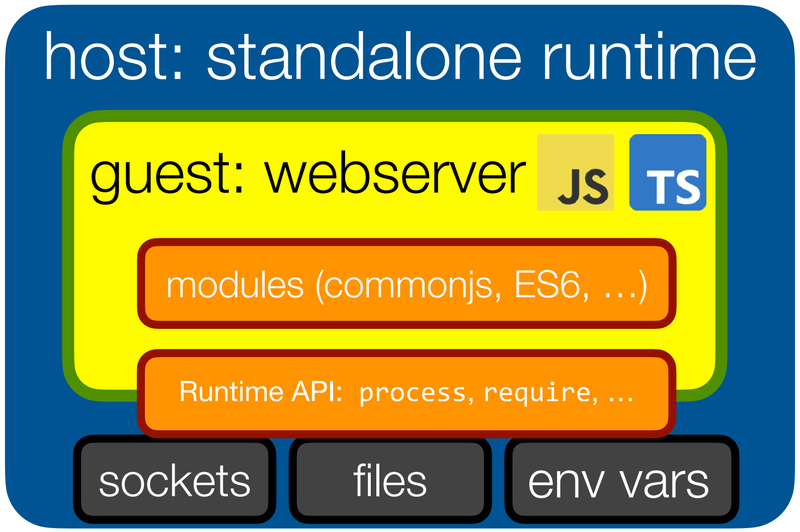
JavaScript's Third Era

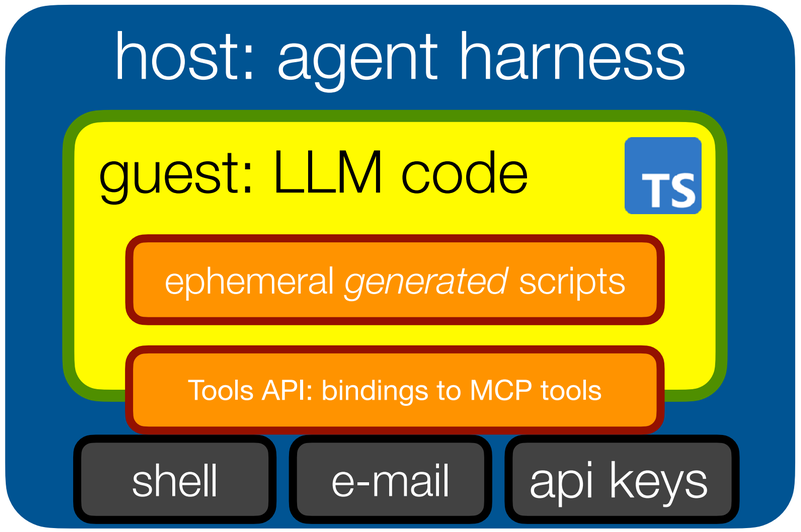
1995: WWW Era



2009: Web APIs Era



2025: AI Agent Era



A **software engineering view** on application security

“Security is just an extreme form of Modularity”

(image generated with Gemini AI)

- Mark S. Miller
(Chief Scientist, Agoric)

Modularity:
avoid needless software dependencies to protect against *unintended bugs*

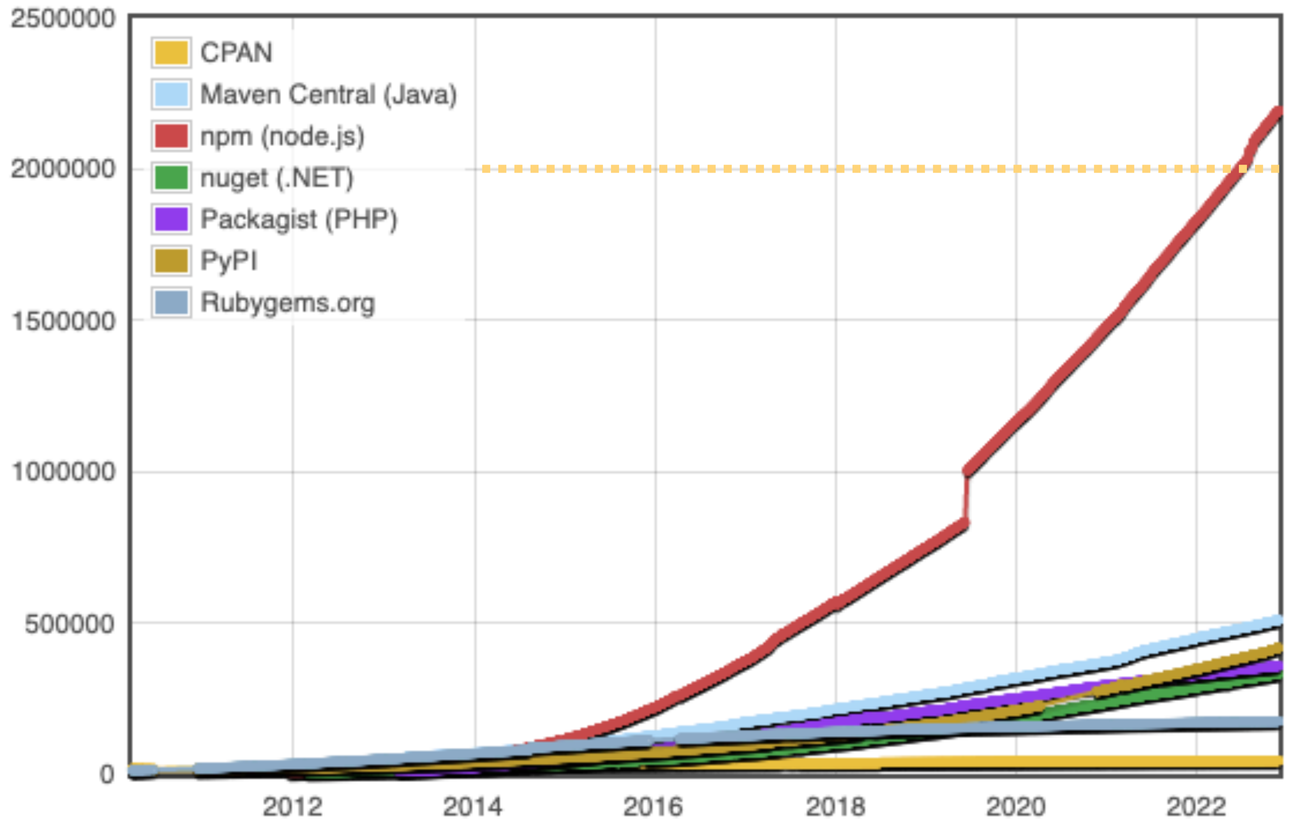
Security:
avoid needless software dependencies to protect against *deliberate exploits*

This Lecture

- Part I: **why module isolation** is critical to modern JavaScript applications
- Part II: the **Principle of Least Authority**, by example (in JavaScript)
- Part III: safely composing modules using **least-authority patterns**

Part I
Why module isolation is critical to modern JavaScript applications

Modern JavaScript applications are built from thousands of modules



2,000,000 modules on NPM

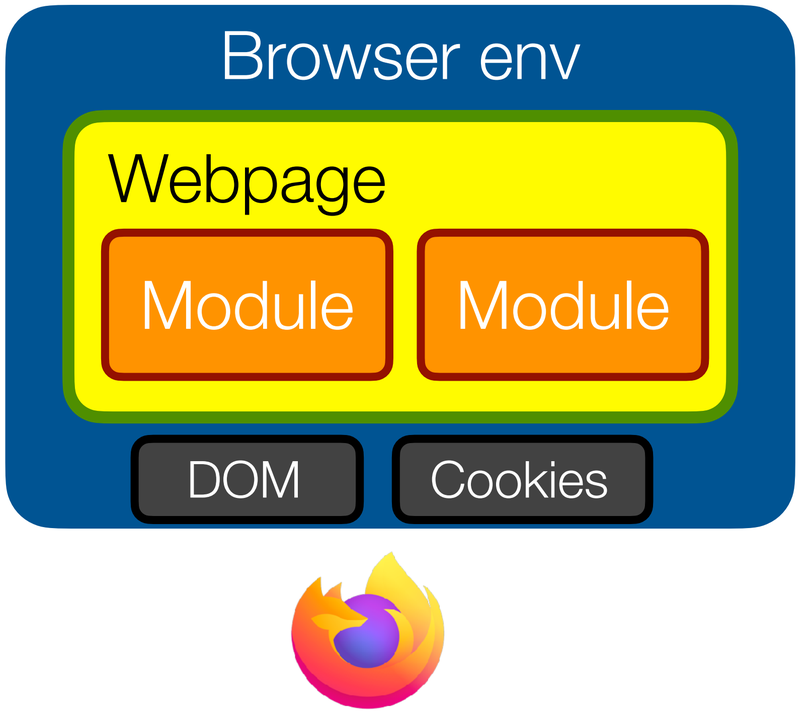
"The average modern web application has over 1000 modules […] ***97% of the code in a modern web application comes from npm***. An individual developer is responsible only for the final 3% that makes their application unique and useful."

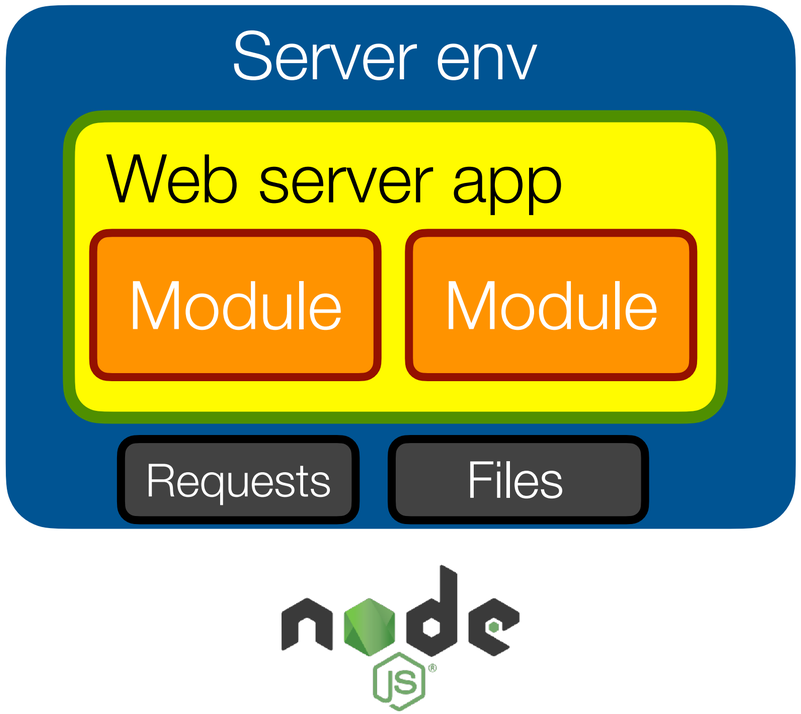
(source: npm blog, December 2018)

(source: modulecounts.com, Nov 2022)

Composing modules: it's all about **trust**

It is exceedingly common to run code you don't know or trust in a common environment





What can happen when a module goes **rogue**?

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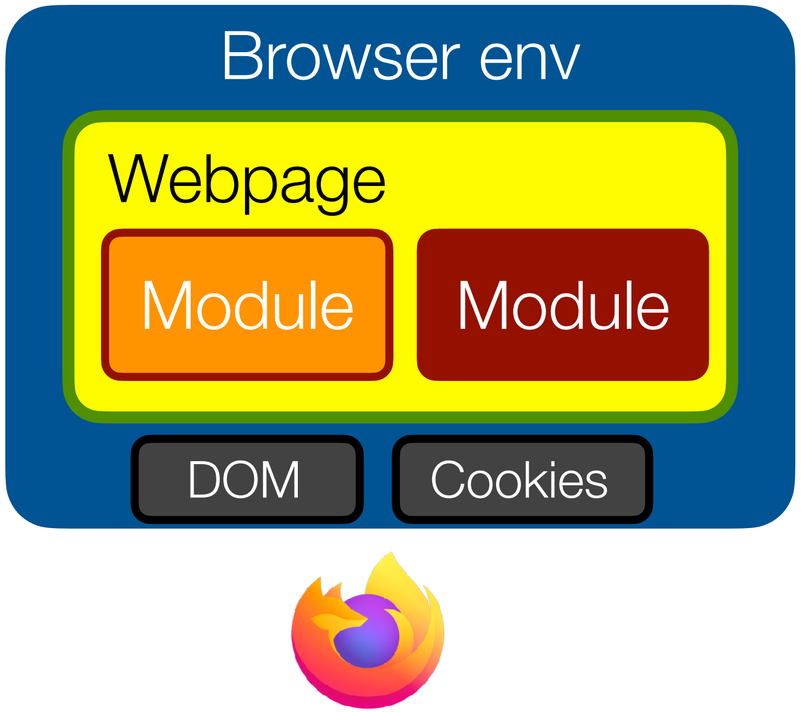

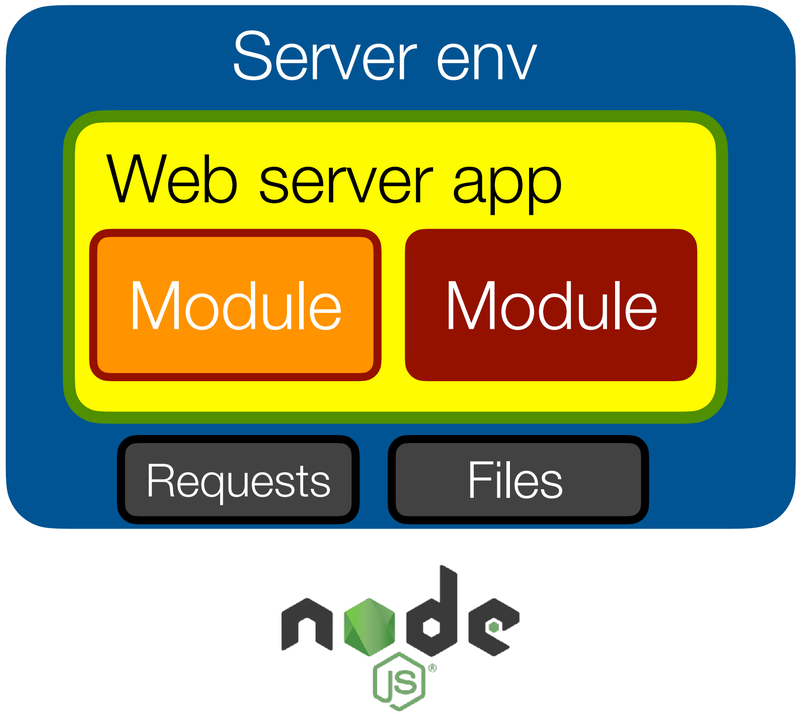

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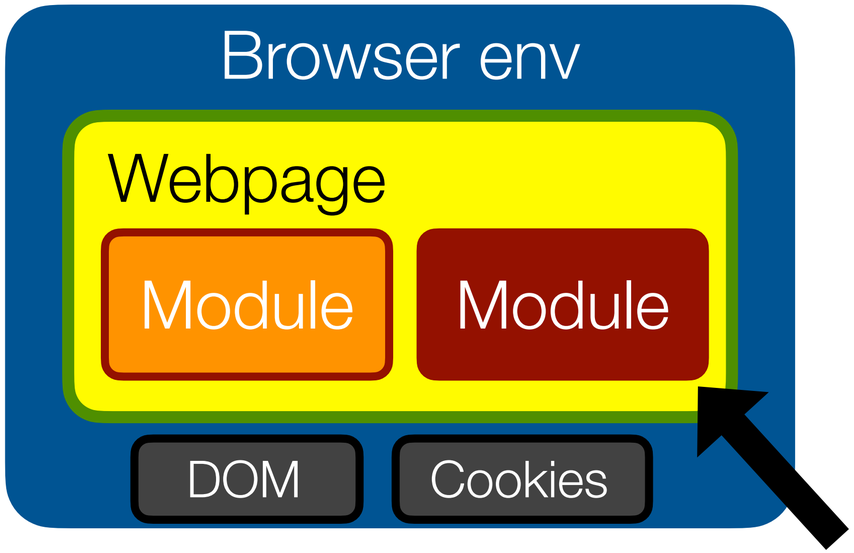
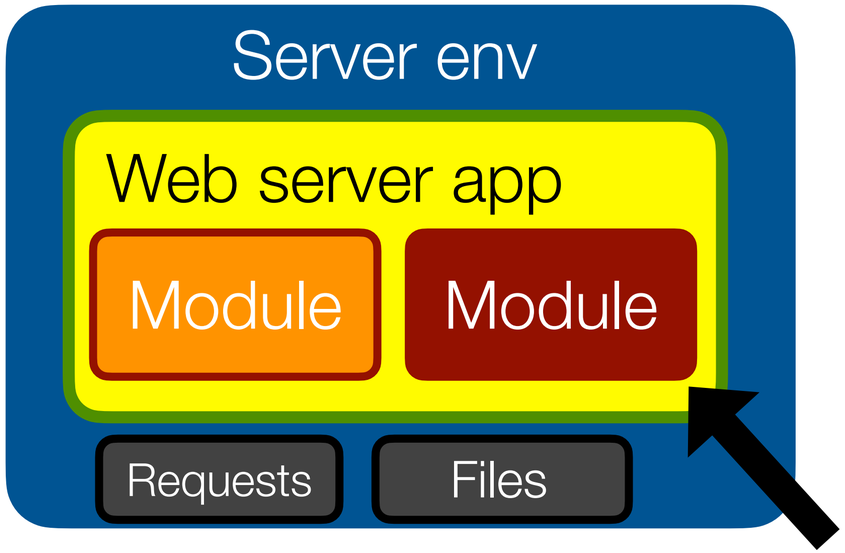


```
<script src="http://evil.com/ad.js">
```

What can happen when a module goes **rogue**?



```
npm install event-stream
```

Check your repos... Crypto-coin-stealing code sneaks into fairly popular NPM lib (2m downloads per week)

Node.js package tried to plunder Bitcoin wallets

By Thomas Claburn in San Francisco 26 Nov 2018 at 20:58 49 SHARE ▼

(source: theregister.co.uk)

The 2025 Shai-Hulud incident

180+ NPM Packages Hit in Major Supply Chain Attack

Moshe Siman Tov Bustan Alexander Chailytko

September 16, 2025 9 mins read Share

(source: ox.security, Sept 2025)

*"The average NPM dependency brings **79 transient dependencies** with it. […] chances are **we'll end up with at least a few hundred dependencies in our projects—and each one is a new door a credential-stealing malware could walk through**."*

- frontendatscale.com issue 52, sept 2025

NPM = **N**eatly **P**ackaged **M**alware?

