Frozen Realms

Proposed Standard Support for Safer JavaScript Plugins

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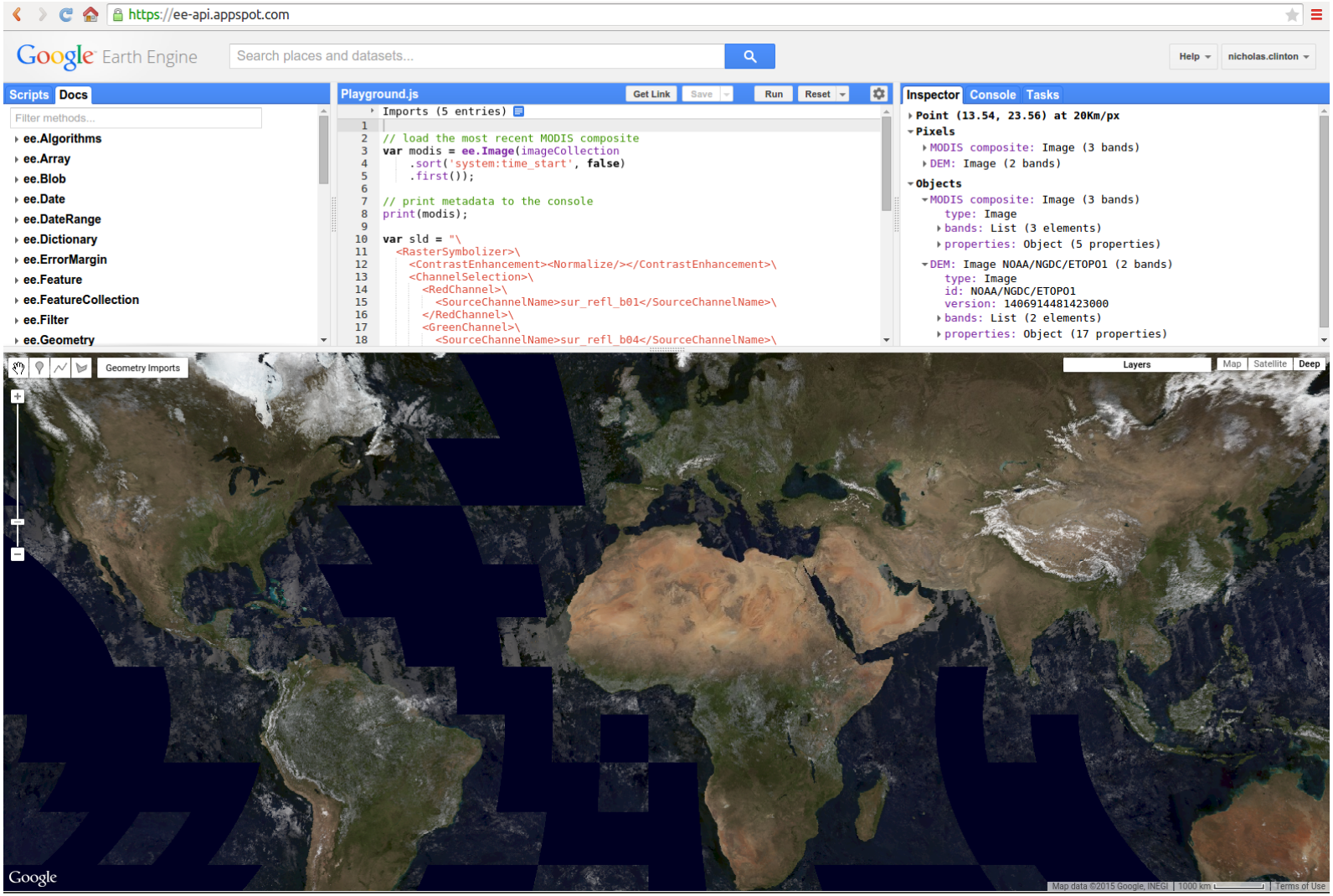
Verified Trustworthy Software Systems 2016

Frameworks with fallible plugins



Enablers of safer plugins

Memory safety
+ Encapsulation
+ **Defensible** objects
+ Effects **only** by using held references
+ No **powerful** references by default

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Reference graph ≡ Access graph

Reachability limits effects

Abstraction boundary ≡ Enforcement mechanism

Java?

- ✓ Memory safety
- ✓ Encapsulation
- ✓ **Defensible** objects

  Effects **only** by using held references

  No **powerful** references by default

From Java to Joe-E

```
// Effects only by held references?
static Array mu = [];
import java.io.File;

// No powerful references by default?
...ClassLoader...
```

From Java to Joe-E

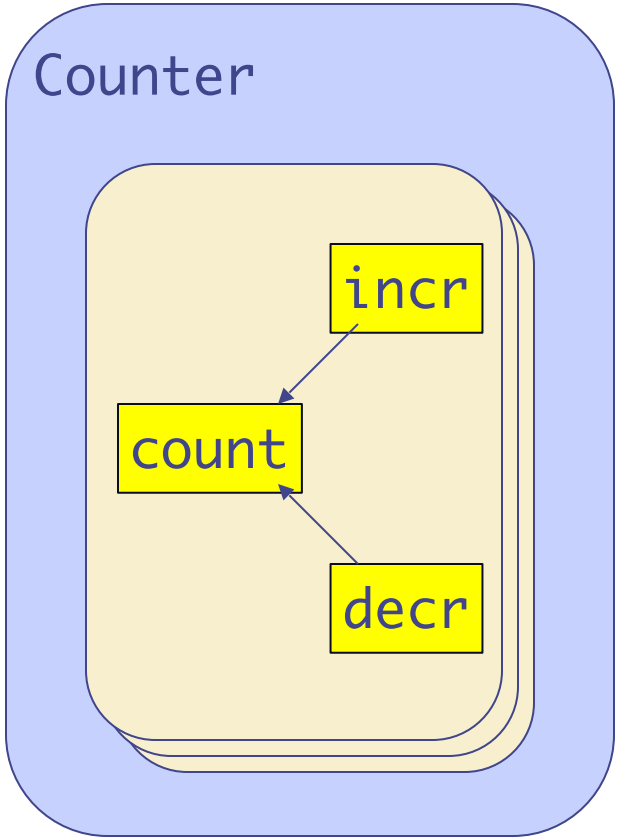
```
// Effects only by held references
static Array mu = [];    // prohibit
import java.io.File;     // tame

// No powerful references by default
...ClassLoader...        // restrict to subset
```

Ancient JavaScript? (ES3, 1999-2009)

- ✓ Memory safety
  Encapsulation
  Defensible objects
- ✓ Effects **only** by using held references
  No **powerful** references by default

