WebAssembly

Concepts of Programming Languages
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- Design
- Demo in WAT and C
- Hello world in Go
- Exercise
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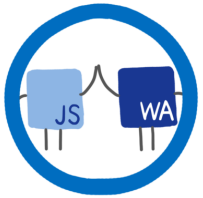
- Exercise
- Future of WebAssembly



What is WebAssembly?

webassembly.org (https://webassembly.org)

- WebAssembly is a portable binary-code format for executable programs.
- Timeline

```
- 1995: JavaScript is developed within 10 days by Brendan Eich

- ... Java Applets, Flash, ActiveX, Silverlight
- ... JavaScript improvements, ...

- 2015: First presentation of WebAssembly from the W3C WebAssembly Working Group
- 2016: Google, Microsoft and Mozilla show their first implementations
- 2017: WebAssembly is offically supported by all Web Browsers
- 2019: A WebAssembly system interface is specified for portable applications outside the browser
- Now:  WebAssembly is constantly enhanced (https://webassembly.org/roadmap/)
```

After the introduction of JavaScript in the 90s, it is the second language supported directly by web browsers

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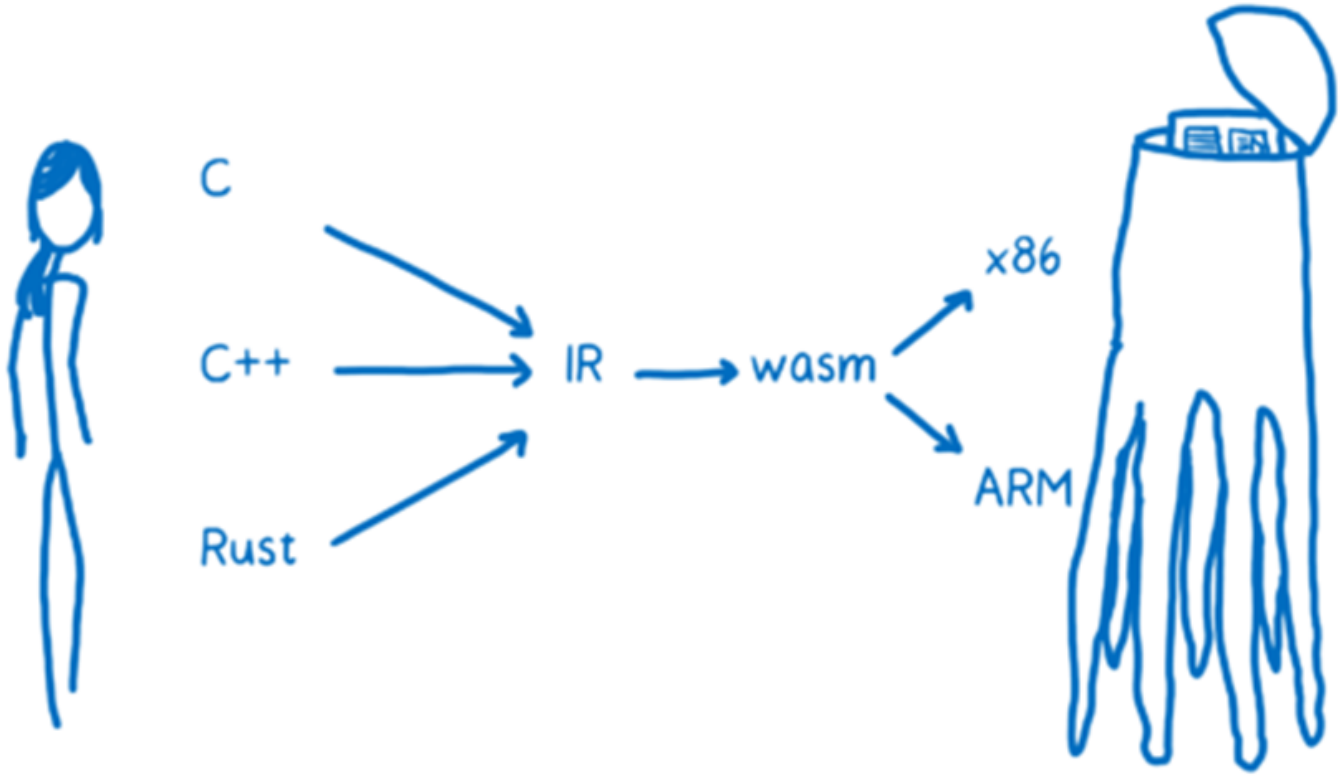
What is WebAssembly?

- WebAssembly is designed as a portable target for compiling high-level languages



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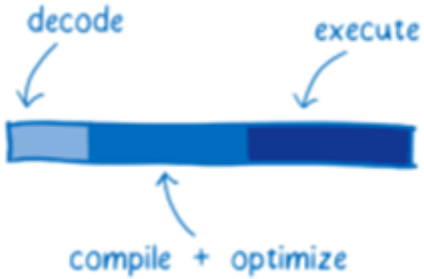
JavaScript vs. WebAssembly?

