# How to Rust when standards are defined in C

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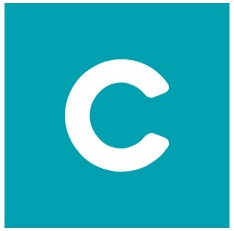
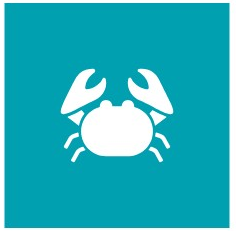
# AUTOMOTIVE & STANDARDS

# I CAN DO ANYTHING IN C!

# VALUES MATTER




SIMPLE

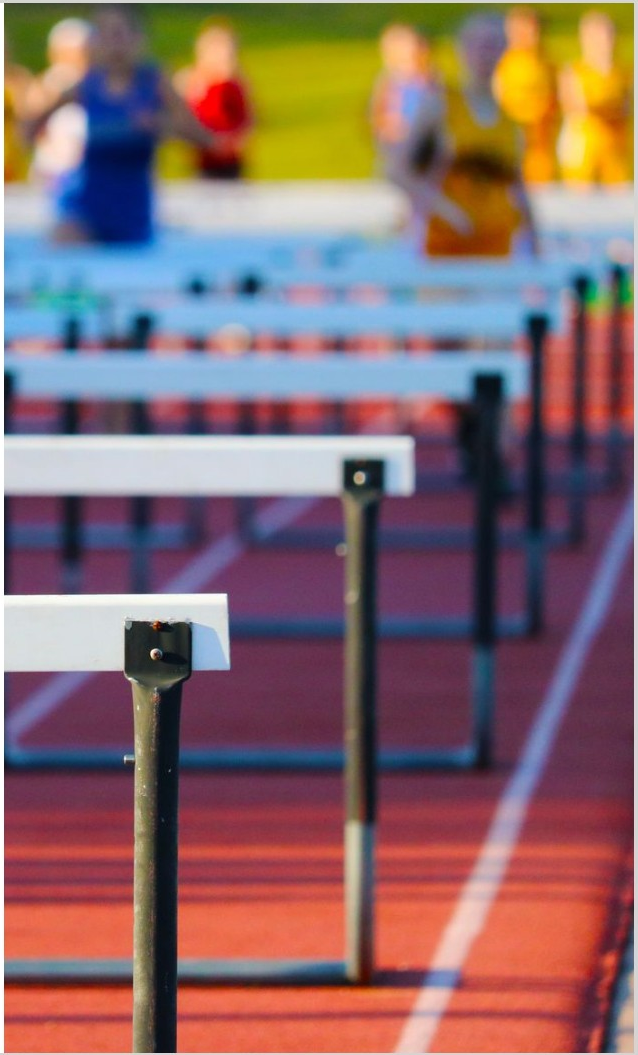


MEMORY SAFE

See video: Scale By The Bay 2018: Bryan Cantrill, Rust and Other Interesting Things