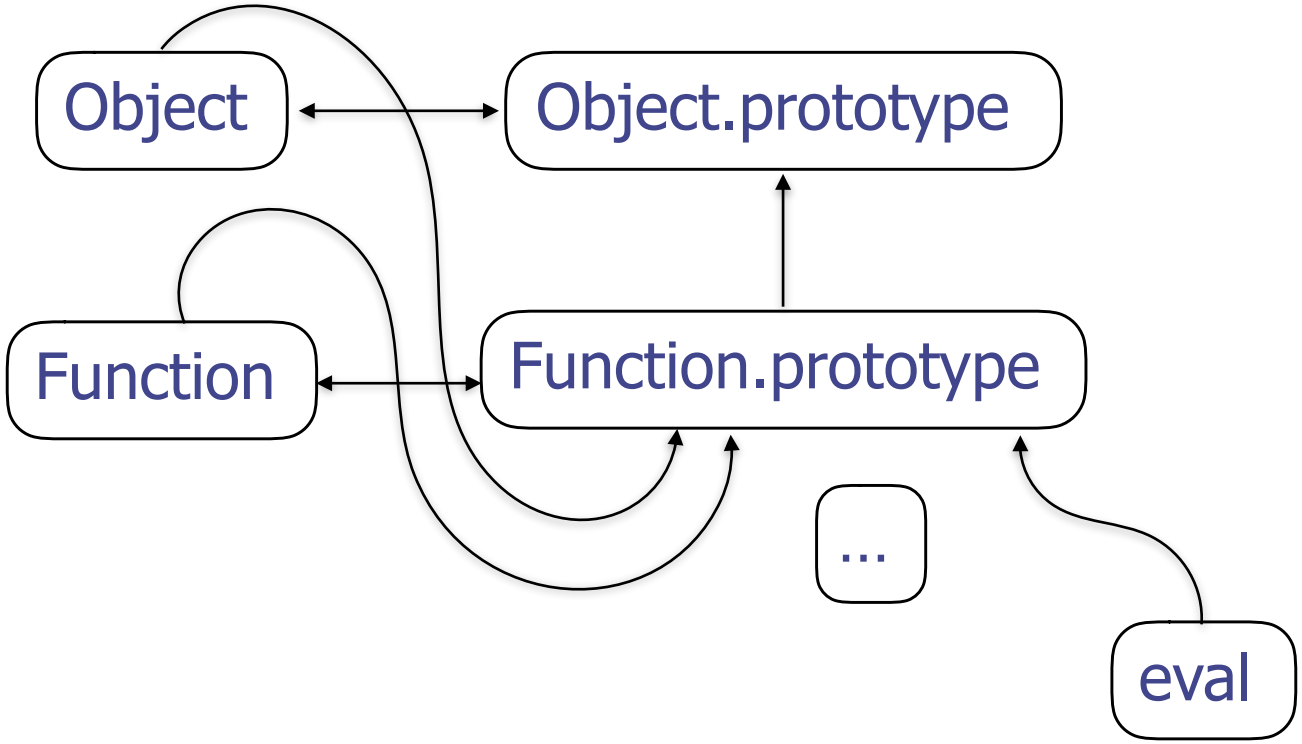
Just Enough JavaScript



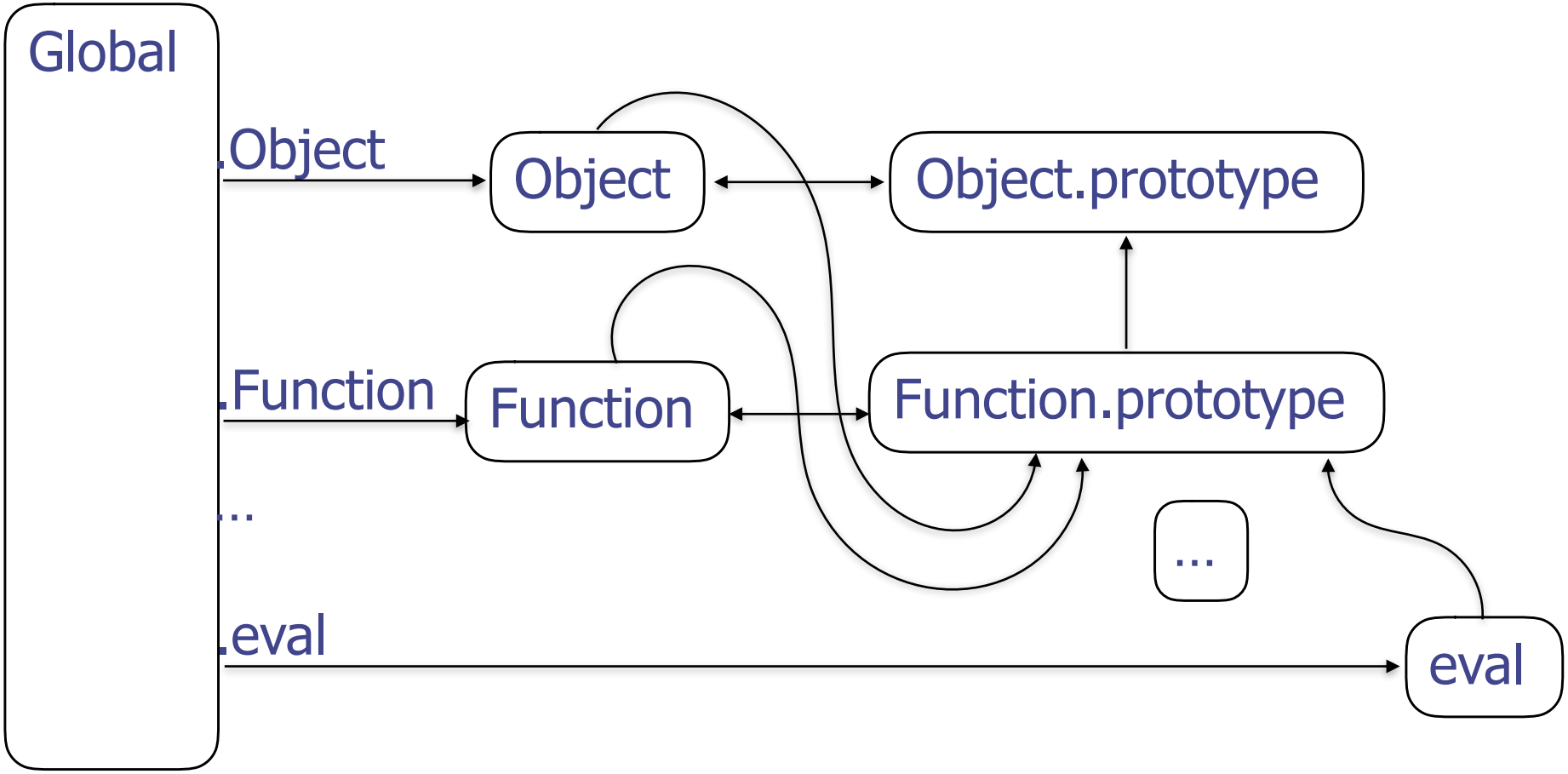

```
function Counter() {
    let count = 0;
    return {
        incr: () => ++count,
        decr: () => --count
    };
}
```

A record of closures hiding state
is a fine representation of an
object of methods hiding instance vars

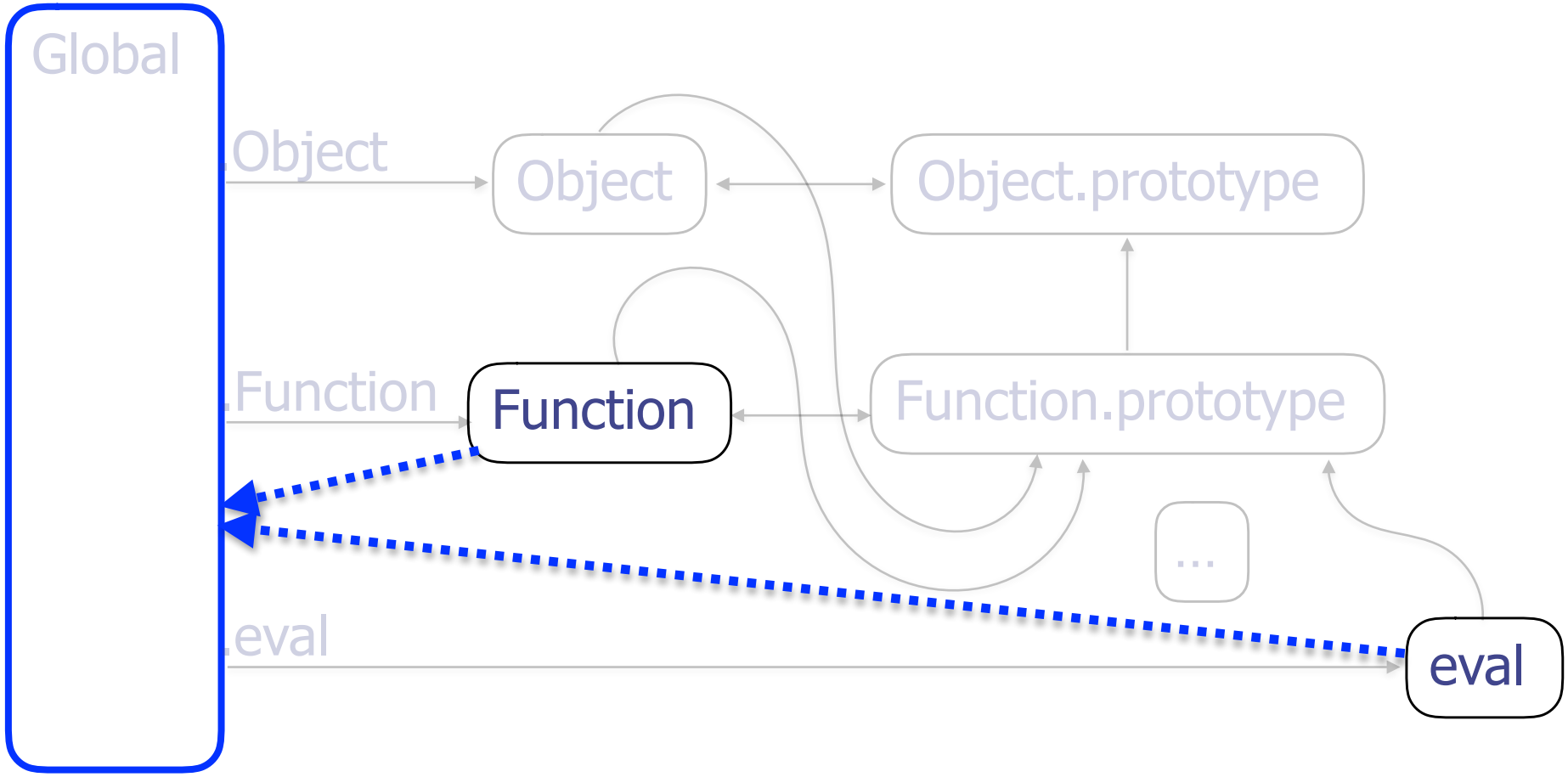
Primordials
Objects that must exist before code runs



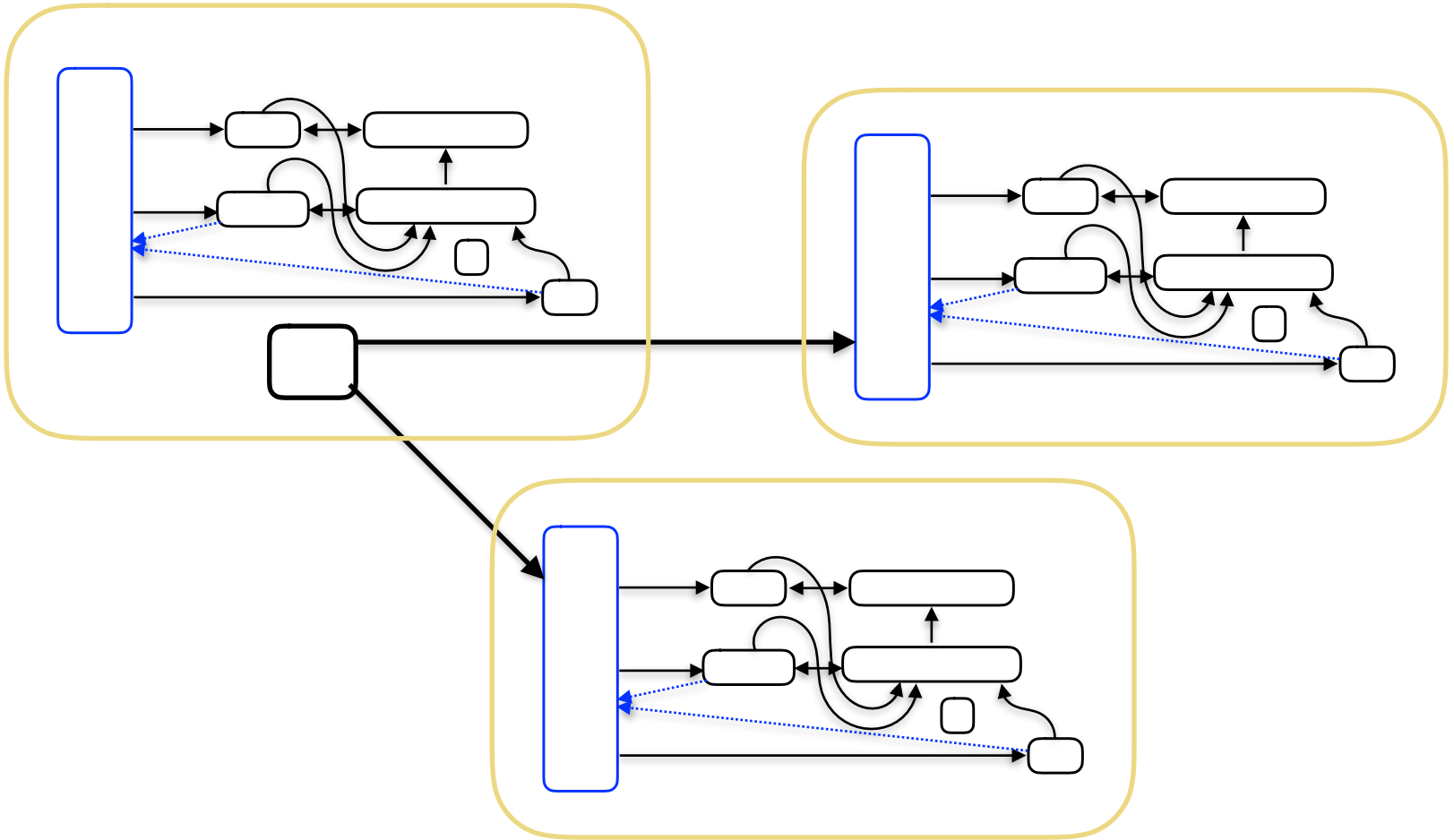
Global object ("window" in browsers)



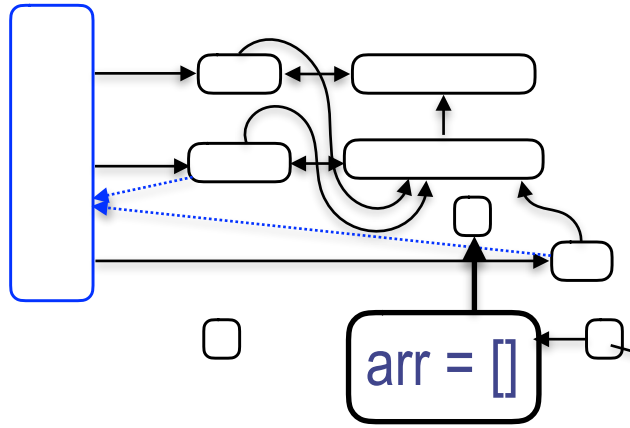
Evaluators: eval, Function
Evals code in scope of global's names



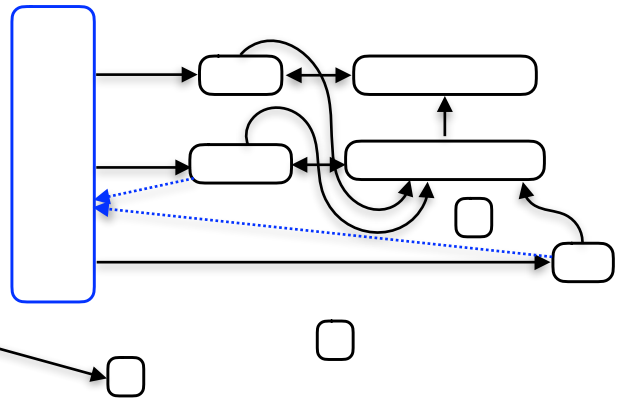
Multiple Isolated Realms
In browser: same-origin iframes



Identity Discontinuities



Alice says: const arr = [];
// pass arr to Bob



Bob says: arr instanceof Array
// false!

