

a



b



c



d



e



f



g



h



i



j



k



Carcinization

NOT crabs →



Carcinization

Carcinisation is a form of **convergent evolution** in which **non-crab** crustaceans evolve a **crab-like body plan**.

NOT crabs →



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The term was introduced into **evolutionary biology** by L.A. Borradaile, who described it as:

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"the many attempts of Nature to evolve a crab"

NOT crabs ➡



Thursday Room 1 13:40 - 14:40 (UTC+02)
Talk (60 min)

How to Change the World ✨

Have you noticed that some people make a big difference? That they somehow create changes in a team, a company, or even an industry? Are there things you wish would change in your world? Or in your team, your company, your industry? Would you like to know how to be the "Somebody" in "Somebody Should"?



Kate Gregory

Kate Gregory is an enthusiastic C++ programmer and teacher, and has been paid to program since 1979. She believes that software should make our lives easier. That includes making the lives of developers easier! She'll stay up late arguing about deterministic destruction or how modern C++ is not the C++ you remember. She is one of the three leads of the Carbon Language project, a founder of #include <C++>, and on the board of C++ Toronto, which runs CppNorth. Kate also develops courses for Pluralsight, primarily on C++.

Kate runs a small consulting firm in rural Ontario that provides mentoring and management consultant services, and tries to write code

Me: Rust/C++ interop 🥹



Why do you care?
Why are you here?

Why do you care?

Why are you here?

When **Rust folks** are looking into C/C++ interop, it's natural...
they **NEED** it in order to call into existing libs they don't yet have.


Why do you care?

Why are you here?

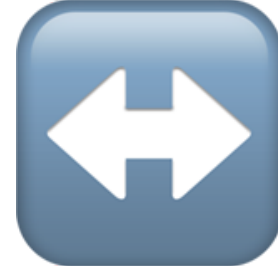
When **Rust folks** are looking into C/C++ interop, it's natural...
they NEED it in order to call into existing libs they don't yet have.

But when **C++ folks** look into Rust interop, it's more than curiosity...
you know some degree of desperation has occurred 🔥

Rust code everywhere is increasing at an accelerated rate...

Rust  **C++**

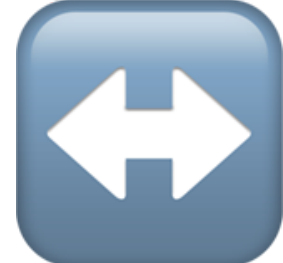
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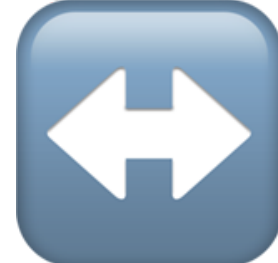
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Hybrid codebases are quickly becoming the norm (whether we like it or not)

Rust  **C++**

They need to play nice together... for a looong time!

Who thinks **interop** is about... C FFI



Who thinks **interop** is about... **C FFI**
glue code



Who thinks **interop** is about... C FFI

glue code

coge generators



Who thinks **interop** is about...

C FFI

glue code

coge generators

(fat) compilers



Who thinks **interop** is about...



C FFI

glue code

coge generators

(fat) compilers

linkers

Who thinks **interop** is about...



C FFI

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linkers



ABI compat

What you're going to get out of this talk

- This presentation aims to highlight:
 - some of the major interop **challenges**
 - existing **solutions** out there
 - tease out the **avenues** at the forefront of this **pursuit**



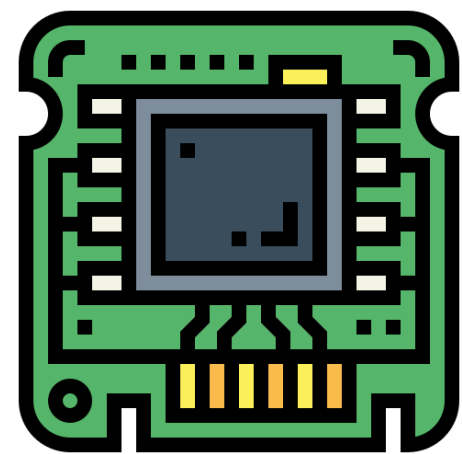
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 - tease out the **avenues** at the forefront of this **pursuit** 
- General **high-fidelity** interoperability has yet to be achieved 
- Just "*making things work*" is not enough in the domain space of C++ and Rust
- Many of the explored solutions so far **fail** to deliver on **all needed requirements**

A vignette in 3 parts

- Attach of the Codegen
- The ABI Menace
- "Beam me up, Scotty!"
(sorry, wrong franchise)

Rust extreme **range** of operation



Choose... none some?



Rust / C++ interoperability

- No perf overhead (avoid marshaling costs, eg. copying strings)

Choose... none some?



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- Avoid lowering through C FFI

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- Ergonomics - with safety

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- Easily automated

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- Easily automated
- Debuggable

Rust / C++ interoperability

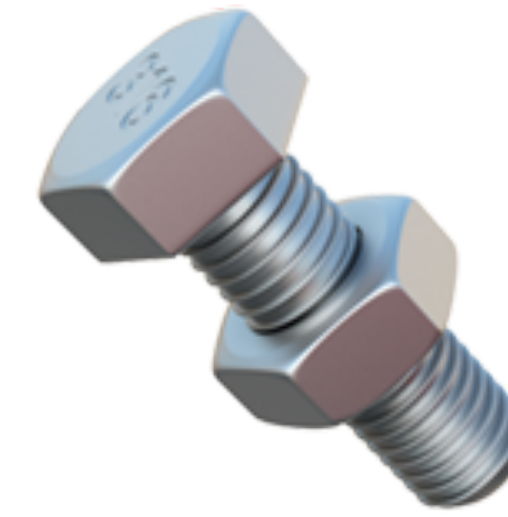
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- Easily automated
- Debuggable
- Hybrid build systems (CMake, cargo, MSBuild, bazel, buck...)



Compiler



Interop Library



Debugger



Linker



ABI guarantees



Packaging



Build systems & CI

Rust/C++ Interop: Carcinization or Intelligent Design?

NDC TechTown

September 2025

 @ciura_victor

 @ciura_victor@hachyderm.io

 @ciuravictor.bsky.social

Victor Ciura

~~Principal Engineer~~

Rambling Idiot

Rust Tooling @ Microsoft

About me



Advanced Installer



Clang Power Tools



Oxidizer SDK



Visual C++



Rust Tooling
Microsoft

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 @ciura_victor@hachyderm.io

 [@ciuravictor.bsky.social](https://bsky.app/profile/ciuravictor.bsky.social)