# CAN WE RUST?

1. AUTOSAR STANDARD
2. C, ASM & RUST INTEGRATION
3. KNOWN (RUST) PROBLEMS
4. ENGINEERS & MANAGERS
5. LEGACY SOFTWARE



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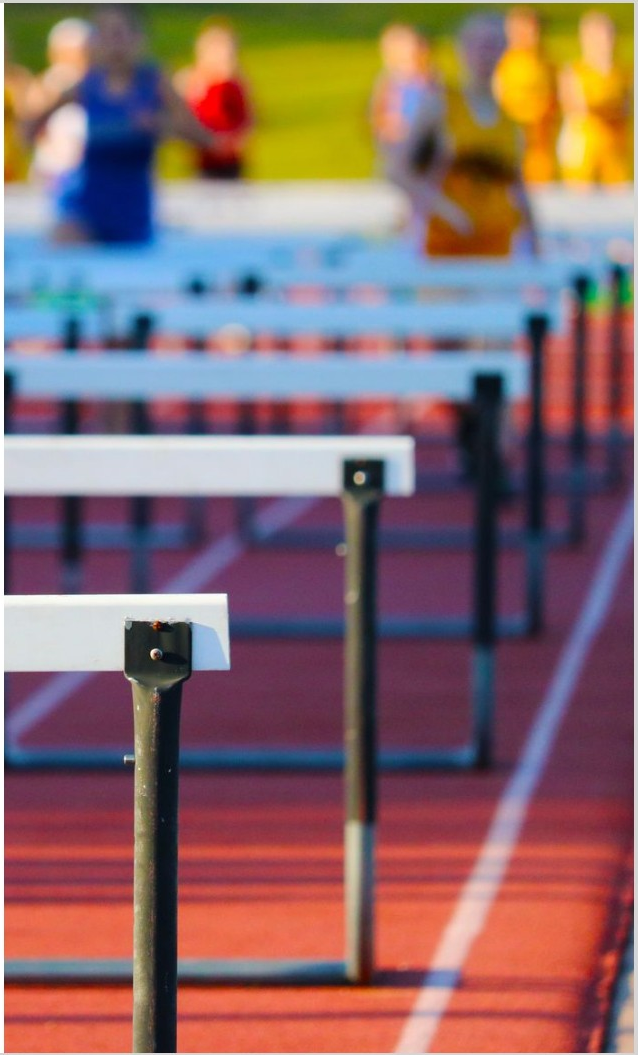

# QUOTES FROM THE AUTOSAR STANDARD


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https://www.autosar.org/fileadmin/user_upload/standards/classic/4-0/AUTOSAR_SRS_BSWGeneral.pdf

# SPECIFICATION OF OPERATING SYSTEM

V5.0.0 R4.0 Rev 3 - 4.6.2 Programming Language

The API of the operating system is defined as **C89** [23] function calls or macros. **If other languages are used they must adapt to the C interface.** This is because C99[24] allows for internal dynamic memory allocation during subroutine calls. Most automotive applications are **static (non-heap based).**

https://www.autosar.org/fileadmin/user_upload/standards/classic/4-0/SystemServices.zip
Standard Specifications/AUTOSAR_SWS_OS.pdf

# REALITY CHECK!

BSW171: [..] functionalities [..] which are disabled by static configuration shall not consume resources (RAM, ROM, runtime).

# OPTIMIZING RAM USAGE IN C (PREPROCESSOR)

```
#if (OS_NO_OF_RESOURCES > 0U)

    #if (OS_NO_OF_RESOURCES <= 8U)
        typedef uint8_t res_t;

    #elif OS_NO_OF_RESOURCES <= 16U)
        typedef uint16_t res_t;

    #elif OS_NO_OF_RESOURCES <= 32U)
        typedef uint32_t res_t;

    #else
        /* typically somewhere else, maybe computed by a cfg generator */
        #define OS_RES_ARRAY_SIZE \
            ((OS_NO_OF_RESOURCES / 8) + ( !!(OS_NO_OF_RESOURCES % 8))
        typedef uint8_t res_t[OS_RES_ARRAY_SIZE];

#endif
```

# OPTIMIZING RAM USAGE IN C - USING THE PREPROCESSOR

```
struct tcb_t {

    TaskIdType id; /* also priority */

    struct ctx_t ctx;

    /* if no memory protection, stack is common */
    #if defined(USE_PREEMPTION) || defined(USE_MEMORY_PROTECTION)
        stack_info *stk; /* ISRs of the same prio share the stack */
    #endif

    #if (OS_NO_OF_RESOURCES > 0U)
        res_t res_mask;
    #endif

    #if (OS_NO_OF_ALARMS > 0U)
        alarm_t alarms;
    #endif

}
```