“user mode” JS vs “system mode” host

JS by itself has no I/O.

- Computes, invokes host-provided objects

All I/O via host-provided global variables

- window, document, XMLHttpRequest, files, sockets

Hosts differ: browser, server (nodejs), devices

- Computational libraries mostly in “user mode” JS

ES5/strict (2009) — **Defensible** Objects

Full static scoping (almost lexical)

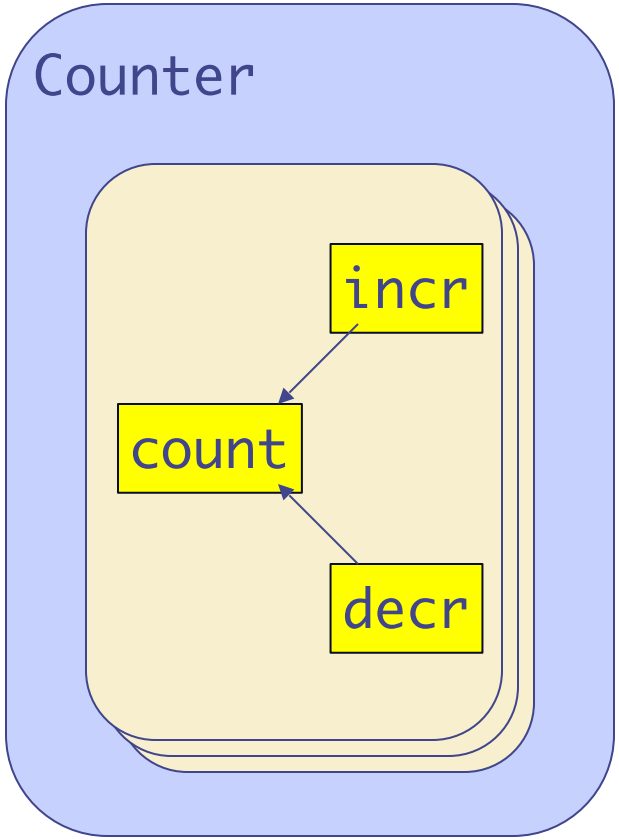
Impenetrable encapsulation

Safe reflection

Object.freeze(obj)

tamper-proof API surface

A Defensive Counter




```
function Counter() {
    let count = 0;
    return Object.freeze({
        incr: Object.freeze(() => ++count),
        decr: Object.freeze(() => --count)
    });
}
```

ES2015 (ES6)

- Full lexical scoping
  - let, const, function-in-block, modules
- Classes (almost) as sugar

- "Full Virtualizability"
  - Proxy, Reflect, WeakMap ==> Membranes
  - Virtualize host-provided "system mode" objects

Modern JavaScript? (2009-present)

- ✓ Memory safety
- ✓ Encapsulation
- ✓ **Defensible** objects
- ✓ Effects **only** by using held references

  No **powerful** references by default

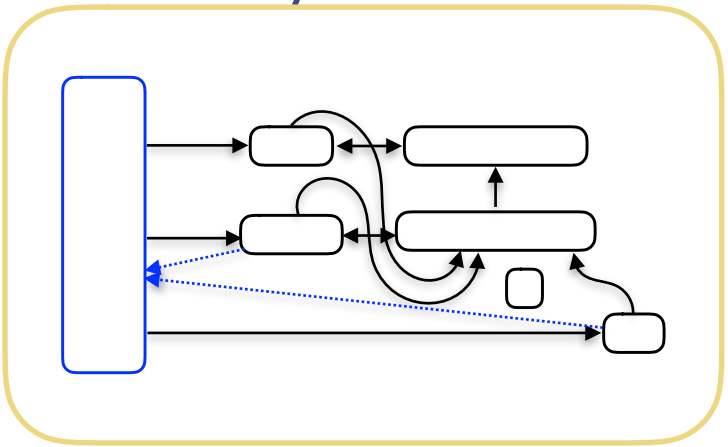
Proposed Frozen Realm API

```
class Realm {
    // From the old Realm API proposal
    const global                // global object of this realm
    eval(stringable)            // completion value

    // New with this "Frozen Realm" proposal
    static immutableRoot()  // immutable root realm
    spawn(endowments)       // lightweight child realm
}
```

Creating an immutable root realm

Alice says: `const rootA = Realm.immutableRoot();`



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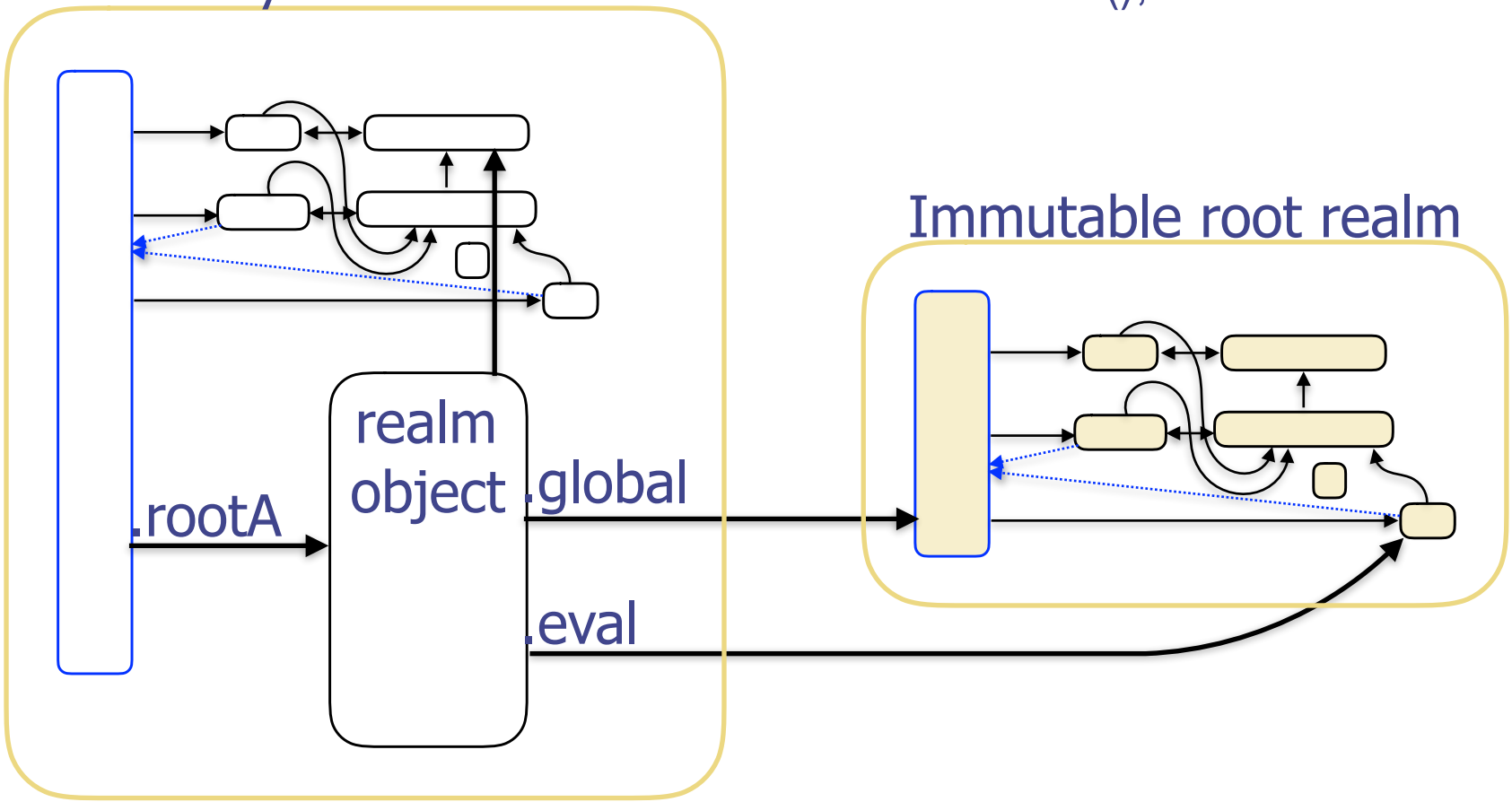