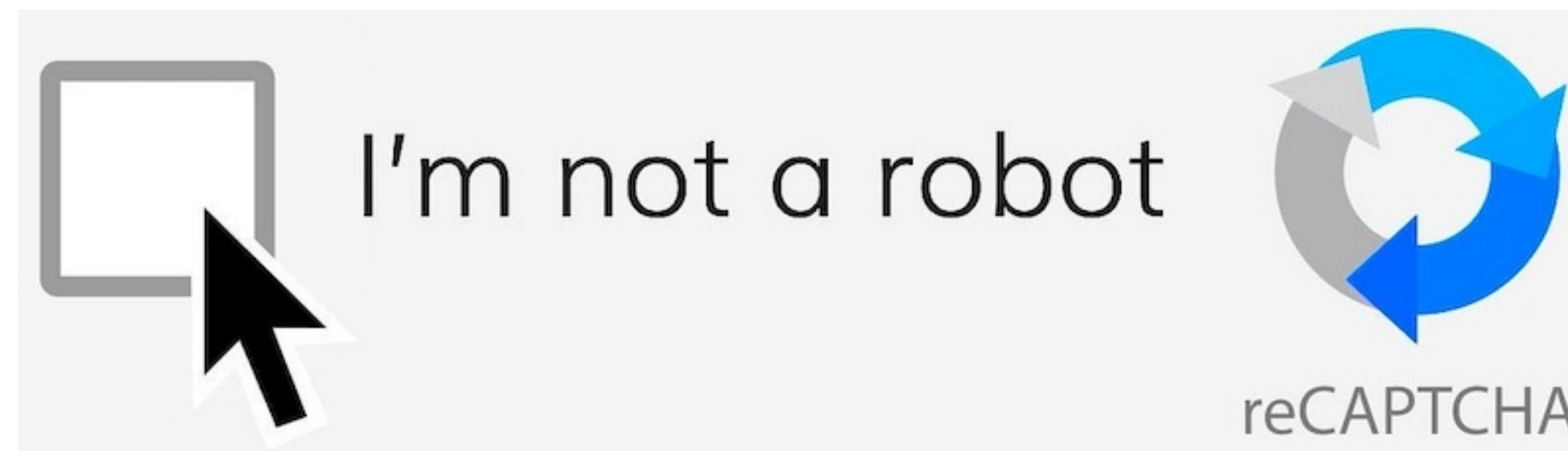
Disclaimer

I'm just an engineer, with some opinions on stuff...



What's out there...

No LLMs were hurt in the making of this presentation



100%
artisanal
code

This presentation was prepared by a *human* agent.
No hallucinations. But errors and 🔥 hot-takes are allowed.

C - The Original Duck Tape



- **C** is the *lingua franca* FFI systems language
- Every API consumable from most languages
- The only ABI-stable "universal interop glue"



- Poor abstraction
- No safety
- Naked structs (public fields)
- Raw pointers
- Manual lifetimes

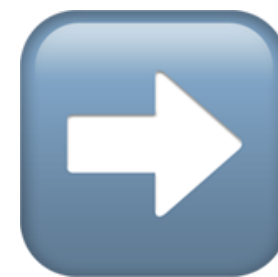


bindgen

Allows Rust to call into C APIs

C headers ➡ Rust FFI bindings

```
typedef struct Widget {  
    ...  
} Widget;  
  
void action(Widget * w);
```



```
#[repr(C)]  
pub struct Widget {  
    ...  
}  
  
extern "C" {  
    pub fn action(w: *mut Widget);  
}
```

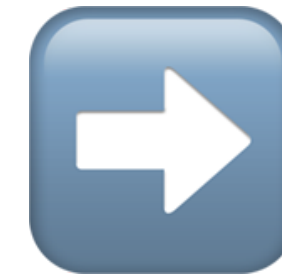
Source generation (build step)

Allows C code to call Rust APIs

.rs ➡ C headers

```
#[repr(C)]  
pub struct Widget {  
    ...  
}
```

```
#[unsafe(no_mangle)]  
pub extern "C" fn action(w: *mut Widget) {  
    ...  
}
```



```
typedef struct Widget {  
    ...  
} Widget;  
  
void action(Widget * w);
```

Source generation (build step)

bindgen / cbindgen

- Works directly on source files (not IDL)
- Source generation (build step)
- Types: `repr(C)` ABI only
- Pass by value: for C types
- ~~Structs with private fields~~
- ~~C++ classes~~
- ~~`std::unique_ptr`, `std::optional`~~
- ~~`Box<T>`, `Option<T>`~~
- ~~Rust enums~~
- ~~`&str`, `String`~~
- ~~`std::string`~~
- ~~`&[T]`~~
 - Lots of complicated, unsafe code on the Rust side
 - `unsafe{}` required to convert to/from C representation
 - Requires scaffolding to make decent C++ interfaces

Slice representation
is not guaranteed

Macro-based IDL

Needs to be separately maintained (manually)

```
#[cxx::bridge]
mod ffi {
    struct Widget {
        things: Vec<String>
    }
}
```

```
#[repr(C)]
struct Widget {
    things: Vec<String>
}
```

```
struct Widget {
    rust::Vec<rust::String> things;
};
```

- Types: standard types (mostly), slices, IDL structs
- C++ classes
- `std::unique_ptr`, `std::optional`
- `Box<T>`, `Option<T>`
- `&str`, `String`
- `std::string`
- `std::vector`
- `Vec<T>`
- `&[T]`
- Intentionally **restrictive** and **opinionated**
- cxx doesn't know the **memory layout** of user types
- **✗ Pass-by-value** => need to `Box<T>` or `unique_ptr<T>`
- Relies heavily on **pinning** (reduced ergonomics)
- Dealing with **callbacks**, **allocators**, etc. is painful


```

struct Widget {
    id: u32,
    things: Vec<String>
}

impl Widget {
    fn new_empty(id: u32) -> Self {
        Self {
            id: id,
            things: vec![],
        }
    }

    fn work() -> f32 {
        ...
    }
}

```

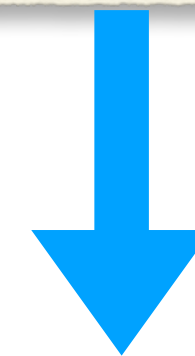
Custom IDL (.zng)

```

type crate::Widget {
    #layout(size = 32, align = 8)

    fn new_empty(u32) -> crate::Widget;
    fn work() -> f32;
}

```



```
#include "generated.h"
```

```

void cpp_caller() {
    auto w = rust::crate::Widget::new_empty(42);
    w.work();
}

```

- Custom **IDL** (.zng)
 - Needs to be separately **maintained** (**manually**)
- Types: standard types (mostly), slices, IDL structs
- ✓ **Pass-by-value**: have to manually annotate types with: **#[layout(size, align)]**
 - no need for indirection/boxing and heap allocation
- Reduced need for **pinning**
- Favors Rust-friendly APIs and developer experience, accepting *occasional runtime cost* to get there

- Bold **new** project with the goal of **high-fidelity** lang interop between Rust and C++