These are examples of **software supply chain** attacks

Timeline of major incidents on npm/Crates/PyPI/etc

- 2022-05-10: Cargo: rustdecimal ships with malicious code
- 2022-05-09: npm: foreach is taken over via an expired email domain
- 2022-03-17: npm: node-ipc ships malware targeting Russia and Belarus
- 2022-01-09: npm: colors and faker are deliberately sabotaged
- 2021-11-19: PyPI: 11 malicious packages discovered
- 2021-11-04: npm: rc ships malicious code
- 2021-11-04: npm: coa steals your passwords
- 2021-10-22: npm: ua-parser-js ships malicious code
- 2021-10-11: PyPI: mitmproxy2 typo-squats mitmproxy with an added RCE
- 2021-07-30: PyPI: 8 malicious packages discovered
- 2020-12-16: RubyGems: pretty_color (and one other) steals bitcoin from victims
- 2020-09-11: npm: dozens of packages steal your user's credit card number
- 2020-09-03: npm: bb-builder steals your password
- 2020-04-16: RubyGems: 760+ malicious packages found stealing bitcoin
- 2018-11-28: npm: event-stream ships with a bitcoin theft kit
- 2018-10-21: PyPI: colourama sneaks bitcoin addresses into your clipboard
- 2018-10-13: PyPI: more typo-squatting malware attempts various attacks
- 2018-07-12: npm: eslint-scope ships with malicious code
- 2018-07-08: AUR: acroread is compromised
- 2018-05-11: Snap: a 2048 clone ships a cryptocurrency miner
- 2017-09-09: PyPI: typo-squatted packages published by researchers
- 2016-07-22: npm: left-pad incident

(Source: Drew Devault, https://drewdevault.com/blog/Supply-chain-when-will-we-learn/)

All major software ecosystems are increasingly affected, but JS and npm especially so

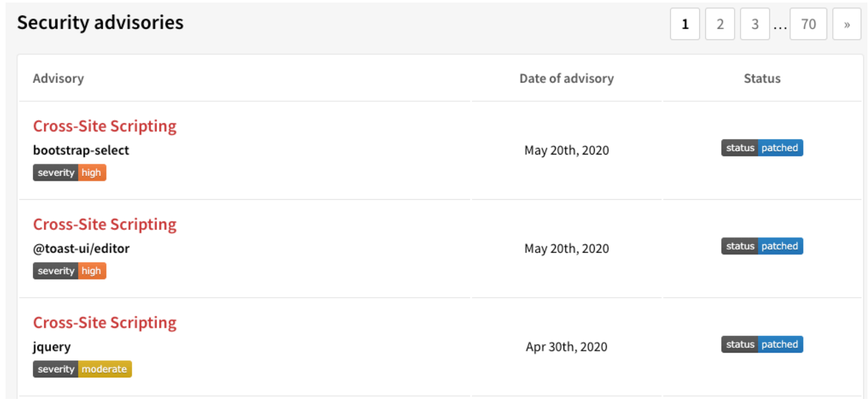
"2025 was a huge year for npm malware advisories. Due to large malware campaigns, such as [Shai-Hulud], ***GitHub saw a 69% increase in published malware advisories*** *compared to 2024"*

- J. Evans, GitHub Security Blog, March 2026

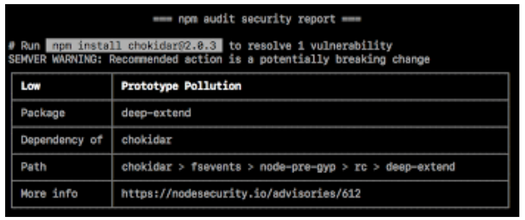
Increasing awareness

Great tools, but address the **symptoms**, not the **root cause**

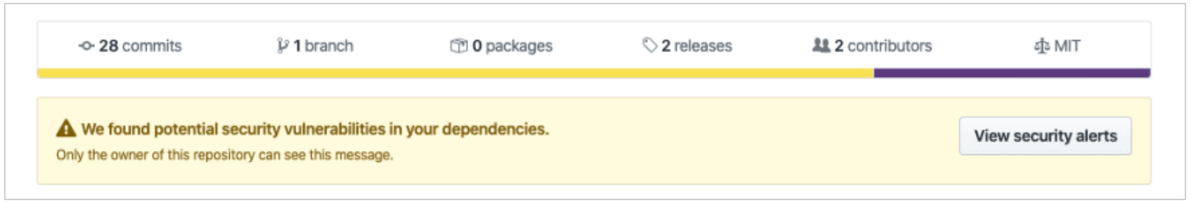
npm security advisories



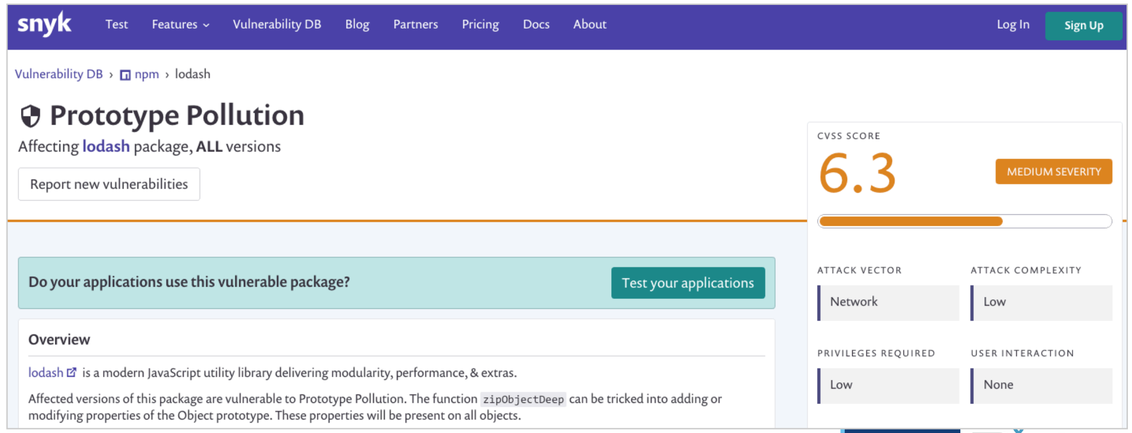
npm audit



GitHub security alerts

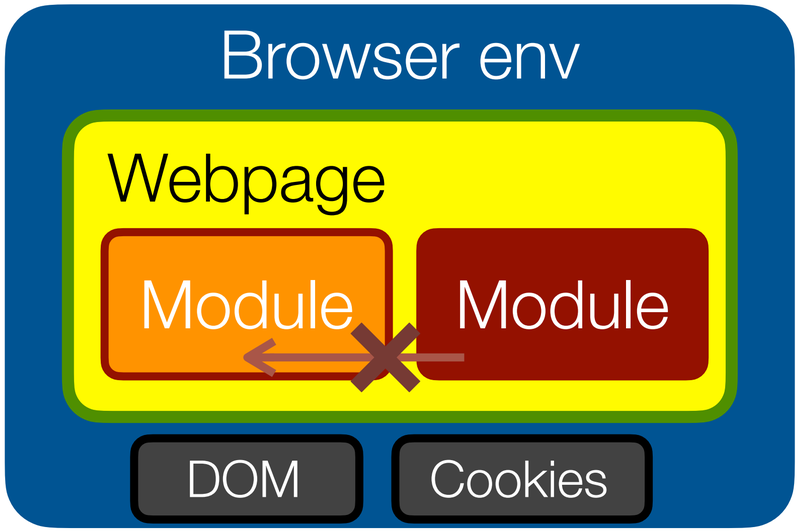


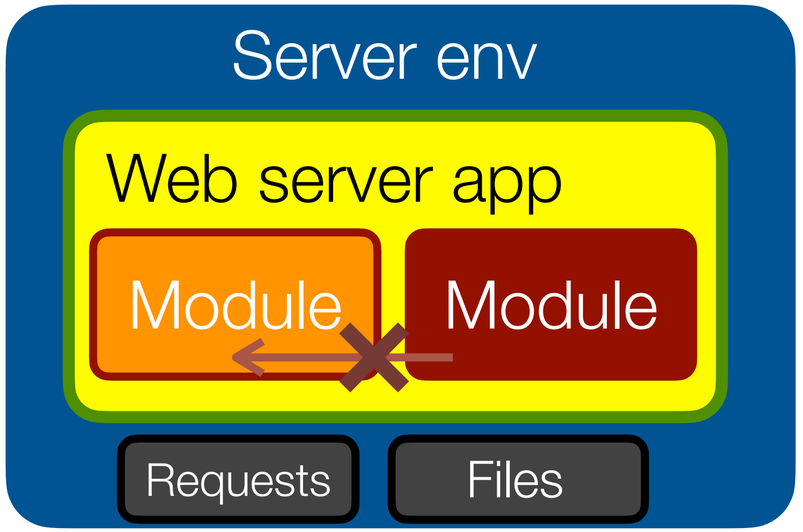
Snyk vulnerability DB



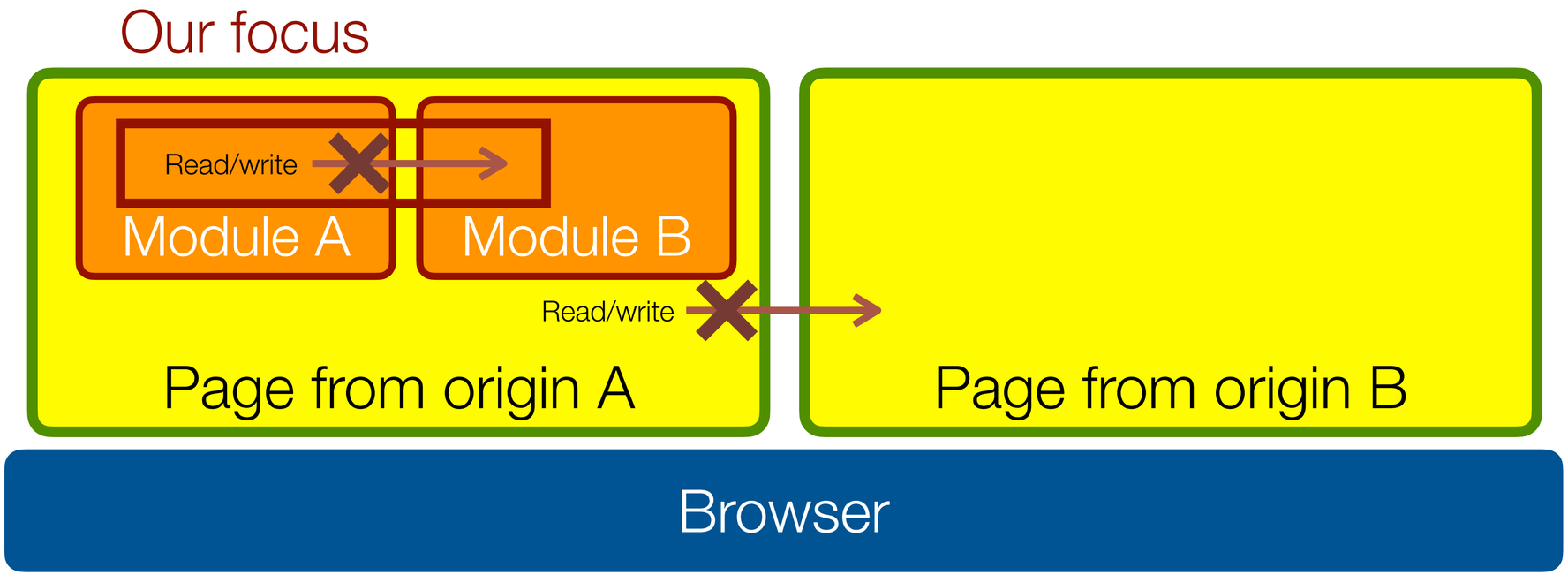
Avoiding interference is the name of the game

- Shield important resources/APIs from modules that don't need access
- Apply **Principle of Least Authority** (POLA) to application design





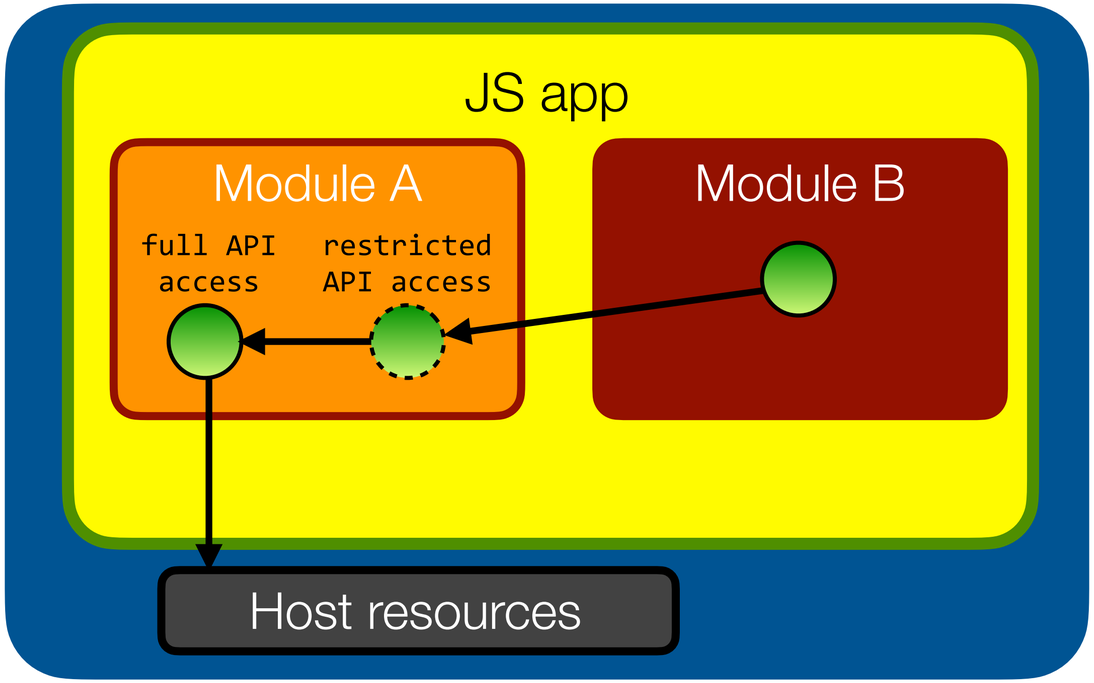
We'll need more than simply relying on Browser Same-origin Policy



Part II
The Principle of Least Authority, by example (in JavaScript)

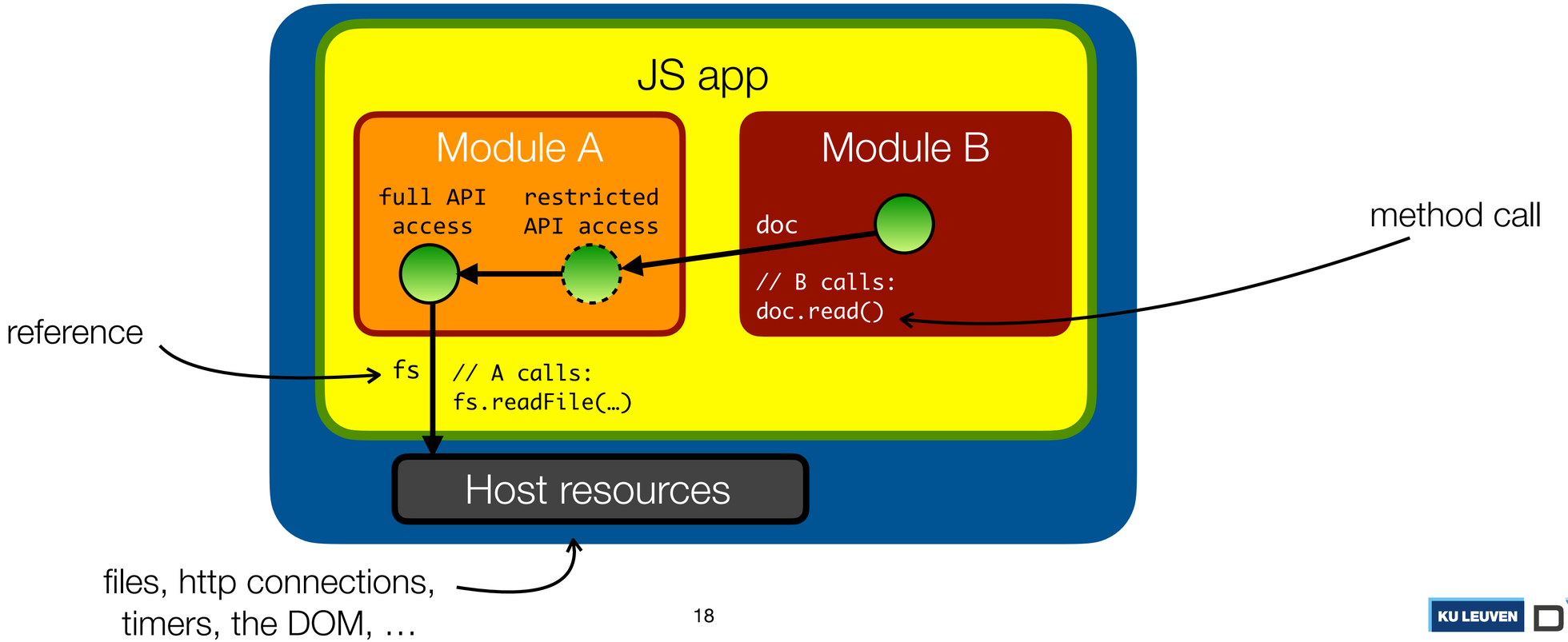
Principle of Least Authority (POLA)