# (AB)USING THE PREPROCESSOR / A POWERFUL TOOL

https://github.com/evidence/erika3/blob/GH63/pkg/kernel/oo/ee_ar_sched_table.c#L52

```
52  #include "ee_internal.h"
53
54  FUNC(StatusType, OS_CODE)
55    osEE_st_start_rel
56  (
57    P2VAR(OsEE_CounterDB, AUTOMATIC, OS_APPL_DATA) p_counter_db,
58    P2VAR(OsEE_SchedTabDB, AUTOMATIC, OS_APPL_DATA) p_st_db,
59    VAR(TickType, AUTOMATIC) offset
60  )
61  {
62    VAR(StatusType, AUTOMATIC) ev;
63    CONSTP2VAR(OsEE_SchedTabCB, AUTOMATIC, OS_APPL_DATA)
64      p_st_cb = osEE_st_get_cb(p_st_db);
65    CONSTP2VAR(OsEE_TriggerDB, AUTOMATIC, OS_APPL_DATA)
66      p_trigger_db = osEE_st_get_trigger_db(p_st_db);
67    CONSTP2VAR(OsEE_TriggerCB, AUTOMATIC, OS_APPL_DATA)
68      p_trigger_cb = p_trigger_db->p_trigger_cb;
69  #if (!defined(OSEE_SINGLECORE))
70    CONST(CoreIdType, AUTOMATIC)
71      counter_core_id = p_counter_db->core_id;
72    /* Lock the Core Lock witch the counter is tied */
73    osEE_lock_core_id(counter_core_id);
74  #endif /* OSEE_SINGLECORE */
75
76    if (p_trigger_cb->status > OSEE_TRIGGER_CANCELED) {
```

# OPTIMIZING RAM USAGE IN RUST

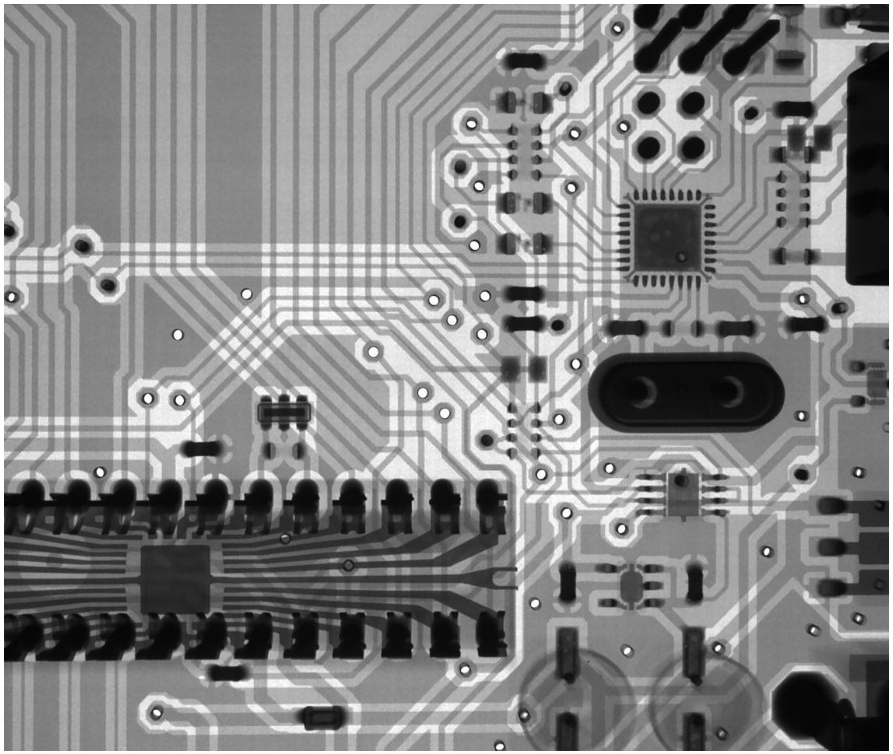
## EMULATE C PREPROCESSOR?

# OPTIMIZING RAM USAGE IN RUST


## IS THIS BEHIND CLOSED DOORS?

It matters only if used in the interface

# OPTIMIZING RAM USAGE IN RUST



## SMART COMPILER?

# RUST: OPTIONAL STRUCT FIELDS

```rust
#[repr(C)]
pub struct TaskControlBlock {
    id: SafeTaskIdType,

    ctx: TaskContext,

    #[cfg(any(mem_protection, preemption))]
    stk: StackInfo,

    #[cfg(resources)]
    res_mask: ResourceType,

    #[cfg(alarms)]
    alarms: Alarms,
}
```