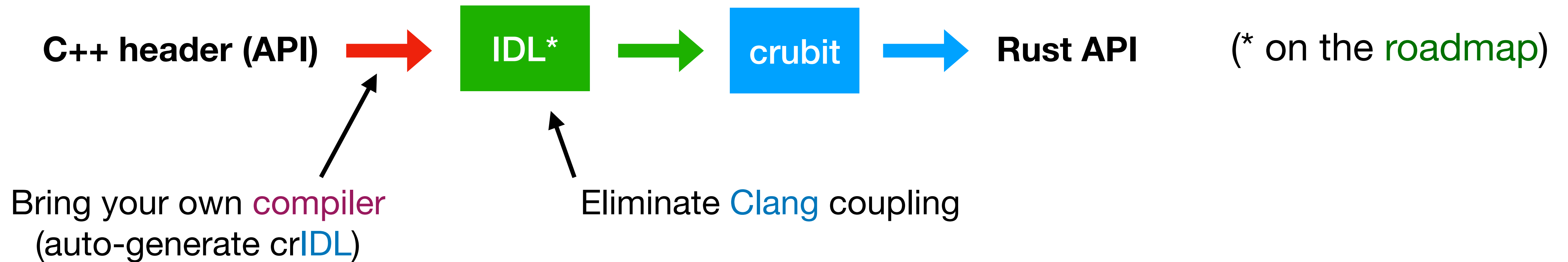
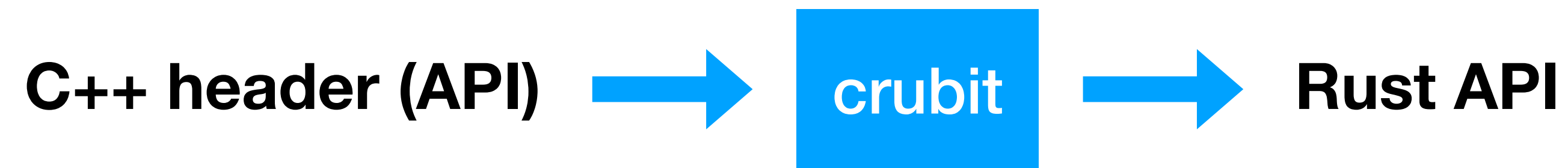
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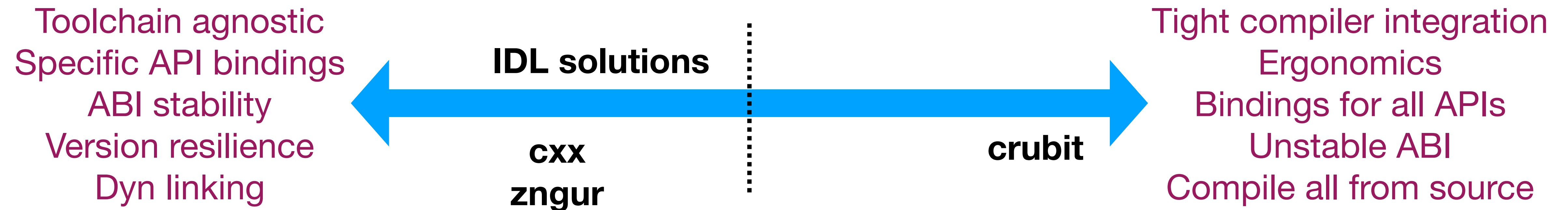
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- **Pass by value**: AllTheThings™ (that's where deep compiler integration comes in)



Tradeoffs...

Projects have very **diverse interop needs**, so no solution fits all (equally)



Language Semantics

Some C++ features not having direct Rust equivalents:

- Overloaded assignment operator
- Overloaded dereference operator
- Overloaded new and delete operators
- Function overloading
- Argument-dependent lookup
- Default function parameters
- Implicit conversions
- SFINAE
- In-place initialization
- Move constructors



Language Semantics

Profound **semantic** differences between language constructs

- Rust semantics is a **subset** of C++ semantics
- Generally, Rust is less expressive than C++

=>




- Using Rust code from C++ is **easier**
- Using C++ code from Rust much **harder**



Level: **HARD!!!**

- C++ features not having direct Rust equivalents (eg. [overloading](#))
- **unsafe**
- [Lifetimes](#)
- [Aliasing](#) (refs)
- Movable types that are non memcopy
- ...

Level: I CAN DO IT

- Rust semantics is a **subset** of C++ semantics
- Rust's **strong type system**
 - easy to grasp **intended semantics** of functions, types
- Querying **rustc** -  Rust ABI is **not** stable: these need to be **refreshed** on each update
 - determine the exact **size** & **alignment** of every Rust type
 - struct fields
 - key **trait** implementations:
 - **Drop**  C++ dtor
 - **Clone**  C++ copy ctor

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Ability for Rust to call **overloaded** C++ functions 😓 (this is a real need!)

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- Need a way to **name-mangle** such that separate functions **map** to the correct overloads

The ABI Menace



What is ABI, anyway?

ABI isn't a property of a programming **language**

It's really a property of a **system** and its **toolchain**

ABI is something defined by the **platform**

Eg.

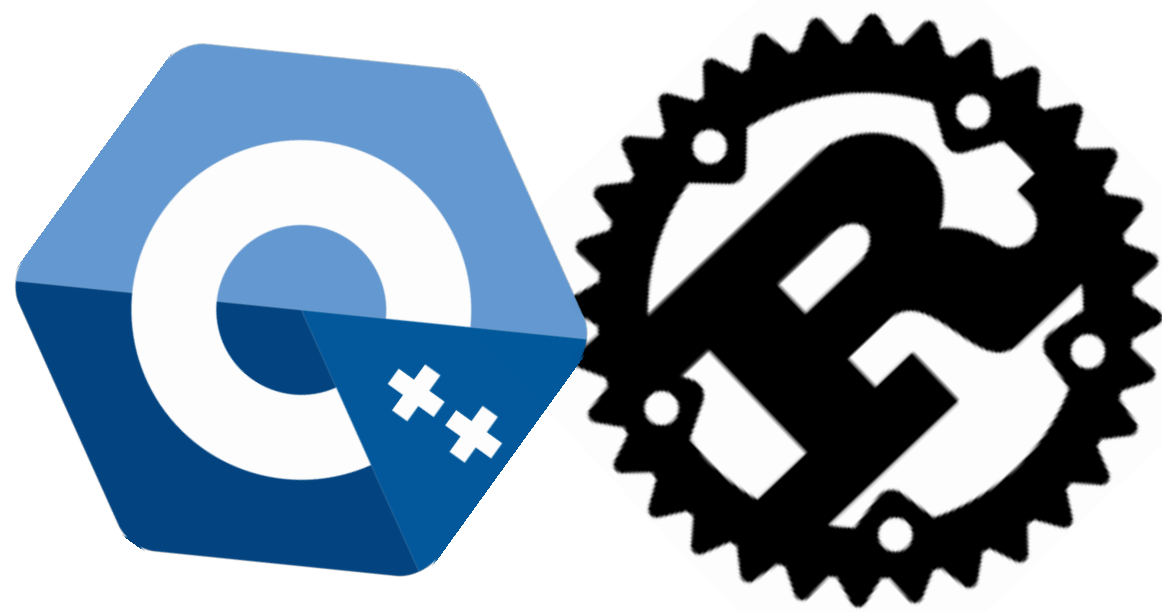
Compilers determine class layout: **✗** portable

- Layout of types
 - size & alignment (stride)
 - offsets & types of fields
 - v-table entries
 - closures
- Calling conventions
- Name mangling (symbols)
- Metadata (if applicable)

ABI Stability - When?