- A module should only be given the authority it needs to do its job, and nothing more

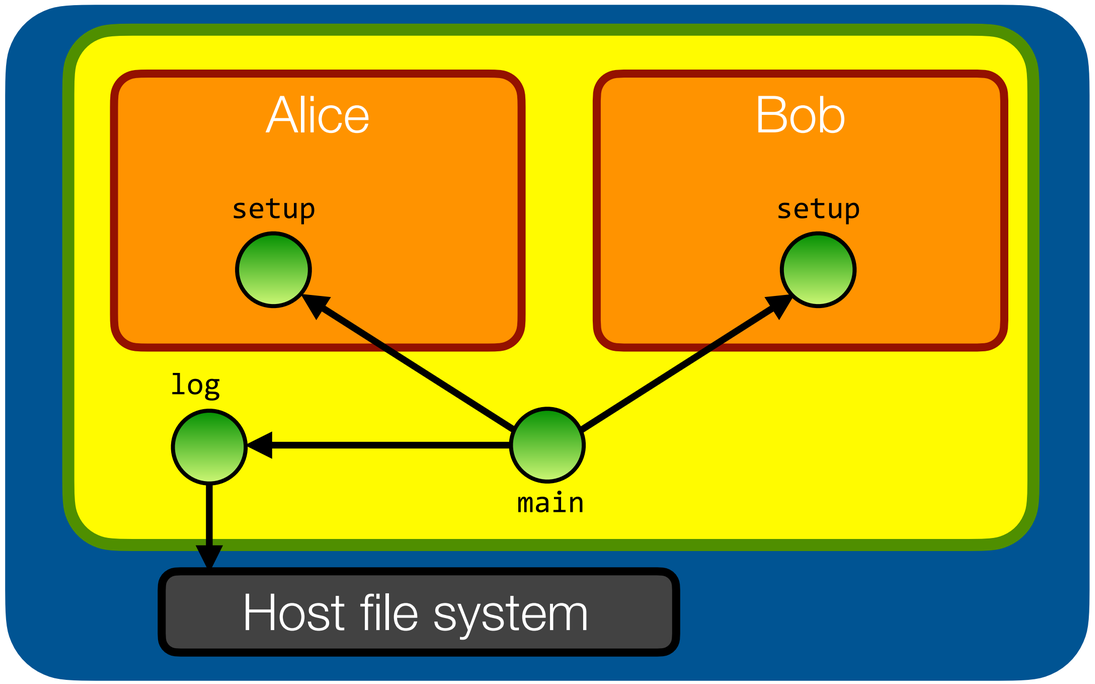


What is “authority” in a JavaScript app?

- Authority is linked to resources represented as objects (or functions)
- Objects can hold references (“pointers”) to resource objects
- The authority to use a resource is expressed by calling a method/function on a reference



Delegating authority == sharing references, under the right assumptions



Consider an app maintaining a message log.

The app loads two untrusted modules Alice and Bob.

We would like Alice and Bob to *only* have access to this log file *and nothing more*.

```
// in our app's main function:
let log = new Log();
alice.setup(log)
bob.setup(log)
```

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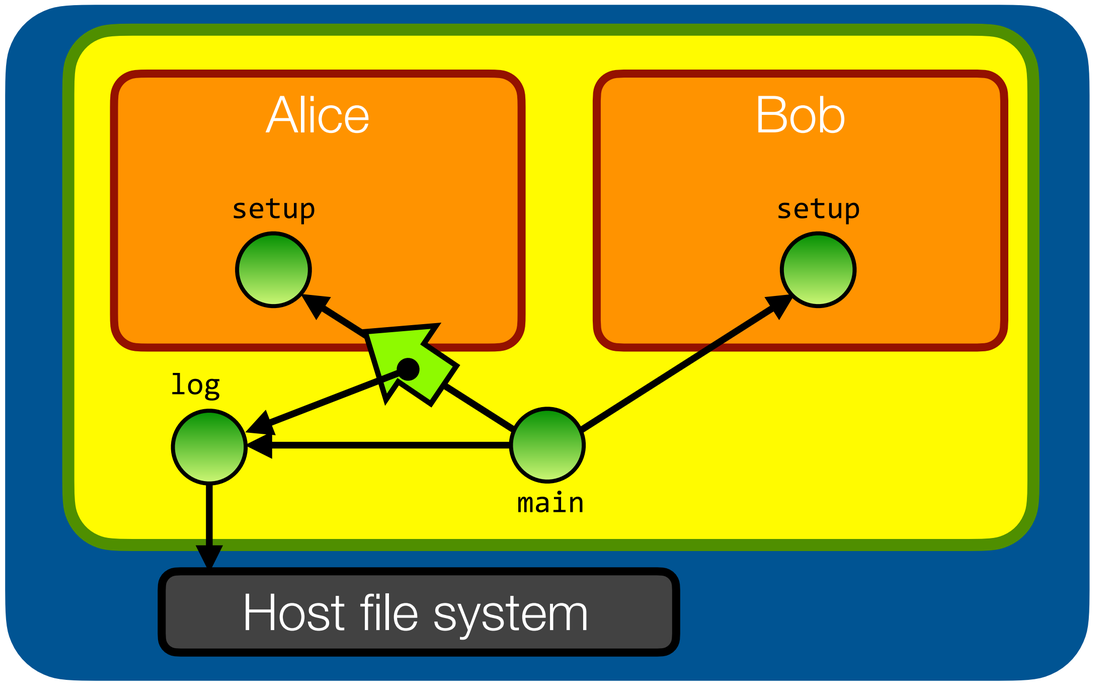

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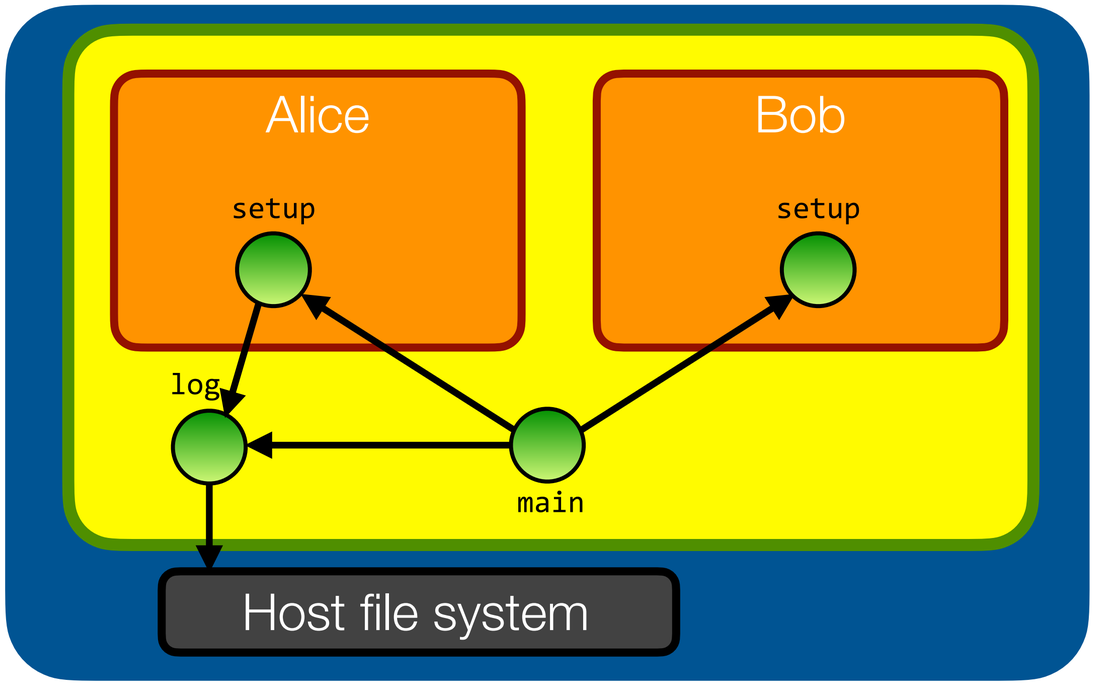

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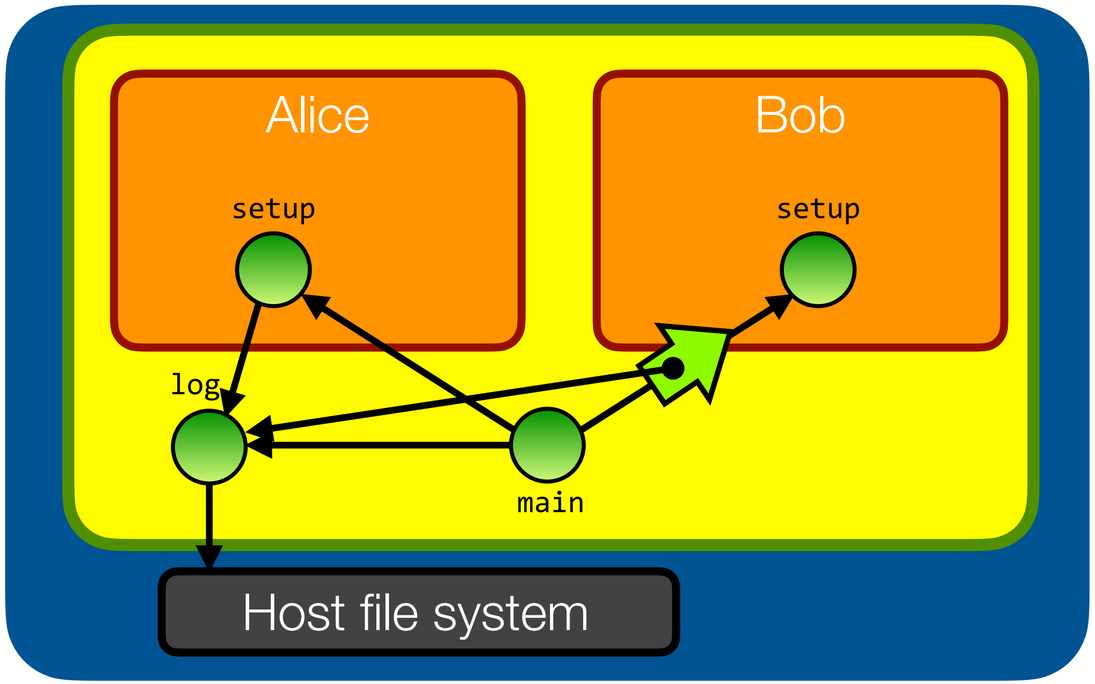

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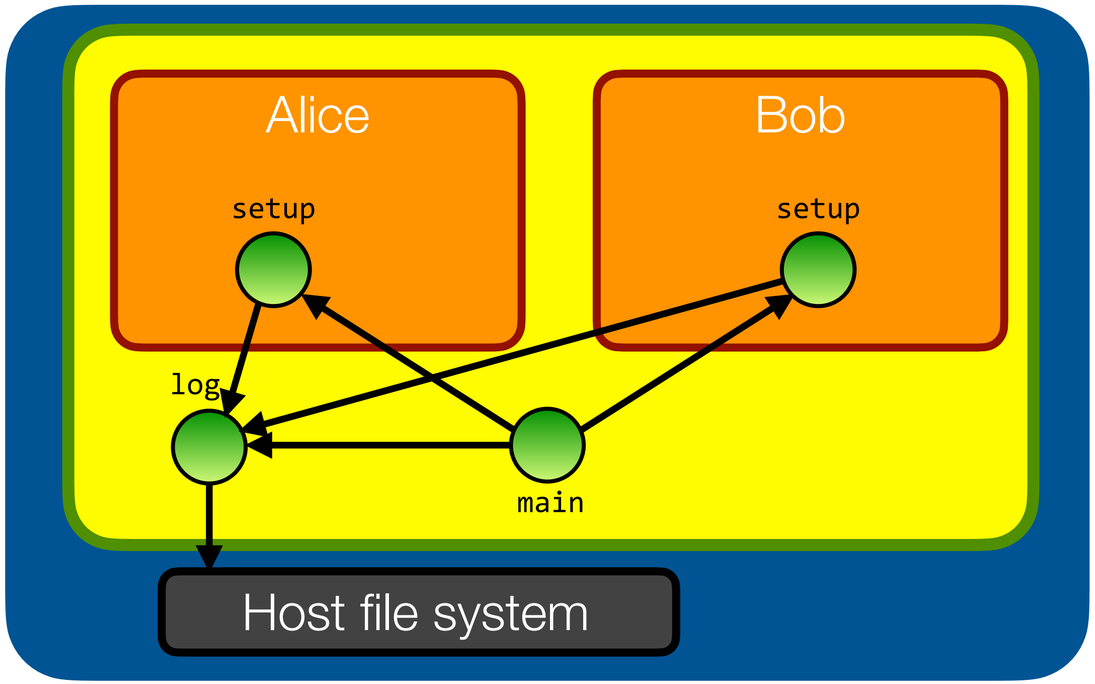

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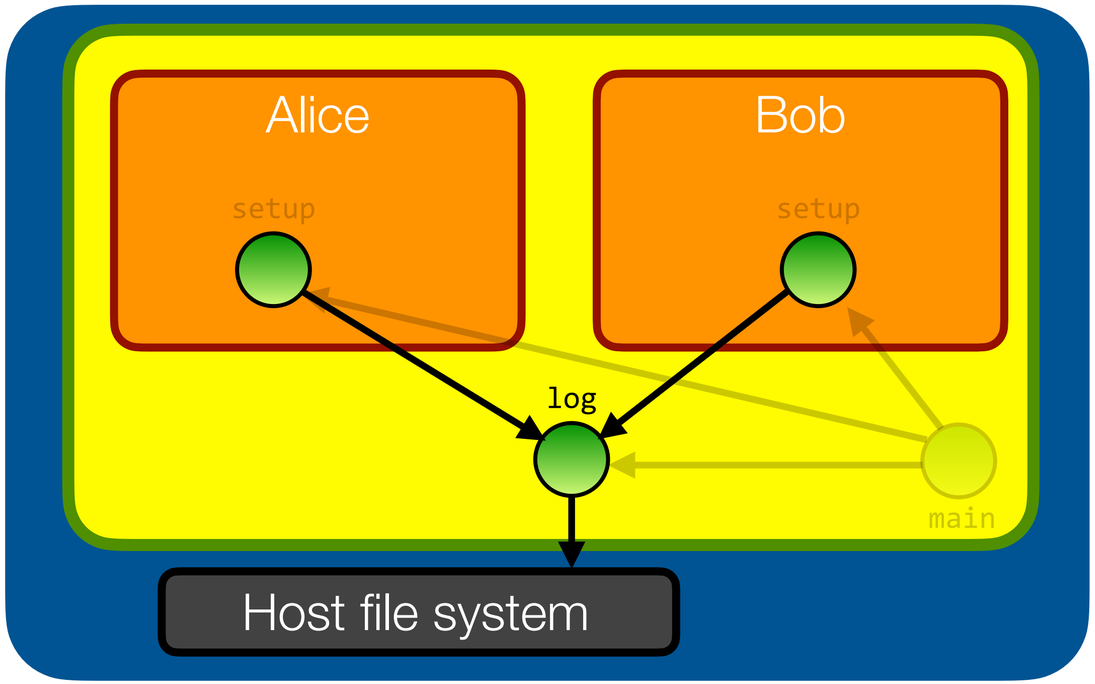

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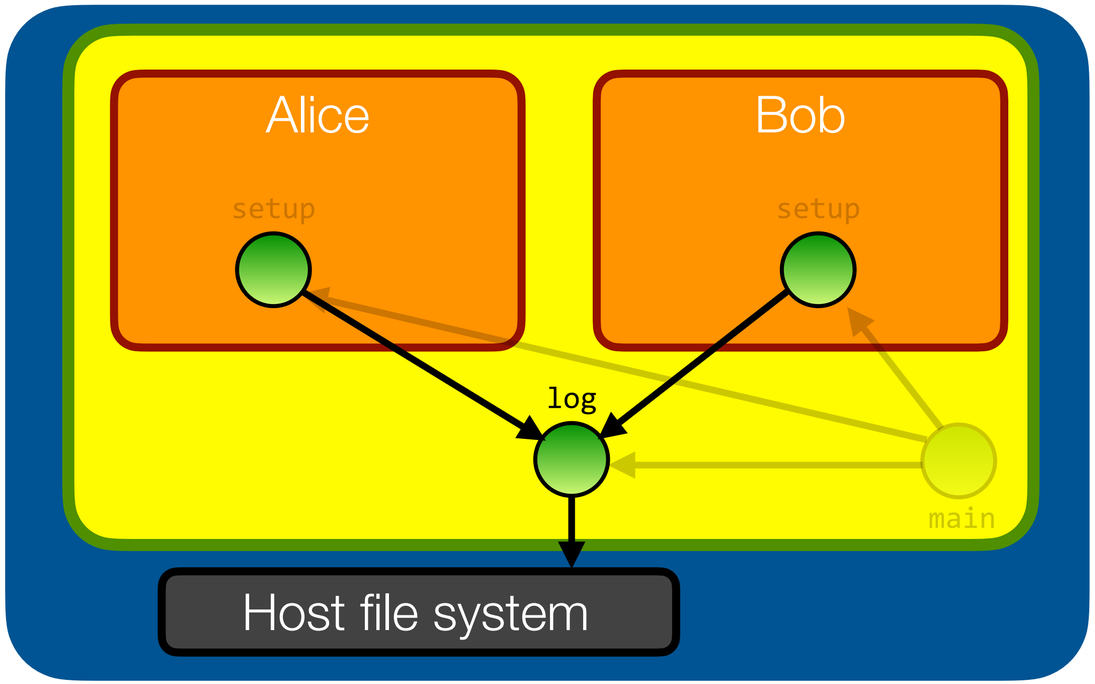
What are our assumptions?