- JavaScript requires a complex optimization

- WebAssembly simplifies processing



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Design

- Binary format

```
- small size and easy to interpret
```

- Stack Machine with local and global variables

```
- Efficient decoding and compilation
```

- Structured control flow and structured use of the stack

```
- One-Pass Verification
```

- Simple types: i32, i64, f32, f64

```
- Representation of today's CPU architecture
```

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Design

- Linear memory with load/store addressing

```
- Sandboxed
- 64kB segmentt. Enables hardware-supported boundary check
- Size adaptable at runtime
```

- Interface via defined interface

```
- Export/import of functions, global variables and so-called tables
```

- Assembler text format

```
- Open and possibility for debugging
```

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Stackmachine in Detail

C input source	Linear assembly bytecode (intermediate representation)	Wasm binary encoding (hexadecimal bytes)

`int factorial(int n) {`
`  if (n == 0)`
`  return 1;`
`  else`
`  return n * factorial(n-1);`
`}`
	`get_local 0`
	`i64.eqz`
	`if (result i64)`
	`  i64.const 1`
	`else`
	`  get_local 0`
	`  get_local 0`
	`  i64.const 1`
	`  i64.sub`
	`  call 0`
	`  i64.mul`
	`end`
		`20 00`
		`50`
		`04 7E`
		`42 01`
		`05`
		`20 00`
		`20 00`
		`42 01`
		`7D`
		`10 00`
		`7E`
		`0B`

Demo in WebAssembly Text Format

- Example in `webassembly/wat` folder

add.wat

```
(module
  (type (;0;) (func (param i32 i32) (result i32)))
  (func (;0;) (type 0) (param i32 i32) (result i32)
    local.get 0
    local.get 1
    i32.add)
  (export "add" (func 0)))
```

add.js

```
const fs = require('fs');
const buf = fs.readFileSync('./add.wasm');

WebAssembly.instantiate(buf)
.then(result => {
    console.log(result.instance.exports.add(5, 2))
});
```

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Supported languages in 2020

- Source:

github.com/appcypher/awesome-wasm-langs (https://github.com/appcypher/awesome-wasm-langs)

.Net	AssemblyScript	Astro
Brainfuck	C	C#
C++	D	Elixir
F#	Faust	Forest
Forth	Go	Grain
Haskell	Java	JavaScript
Julia	Idris	Kotlin/Native
Kou	Lua	Nim
Ocaml	Perl	PHP
Plorth	Poetry	Python
Prolog	Ruby	Rust
Scheme	Speedy.js	Turboscript
Wah	Walt	Wam
Wracket	Xlang	Zig

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Demo in C

- Example in `webassembly/C` folder

add.c

```
int add(int a, int b) {
    return a+b;
}
```

add.js

```
const fs = require('fs');
const buf = fs.readFileSync('./add.wasm');

WebAssembly.instantiate(buf)
.then(result => {
    console.log(result.instance.exports.add(5, 2))
});
```

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Demo in Go

```
package main

func main() {
    println("Hello World")
}
```

index.html

```
<html>
<body>
    <script src="wasm_exec.js"></script>
    <script>
        const go = new Go();

        fetch('lib.wasm')
            .then(response => response.arrayBuffer())
            .then(bytes =>WebAssembly.instantiate(bytes, go.importObject))
            .then(result => {
                go.run(result.instance)
            }
        );
    </script>
</body>
</html>
```

Exercise

- Write Hello world in Go and execute as node app or in the browser.

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Applications

webassembly.org/docs/use-cases/ (https://webassembly.org/docs/use-cases/)

- Better execution for languages and toolkits that are currently cross-compiled to the Web (C/C++, GWT, ...).
- Image / video editing.
- Games:

```
- Casual games that need to start quickly.
- AAA games that have heavy assets.
- Game portals (mixed-party/origin content).
```

- Peer-to-peer applications (games, collaborative editing, decentralized and centralized).
- Music applications (streaming, caching).
- Image recognition.
- Live video augmentation (e.g. putting hats on people's heads).

Applications

- VR and augmented reality (very low latency).
- CAD applications.
- Scientific visualization and simulation.
- Interactive educational software, and news articles.
- Platform simulation / emulation (ARC, DOSBox, QEMU, MAME, ...).
- Language interpreters and virtual machines.
- POSIX user-space environment, allowing porting of existing POSIX applications.
- Developer tooling (editors, compilers, debuggers, ...).
- Remote desktop.
- VPN.
- Encryption.

Outside the browser

- Game distribution service (portable and secure).
- Server-side compute of untrusted code.
- Server-side application.
- Hybrid native apps on mobile devices.
- Generic Plugins for your software.

Calls from and to Go

```
package main

import (
    "syscall/js"
)

func add(this js.Value, input []js.Value) interface{} {
    result := input[0].Float() + input[1].Float()
    return js.ValueOf(result)
}

func main() {
    document := js.Global().Get("document")
    p := document.Call("createElement", "p")
    p.Set("innerHTML", "Hello WASM from Go!")
    document.Get("body").Call("appendChild", p)

    // register function
    js.Global().Set("add", js.FuncOf(add))

    // prevent exit
    c := make(chan struct{}, 0)
    <-c
}
```

Calls from and to Go

index.html

```
        const go = new Go();

        fetch('lib.wasm')
            .then(response => response.arrayBuffer())
            .then(bytes =>WebAssembly.instantiate(bytes, go.importObject))
            .then(result => {
                go.run(result.instance)
                document.body.innerHTML += add(41, 1);
            }
        );
    </script>
```