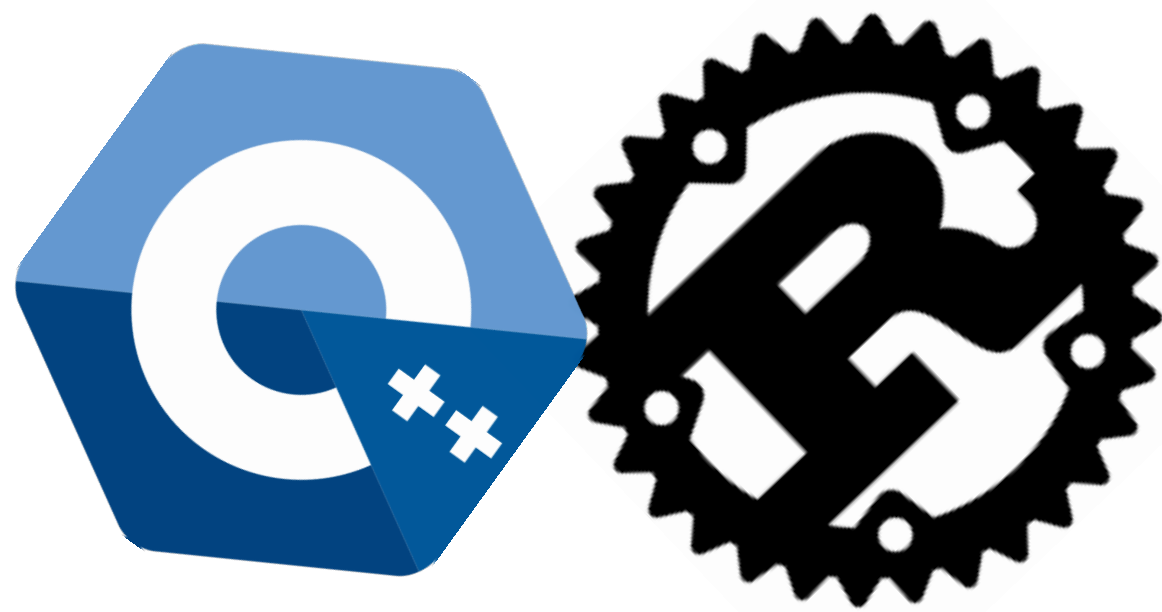
- Don't shut the door on **future** compiler & library **improvements**
- **Stabilizing** the ABI **(too early)**TM might miss **optimization** opportunities:
 - implement a faster custom calling convention
 - implement optimal structure layout
 - improve the way a std utility works
 - make changes affecting v-table
 - (re)use existing padding

ABI Stability - Why?



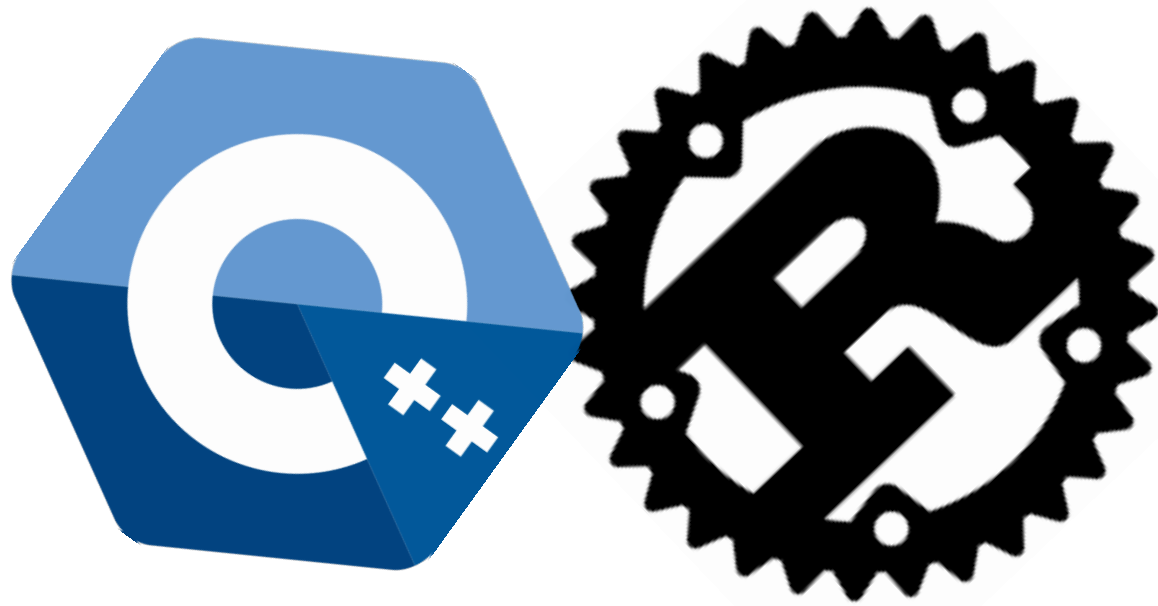
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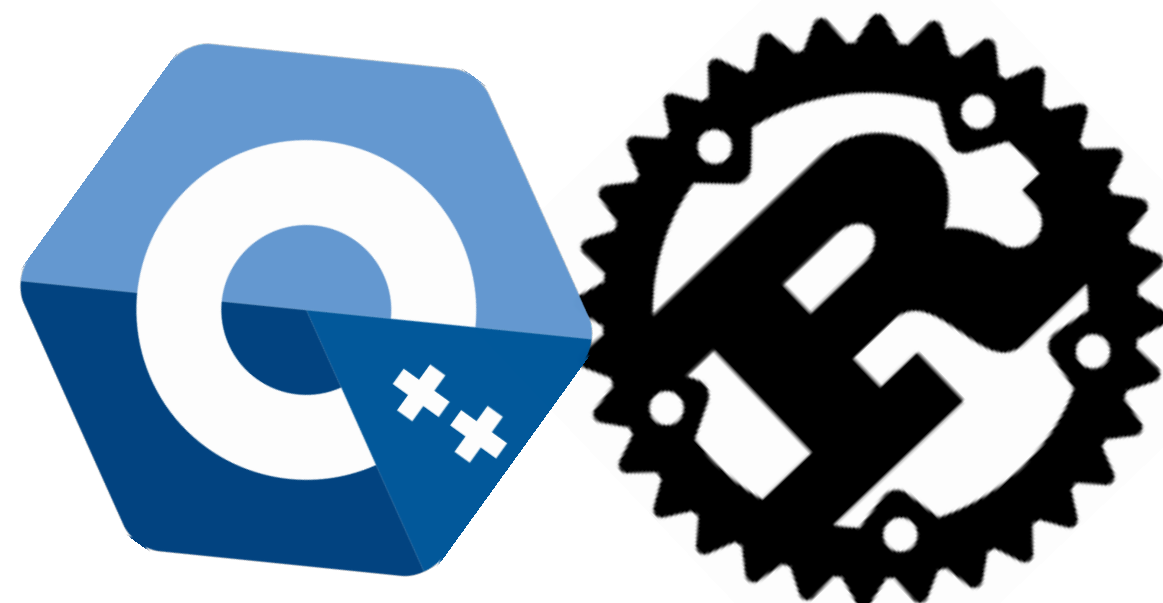


ABI Stability - Why?

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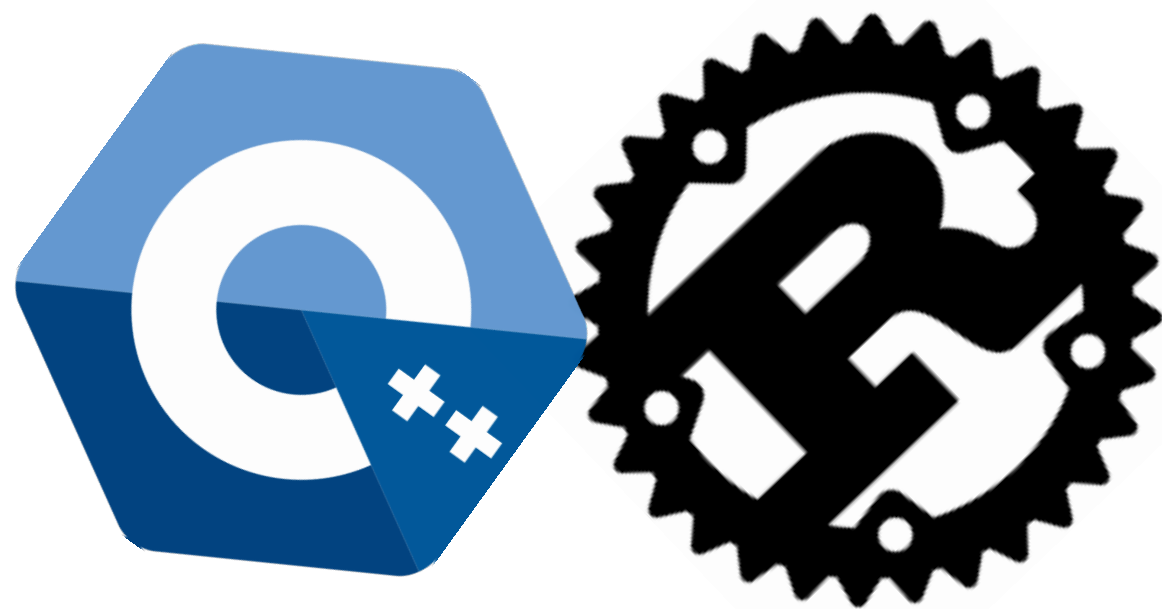


ABI Stability - Why?