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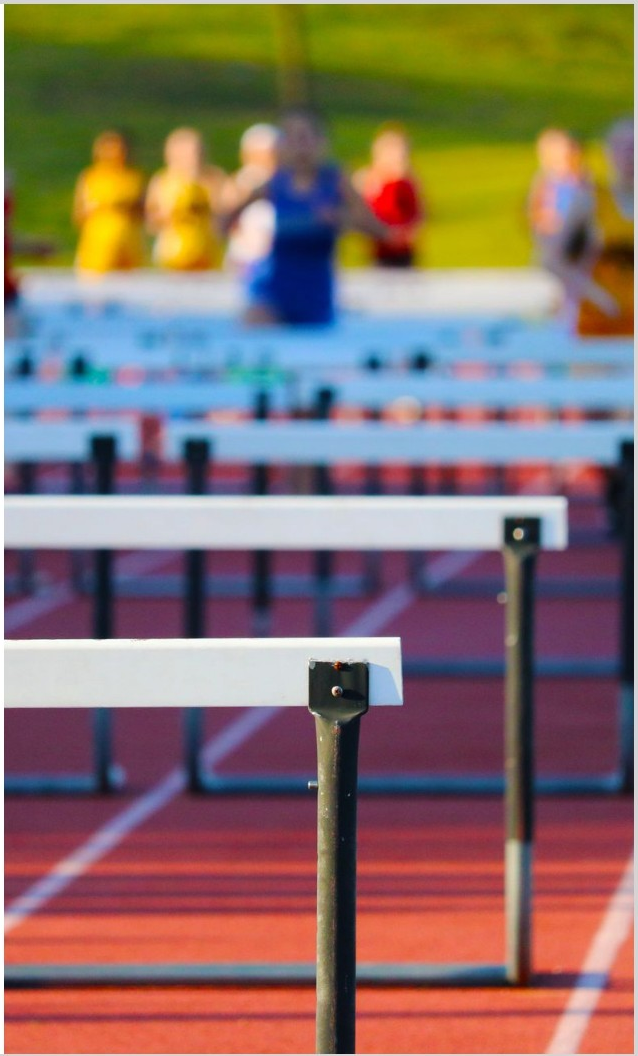
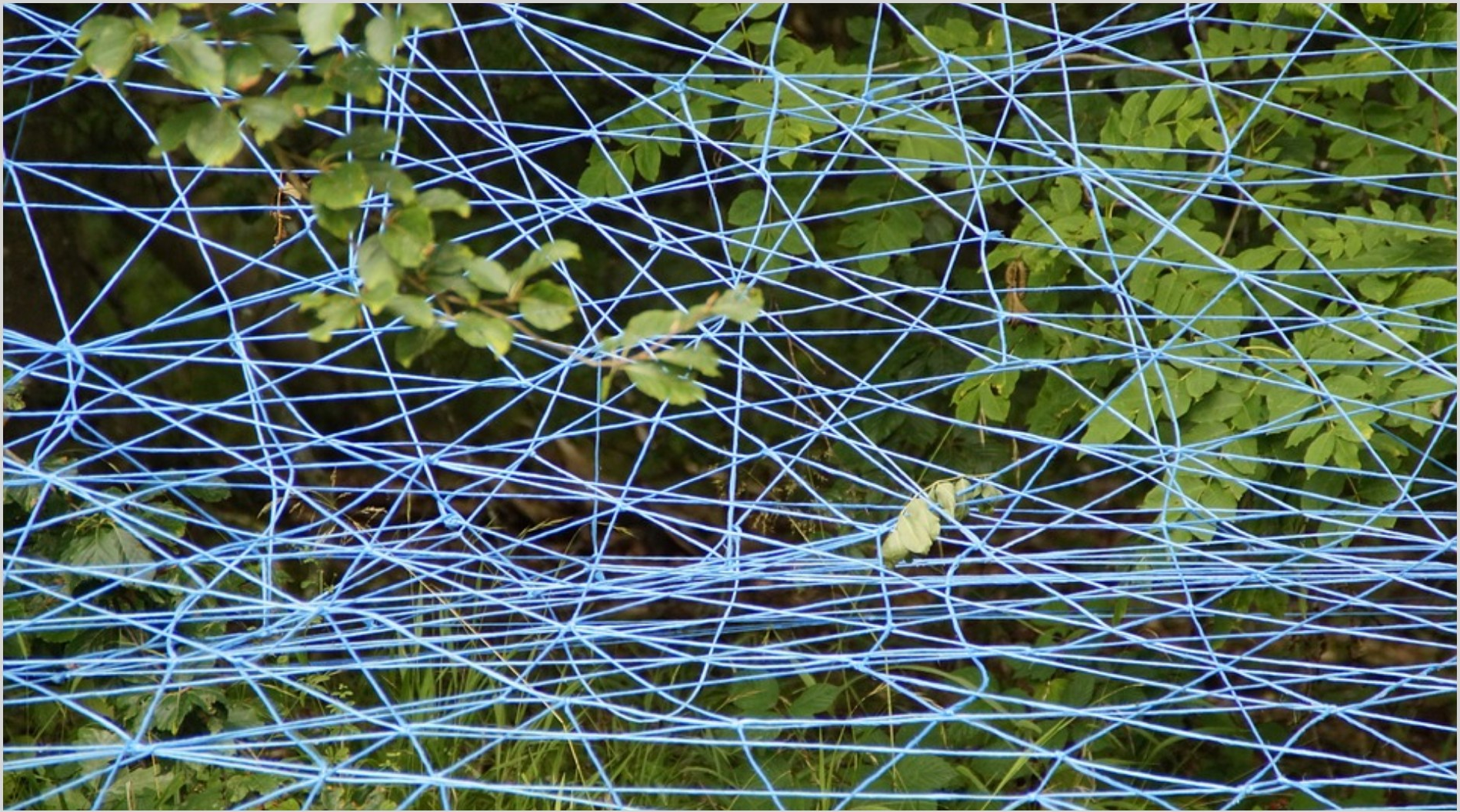