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Exercise

- Show generated image in the browser

WebAssembly and Go Routines

- Demo

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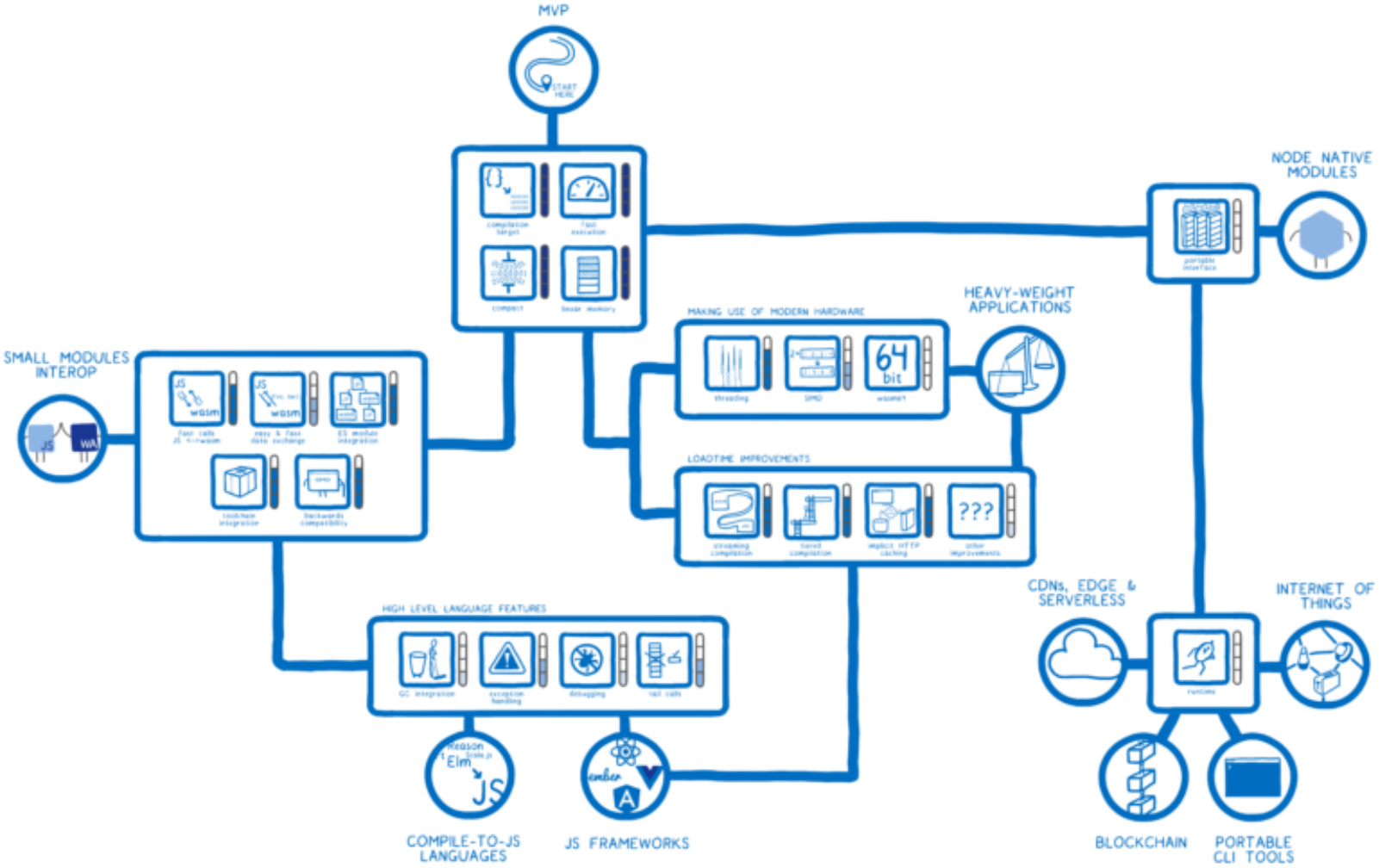
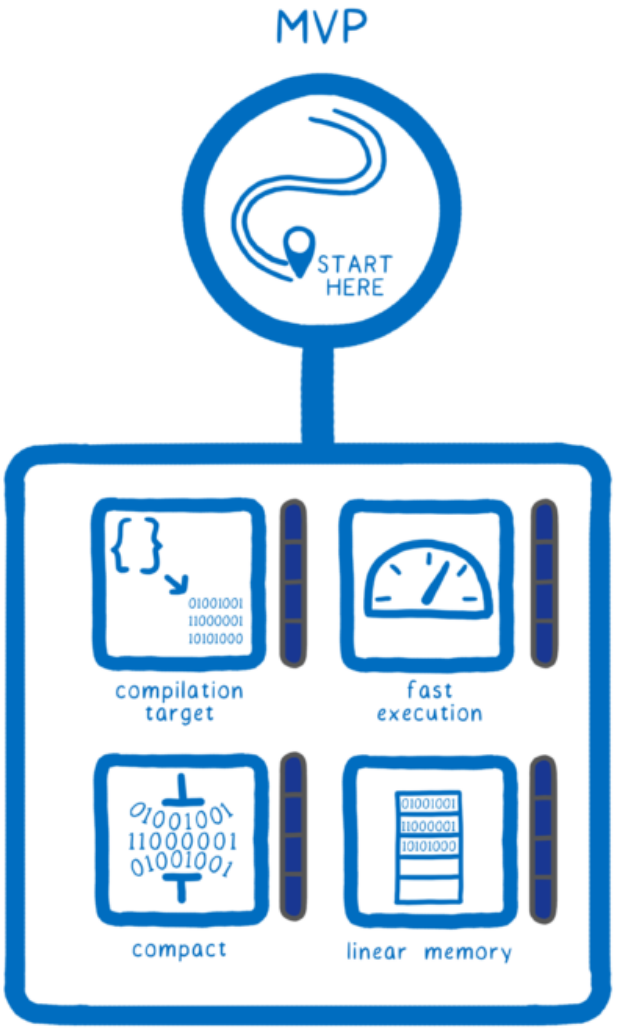
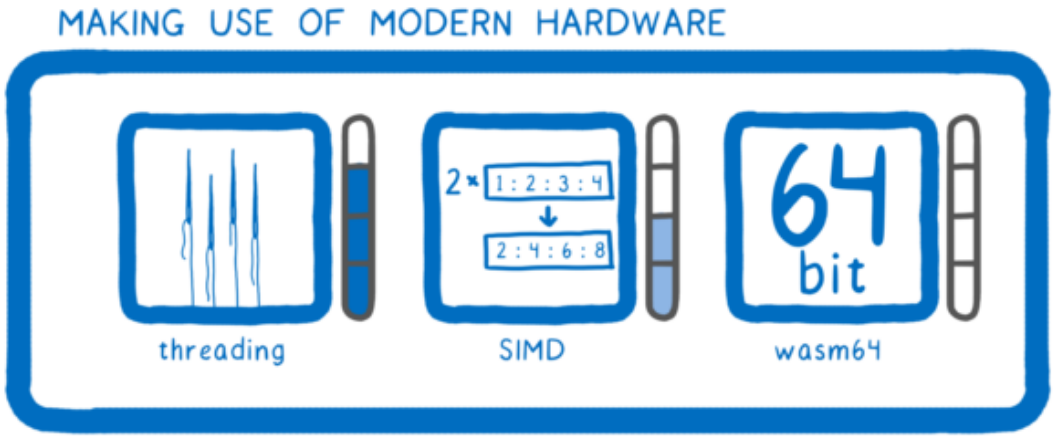
Future - The Skill Tree