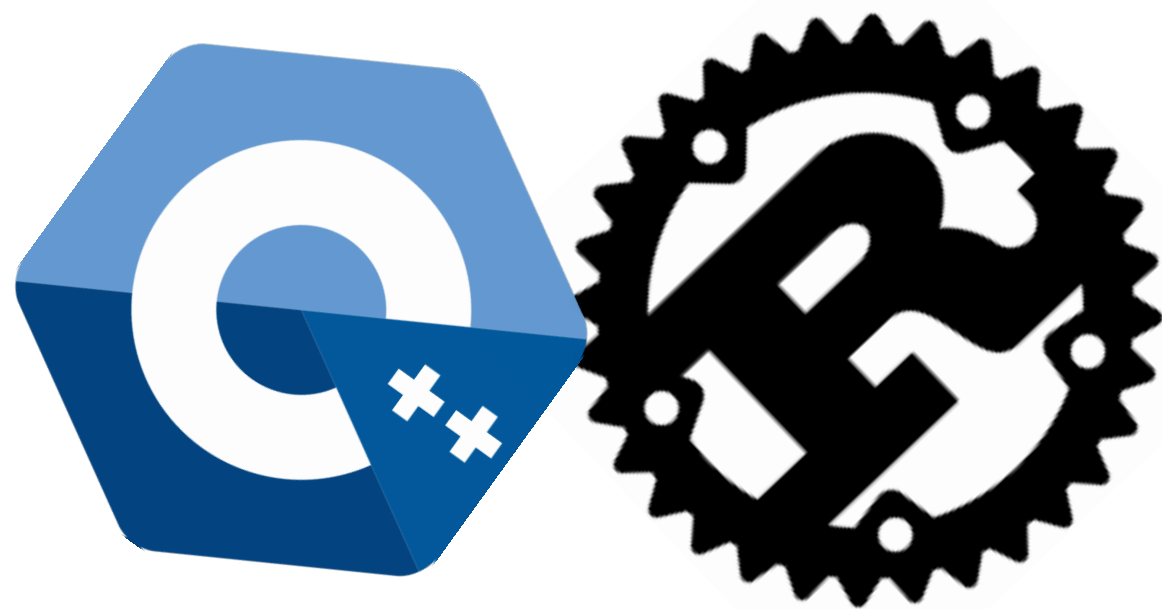
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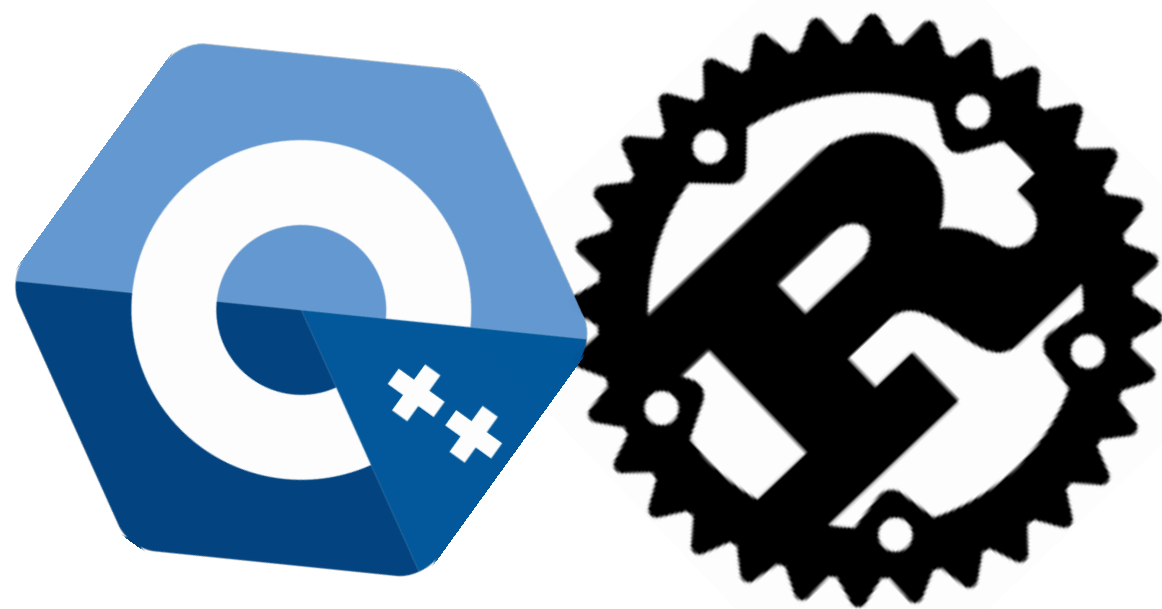
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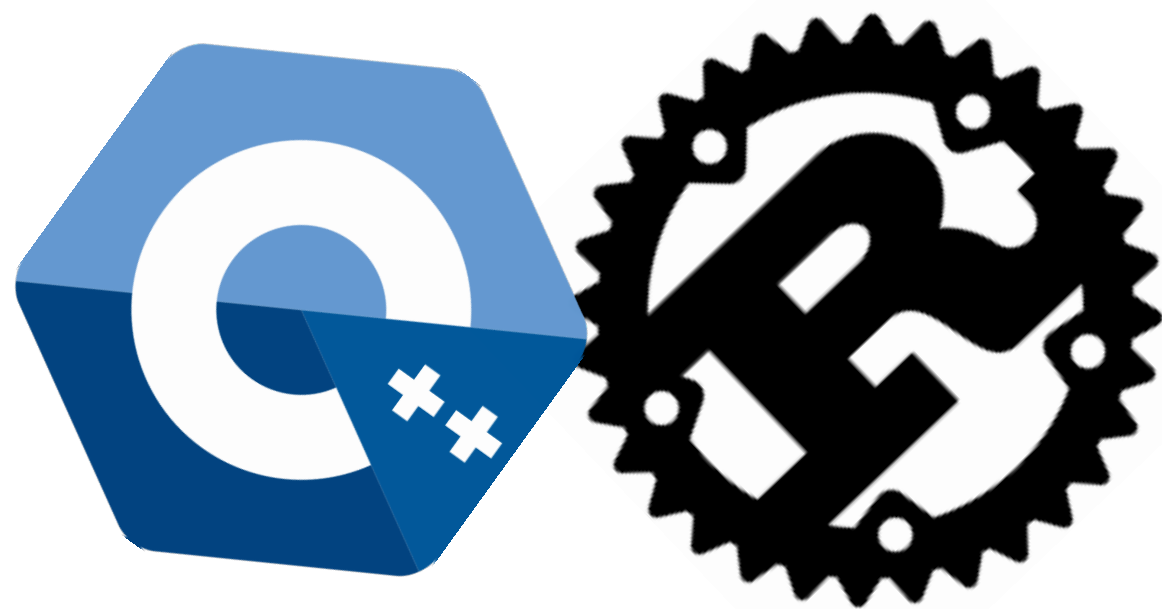
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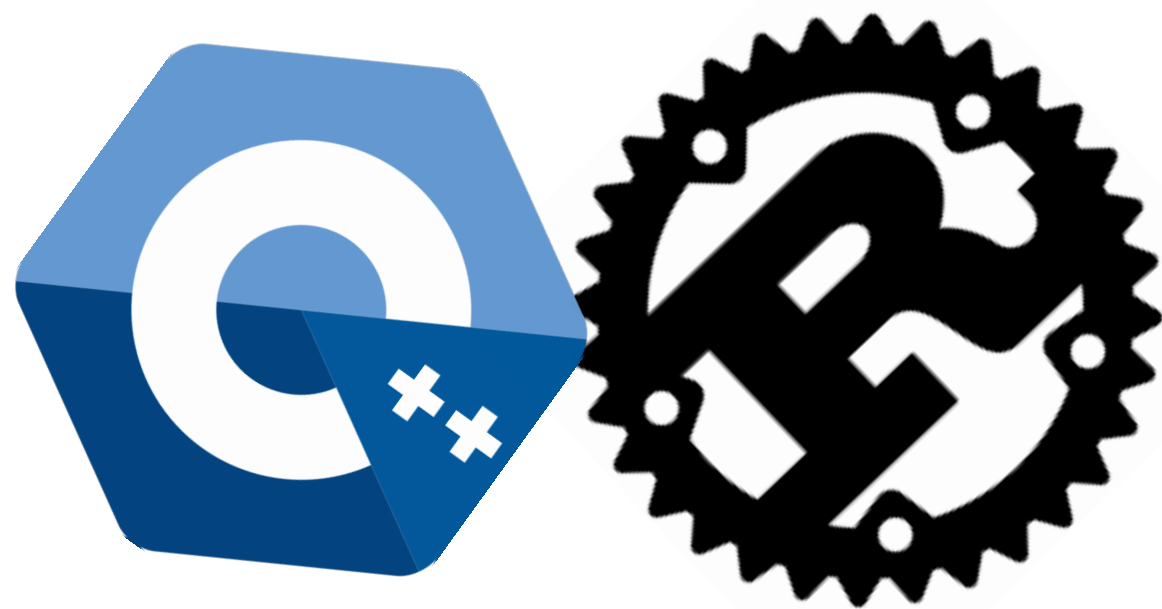
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- Binaries can be shipped and **updated independently** (patches)
- Multiple programs can **share the same library** (incl. std lib)