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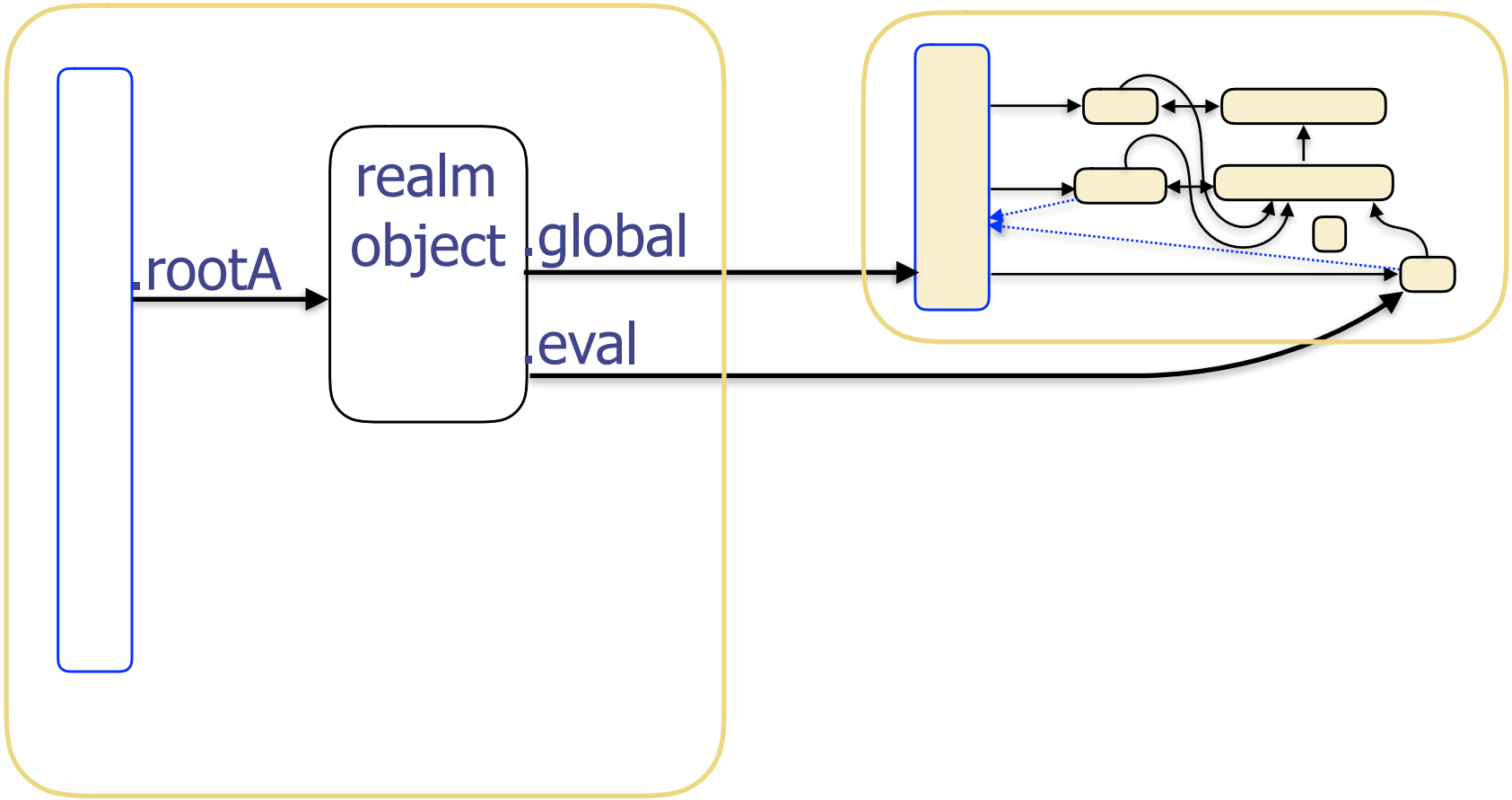

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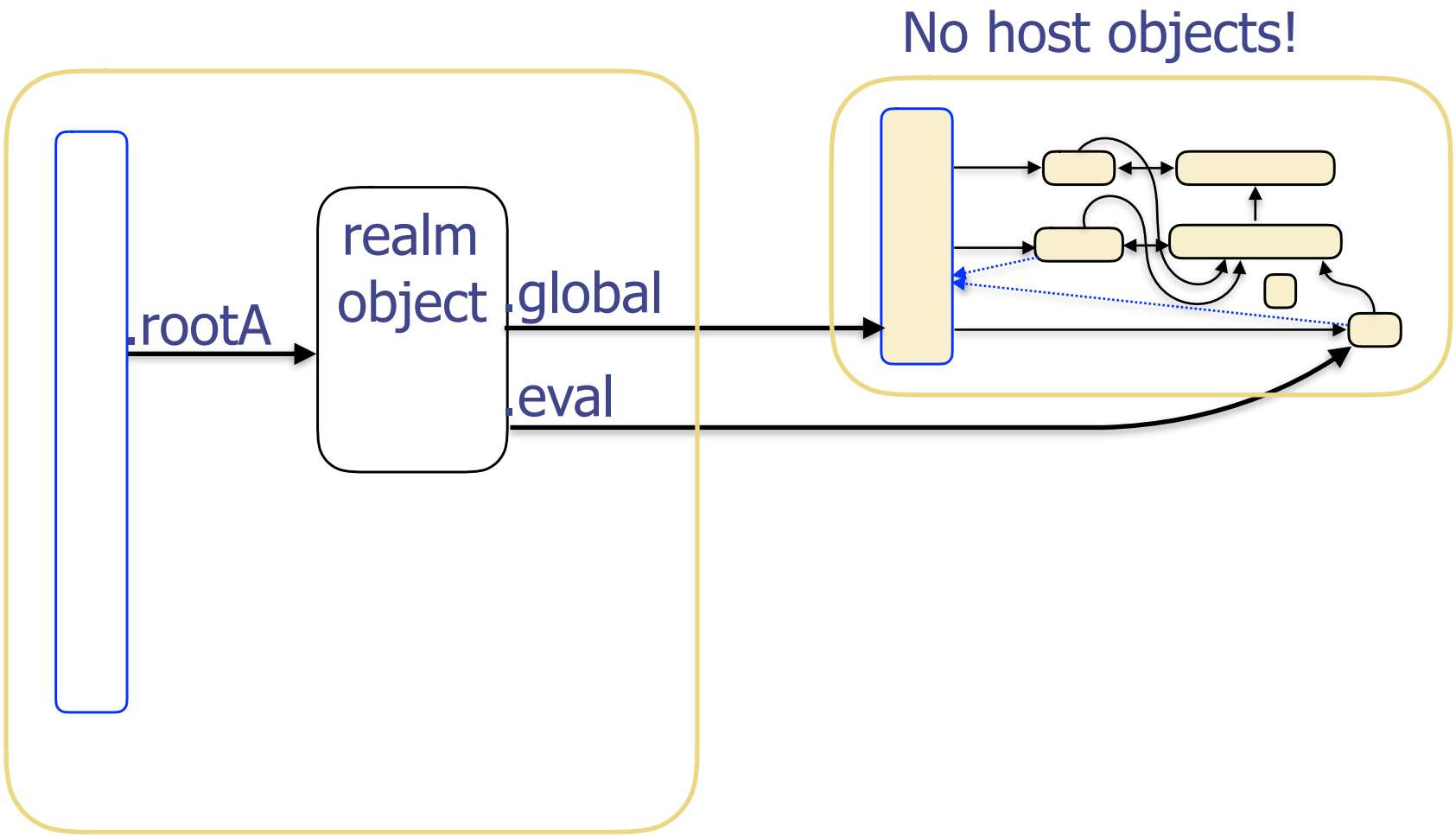
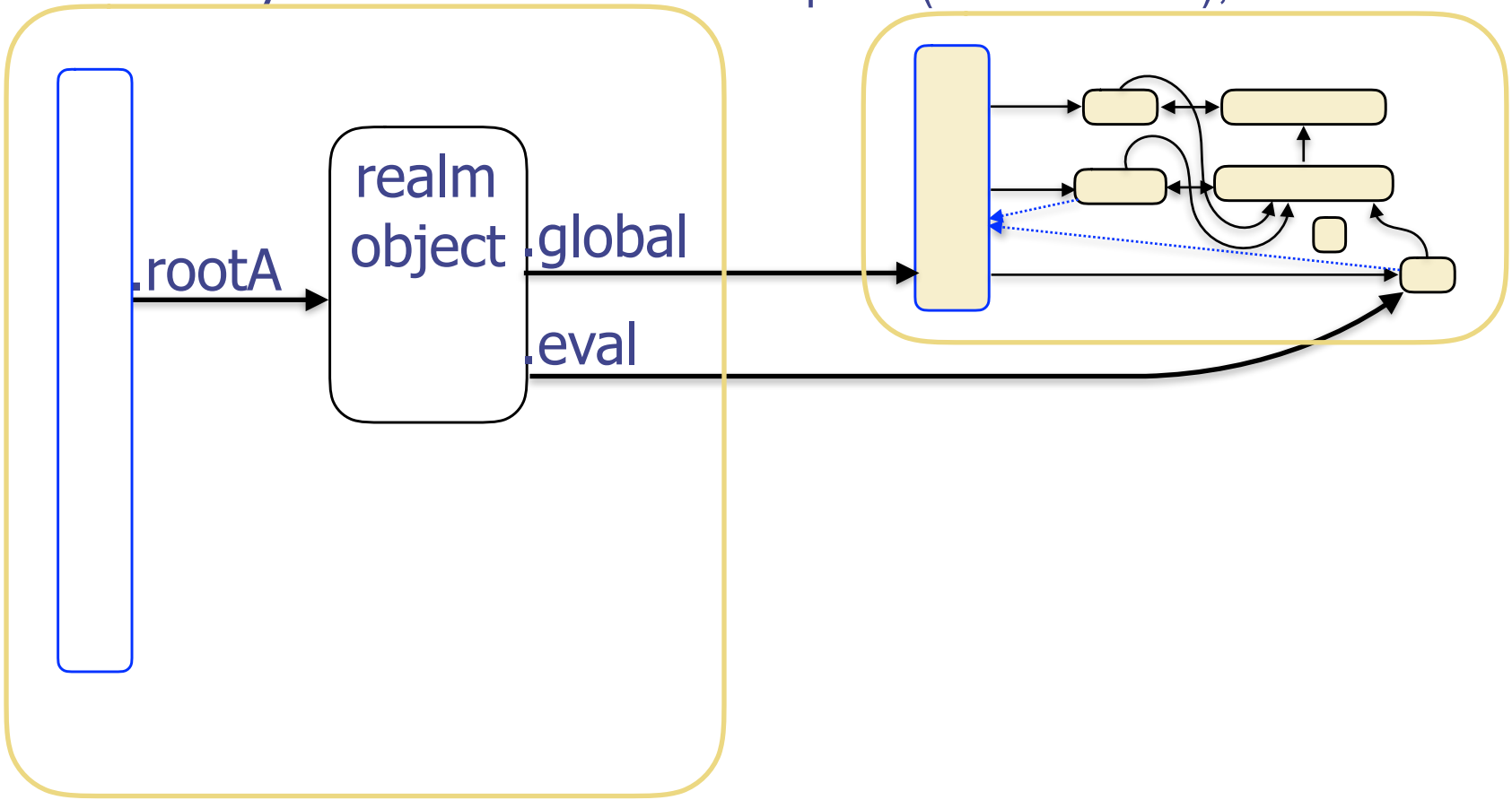


Spawning a lightweight child realm

Alice says: const childB = rootA.spawn(endowments);