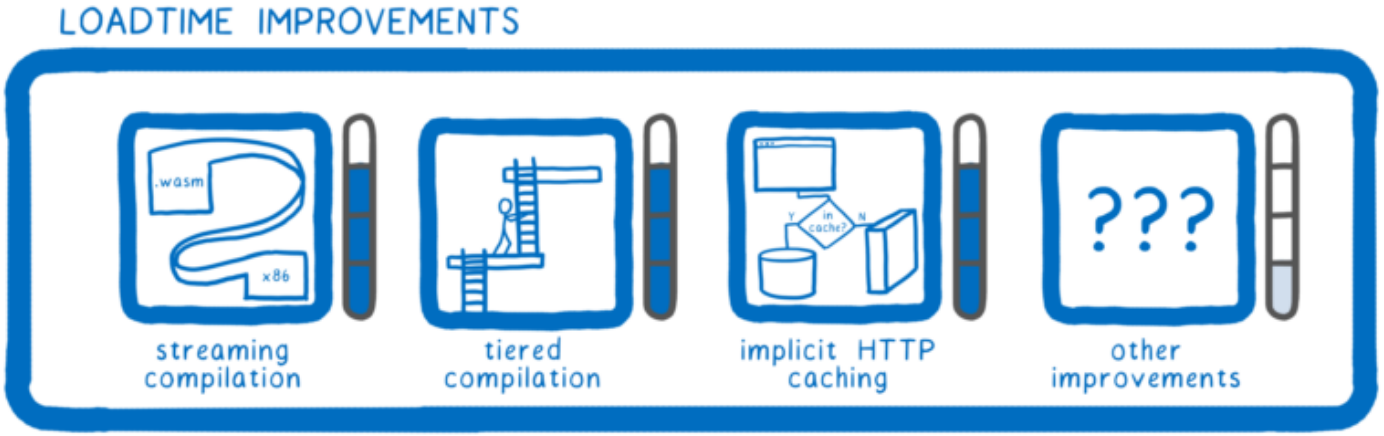


Future - MVP

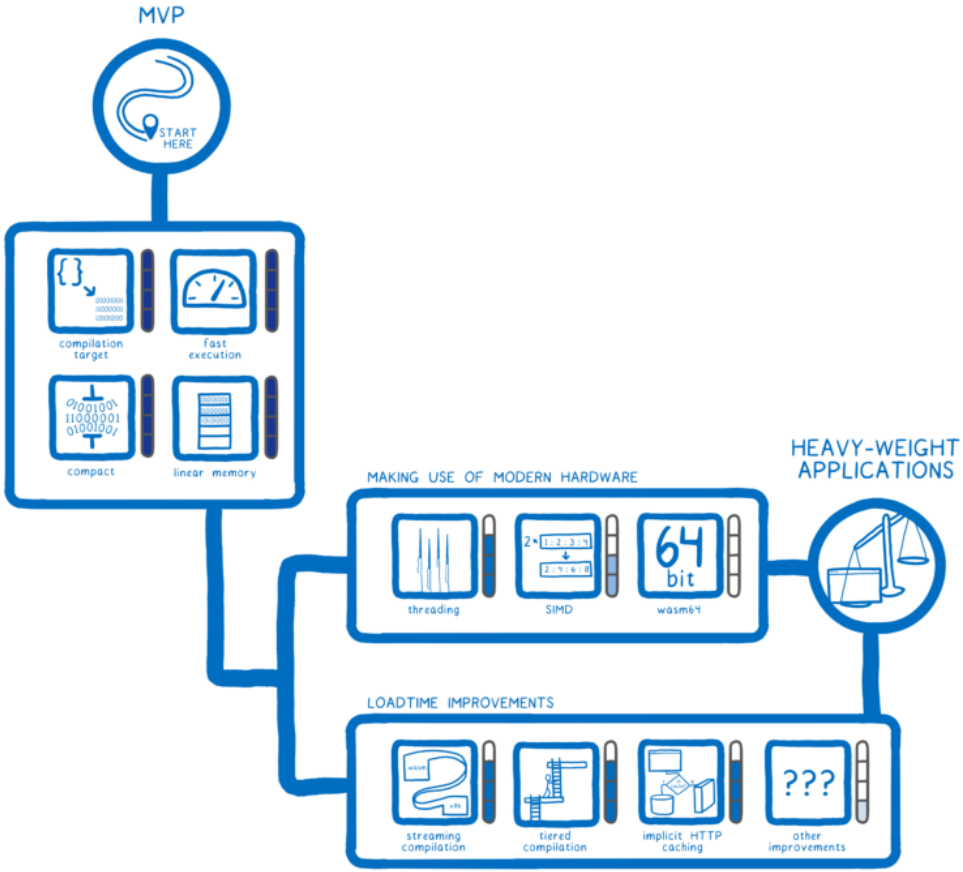

MVP
START HERE
compilation target
fast execution
compact
linear memory

Future


MAKING USE OF MODERN HARDWARE
threading
2×
1 : 2 : 3 : 4
2 : 4 : 6 : 8
SIMD
64
bit
wasm64


LOADTIME IMPROVEMENTS
.wasm
x86
streaming compilation
tiered compilation
Y
in cache?
N
implicit HTTP caching
???
other improvements