• Alice and Bob cannot create references to other app objects.
✅ JavaScript is **memory-safe.** References are unforgeable.

• The log can hide its reference to the host file system from Alice and Bob.
✅ JavaScript has strict **lexical scoping** rules that support **hiding** pointers in **private** local variables.

• Alice and Bob cannot communicate via global mutable vars.
⚠️ App must ensure that there is **no global mutable state**!

• Alice and Bob cannot circumvent the log's public API.
⚠️ App must ensure that all exported API objects are **immutable**.

• Alice and Bob cannot access the host file system by default.
⚠️ App must ensure each module starts out with **no references to powerful globals** by default.

Running example: apply POLA to a basic shared log

We would like Alice to only **write** to the log, and Bob to only **read** from the log.

```
import * as alice from "alice.js";
import * as bob from “bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return this.messages_; }
}

let log = new Log();
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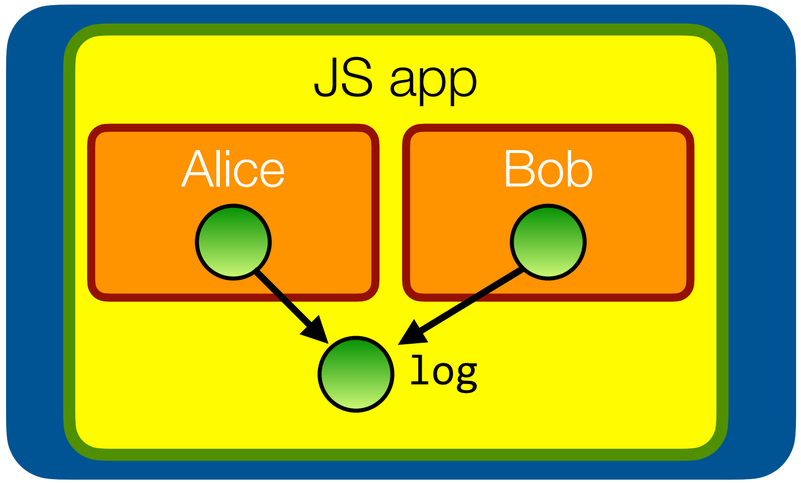

Running example: apply POLA to a basic shared log

If Bob goes rogue, what could go wrong?

```
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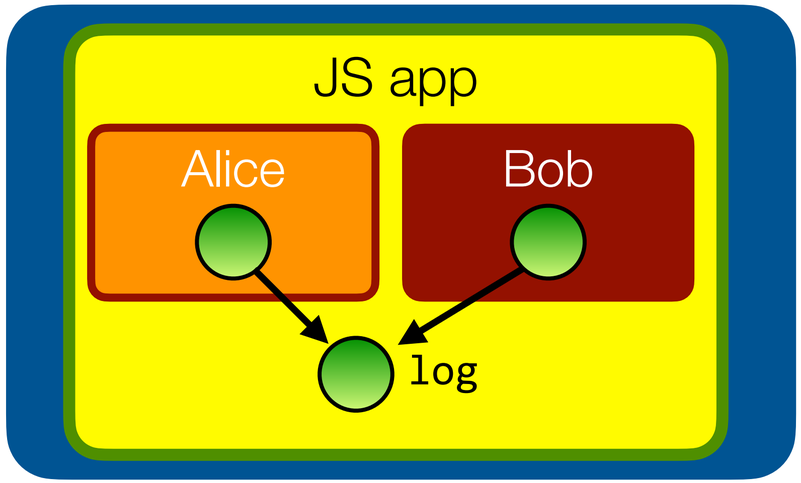
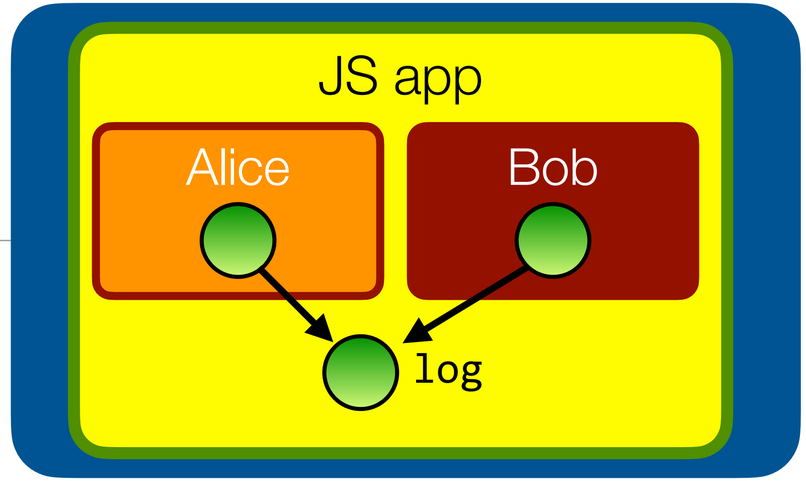


Bob has way too much authority!

Bob inherits access to powerful globals like the file system, can use it to **exfiltrate** credentials

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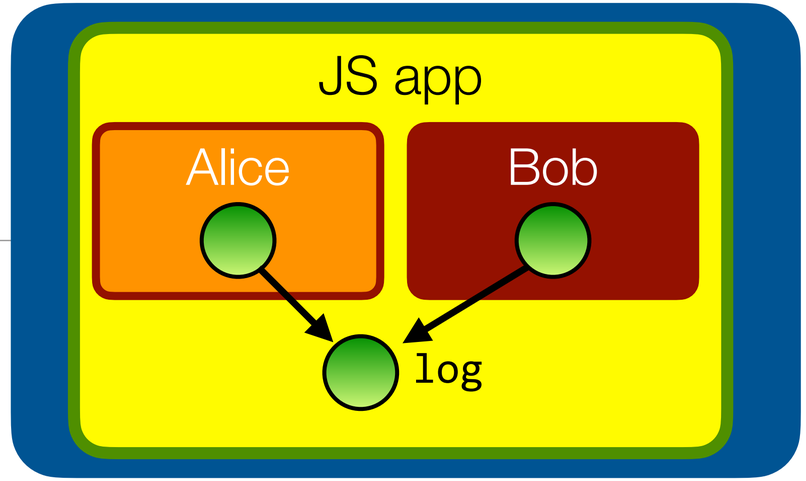
```
import * as fs from "fs";

const raw = fs.readFileSync('./secrets.json', 'utf8');
const secrets = JSON.parse(raw);
console.log('bob: STOLEN CREDENTIALS:');
console.log('apiKey:', secrets.apiKey);
```

Bob has way too much authority!

Bob can also exploit access to shared mutable state to mess with the **integrity** of the log

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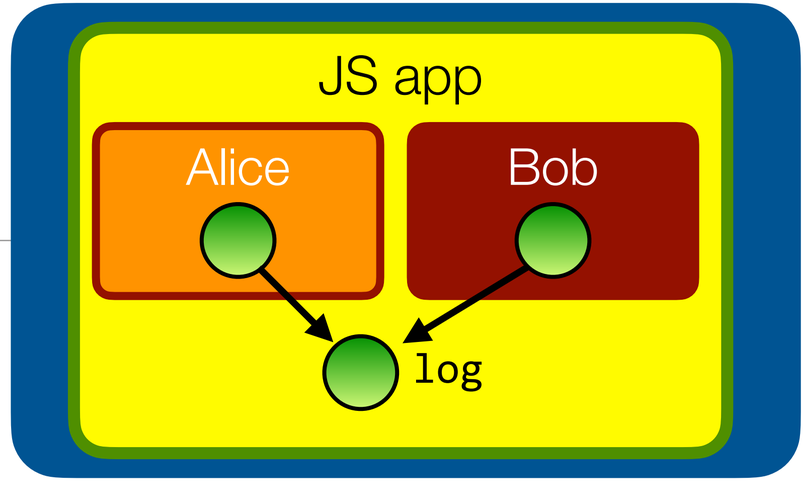
```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)

// Bob can delete the entire log (leak mutable state)
log.read().length = 0

// Bob can replace the ‘write’ function (api poisoning)
log.write = function(msg) {
  console.log(“I’m not logging anything”);
}
// Bob can replace the built-ins (prototype poisoning)
Array.prototype.push = function(msg) {
  console.log(“I’m not logging anything”);
}
```

How to solve “prototype poisoning” attacks?

Load each module in its own environment,
with its own set of “primordial” objects

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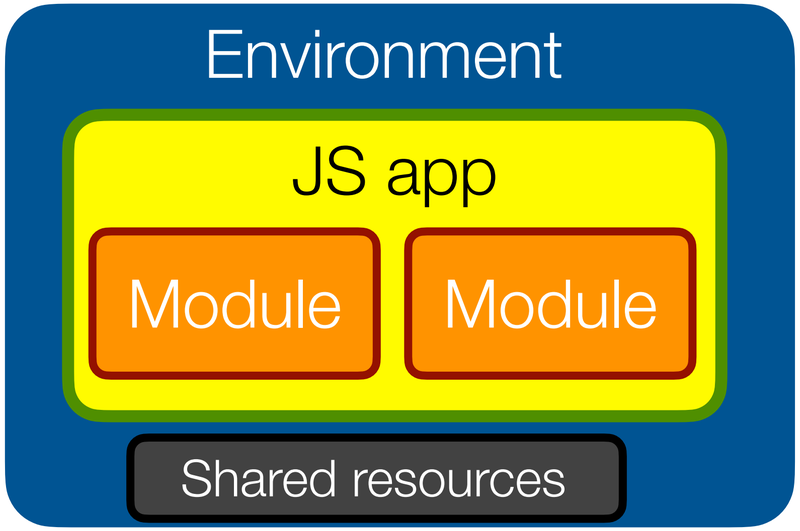
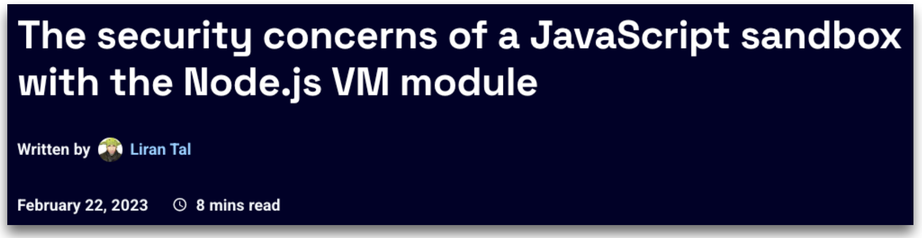
Prerequisite: isolating JavaScript modules

- Today: JavaScript offers no standard way to isolate a module (load it in a separate environment)
- Lots of host-specific isolation mechanisms, but non-portable and ill-defined:
  - **Web Workers**: no shared memory, can only communicate using message-passing
  - **iframes**: mutable primordials, “identity discontinuity”
  - **nodejs** vm **module**: *not* designed for running untrusted code! See article on Snyk blog ->



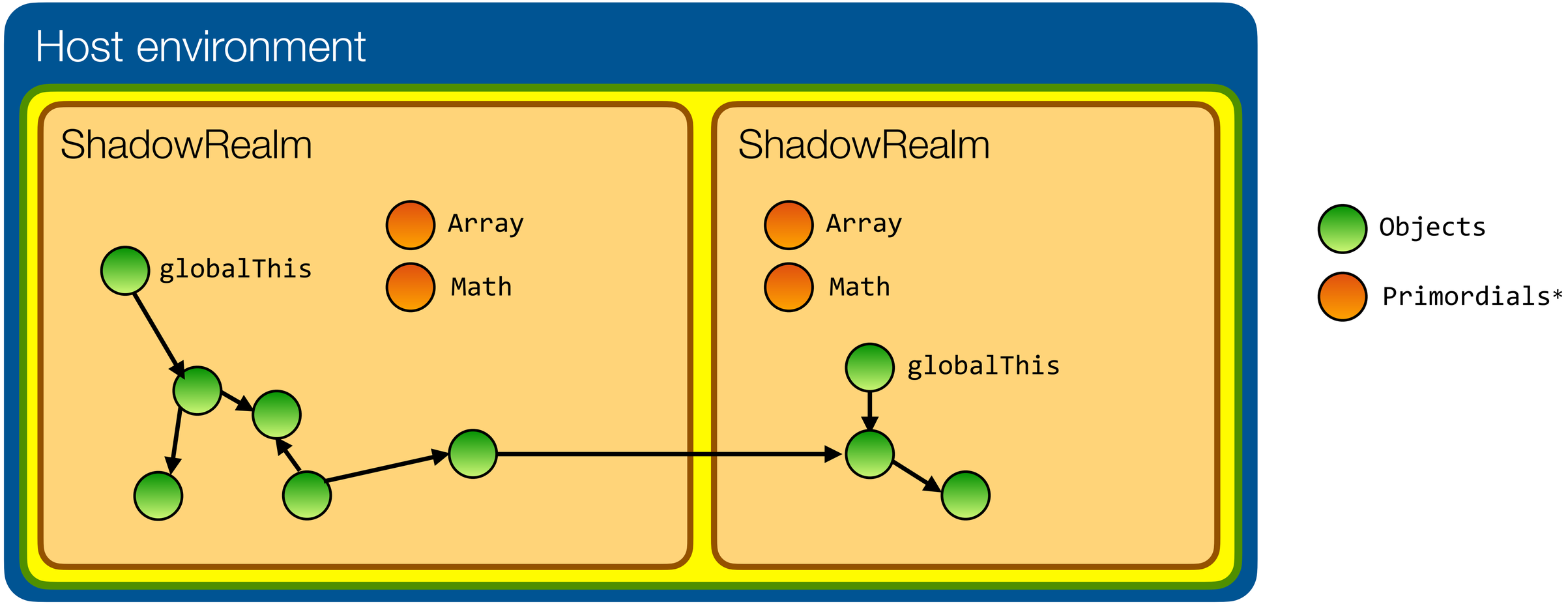


(Source: snyk.io blog, 2023)

ShadowRealms (ECMA TC39 spec proposal)

https://tc39.es/proposal-shadowrealm/

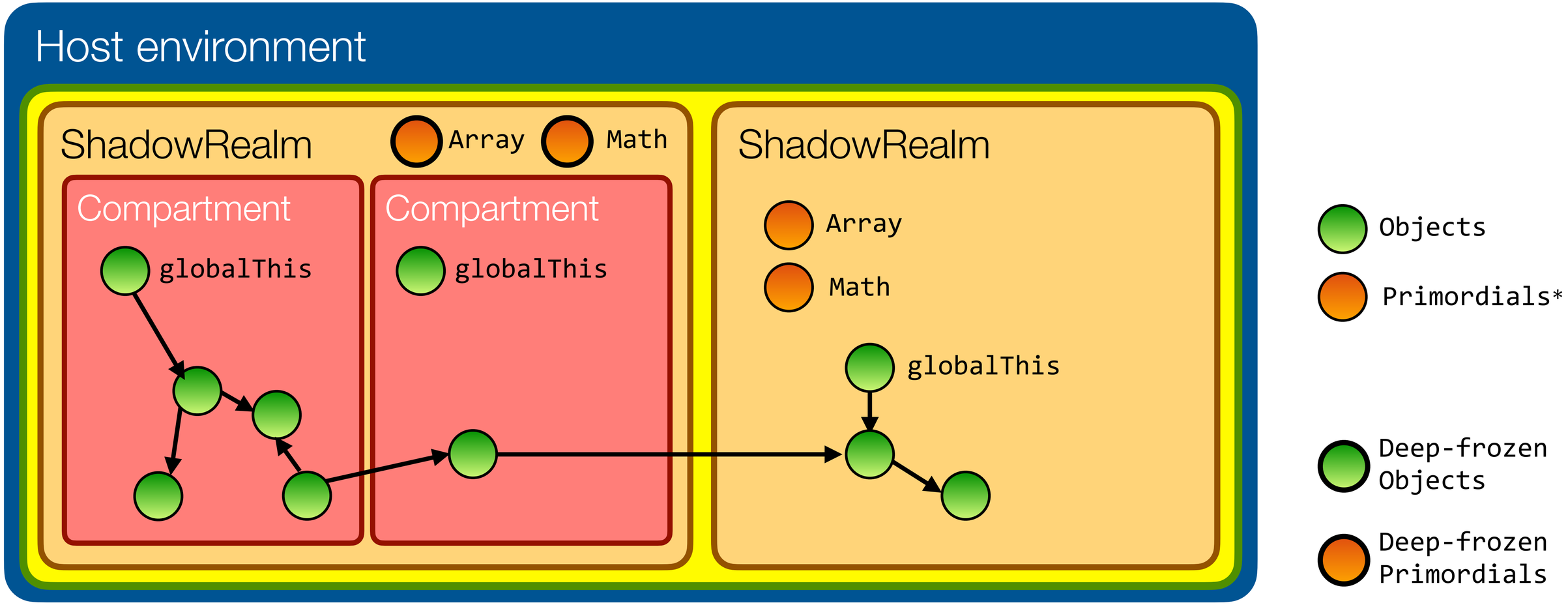
Intuitions: “iframe without DOM”, “principled version of node’s `vm` module”



* Primordials: built-in objects like `Object`, `Object.prototype`, `Array`, `Function`, `Math`, `JSON`, etc.

