
a
b
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k

# Carcinization

NOT crabs ➡️

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*"the many attempts of Nature to evolve a crab"*

NOT crabs ➡️

# Who thinks interop is about... C FFI

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C FFI

glue code

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coge generators

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ABI compat

# When you ask about Rust interop

C ffi, autocxx, bindgen, cbindgen, diplomat,

capigen, cxx, zngur, crubit, wit-bindgen, etc.

# When you ask about Rust interop

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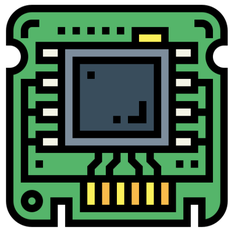
glue code
source annotations
code generators
IDLs
mapping language semantics & constructs

# Rust extreme range of operation




# Rust @Microsoft

- Project Mu
- Pluton security processor
- SymCrypt - rustls
- Azure Integrated HSM
- Azure Boost Agents
- Open VMM / Open HCL
- Hyper-V

- Azure SDK for Rust
- Azure Data Explorer
- Drasi
- MIMIR
- Caliptra
- Hyperlight / WASM
- ... 🤫

TBD:

⚙️ Windows core components

🎛️ Drivers

☁️ Microservices (Azure, M365)

# Oxidation

## More oxidation 🦀 efforts in progress...

## C++ ➡️ Rust ⬅️ C#

- Assist developers making the *transition* from C, C++, C# to Rust
- Investing in Rust developer tooling

# Rust in Production

**Learn** by doing: **Exploration → Flighting → Production**

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- Performance targets, x-language LTO
- Costs of maintaining a hybrid C++/Rust codebase

# Rust ❤️ C++

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

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

Compiler

Debugger

Linker


ABI guarantees

Interop Library

Build system

RustWeek

May 2025


# Duck-Tape Chronicles
## Rust/C++ Interop

**Episode 1**

Victor Ciura

Principal ~~Engineer~~
Rambling Idiot
Rust Tooling @ Microsoft

@ciura_victor
@ciura_victor@hachyderm.io
@ciuravictor.bsky.social

# About me

**Advanced Installer**

**Clang Power Tools**

**Oxidizer SDK**

**Visual C++**

**Rust Tooling**
Microsoft

@ciura_victor
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# Disclaimer

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


# Today: A story in 3 pieces

- ABI / Layout
- Move Semantics
- Codegen & Compilers

# Let me start
# with a ~~sad story~~ cautionary tale

# C++ ABI - Now or Never

February 24, 2020

## The Day The Standard Library Died

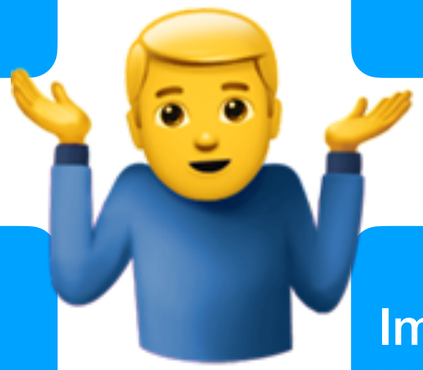
- wg21.link/P2028
- wg21.link/P1863

cor3ntin.github.io/posts/abi/

# C++ the king of mix signals and ambivalent behavior

C++ does not have an ABI resilience model (it's not stable)

The committee will reject* any proposal that could cause ABI breaks in existing STL components



C++ will not officially commit to guaranteeing ABI stability

Implementors* will not change/improve library components if it would cause an ABI break for clients

- wg21.link/P2028
- wg21.link/P1863

# 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)™ 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

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- 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
  - MIDL for interop
  - metadata
  - ABI resilience

# Design for Library Evolution

Principles for ABI-stable 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

C++ compilers could provide a class' data members with layout metadata

=> allow representation of Rust struct fields in C++

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

# Layout

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/External Code

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

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

- performance: indirects only when necessary

- Access a field:
  - ~~read the metadata for the field offset~~
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# Dynamically-sized