Future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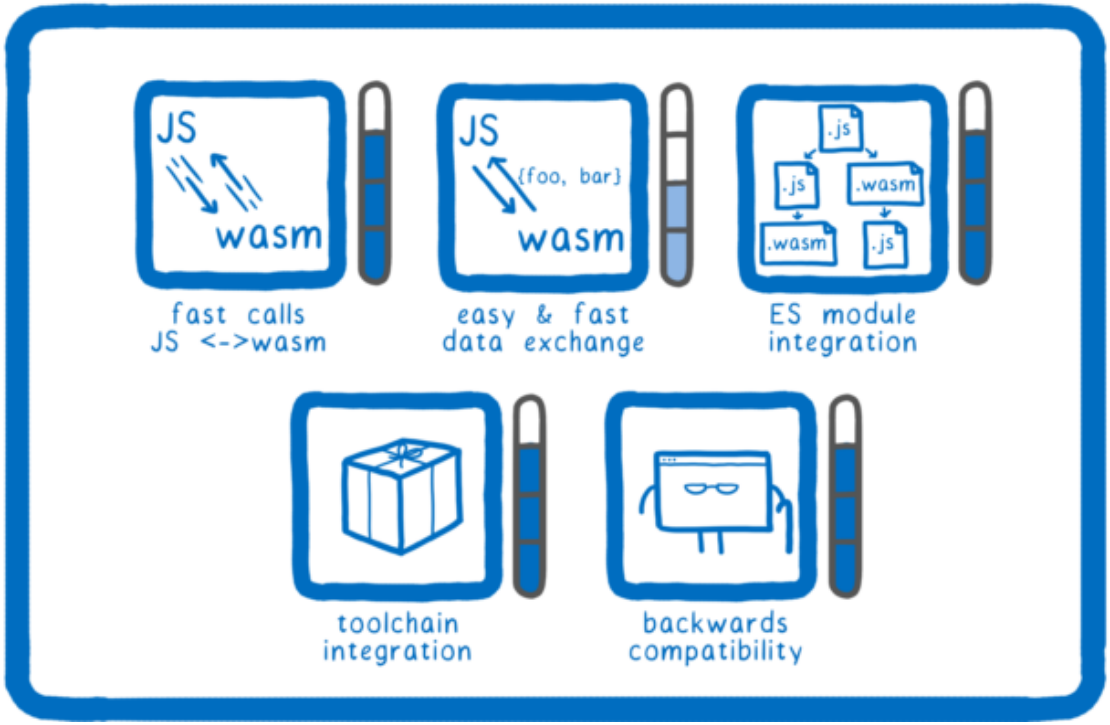
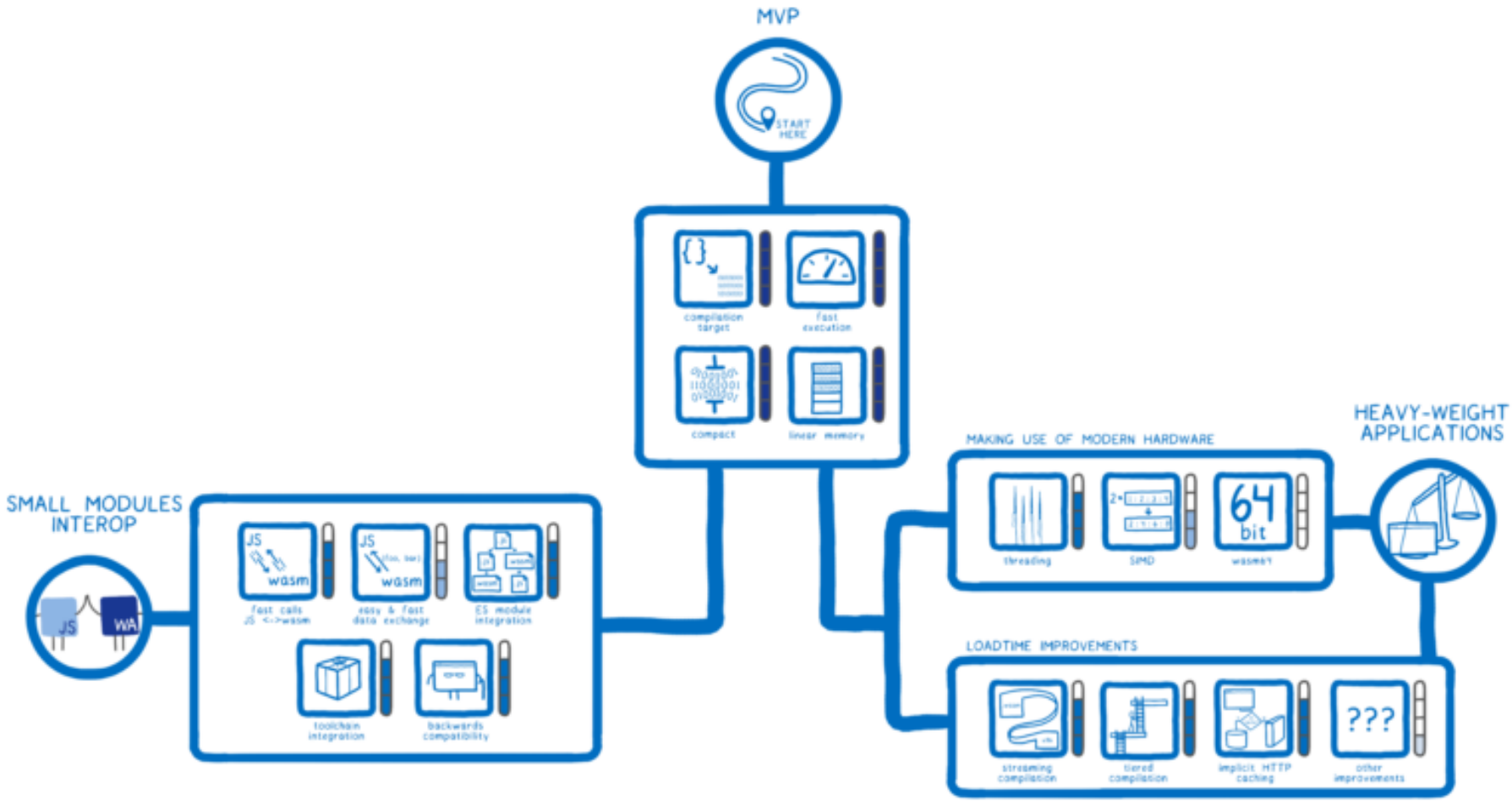

JS
wasm
fast calls
JS <->wasm
JS
{foo, bar}
wasm
easy & fast
data exchange
.js
.js
.wasm
.wasm
.js
ES module
integration
toolchain
integration
backwards
compatibility

25

Future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WA