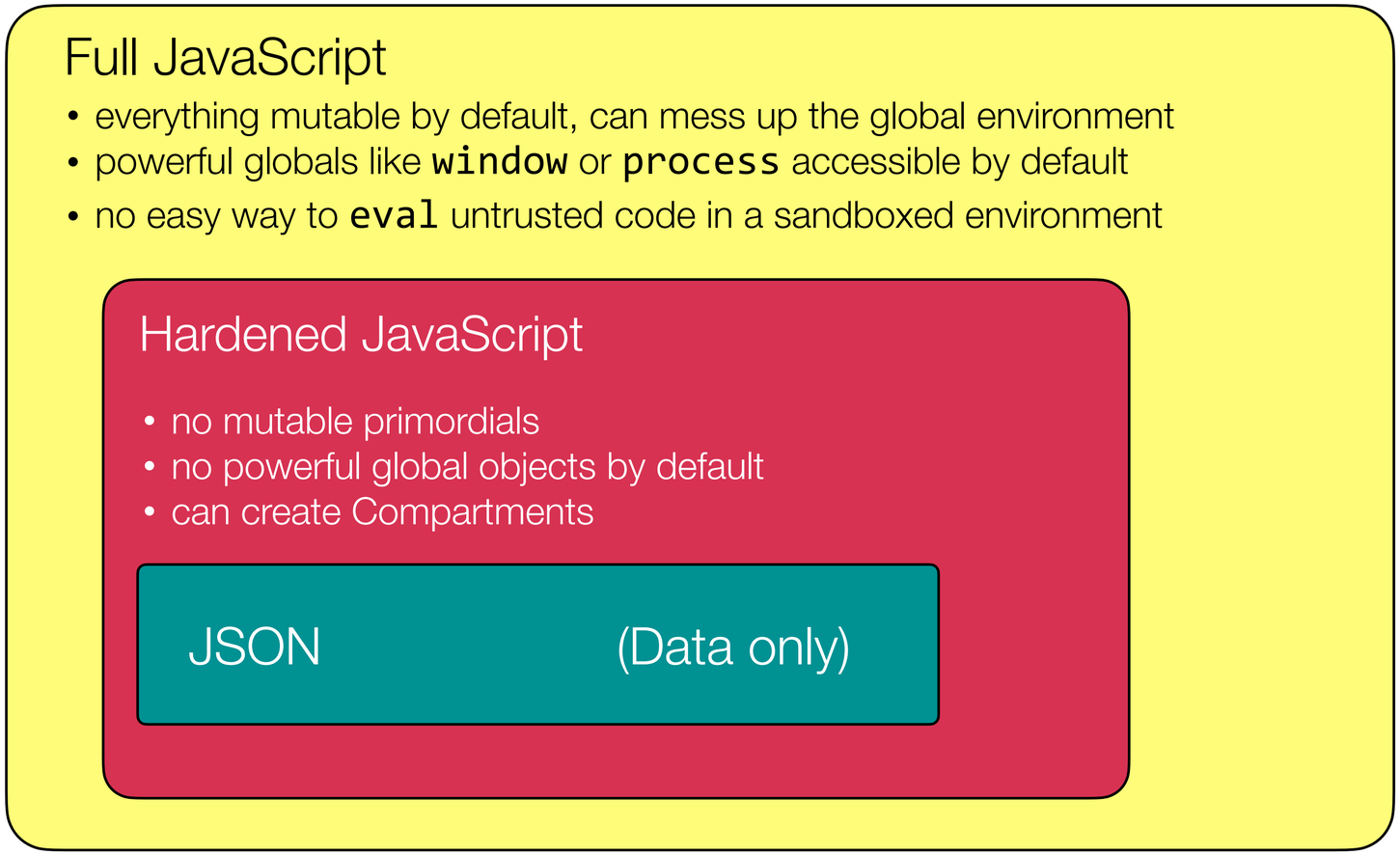
Compartments (ECMA TC39 Stage 1 proposal)

Each Compartment has its own global object but shared (immutable) primordials.



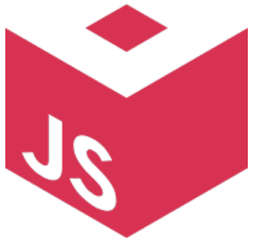
* Primordials: built-in objects like `Object`, `Object.prototype`, `Array`, `Function`, `Math`, `JSON`, etc.

Hardened JavaScript is a secure subset of standard JavaScript



(inspired by the diagram at https://github.com/Agoric/Jessie)

Key idea: code running in hardened JS can only affect the outside world through objects (capabilities) explicitly granted to it from outside.



hardenedjs.org/

Hardened JavaScript: some history

Google develops a project called “**Caja**” for **safe embedding** of dynamic web content (JavaScript scripts) in web pages

2009 — Google Caja

Attempts are made to **standardize** core features that enable secure sandboxing as “**Secure ECMAScript**” (SES) at ECMA TC39

2015 — TC39

Standardisation process got stalled, but work continued on a modified node.js runtime called “**endo**”, supporting SES on the server

2018 — endo

A company called Agoric **rebrands** SES **to “Hardened JavaScript”**, works with Moddable and Metamask on implementation and tooling

2020 — JS

HardenedJS is **used by several companies** to isolate JavaScript modules for IoT (Moddable), Web3 (Agoric), SaaS (Salesforce), …

Today — moddable, salesforce

LavaMoat

- **Command-line tool** that puts each package dependency into its own hardened JS sandbox environment
- Auto-generates config file indicating authority needed by each package
- For front-end (e.g. Webpack) and back-end (node.js)

https://lavamoat.github.io/

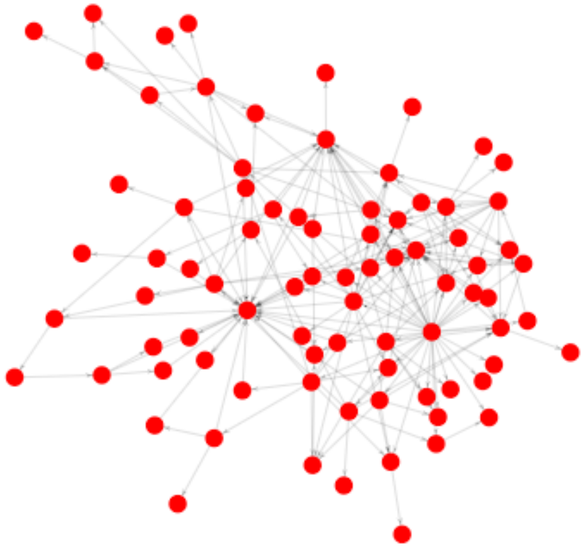
```
app.js
└── some-package
    └── entropoetry
        └── bn.js
```

```
npm install -D lavamoat
npx lavamoat app.js --autopolicy
```

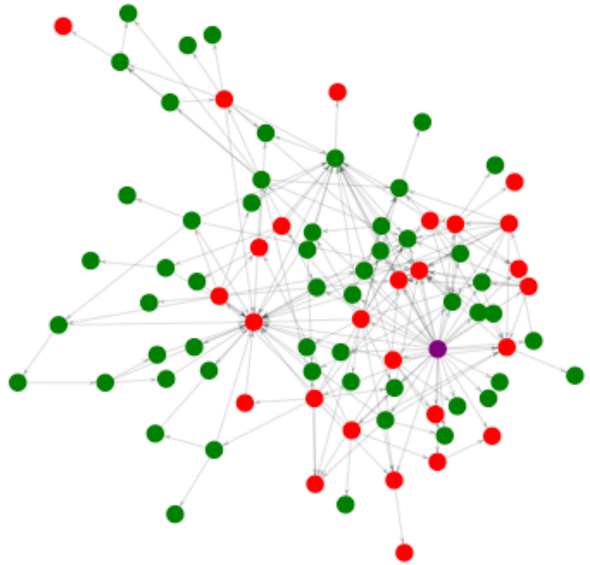

```
{
  "resources": {
    "some-package": {
      "globals": {
        "Buffer.from": true
      },
      "packages": {
        "some-package>entropoetry": true
      }
    },
    "some-package>entropoetry": {
      "builtin": {
        "assert": true,
        "buffer.Buffer": true,
        "zlib": true
      },
      "globals": {
        "console": true,
        "process.exitCode": "write"
      },
      "packages": {
        "some-package>entropoetry>bn.js": true
      }
    },
    "some-package>entropoetry>bn.js": {
      "builtin": {
        "buffer.Buffer": true
      },
      "globals": {
        "Buffer": true
      }
    }
  }
}
```

LavaMoat enables more focused security reviews

Exposure to package dependencies
without LavaMoat sandboxing



Exposure to package dependencies
with LavaMoat sandboxing



lavamoat-viz: https://github.com/LavaMoat/LavaMoat/tree/lavamoat-viz

Bonus: avoiding unwanted post-install scripts

- Package managers like `npm` allow packages to run install scripts
- A compromised dependency can exploit this to run code as part of your project installation script
- Lavamoat's `allow-scripts` tool configures your project to disable running install scripts by default
- Supports **allow-listing**. Edit allowed packages in `package.json`
- **New install scripts** entering your dependency tree will **no longer run automatically** unless approved

https://www.npmjs.com/package/@lavamoat/allow-scripts

```
npm install -D @lavamoat/allow-scripts
npm exec allow-scripts setup
```

```
// in package.json
{
  "lavamoat": {
    "allowScripts": {
      "keccak": true,
      "core-js": false,
      "@lavamoat/preinstall-always-fail": true
    }
  }
}
```

Beyond server-side: LavaMoat on Front-end & Mobile

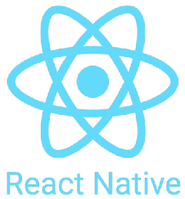
- LavaMoat plugs into bundler tools like Webpack and Browserify for front-end use.


```
npm i -D browserify lavamoat-browserify

browserify index.js --plugin [ lavamoat-browserify --autopolicy ]
```

https://github.com/LavaMoat/LavaMoat/tree/main/packages/browserify

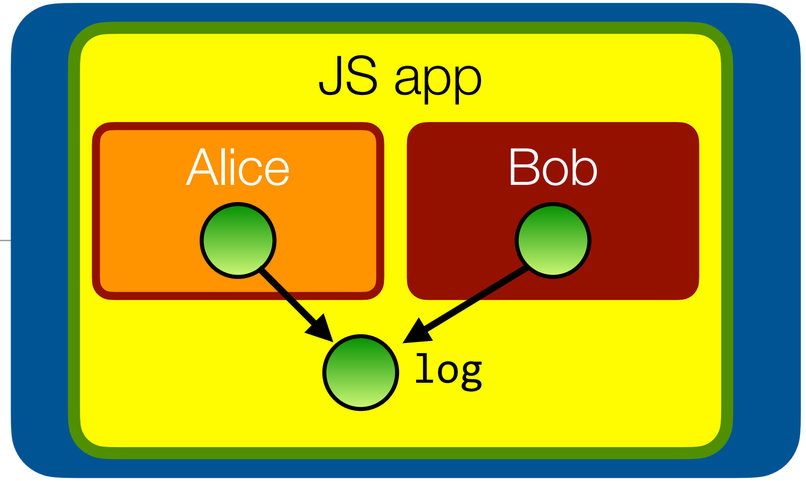
- The package `react-native-lockdown` sets up Hardened JavaScript for **React Native** apps




```
npm i @lavamoat/react-native-lockdown
```

https://github.com/LavaMoat/LavaMoat/tree/main/packages/react-native-lockdown

Back to our example



With Alice and Bob's code running in their own Compartment, we mitigate the credentials stealing attack.

Example Lavamoat policy that gives Bob access to console but nothing else (no 'fs'):

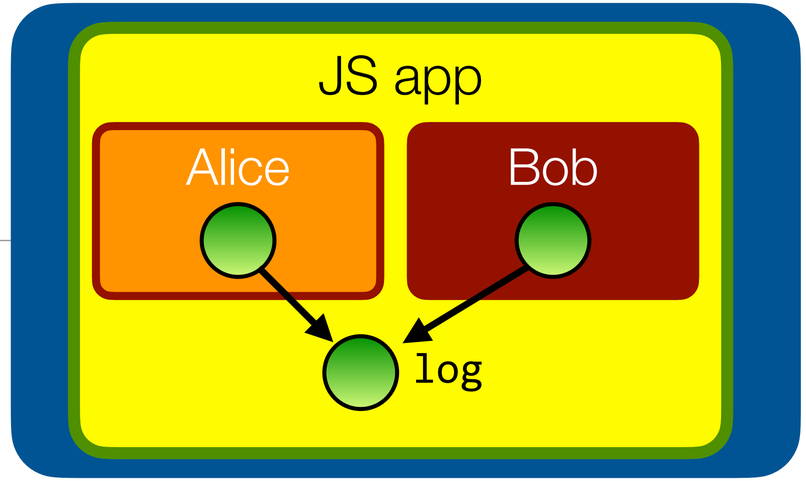
```
// lavamoat/node/policy.json
{
  "resources": {
    "bob": {
      "globals": {
        "console": true
      }
    }
  }
}
```

```
import * as fs from "fs";

const raw = fs.readFileSync('./secrets.json', 'utf8');
const secrets = JSON.parse(raw);
console.log('bob: STOLEN CREDENTIALS:');
console.log('apiKey:', secrets.apiKey);
```

```
error: LavaMoat - required node builtin package not in
allowlist: package "bob" requested "fs" as "fs"
```

Back to our example



With Alice and Bob's code running in their own Compartment, we also mitigate the prototype poisoning attack

```
import * as alice from "alice.js";
import * as bob from “bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return this.messages_; }
}

let log = new Log();
alice.setup(log);
bob.setup(log);
```

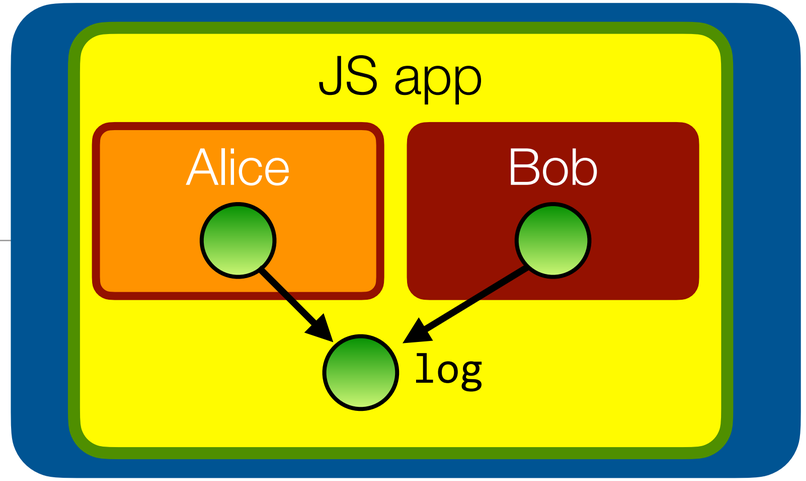
```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)

// Bob can delete the entire log (leak mutable state)
log.read().length = 0

// Bob can replace the ‘write’ function (api poisoning)
log.write = function(msg) {
  console.log(“I’m not logging anything”);
}
// Bob can replace the built-ins (prototype poisoning)
Array.prototype.push = function(msg) {
  console.log(“I’m not logging anything”);
}
```

One down, three to go

POLA: we would like Alice to only write to the log, and Bob to only read from the log.




```
import * as alice from "alice.js";
import * as bob from “bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return this.messages_; }
}

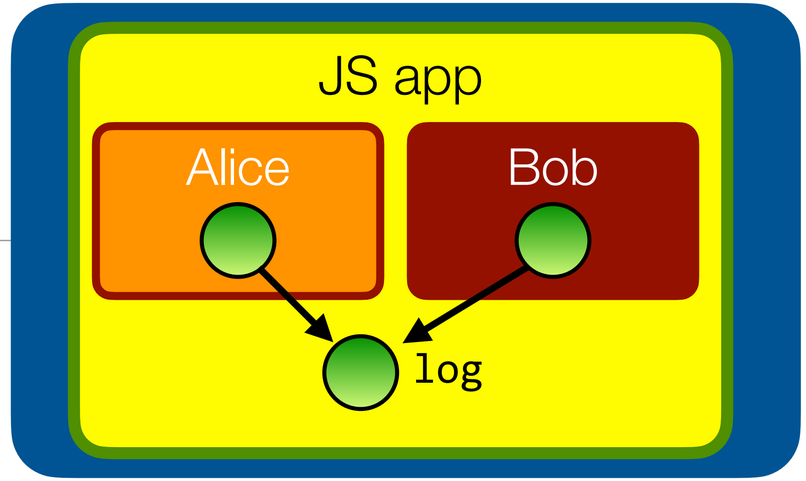
let log = new Log();
alice.setup(log);
bob.setup(log);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)

// Bob can delete the entire log (leak mutable state)
log.read().length = 0
```

```
// Bob can replace the ‘write’ function (api poisoning)
log.write = function(msg) {
  console.log(“I’m not logging anything”);
}
```

Make the log's interface **tamper-proof**



Object.freeze makes property bindings (not their values) immutable

```
import * as alice from "alice.js";
import * as bob from “bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return this.messages_; }
}

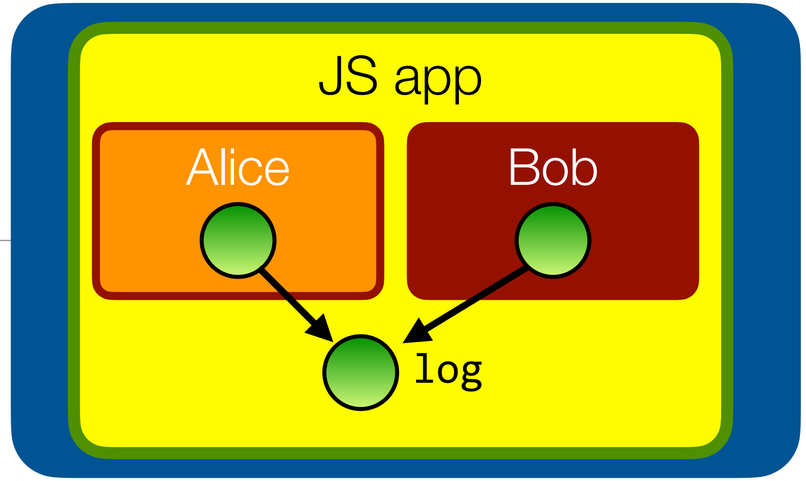
let log = Object.freeze(new Log());
alice.setup(log);
bob.setup(log);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)

// Bob can delete the entire log (leak mutable state)
log.read().length = 0

// Bob can replace the ‘write’ function (api poisoning)
log.write = function(msg) {
  console.log(“I’m not logging anything”);
}
```

Make the log's interface tamper-proof. Oops.