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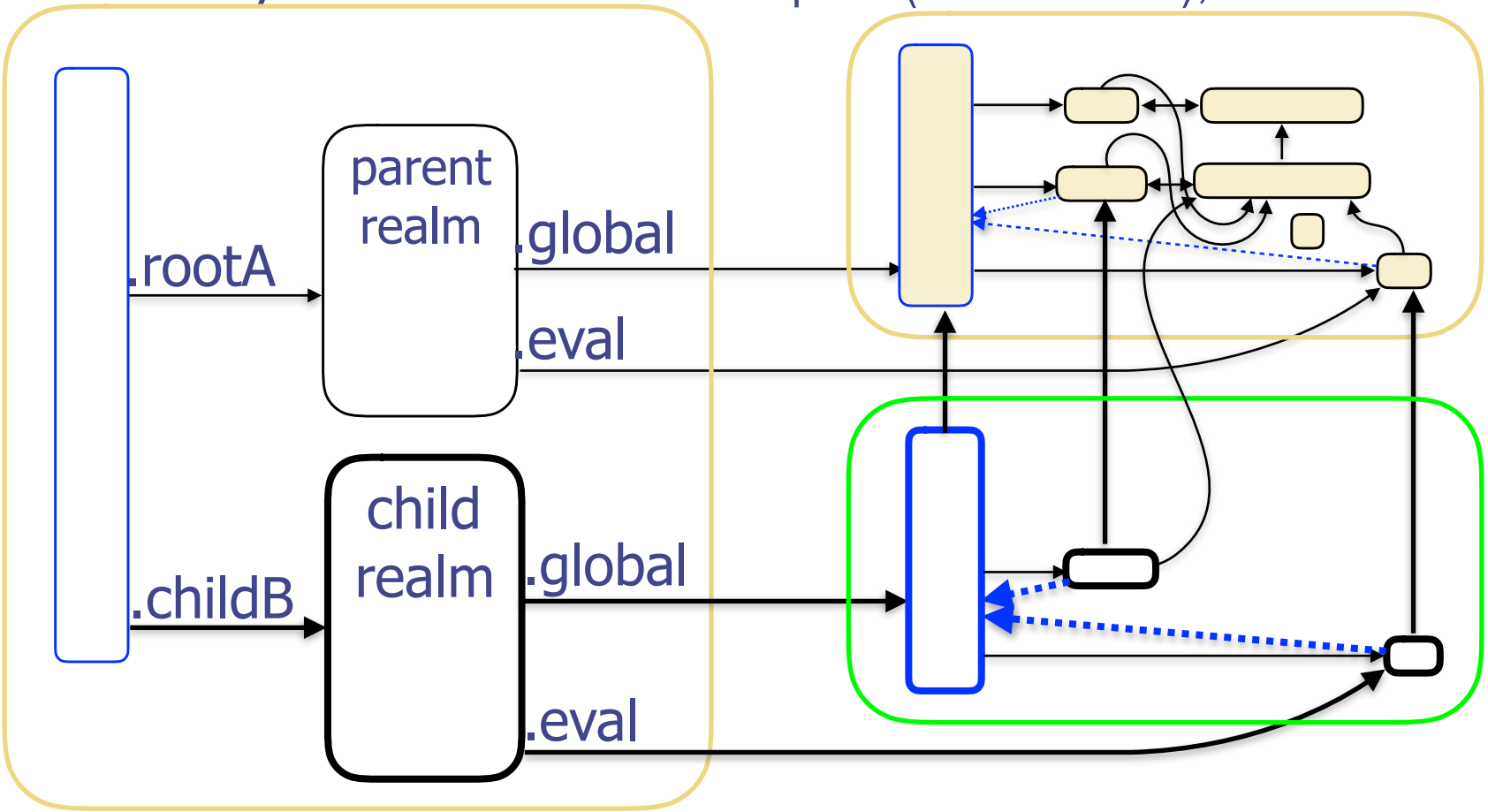
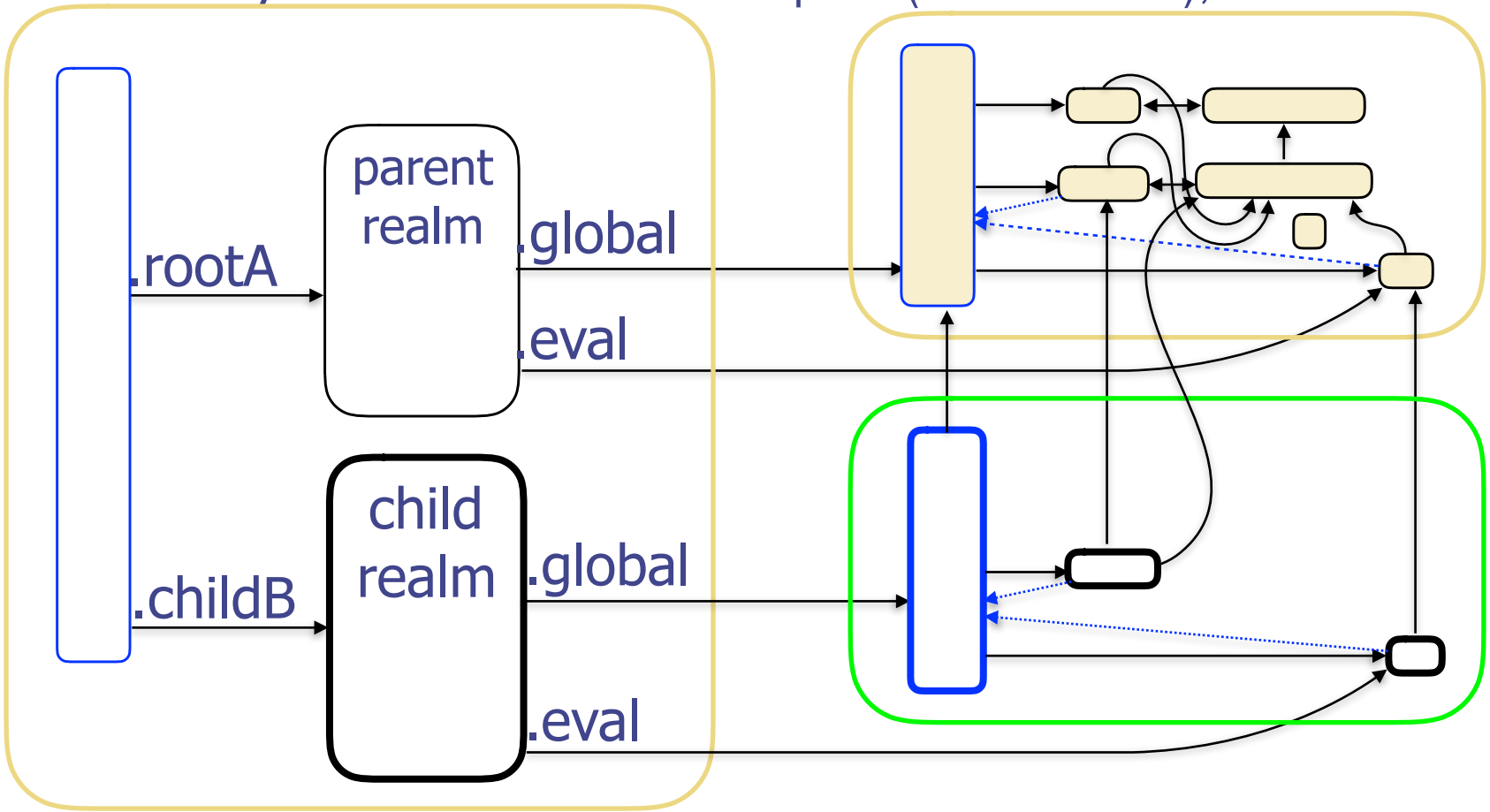


Lightweight? Only four objects

Alice says: const childB = rootA.spawn(endowments);



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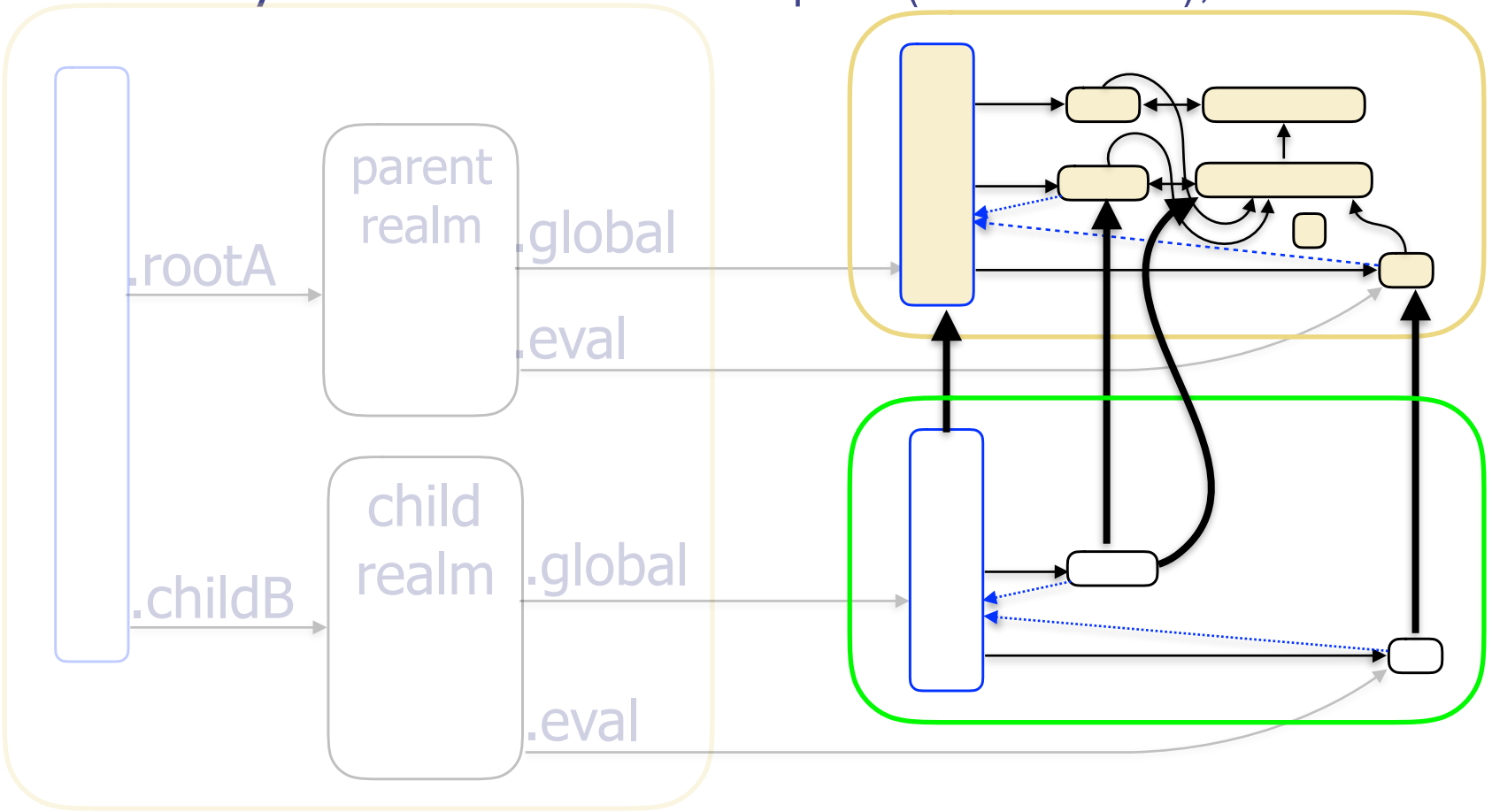
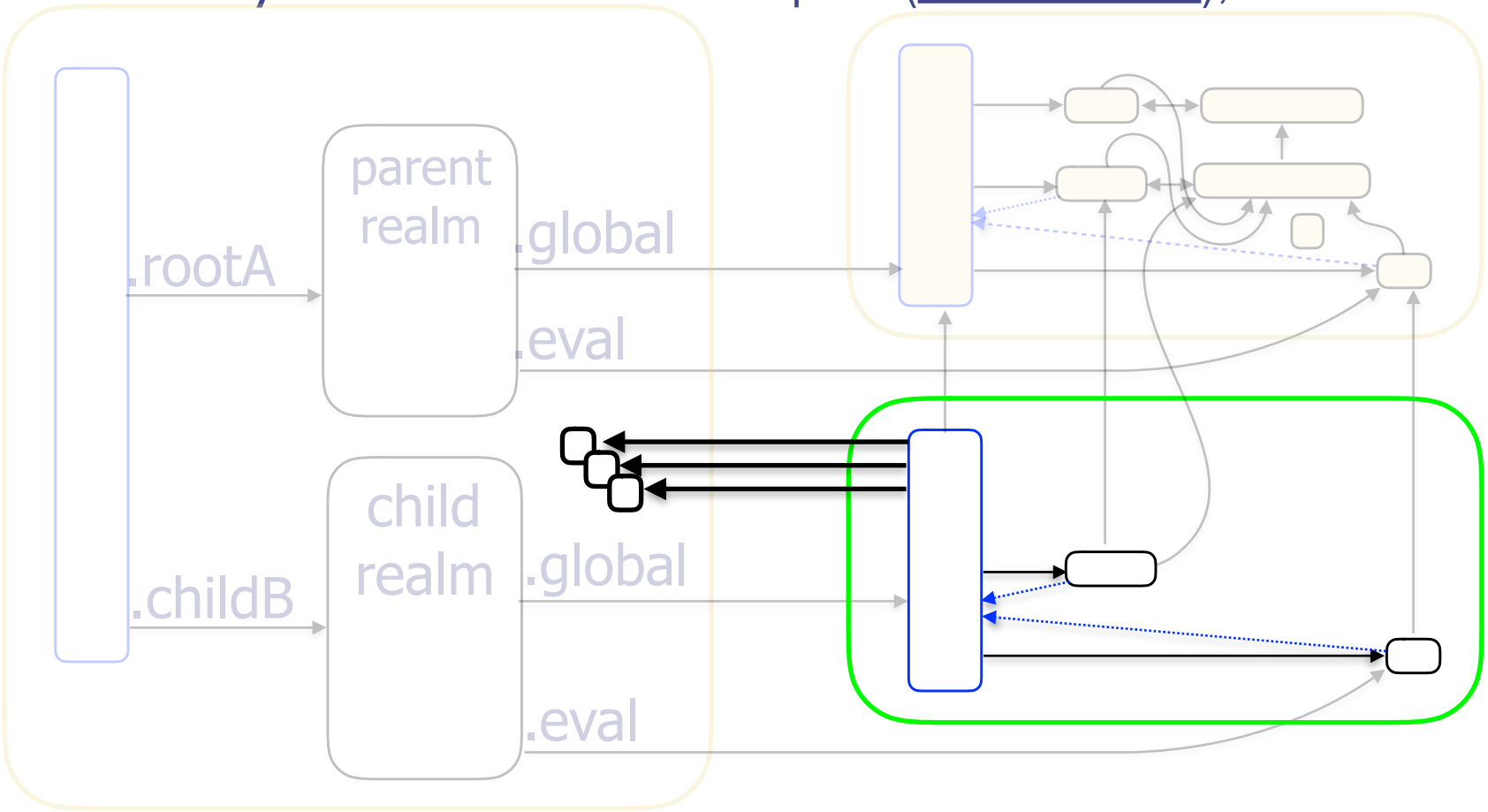