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wasm
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JS
wasm
easy & fast data exchange
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toolchain integration
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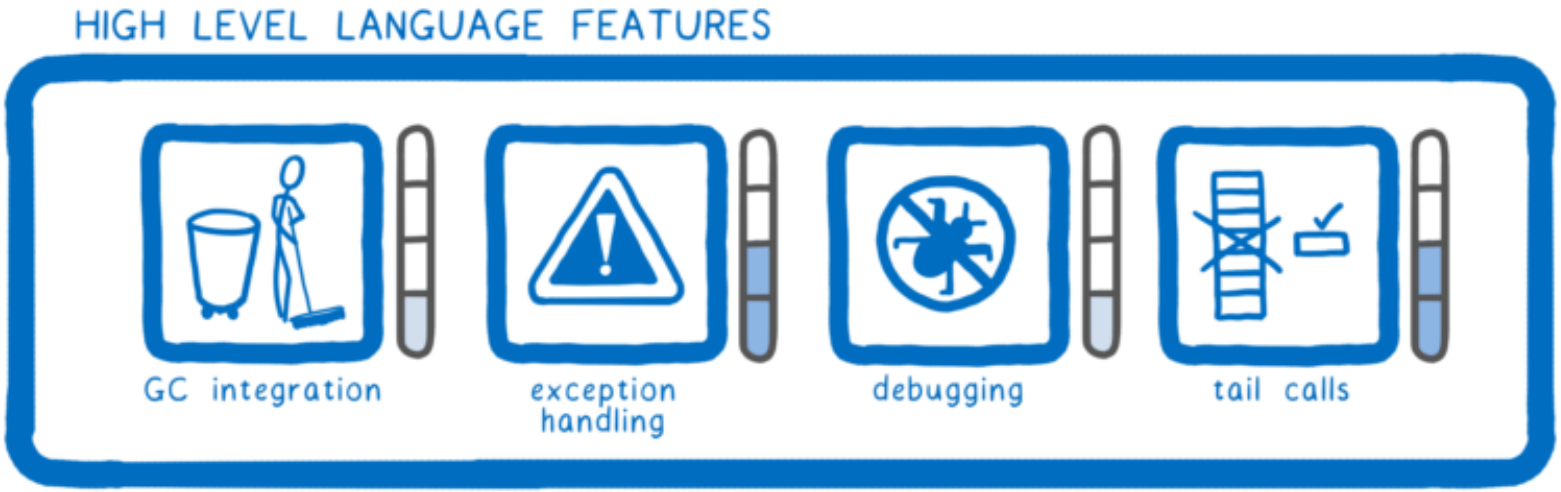
HIGH LEVEL LANGUAGE FEATURES
GC integration
exception handling
debugging
tail calls