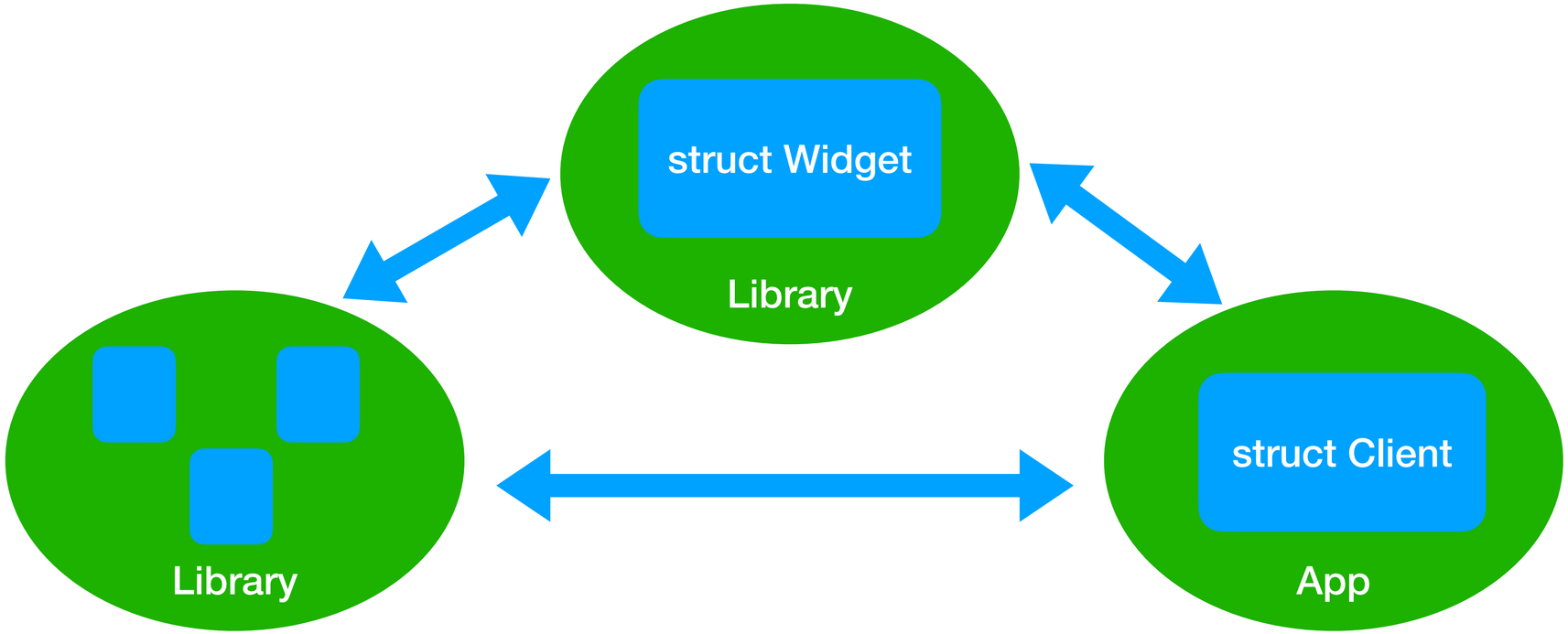
- Support for dynamically-sized things on the stack is key (eg. LLVM)
- Compilers can use of this for of ABI-stable value types:
  - you have local variable of some struct defined in an ABI-stable library
  - so you don’t know it’s size until load time
- Dynamic allocs can handle this nicely (with minimal 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

# Interop Domains

**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

# 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)]`

# Rust ABI

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

- Using the C calling convention for function definitions and calls `extern "C" fn`
- Using the C data layout for a type `#[repr(C)]`
- Definitions of C types like char, int, long, etc. `std::ffi::c_*`
- Exporting an item under a stable linking symbol `#[no_mangle]`
- Limited to C types, mostly
- No slices

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

# Rust ABI

The Future™: calling convention and data layout

- Stable calling convention that supports common data types — `extern "crabi" fn`
  - `&str` `&[u8]` `etc.`
- Standard data layout that supports enums (with data), etc. — `#[repr(crabi)]`
  - `enum` `struct`
- Stable layout guarantees of common standard library types — `#[repr(crabi)] in std`
  - `Option` `Result` `etc.`

**crABI**
github.com/joshtriplett/rfcs/blob/text/3470-crabi.md

# Rust ABI

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`

# Rust ABI

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.`

# Rust ABI

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/

# I like to move it, move it...

## 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

# I like to move it, move it...

## 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

# I like to move it, move it...

## Trivial Relocatability For C++26

Proposal to safely relocate objects in memory

wg21.link/P2786

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Many types in C++ cannot be trivially moved or destroyed, but do support trivially moving an object from one location to another by copying its bits — an operation known as trivial relocation

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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

# I like to move it, move it...

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

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

Get standard library to be relocatable
=> allow most C++ types on the Rust stack (efficiency)

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📦 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

# Compilers & Interop

Many of the tricks here require deep compiler involvement:

- on C++ side (pick your poison 🙂)
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- toolchain independent IR
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Binary-level fidelity, ABI, linking, dylib, etc.

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

# Active Effort

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  - Tyler Mandry is the point-of-contact for project goal
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Rust Foundation joined INCITS in order to participate in the C++ ISO standards process

Jon Bauman attended the February WG 21 meeting in Austria, where he outlined some the Rust/C++ interop strategy, as seen from the Rust side

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## Meetings:

- (Feb 26) We held our first lang-team design meeting on the topic
- (Apr 23) Short-sync on interop interest in industry (attendees)
- Notes: Enabling seamless interop 

# Join the conversation

Anyone who is interested in the topic, please join the Rust Project Zulip server and start engaging on the **#t-lang/interop** channel

You'll find there some familiar Rust and C++ names 🙂

rust-lang.zulipchat.com

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The next *meetings* on the interop will be 🇳🇱HERE, on **May 15-17** at **Rust All-Hands**

rust-lang.zulipchat.com

# Open Discussion

What does interop mean for you?

What are the interop requirements/challenges of your project?

RustWeek

May 2025


# Duck-Tape Chronicles
## Rust/C++ Interop

**Episode 1 – The ABI Menace**


**Episode 2 – Attack of the Codegen**

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