Functions are mutable too. Freeze doesn't recursively freeze the object's functions.

```
import * as alice from "alice.js";
import * as bob from “bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return this.messages_; }
}

let log = Object.freeze(new Log());
alice.setup(log);
bob.setup(log);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)

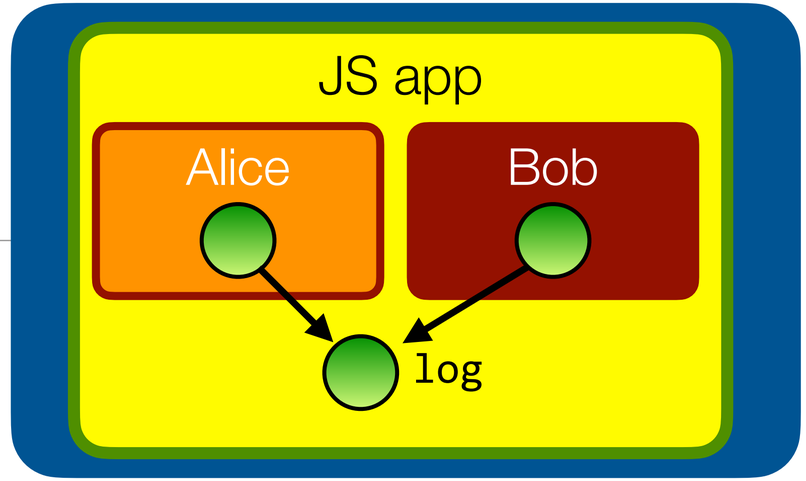
// Bob can delete the entire log (leak mutable state)
log.read().length = 0

// Bob can replace the ‘write’ function (api poisoning)
log.write = function(msg) {
  console.log(“I’m not logging anything”);
}

// Bob can still modify the write function object
log.write.apply = function() { “gotcha” };
```

Make the log's interface tamper-proof

Hardened JavaScript provides a `harden` function that "deep-freezes" an object




```
import * as alice from "alice.js";
import * as bob from "bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return this.messages_; }
}

let log = harden(new Log());
alice.setup(log);
bob.setup(log);
```

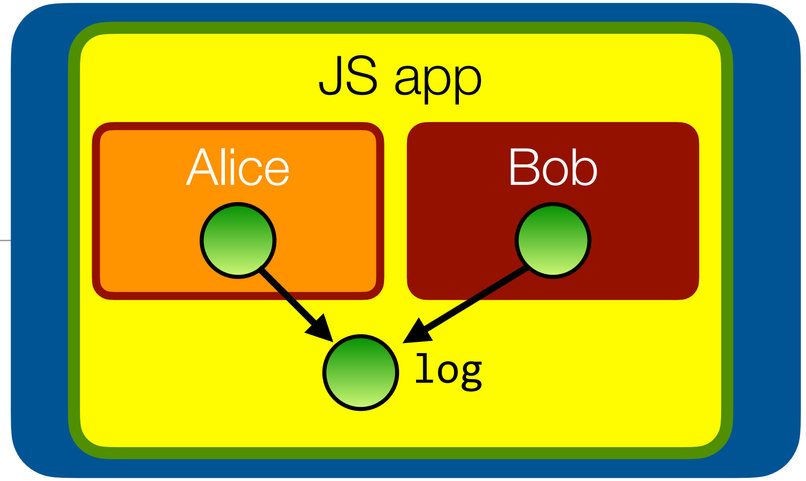
```
// in bob.js
// Bob can just write to the log (excess authority)
log.write("I'm polluting the log")

// Bob can delete the entire log (leak mutable state)
log.read().length = 0

// Bob can replace the 'write' function (api poisoning)
log.write = function(msg) {
  console.log("I'm not logging anything");
}

// Bob can still modify the write function object
log.write.apply = function() { "gotcha" };
```

Two down, two to go




```
import * as alice from "alice.js";
import * as bob from “bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return this.messages_; }
}

let log = harden(new Log());
alice.setup(log);
bob.setup(log);
```

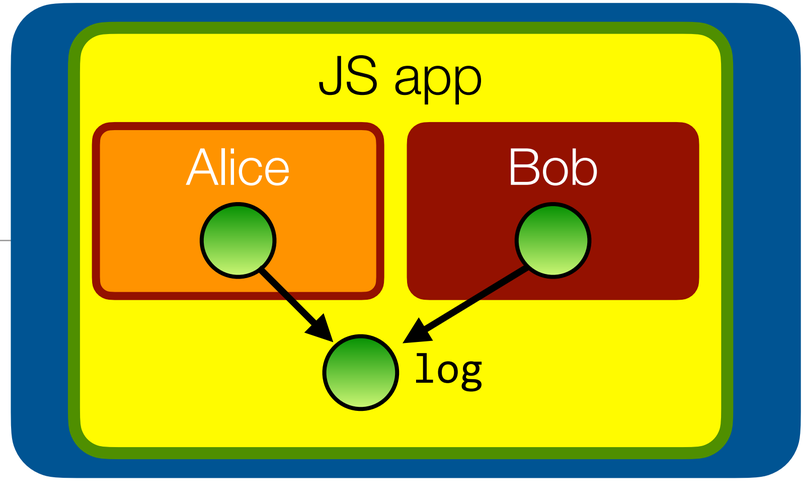
```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)

// Bob can delete the entire log (leak mutable state)
log.read().length = 0

// Bob can replace the ‘write’ function (api poisoning)
log.write = function(msg) {
  console.log(“I’m not logging anything”);
}

// Bob can still modify the write function object
log.write.apply = function() { “gotcha” };
```

Two down, two to go




```
import * as alice from "alice.js";
import * as bob from “bob.js";

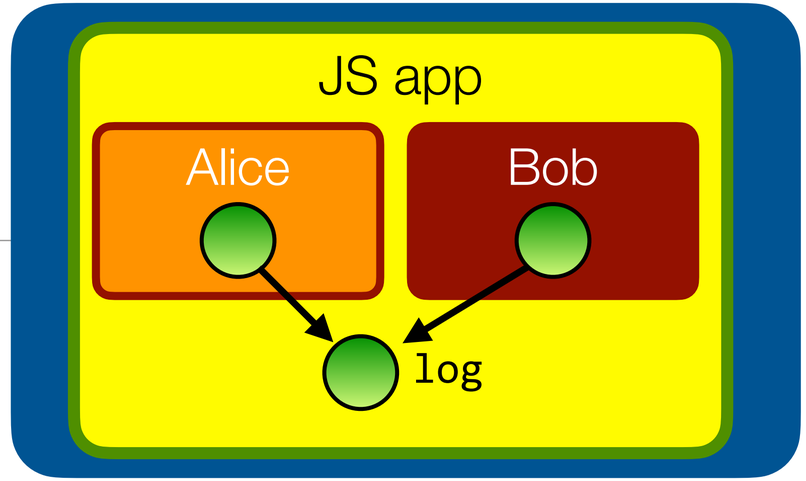
class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return this.messages_; }
}

let log = harden(new Log());
alice.setup(log);
bob.setup(log);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)
```

```
// Bob can delete the entire log (leak mutable state)
log.read().length = 0
```

Don’t share access to mutable internals



- Modify `read()` to return a copy of the mutable state.
- Even better would be to use a more efficient copy-on-write or “immutable” data structure (see immutable-js.com)

```
import * as alice from "alice.js";
import * as bob from “bob.js";

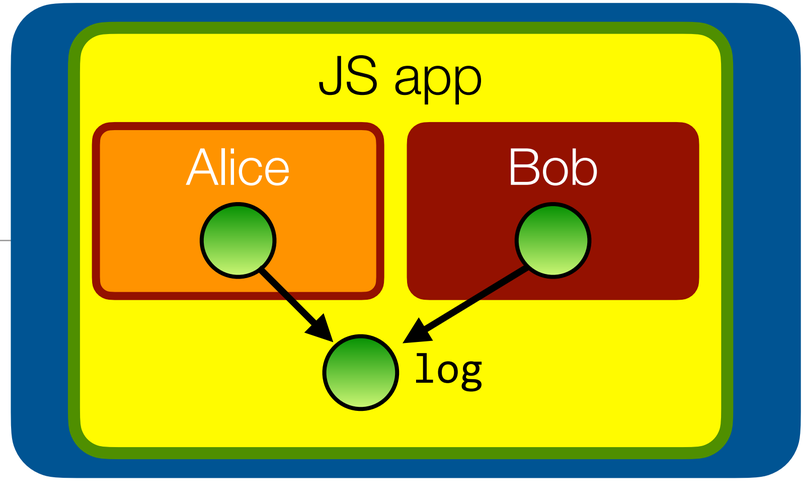
class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return [...this.messages_]; }
}

let log = harden(new Log());
alice.setup(log);
bob.setup(log);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)

// Bob can delete the entire log (leak mutable state)
log.read().length = 0
```

Three down, one to go




```
import * as alice from "alice.js";
import * as bob from “bob.js";

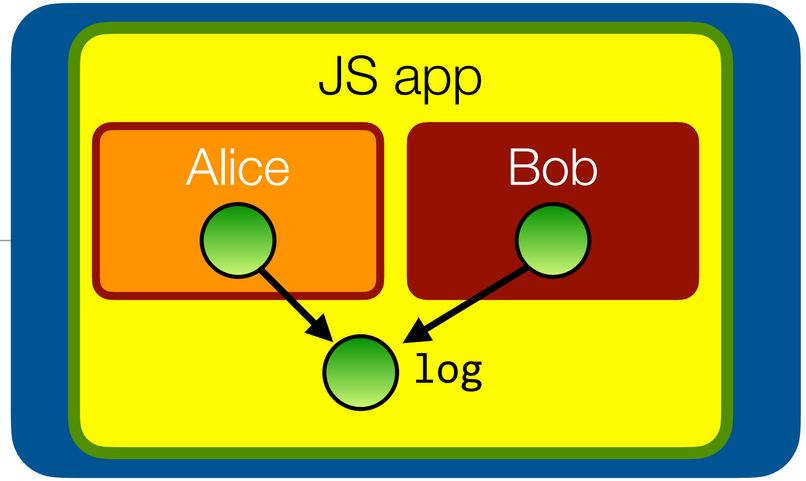
class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return [...this.messages_]; }
}

let log = harden(new Log());
alice.setup(log);
bob.setup(log);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)

// Bob can delete the entire log (leak mutable state)
log.read().length = 0
```

Three down, one to go



- Recall: we would like Alice to only write to the log, and Bob to only read from the log.
- Bob receives too much authority. How to limit?

```
import * as alice from "alice.js";
import * as bob from “bob.js";

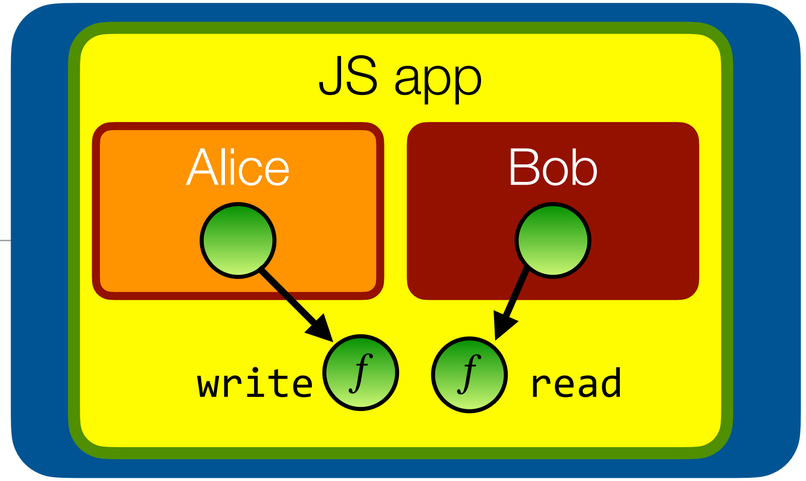
class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return [...this.messages_]; }
}

let log = harden(new Log());
alice.setup(log);
bob.setup(log);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)
```

Pass only the authority that Bob needs.

Just pass the write function to Alice and the read function to Bob.



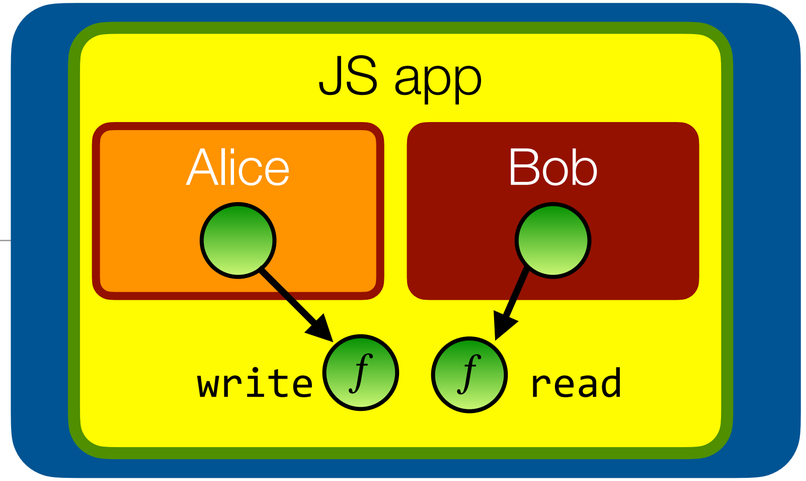

```
import * as alice from "alice.js";
import * as bob from “bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return [...this.messages_]; }
}

let log = new Log();
let read = harden(() => log.read());
let write = harden((msg) => log.write(msg));
alice.setup(write);
bob.setup(read);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)
```

Success! We thwarted all of Evil Bob's attacks.




```
import * as alice from "alice.js";
import * as bob from “bob.js";

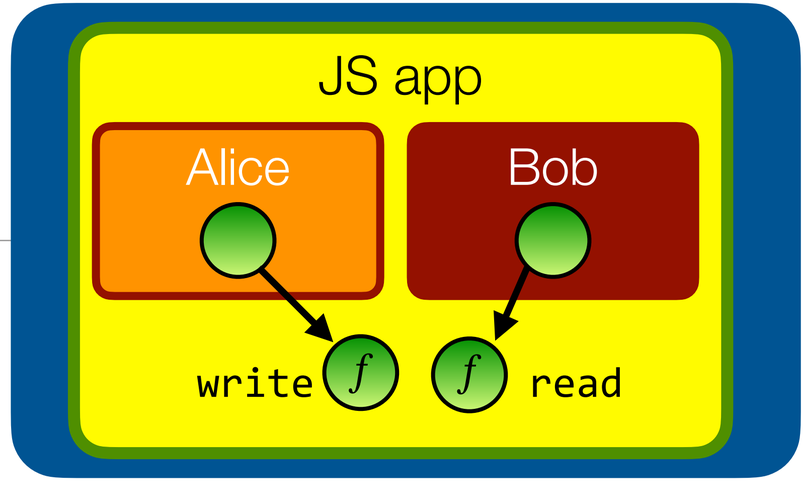
class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return [...this.messages_]; }
}

let log = new Log();
let read = harden(() => log.read());
let write = harden((msg) => log.write(msg));
alice.setup(write);
bob.setup(read);
```

```
// in bob.js
// Bob can just write to the log (excess authority)
log.write(“I’m polluting the log”)
```

Is there a better way to write this code?

The burden of correct use is on the *client* of the class. Can we avoid this?