No powerful references **by default**

Alice says: const childB = rootA.spawn(**endowments**);



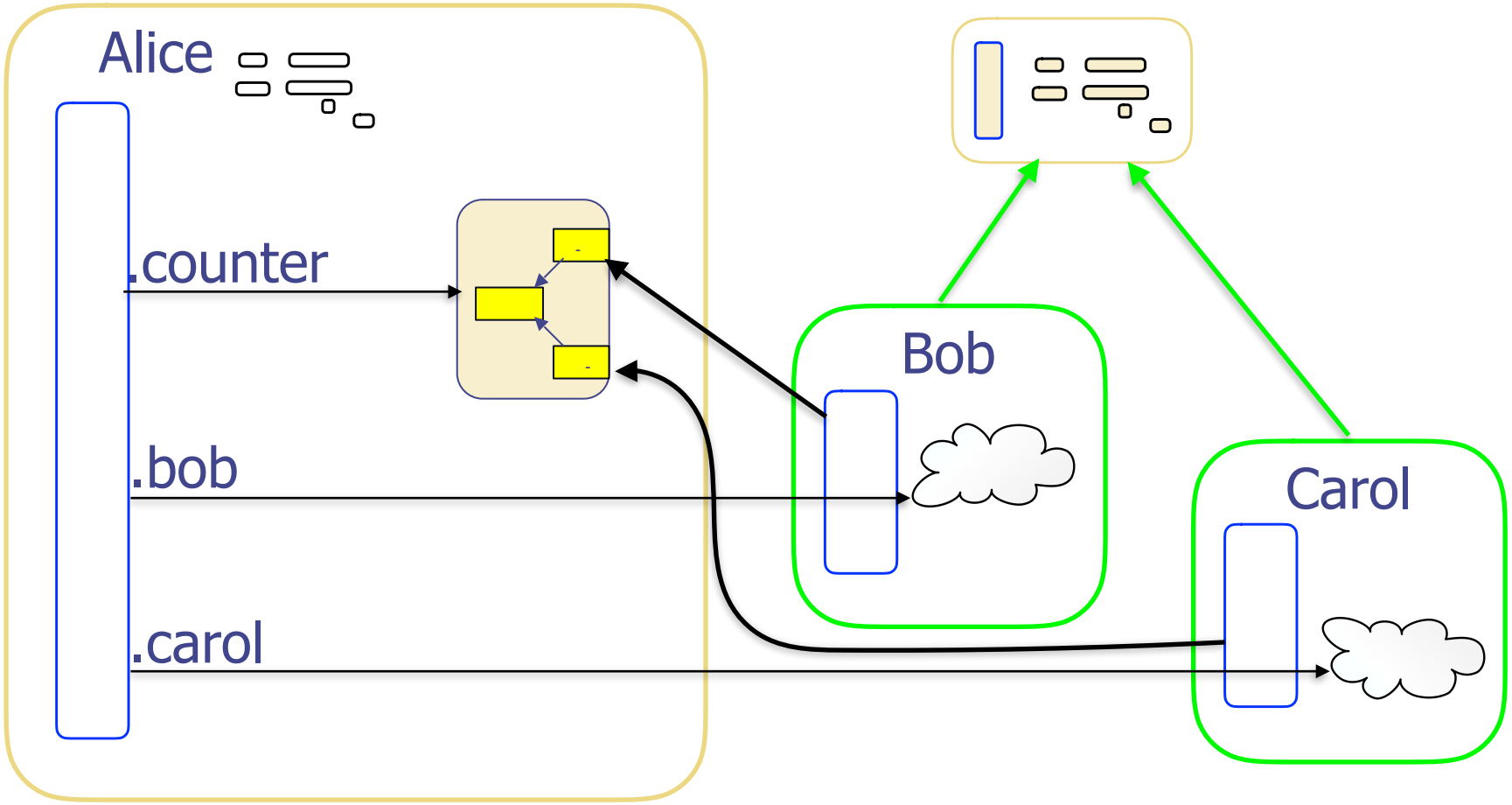
Example: Overt Confinement

```
function confine(src, endowments) {
  return rootA.spawn(endowments).eval(src);
}

confine("x + y", {x: 3, y: 4})  // 7

confine("Array", {})  // Array constructor of immutable root realm

confine("window", {})  // ReferenceError: window not it scope
```

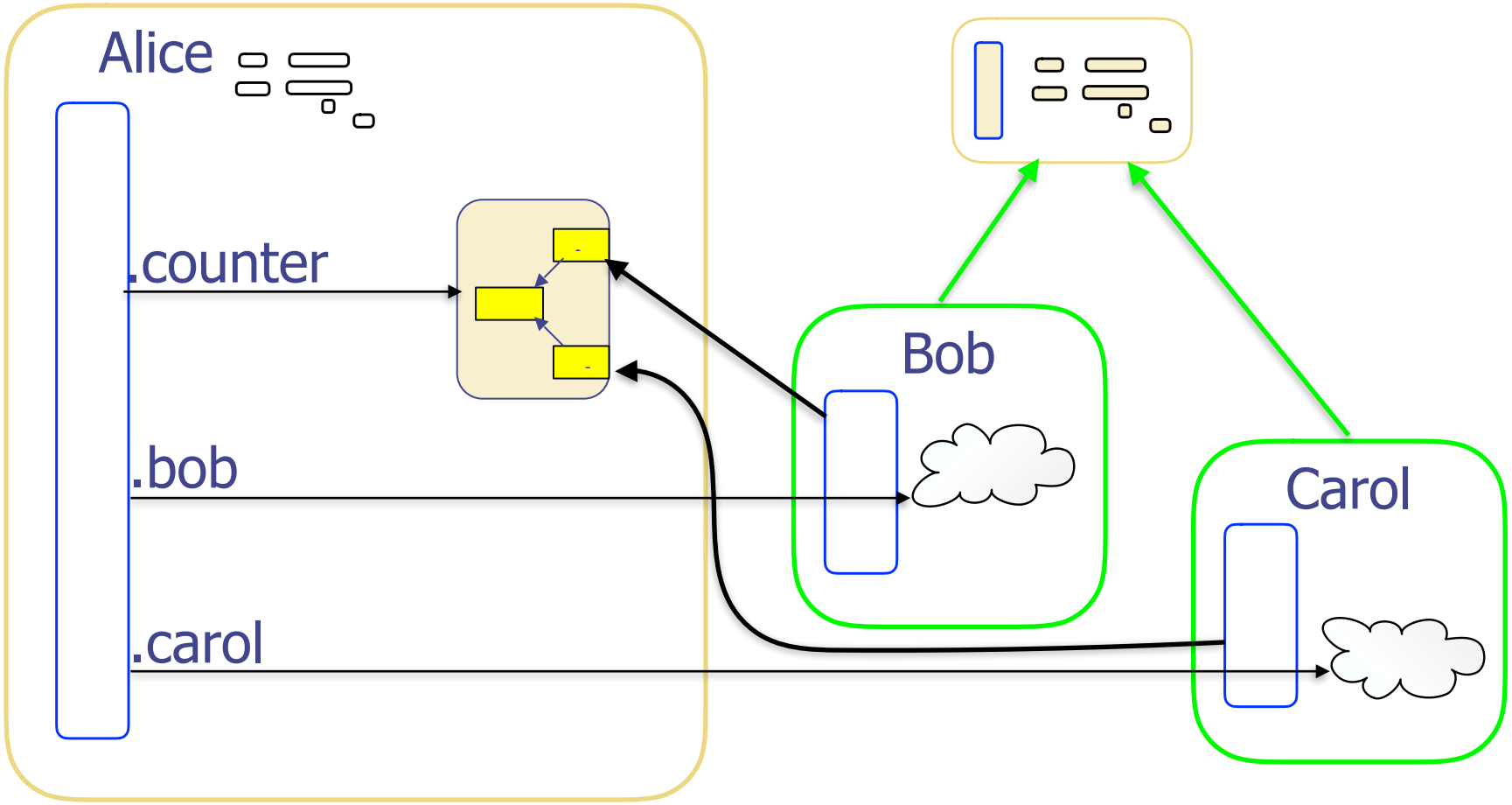
Alice loads fallible plugins

```
// Alice makes API surface
const counter = Counter();

// Alice loads fallible plugins bobSrc and carolSrc
const bob = confine(bobSrc, {change: counter.incr});
const carol = confine(carolSrc, {change: counter.decr});

// Alice uses bob, carol, counter
```