ABI Stability - Why?



- You don't have to share the **source code** of your library
- You can use the most **recent compiler** for your library
- Use libraries compiled with a **different compiler** version
- You don't have to **recompile everything** (full project visibility)
- Binaries can be shipped and **updated independently** (patches)
- Multiple programs can **share the same library** (incl. std lib)
- **Plugins**/extensions (dynamically loaded)

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- **Plugins**/extensions (dynamically loaded)
- Language **interop** (hybrid projects)

The (early) 90s are calling...

- Old-school interop 😅: COM, CORBA, XPCOM, ...
- COM
 - **MIDL** for interop
 - metadata
 - ABI resilience



Design for Library Evolution

Principles for ABI-**resilient** library evolution:

- make all promises **explicit**
- **delineate** what can and cannot change in a stable ABI
- provide a performance model that **indirects** only when necessary
- let the authors of libraries & consumers be **in control**

Doug Gregor

*Implementing Language Support for
ABI-Stable Software Evolution in **Swift** and **LLVM***

youtube.com/watch?v=MgPBetJWkmc

Struct Layout

Compilers could provide a class' data members with **layout metadata**

=> allow representation of Rust struct fields

🔍 Retrieve **layout** via the C++ **AST** and the **rustc query** API



Type Layout should be *as-if* we had the whole program:

- Widget library should layout the type *without* indirection
- Expose metadata with layout information:
 - size/alignment of type
 - offsets of each of the public fields
 - overlapping sub-objects
 - padding tricks & vtables
- Attributes, annotations, or compiler synthesized

```
size_t Widget_size = 32;  
size_t Widget_align = 8;  
size_t Widget_field1_offset = 0;  
size_t Widget_field2_offset = 8;
```

Client code (external) **indirects** through **layout metadata**

- **Access** a field:
 - read the metadata for the **field offset**
 - add that offset to the base object
 - cast the new pointer and load the field
- Store an instance on the **stack**:
 - read the metadata for instance **size**
 - emit **alloca** instruction, to setup as needed

Library code (internal) eliminates all ~~indirection~~

- performance: **indirects** only when necessary
- **Access** a field:
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Dynamically-sized

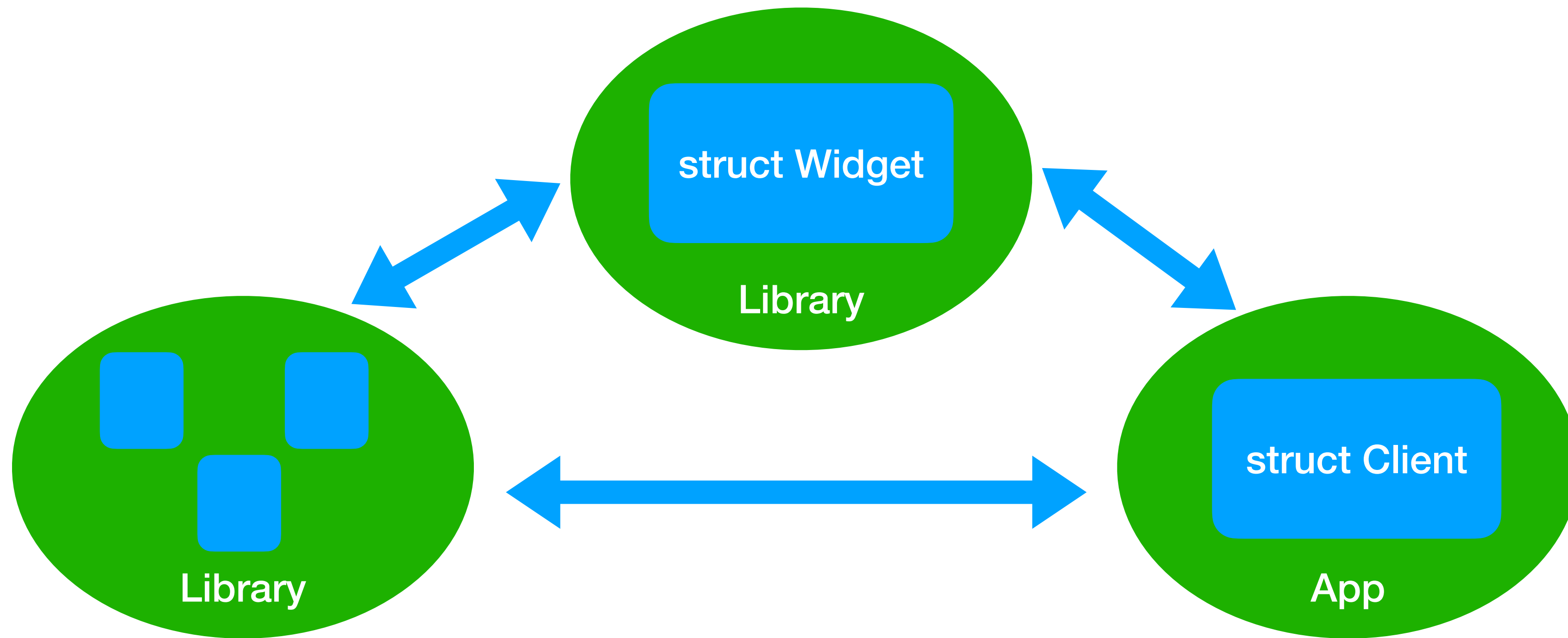
- Support for **dynamically-sized** things on the **stack** is key (eg. LLVM)
- Compilers can make use of this for of **ABI-stable value types**:
 - you have local variable of some struct defined in an **ABI-stable library**
 - so you don't know it's size until **load time**
- Dynamic allocs can handle this nicely (with **minimal perf impact**)
- C++ desperately wants all objects to have **compile-time-constant size**
 - **✗** the notion of **sizeof/alignof** being **runtime values** clashes with the C++ model