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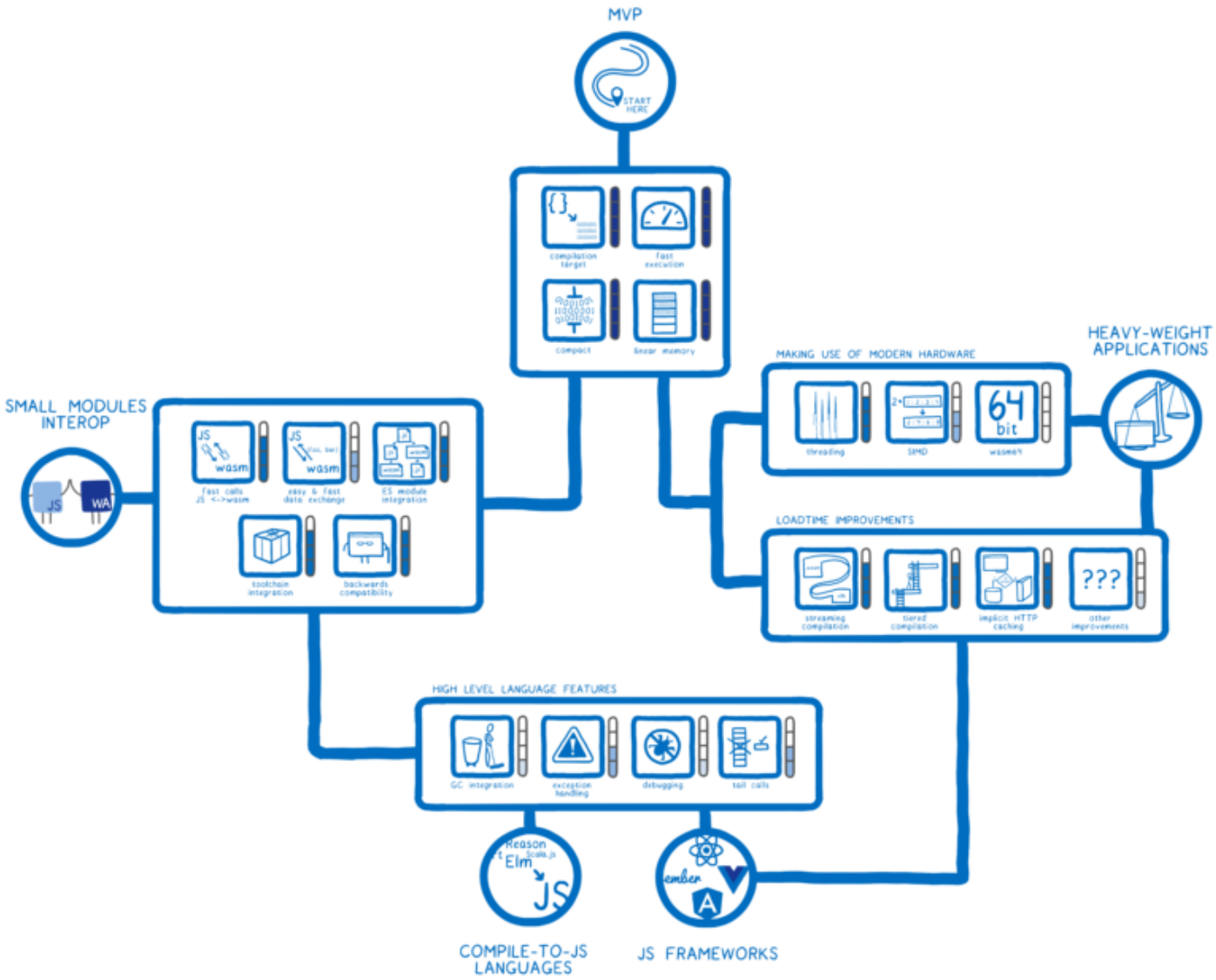
Future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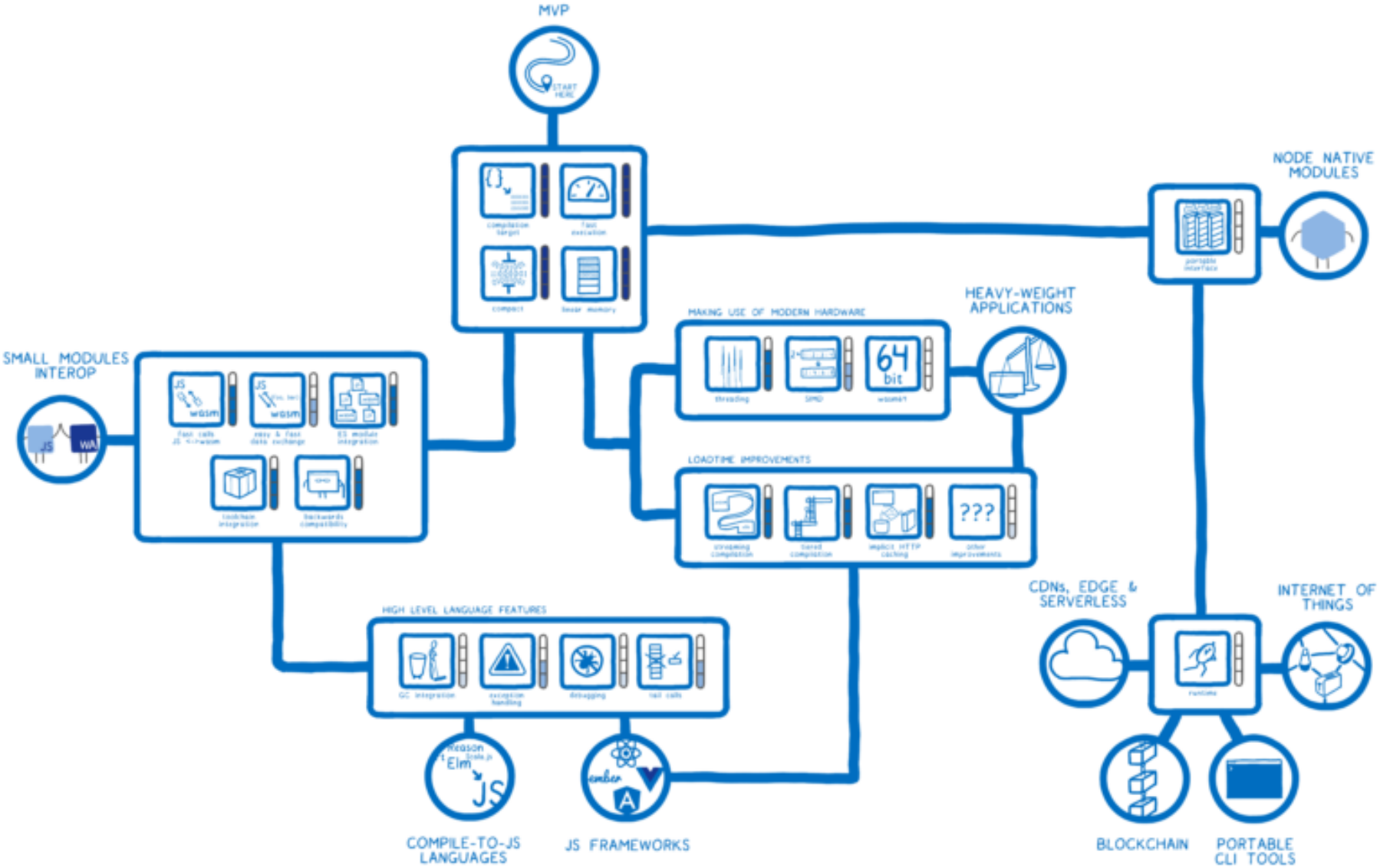
exception handling
debugging
tail calls
Reason
Elm
scala.js
JS
ember
COMPILE-TO-JS LANGUAGES
JS FRAMEWORKS