Bob and Carol are mostly confined

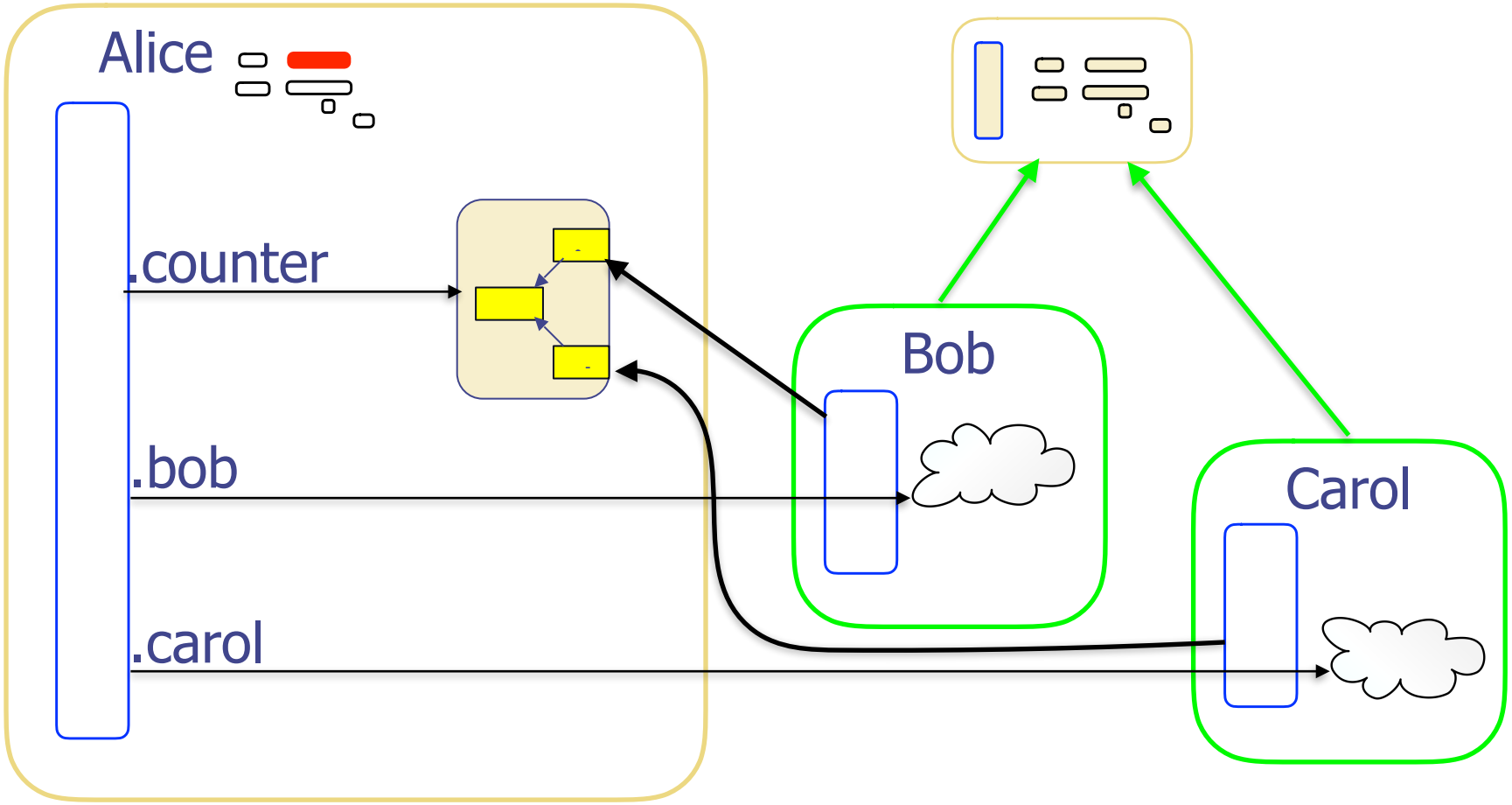


Is Alice's API surface defensive?



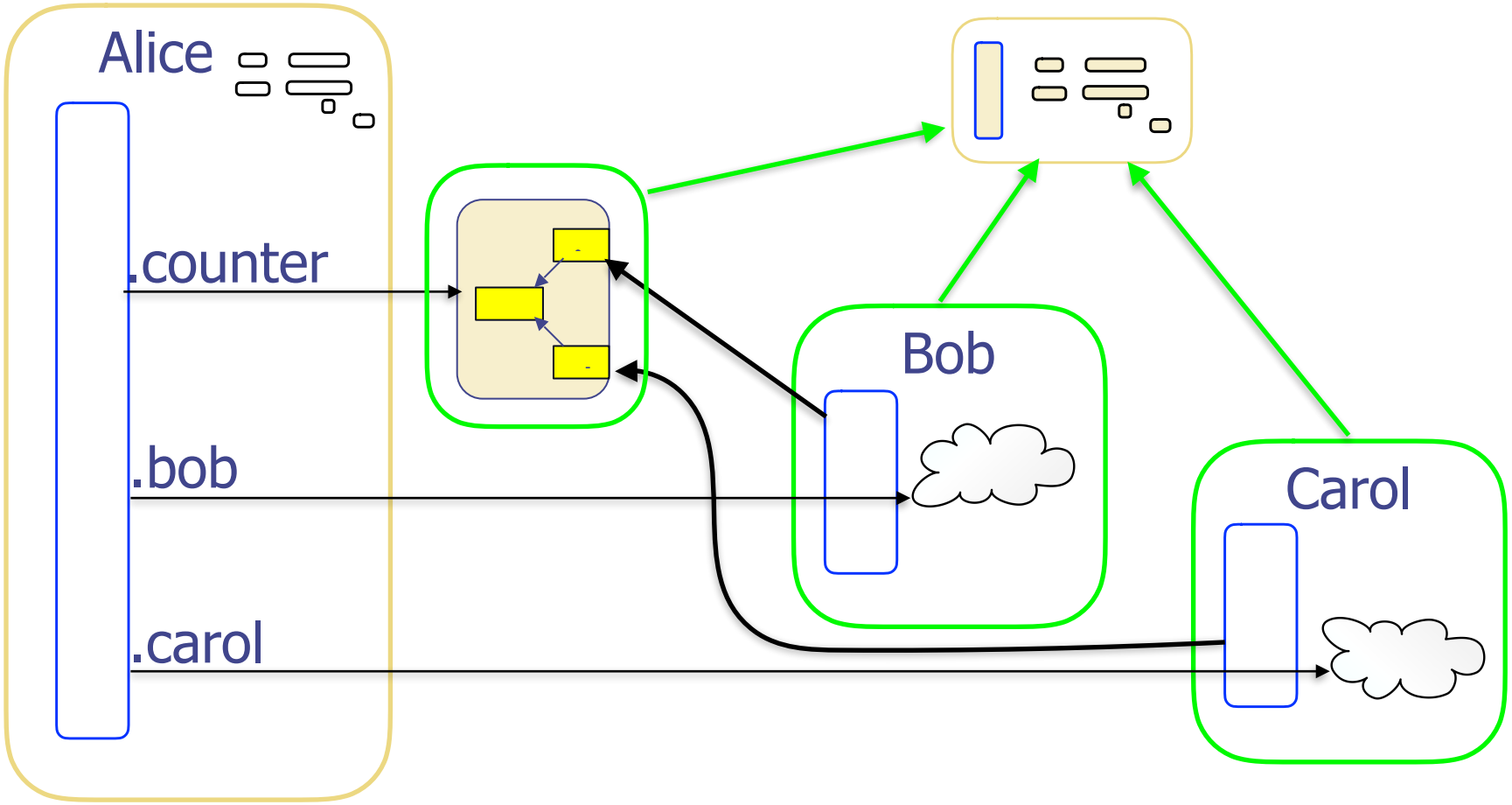
Is Alice's API surface defensive?

Bob says: change.__proto__.__proto__.toString = function() { stash = this; };