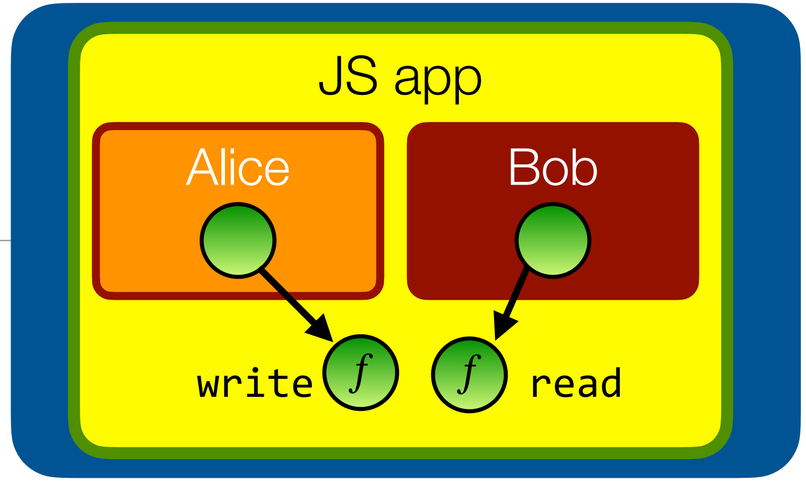



```
import * as alice from "alice.js";
import * as bob from “bob.js";

class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return [...this.messages_]; }
}

let log = new Log();
let read = harden(() => log.read());
let write = harden((msg) => log.write(msg));
alice.setup(write);
bob.setup(read);
```

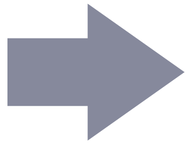
Use the **Function as Object** pattern



- A record of closures hiding state is a fine representation of an object of methods hiding instance vars
- Pattern long advocated by Doug Crockford instead of using classes or prototypes

```
class Log {
  constructor() {
    this.messages_ = [];
  }
  write(msg) { this.messages_.push(msg); }
  read() { return [...this.messages_]; }
}

let log = new Log();
let read = harden(() => log.read());
let write = harden((msg) => log.write(msg));
alice.setup(write);
bob.setup(read);
```

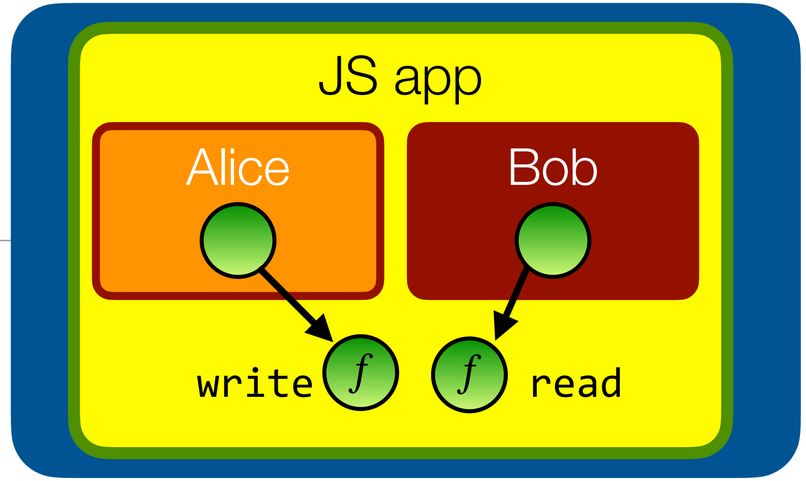


```
function makeLog() {
  const messages = [];
  function write(msg) { messages.push(msg); }
  function read() { return [...messages]; }
  return harden({read, write});
}


let log = makeLog();
alice.setup(log.write);
bob.setup(log.read);
```

(See also https://martinfowler.com/bliki/FunctionAsObject.html)

Use the Function as Object pattern




```
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import * as bob from “bob.js";

function makeLog() {
  const messages = [];
  function write(msg) { messages.push(msg); }
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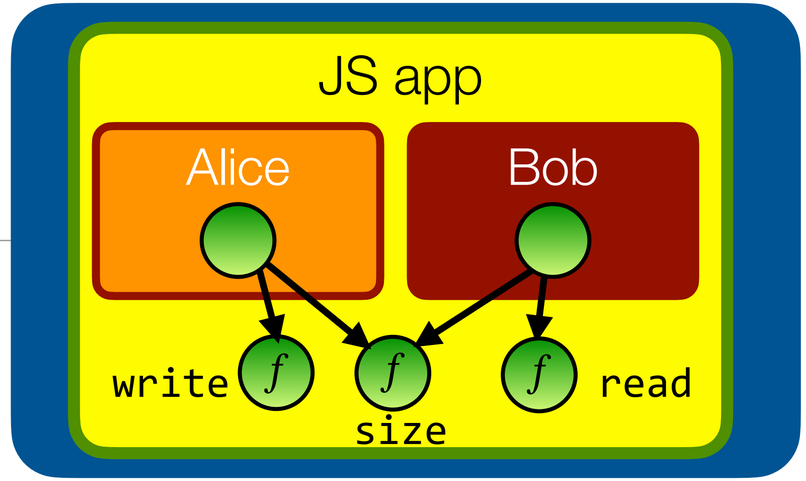
  return harden({read, write});
}


let log = makeLog();
alice.setup(log.write);
bob.setup(log.read);
```

What if Alice and Bob need more authority?

If over time we want to expose more functionality to Alice and Bob, we need to refactor all of our code.

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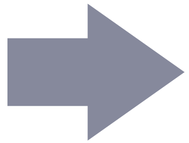

```
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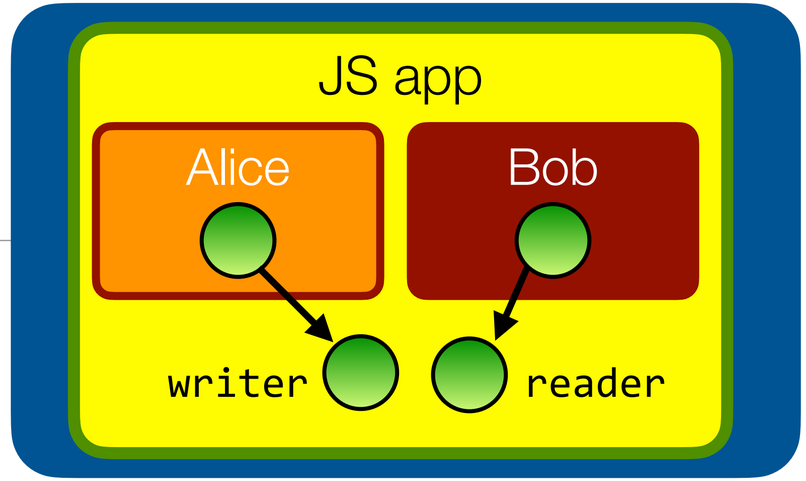
import * as bob from "bob.js";

function makeLog() {
  const messages = [];
  function write(msg) { messages.push(msg); }
  function read() { return [...messages]; }
  function size() { return messages.length; }
  return harden({read, write, size});
}

let log = makeLog();
alice.setup(log.write, log.size);
bob.setup(log.read, log.size);
```

Expose distinct authorities through **facets**

Easily deconstruct the API of a single powerful object into separate interfaces by nesting objects

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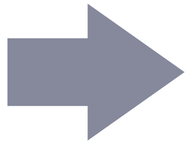
bob.setup(log.read, log.size);
```



```
import * as alice from "alice.js";
import * as bob from "bob.js";

function makeLog() {
  const messages = [];
  function write(msg) { messages.push(msg); }
  function read() { return [...messages]; }
  function size() { return messages.length; }
  return harden({
    reader: {read, size},
    writer: {write, size}
  });
}

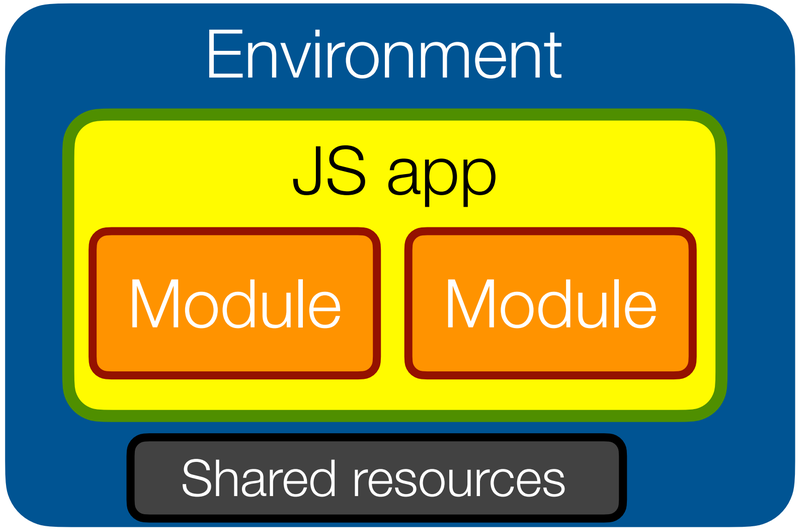
let {reader, writer} = makeLog();
alice.setup(writer);
bob.setup(reader);
```

Demo

https://github.com/tvcutsem/lavamoat-demo

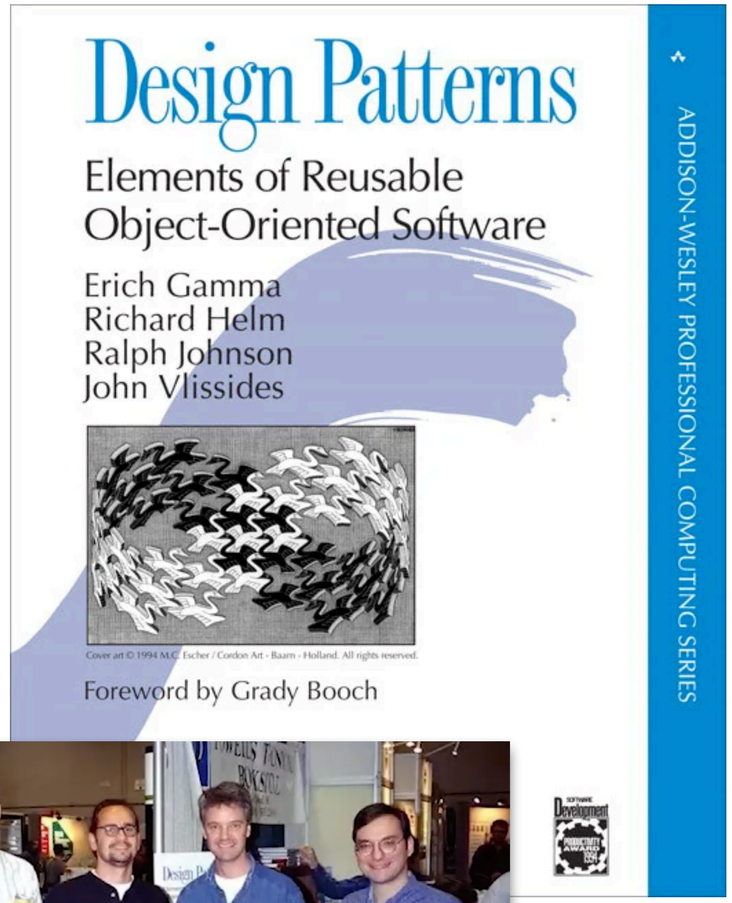
End of Part II: recap

- Modern JS apps are composed from many packages. You can't trust them all.
- Traditional security boundaries don't exist between modules from different packages. Compartments add basic isolation.
- **Isolated modules must still interact!**
- **Compose** functionality from untrusted modules in a **least-authority** manner
- This can be done via **repeatable programming patterns** that rely on object-capability security



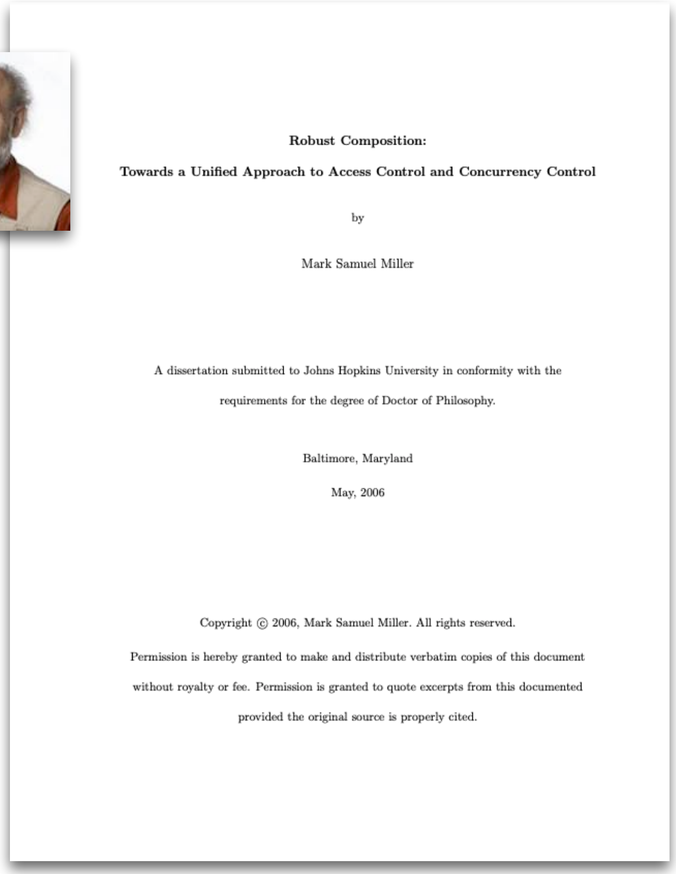
Part III
Safely composing modules using least-authority patterns

Design Patterns (“Gang of Four”, 1994)



- Visitor
- Factory
- Observer
- Singleton
- State
- …

Design Patterns for **robust composition** (Mark S. Miller, 2006)



Robust Composition:

Towards a Unified Approach to Access Control and Concurrency Control

by

Mark Samuel Miller

A dissertation submitted to Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy.

Baltimore, Maryland

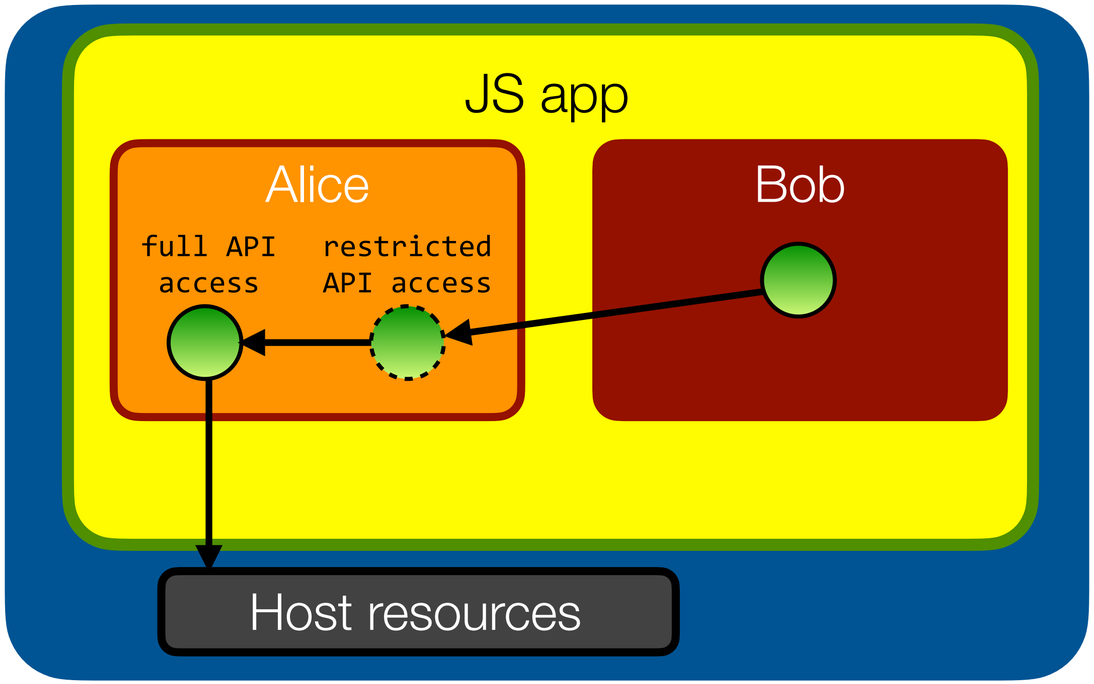
May, 2006

http://www.erights.org/talks/thesis/markm-thesis.pdf

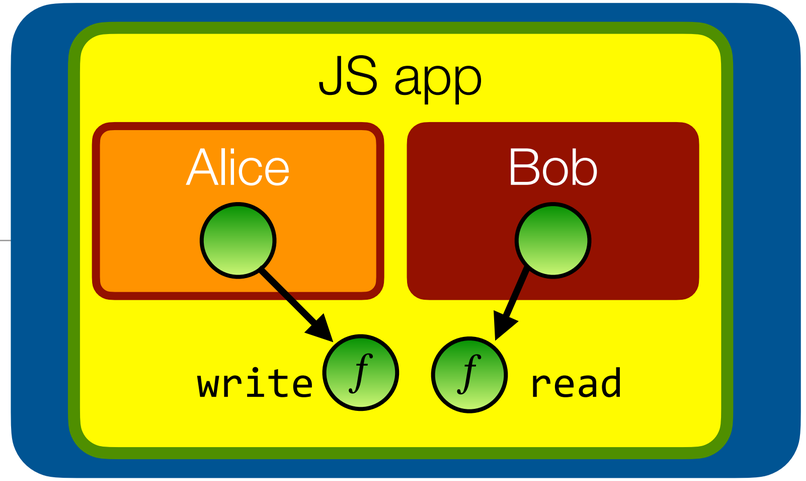
- Facets
- Taming
- Caretaker
- Membrane
- Sealer/unsealer pair
- …

Recall: the Principle of Least Authority (POLA)

- A module should only be given the authority it needs to do its job, and nothing more



Further limiting Bob's authority



We would like to give Bob only **temporary** read access to the log.