Future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HEAVY-WEIGHT APPLICATIONS
MAKING USE OF MODERN HARDWARE
64 bit
SMALL MODULES INTEROP
LOADTIME IMPROVEMENTS
???
HIGH LEVEL LANGUAGE FEATURES
CDNs, EDGE & SERVERLESS
INTERNET OF THINGS
COMPILE-TO-JS LANGUAGES
JS FRAMEWORKS
BLOCKCHAIN
PORTABLE CLI TOOLS

Links

- Awesome-wasm, Curated list of awesome things regarding WebAssembly

  github.com/mbasso/awesome-wasm (https://github.com/mbasso/awesome-wasm)

- WasmWeekly, WebAssembly Today, Newletter

  wasmweekly.news/ (https://wasmweekly.news/)

  webassemblytoday.substack.com/ (https://webassemblytoday.substack.com/)

- Webassembly Binary Toolkit

  github.com/WebAssembly/wabt (https://github.com/WebAssembly/wabt)

- Binaryen, Compiler infrastructure and toolchain library

  github.com/WebAssembly/binaryen (https://github.com/WebAssembly/binaryen)

Links

- WebAssembly Studio

webassembly.studio/ (https://webassembly.studio/)

- WebAssembly Roadmap

webassembly.org/roadmap/ (https://webassembly.org/roadmap/)

Thank you

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