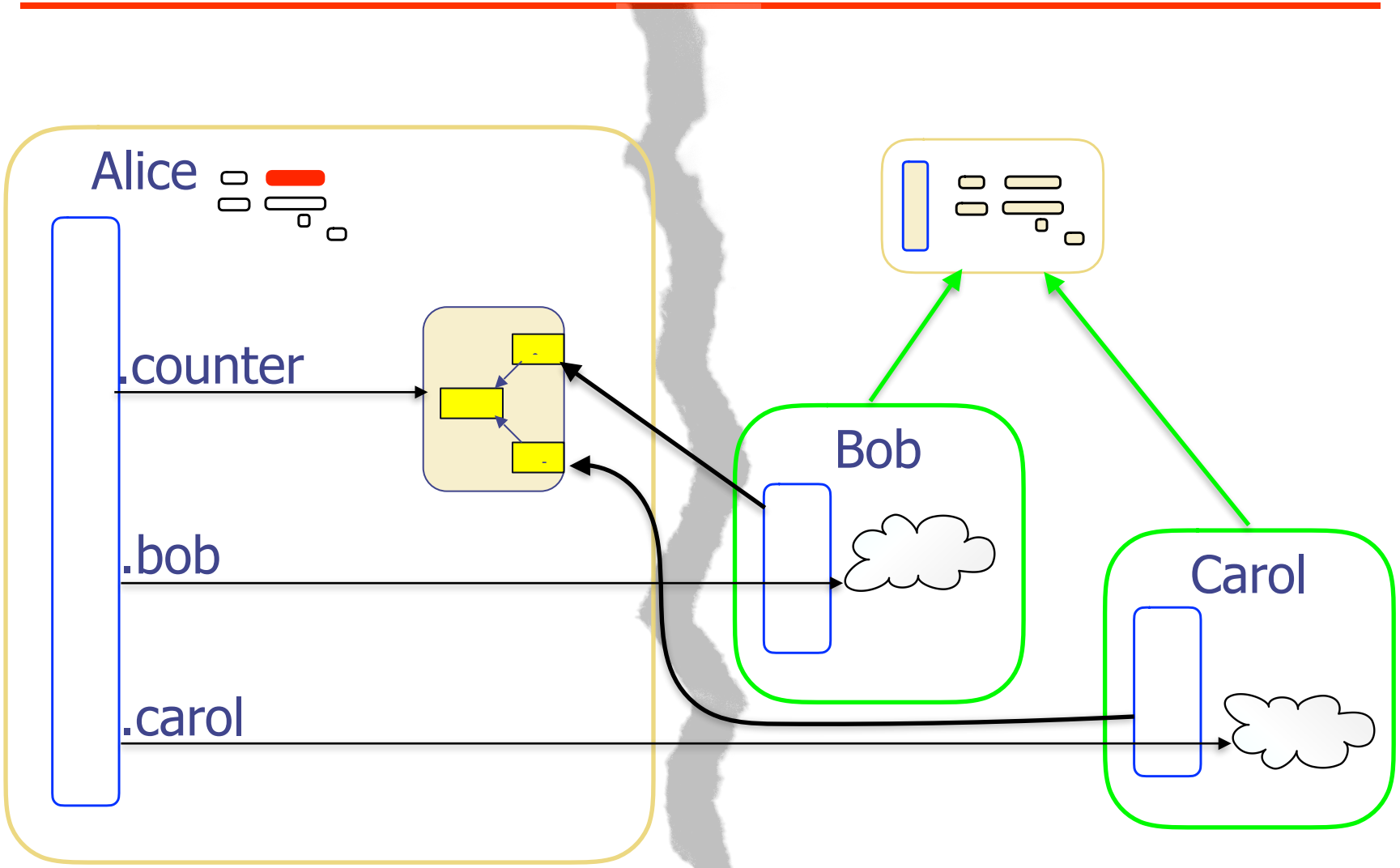


Alice's API surface is defensive…

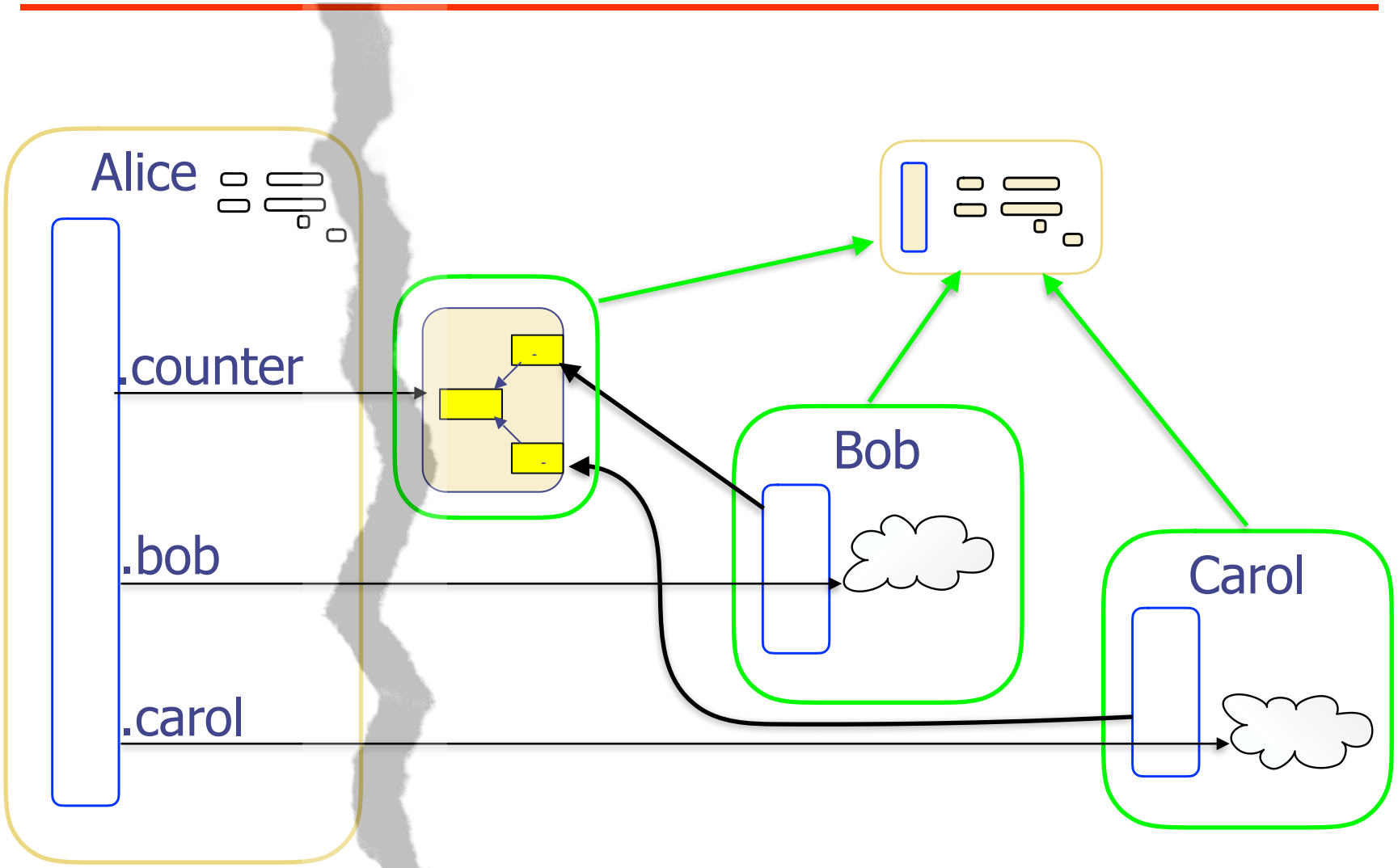
…if Alice had said: const counter = confine(String(Counter)), {})();



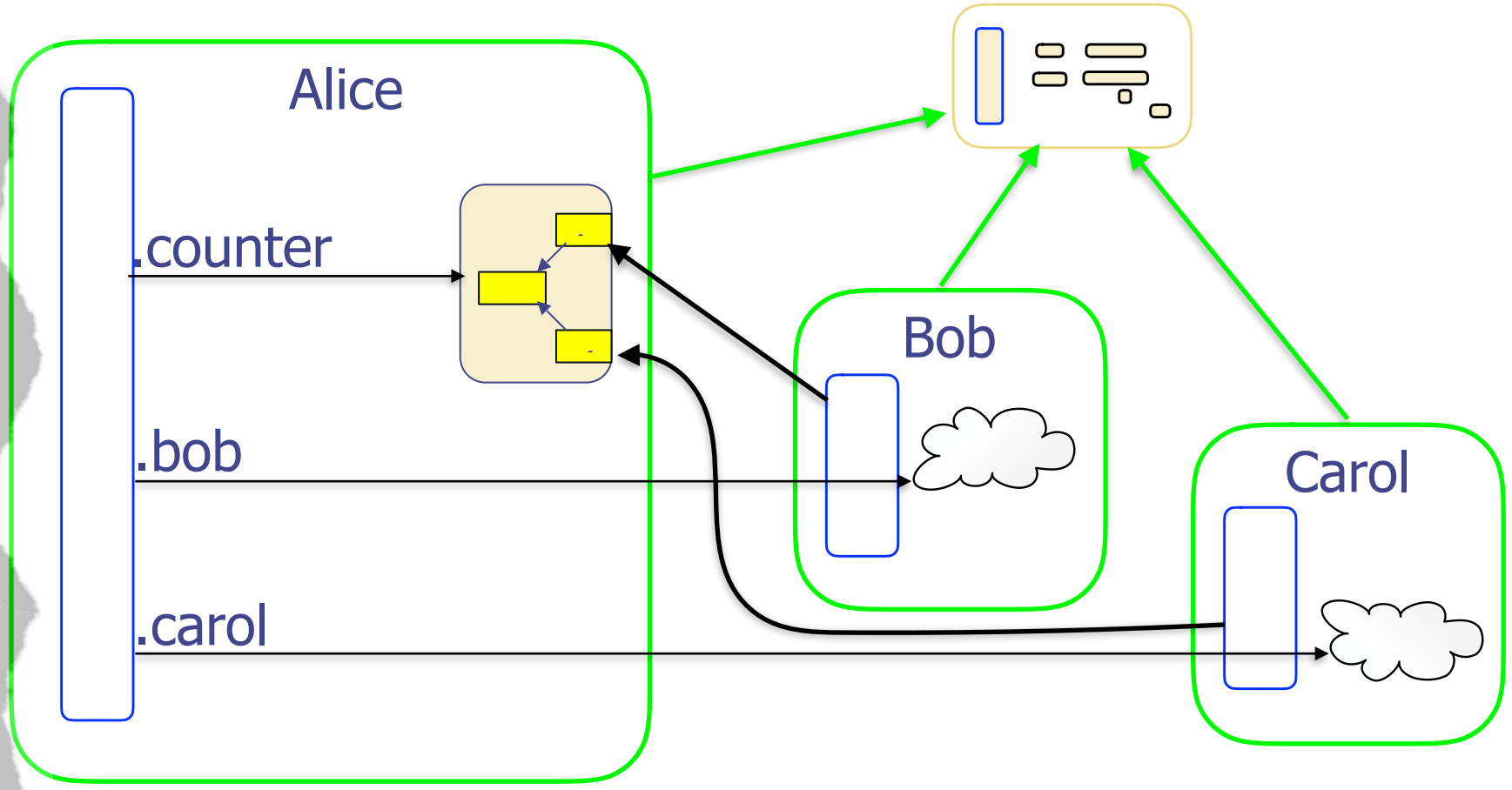
Discontinuity between API & plugin



Discontinuity between Alice & API



Discontinuity between init & Alice



Links

Draft proposal document, more examples

github.com/FUDCo/frozen-realms

Relevant ES5-era formal semantics

research.google.com/pubs/pub37199.html

ES5-era shim — similar functionality, different API

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ES2015-era shim coming soon

Questions?

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Prior language retrofits

Scheme	W7
Java	J-Kernel, Joe-E
Mozart/Oz (constraints)	Oz-E
OCaml (ML)	Emily
Squeak (Smalltalk)	Squeak-E
Python	Monte
Pict (π calculus)	Tamed Pict
ES3 (Early JavaScript)	FBJS, MS WebSandbox ADSafe, Jacaranda, JSand, Cajita, Valija, ES5/3

Why do we retrofit JavaScript?

Because that's where the attack surface is.

(with apologies to Willie Sutton)

What JavaScript always got right

- "user-mode" vs "system-mode" separation
  - ECMA vs W3C jurisdiction boundary

organizations which design systems ... produce designs which are copies of the communication structures of these organizations

—Conway's Law

What JavaScript always got right

No undefined behaviors!

Few implementation-defined behaviors

Little room for accidental non-determinism

What JavaScript always got right

- Effects **only** by held references
  - No "import" (yet)
  - I/O reached only by scoping (window, document, …)
- Multiple Isolated Realms
  - mobile code as protocol
- Great concurrency model
  - Shared-nothing Communicating Event Loops