# WHERE IS THE RUST CODE?

RUST COMPONENT SOURCES → RUST COMPONENT - BINARIES & GENERATOR → CONFIGURATION → LINKING INTO INTEGRATION APP

# THE BRIDGE BETWEEN C & RUST

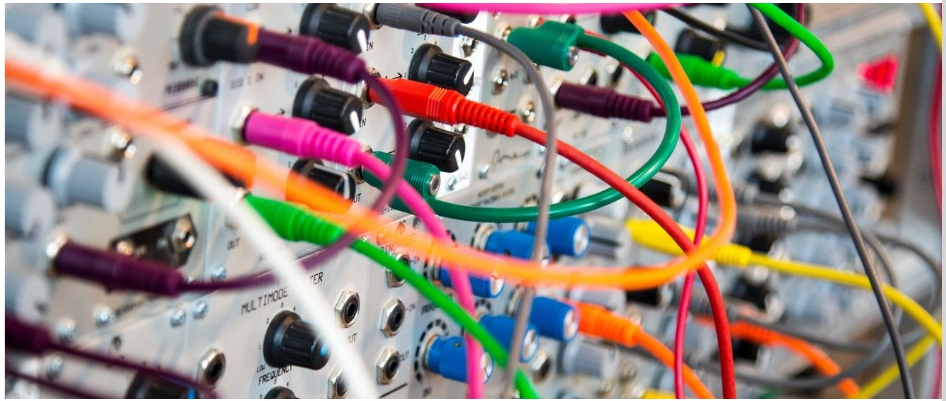
Config files:
Os_cfg.h, Os_cfg.c



# LET'S TAKE IT EASY ...


IN

# THE EASY “MUSTS”



# THE EASY “MUSTS” - LINKER FILES

linker.ld

```
1
2   SECTIONS
3   {
4     . = 0x10000;
5     .ostext : { librust.os.a(.text) }
6     .text : { *(.text) }
7     . = 0x8000000;
8     .data : { *(.data) }
9     .bss : { *(.bss) }
10  }
11
```