Interop Domains

By explicitly modeling the **boundaries** between software modules that **evolve separately** vs. **together**:

- introduce appropriate **indirections** across **separately-evolved** software modules
- while **optimizing away that indirection** within software modules that are **always compiled together**

Interop Domains



An **interop domain** contains code that will always be **compiled together**

Domains can control where the costs of interop are paid

Optimization vs. Resilience

- **Across** resilience domains => maintain **stable** ABI
- **Within** a resilience domain => all implementation details are **fair game**
 - no indirections (direct access, no computed metadata)
 - no guarantees made
- Optimizations need to be aware of resilience **domain boundaries**
- A program can have just 1 resilience domain

Tail Padding & Rust ABI



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- A field with `[[no_unique_address]]` may have its tail padding **reused** for a neighbor field
- Prevents Rust from turning a C++ **child reference** into a **base** class reference
 - doing so would allow **overwriting** the tail padding (and thereby the child fields)

Rust ABI Stability

Rust dev: "Can we have stable ABI?"

Rust dev: "We have stable ABI at home."

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Stable ABI at home: `#[repr(C)]`

Status quo: `repr(C)` - fake it, till you make it 😊

- Using the C calling convention for function definitions and calls
- Using the C data layout for a type
- Definitions of C types like char, int, long, etc.
- Exporting an item under a stable linking symbol
- Limited to **C types**, mostly
- **No slices**

```
extern "C" fn  
#[repr(C)]  
std::ffi::c_*  
#[no_mangle]
```

```
u8, i64, c_int, c_char, ...  
&T, &mut T  
*const T, *mut T  
struct
```


The Future™: calling convention and data layout

- Stable calling convention that supports common data types
 - `&str` `&[u8]` etc.
- Standard data layout that supports enums (with data), etc.
 - `enum` `struct`
- Stable layout guarantees of common standard library types
 - `Option` `Result` etc.

```
extern "crabi" fn
```

```
#[repr(crabi)]
```

```
#[repr(crabi)] in std
```

crABI

github.com/joshtrippett/rfcs/blob/text/3470-crabi.md

The Future™: mechanism for exporting/importing, naming symbols and working with dynamic libraries

- Exporting items under stable linking symbols, supporting crates, modules, methods `#[export]`
- Use a crate as dynamic library, only importing the exported items `extern dyn crate`
- Cargo features for dynamically linking to Rust libraries `cargo dynamic deps`

The Future™: trait objects/vtables and typeid

- A standard data layout for dynamic **trait objects** (v-tables)
 - `&dyn T` `&mut dyn T` `Box<dyn T>`
- A way of dealing with types that depend on global state (eg. **allocated objects**)
 - `Box` `Vec`
- **Stable typeid**
 - `Any` `catch_unwind`
- Access to std structures like maps through dynamic **std trait objects**
 - `&dyn HashMap` `etc.`

The Future™: *"Don't stop me now!"* 🎵

- Turning parts of std into an opt-in dynamic library with a stable ABI ([std as dylib](#))
- [Tools](#) to help with [detect](#)/maintaining ABI compatibility and tools to debug ABI issues
- Store signatures, data layouts in binaries ([introspection](#))

ABI Cafe 🧩 ☕

faultlore.com/abi-cafe/book/

Pair Your Compilers At The ABI Café:
faultlore.com/blah/abi-puns/



Object Relocation

One particularly sensitive topic about handling C++ **values** is that they are all *conservatively* considered **non-relocatable**

Object Relocation

In contrast, a **relocatable value** would preserve its **invariant**, even if its bits were moved arbitrarily in memory

For example, an `int32` is relocatable because moving its 4 bytes would preserve its actual value, so the address of that value does not matter to its integrity

Object Relocation

C++'s assumption of **non-relocatable values** hurts everybody
for the benefit of a few questionable designs

Object Relocation

Only a *minority* of objects are genuinely **non-relocatable**:

Eg.

- objects that use internal **pointers**
- objects that need to update **observers** that store pointers to them

Trivially Relocatable

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- Relocating an object to a distinct physical location is a **destructive** move
 - **create** new object having original value at destination
 - **destroy** the source object

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- Trivial relocation **standardizes** this important optimization

I like to move it, move it...

Trivial Relocatability C++26

Safely relocate objects in memory

wg21.link/P2786

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Optimizing containers to take advantage of this property of a type is [already in widespread use](#) throughout the industry, but is [undefined behavior](#) as far as the language is concerned

[wg21.link/P2786](https://ericniebler.com/2025/01/01/wg21-link-p2786/)

Trivially Relocatable

#def

A class is trivially relocatable if:

- it has no virtual base classes
- all of its **sub-objects** are trivially relocatable
- it has no *deleted* destructor
- **AND:**
 - its move constructor, move-assignment operator, and destructor are *defaulted*
 - **OR**
 - it's tagged with the **trivially_relocatable_if_eligible** keyword



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- Rust **Pin** solves the issue with **self-referential** types
 - not ergonomic (pollutes the context)

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✗ Place a C++ object on a Rust stack since it cannot be safely memcopy-moved (relocated)

C++26: Make C++ types trivially relocatable (annotate types)

Get standard library to be relocatable

=> allow most C++ types on the Rust stack (efficiency)



Improving Rust/C++ Interop with Trivial Relocatability:

camio.github.io/trivially_relocate_rust/trivially_relocate_rust.pdf

I like to move it, move it...

Support for **destructive moves** in C++ would match the behavior of Rust **drop** mechanics

moveit

- safe in-place construction of Rust and C++ objects
- mirrors Rust's drop semantics in its destructive moves
- moved-from values can no longer be used afterwards

crates.io/crates/moveit

Let's talk compilers!