```
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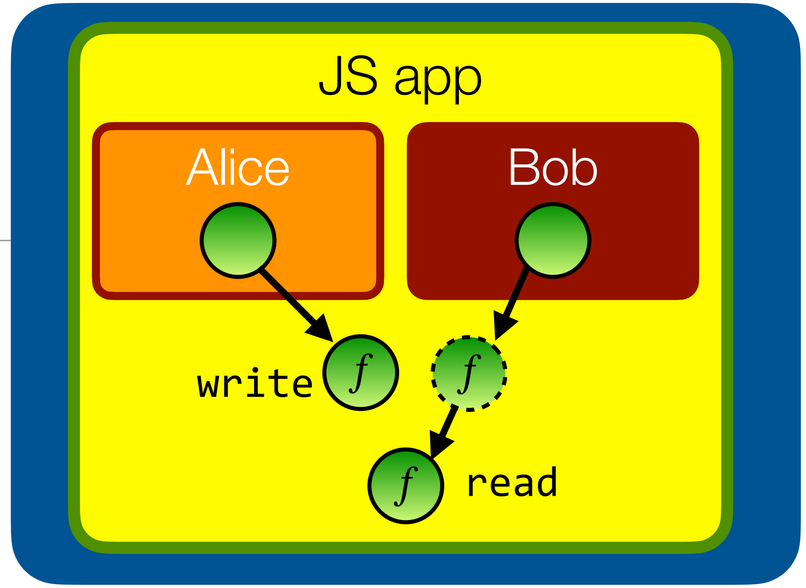
}

let log = makeLog();

alice.setup(log.write);
bob.setup(log.read);
```

Use **caretaker** to insert access control logic



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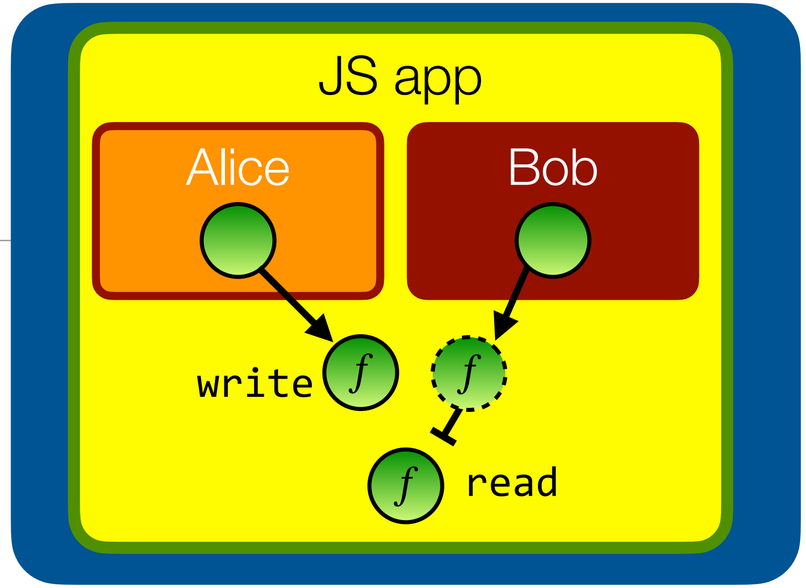
}

let log = makeLog();
let [rlog, revoke] = makeRevokableLog(log);
alice.setup(log.write);
bob.setup(rlog.read);
```

Use **caretaker** to insert access control logic



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revoke();
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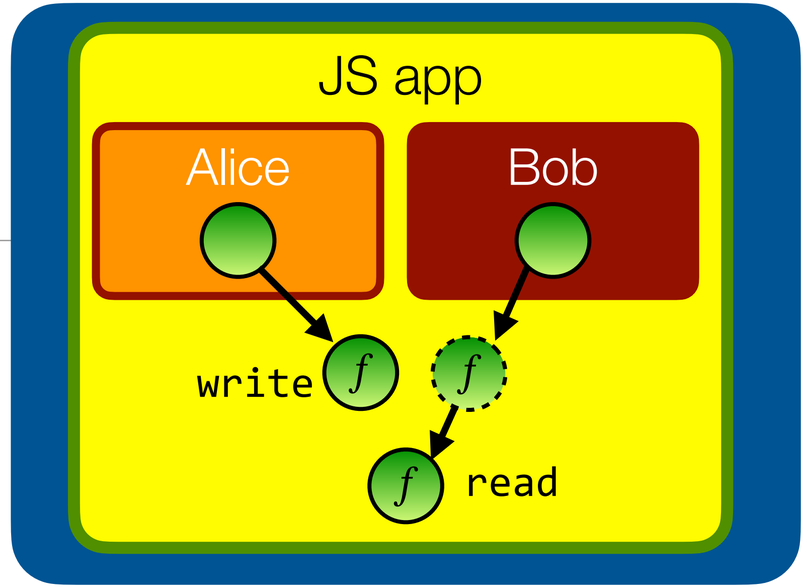


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// to revoke Bob’s access:
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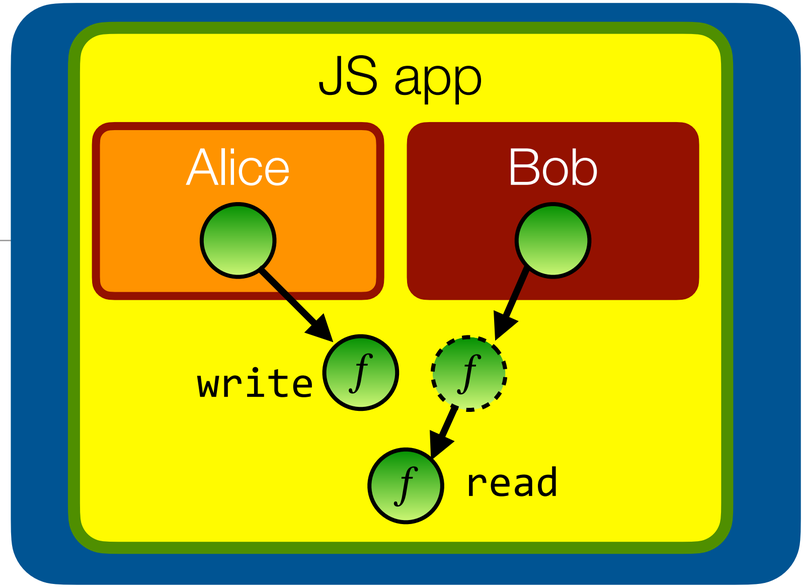
```
function makeRevokableLog(log) {
  function revoke() { log = null; };
  let proxy = {
    write(msg) { log.write(msg); }
    read() { return log.read(); }
  };
  return harden([proxy, revoke]);
}
```

A caretaker is just a proxy object

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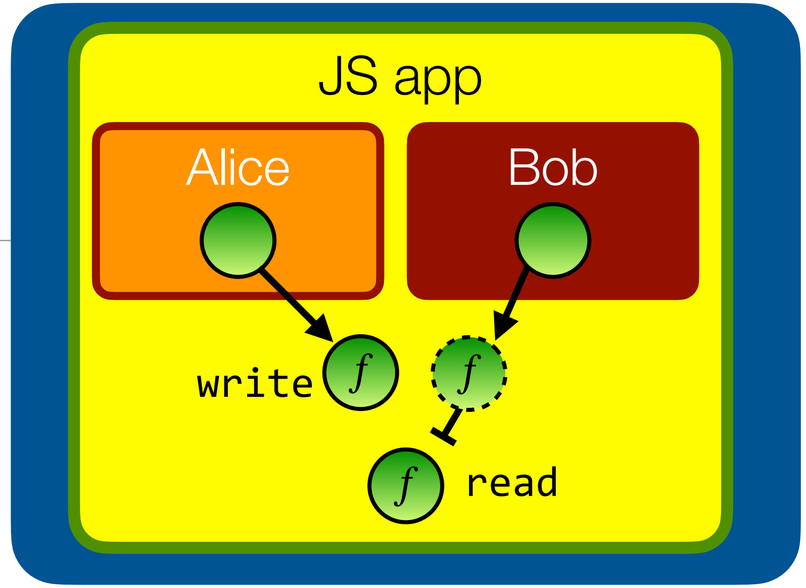


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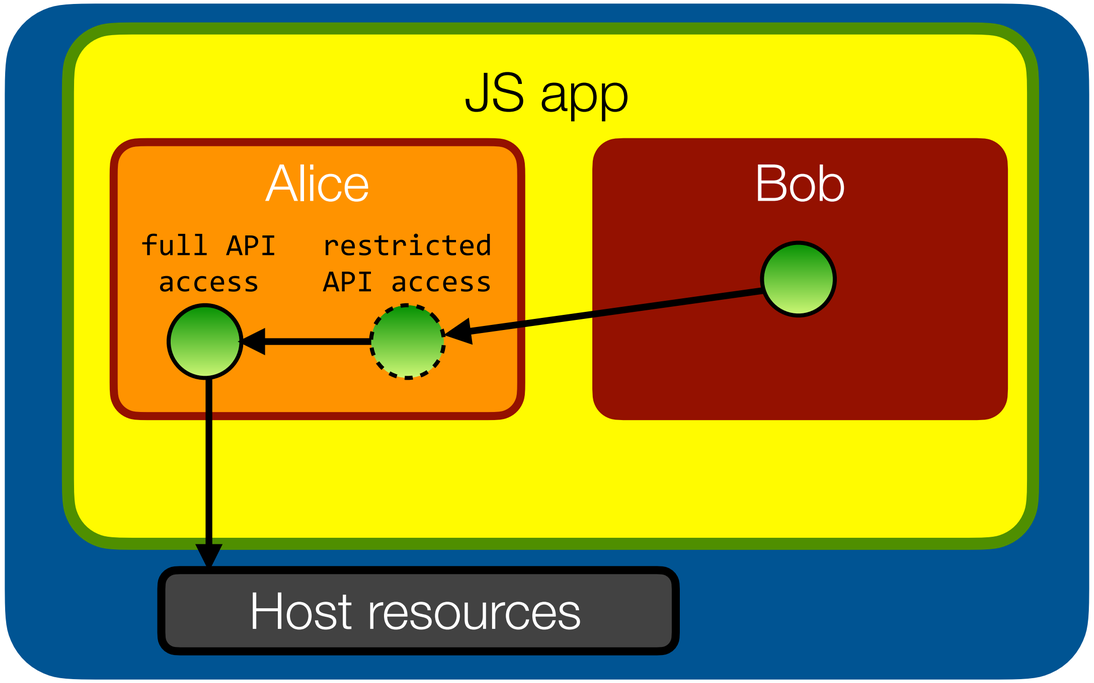
  return harden([proxy, revoke]);
}
```

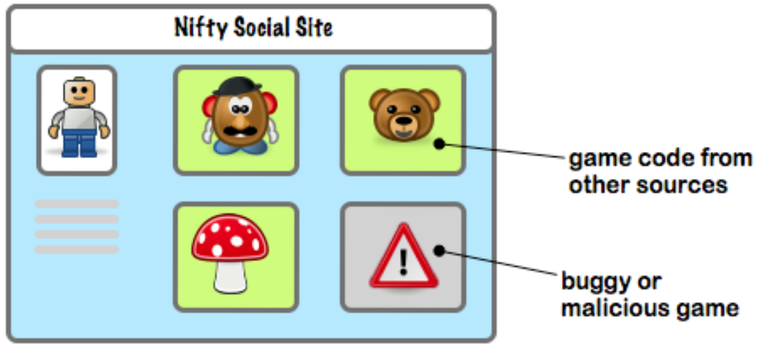
Taming is the process of restricting access to powerful APIs

- Expose powerful objects through restrictive proxies to third-party code
- E.g. Alice might give Bob access to console.log but not to process.env or the ‘fs’ filesystem API.

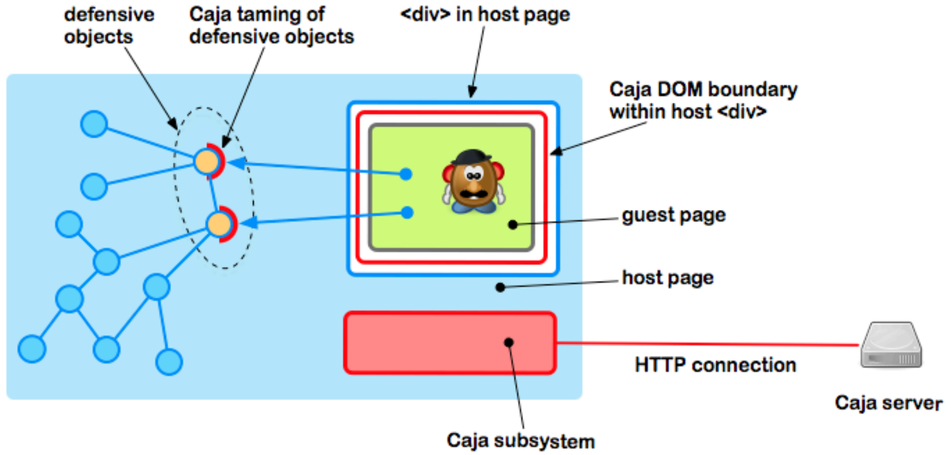


Least-authority patterns are used in industry

Example: how Google Caja uses **taming** to restrict access to the browser DOM



Google Caja



(source: Google Caja documentation: https://developers.google.com/caja/docs/about)

Least-authority patterns are used in industry

Moddable XS

Uses **Compartments** for safe end-user scripting of IoT products

MetaMask Snaps

Uses **LavaMoat** to sandbox plugins in their crypto web wallet

Agoric Zoe

Uses **Hardened JS** to write smart contracts and Dapps

Figma plugins

Used **Realms** and **membranes** to embed third-party plugins for their editor

Mozilla Firefox

Uses **membranes** to isolate site origins from privileged JS code

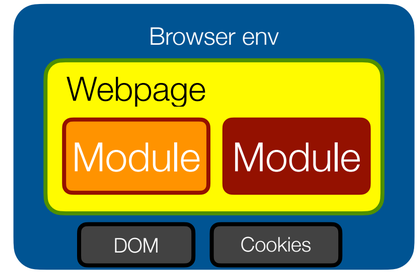
Salesforce Lightning

Uses **Realms** and **membranes** to isolate & observe UI components

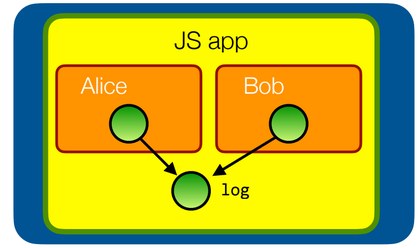
Summary

This Lecture: Recap

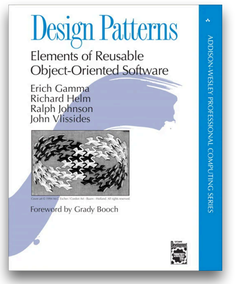
- Part I: **why module isolation** is critical to modern JavaScript applications

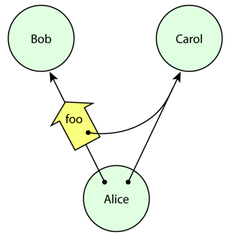


- Part II: the **Principle of Least Authority**, by example



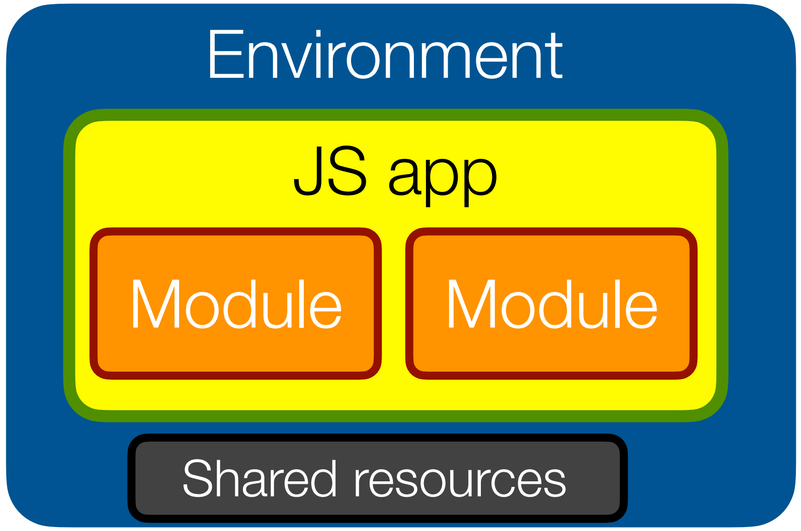
- Part III: safely composing modules using **least-authority patterns**





The take-away messages

- Modern applications are **composed from many modules across packages**.
- We now live in a world where third-party **packages are increasingly compromised** (**N**eatly **P**ackaged **M**alware!)
- Today: most attacks target package install scripts. As defences improve, **attackers will shift to compromising module code run when the package is imported**, in production environments.
- Apply the “principle of least authority” to **limit trust**.
  - Step 1: **Isolate modules** originating from different packages (use Hardened JS & Lavamoat)
  - Step 2: let modules **interact with “least authority”** (using repeatable programming patterns)



“Security is just an extreme form of Modularity”

- Mark S. Miller
(Chief Scientist, Agoric)

KU LEUVEN

DistriNet

Designing “least-authority” JavaScript apps

Tom Van Cutsem
KU Leuven

Questions?
tom.vancutsem@kuleuven.be

tvcutsem.github.io be.linkedin.com/in/tomvc github.com/tvcutsem @tvcutsem.bsky.social

Further Reading

- **JavaScript-specific tools and resources**
- Hardened JavaScript: https://hardenedjs.org/
- Lavamoat: https://lavamoat.github.io/
- Compartments: https://github.com/tc39/proposal-compartments and https://github.com/Agoric/ses-shim
- ShadowRealms: https://github.com/tc39/proposal-realms and github.com/Agoric/realms-shim
- Hardened JS (SES): https://github.com/tc39/proposal-ses and https://github.com/endojs/endo/tree/master/packages/ses
- Subsetting ECMAScript: https://github.com/Agoric/Jessie
- Kris Kowal (Agoric): “Hardened JavaScript” https://www.youtube.com/watch?v=RoodZSIL-DE
- Making Javascript Safe and Secure: Talks by Mark S. Miller (Agoric), Peter Hoddie (Moddable), and Dan Finlay (MetaMask): https://www.youtube.com/playlist?list=PLzDw4TTug5O25J5M3fwErKImrjOrqGikj
- Moddable: XS: Secure, Private JavaScript for Embedded IoT: https://blog.moddable.com/blog/secureprivate/
- Membranes in JavaScript: tvcutsem.github.io/js-membranes and tvcutsem.github.io/membranes
- Caja: https://developers.google.com/caja (Capability-secure subset of JavaScript)

- **General background on capability-based security and POLA**
- Mark Miller, Ka-Ping Yee, Jonathan Shapiro, “Capability Myths Demolished”: https://srl.cs.jhu.edu/pubs/SRL2003-02.pdf
- Chip Morningstar, “What are capabilities”: http://habitatchronicles.com/2017/05/what-are-capabilities/ (broad historical perspective)
- Thomas Leonard, “Lambda capabilities”: https://roscidus.com/blog/blog/2023/04/26/lambda-capabilities/ (excellent intro to capabilities for functional programmers)
- Why KeyKOS is fascinating: https://github.com/void4/notes/issues/41 (sketches the early history of capabilities as used in operating systems)
- Neil Madden, “Capability-Based Security and Macaroons” https://freecontent.manning.com/capability-based-security-and-macaroons/#id_ftn3 (capabilities in REST APIs)

Acknowledgements

- Mark S. Miller (for the inspiring and ground-breaking work on Object-capabilities, Robust Composition, E, Caja, JavaScript and Secure ECMAScript)
- Marc Stiegler's "PictureBook of secure cooperation" (2004) is a great source of inspiration for patterns of robust composition
- Doug Crockford's "JS: the Good Parts" and "How JS Works" books provide a highly opinionated take on how to write clean, good, robust JavaScript code
- Kate Sills and Kris Kowal at Agoric for helpful comments on earlier versions of this presentation
- The Cap-talk and Friam online communities for inspiration on capability-security and capability-secure design patterns
- TC39 and the es-discuss community, for the interactions during the design of ECMAScript 2015, and in particular all the feedback on the Proxy API
- The SES secure coding guide: https://github.com/endojs/endo/blob/master/packages/ses/docs/secure-coding-guide.md
- Dan Finlay and the Metamask team for their work on Lavamoat