# THE EASY “MUSTS” - NO MANGLING

lib.rs

```
75
76  // fn get_safe_task_id(unsafe_task_id: TaskIdType) -> Result<SafeTaskIdType, StatusType>
77
78  // C declaration: StatusType ActivateTask (TaskType TaskID);
79  #[allow(non_snake_case)]
80  #[no_mangle]
81  pub fn ActivateTask(TaskID: TaskIdType) -> StatusType {
82      match get_safe_task_id(TaskID) {
83          Ok(_safe_task_id) => {
84              // really activate task
85          }
86          Err(status) => return status,
87      }
88
89      StatusType::E_OK
90  }
```

# THE EASY “MUSTS” - C REPRESENTATION

The Rustonomicon / Alternative representations: https://doc.rust-lang.org/nomicon/other-reprs.html

Cargo.toml lib.rs

```
10
11  #[repr(C)]
12  pub struct TaskIdType
13  {
14      id: libc::uint32_t,
15  }
16
17  #[allow(non_camel_case_types)]
18  #[repr(C)]
19  pub enum StatusType {
20      E_OK = 0,
21      E_OS_ACCESS = 1,
22      E_OS_CALLEVEL = 2,
23      E_OS_ID = 3,
```

# THE EASY “MUSTS” - FFI: WHAT TO AVOID

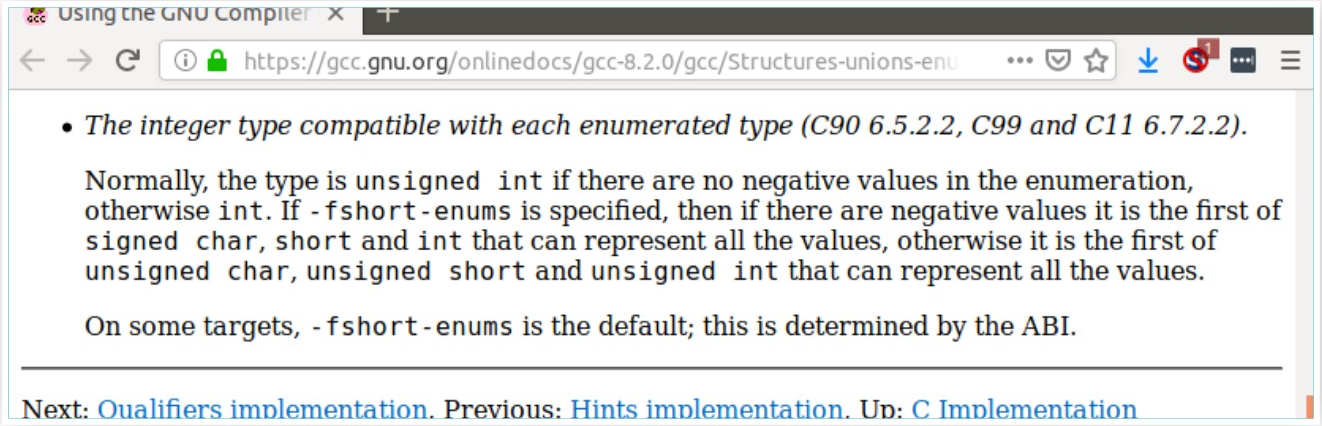
https://doc.rust-lang.org/nomicon/other-reprs.html#reprc

```
repr(C) will be nonsensical or problematic:

* ZSTs are still zero-sized even though
    * is not standard behavior in C
    * in C++ they should consume a byte
* Enums with fields
    * aren't a concept in C or C++
    * a valid bridging is defined - unimplemented!
* Tuple struct: like struct but fields aren’t named
[..]
```

# ENUM: SHORT/SMALL/BEST & SIGNED/UNSIGNED

ABI compatibility matters




# MORE UNDEFINED BEHAVIOR, NOW 100% ALIGNED

Technically correct, but still undefined behavior

```
3
4   struct aXc {
5       uint32_t a;
6       uint16_t X;
7       uint32_t c;
8   };
9
10  //       0   1   2   3                   0   1   2   3
11  //    +---------------+               +---------------+
12  // 0  | a | a | a | a |            0  | a | a | a | a |
13  //    +---------------+               +---------------+
14  // 4  | X | X |   |   |            4  |   |   | X | X |
15  //    +---------------+               +---------------+
16  // 8  | c | c | c | c |            8  | c | c | c | c |
17  //    +---------------+               +---------------+
18
```