Compilers & Interop

Many of the tricks here require deep **compiler** involvement:

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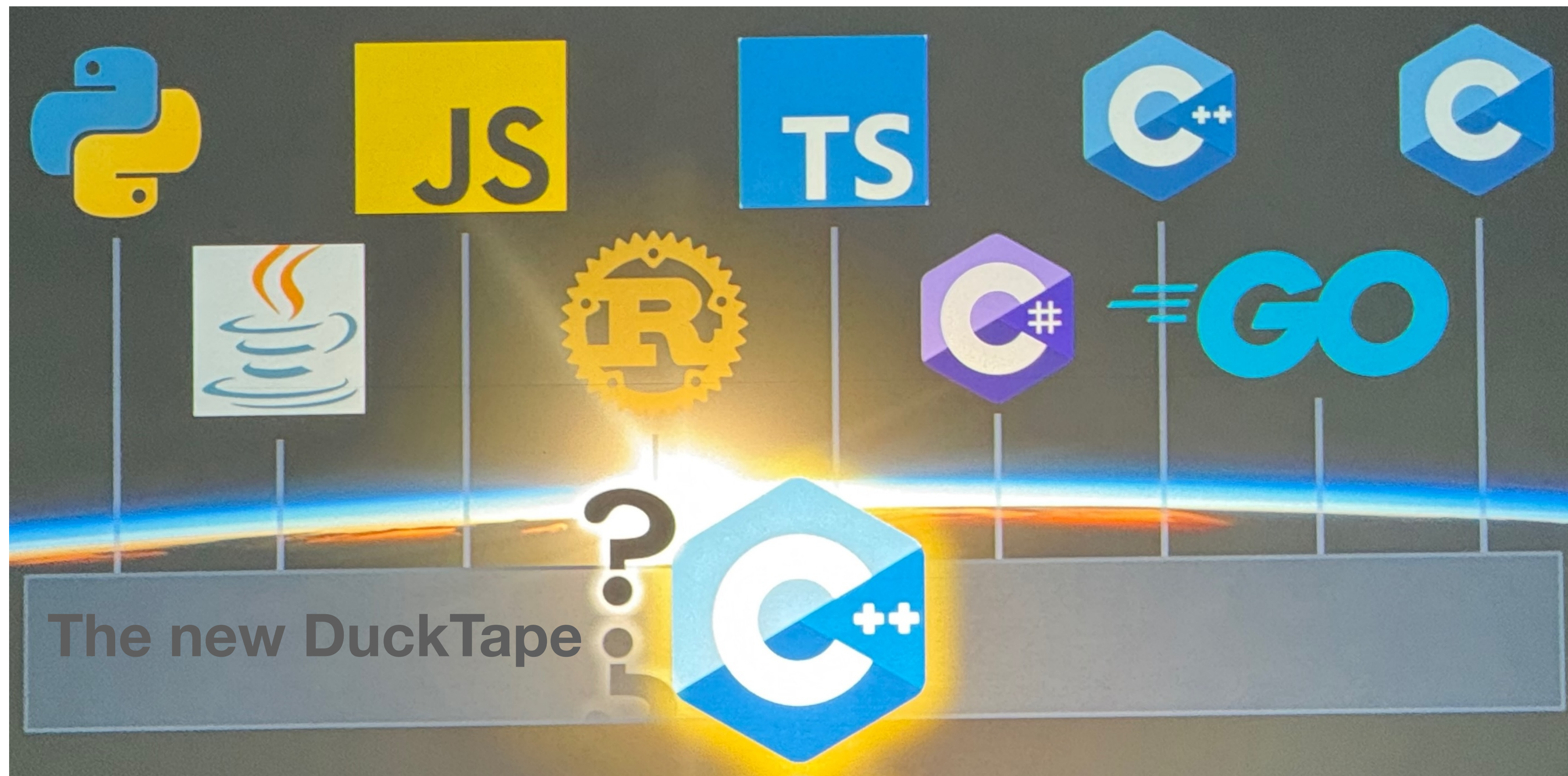
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Binary-level fidelity, ABI, linking, dylib, etc.

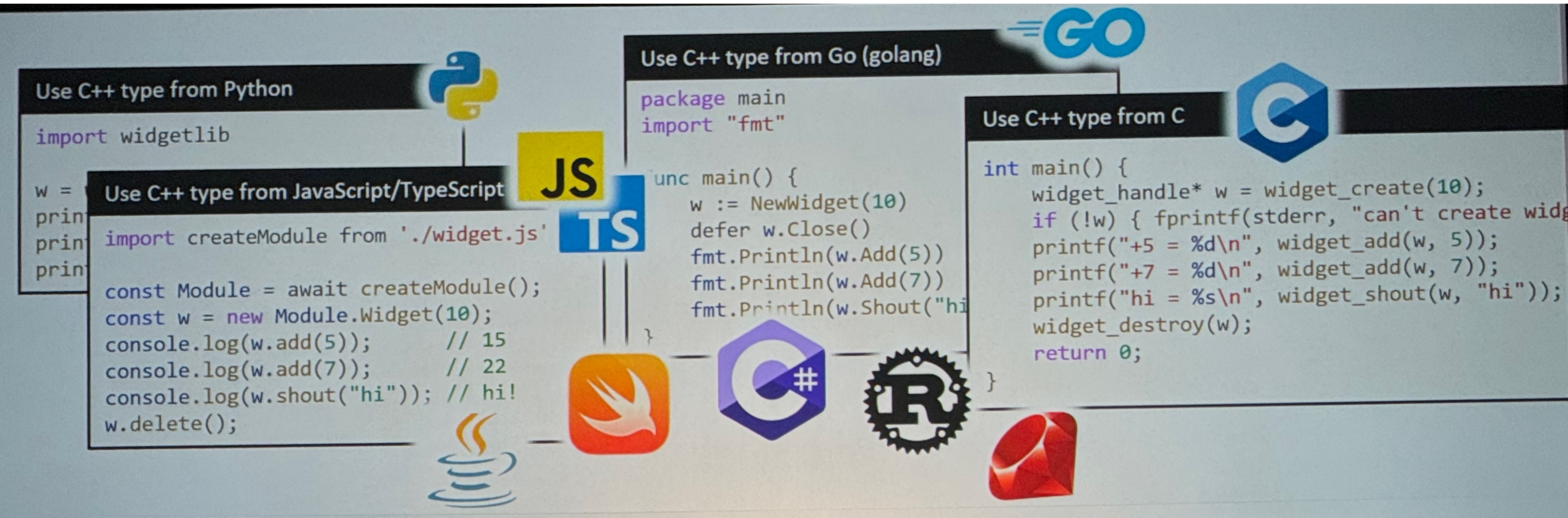
- platform integration
- post-build tooling
- codegen / **back-end**



C++26 Reflection will be a game changer for lang interop!



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Herb Sutter: "Reflection: C++'s Decade-Defining Rocket Engine" (CppCon 2025)

youtube.com/watch?v=7z9NNrRDHQU

Who's driving this thing?

Active Effort

This year, there have been effervescent talks in the Rust Project & community about this topic (in the broader interop context, not just C++)

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[Rust Foundation](#) joined INCITS in order to participate in the [C++ ISO standards process](#) ([Jon Bauman](#), David Sankel, et.al.)

Rust/C++ Interop Study Group

Interested? join the Rust Project [Zulip](#) server

- rust-lang.zulipchat.com
- [#t-lang/interop](#) channel

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Meetings:

- [Feb 26](#) First lang-team design meeting on the topic - [Notes](#) 
- [Apr 23](#) Short-sync on interop interest in industry
- [May 15-17](#) Interop study group @ Rust-All-Hands - [Notes](#) 
- [Sep 2](#) Interop study group @ RustConf - [Notes](#) 



Must watch 🍿

Zngur

Simplified Rust/C++ Integration

David Sankel

youtube.com/watch?v=k_sp5wvoEVM

Fine-grained Rust / C++ interop

Taylor Cramer and Tyler Mandry

The original annual Rust programming language conference.

Learn more at rustconf.com

We are crubit



Open Discussion

What does Rust/C++ **interop** mean for you?

What are the **interop** requirements/challenges of your project?

Rust/C++ Interop: Carcinization or Intelligent Design?

NDC TechTown

September 2025

 @ciura_victor

 @ciura_victor@hachyderm.io

 @ciuravictor.bsky.social

Victor Ciura

~~Principal Engineer~~

Rambling Idiot

Rust Tooling @ Microsoft