# THE CURIOUS CASE OF DIAB STRUCT PACK - (2, 8, *)

#pragma pack(max_member_align, min_struct_align, byte-swap)

```
#pragma pack (2, 8[, byte-swap])
struct aXc_pack_maxmember2_minstruct8 {
    uint32_t a;
    uint16_t X;
    uint32_t c;
} vec_2_8[2];

//       +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
//       | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | a | b | c | d | e | f |
//       +-------------------------------------------------------------------+
// 0x10 | a | a | a | a | X | X | c | c | c | c |   |   |   |   |   |   |
// 0x20 | a | a | a | a | X | X | c | c | c | c |   |   |   |   |   |   |
//       +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

# THE CURIOUS CASE OF DIAB STRUCT PACK - (4, 8, *)

#pragma pack(max_member_align, min_struct_align, byte-swap)

```
#pragma pack (4, 8[, byte-swap])
struct aXc_pack_maxmember4_minstruct8 {
    uint32_t a;
    uint16_t X;
    uint32_t c;
} vec_4_8[2];

//      +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
//      | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | a | b | c | d | e | f |
//      +-------------------------------------------------------------------+
// 0x10 | a | a | a | a | X | X |   |   | c | c | c | c |   |   |   |   |
// 0x20 | a | a | a | a | X | X |   |   | c | c | c | c |   |   |   |   |
//      +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

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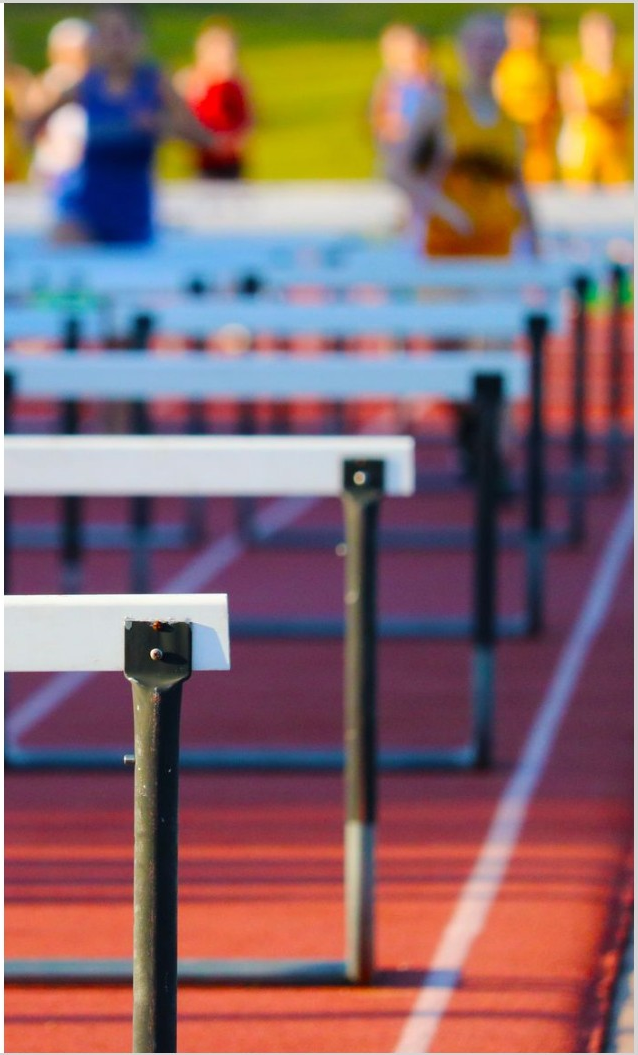

# RUST IS PERFECT!!!11

# RUST GUARANTEES DATA-RACE FREE CODE & THREAD SAFE/MULTI-CORE SCALABILTY [1]

EVEN FOR µC [2] [3]

# RUST GUARANTEES DATA-RACE FREE CODE & THREAD SAFE/MULTI-CORE SCALABILTY [1]

## EVEN FOR µC [2] [3]

[1] with an OS/std, since that provides `Arc<>`, `Mutex<>` etc.

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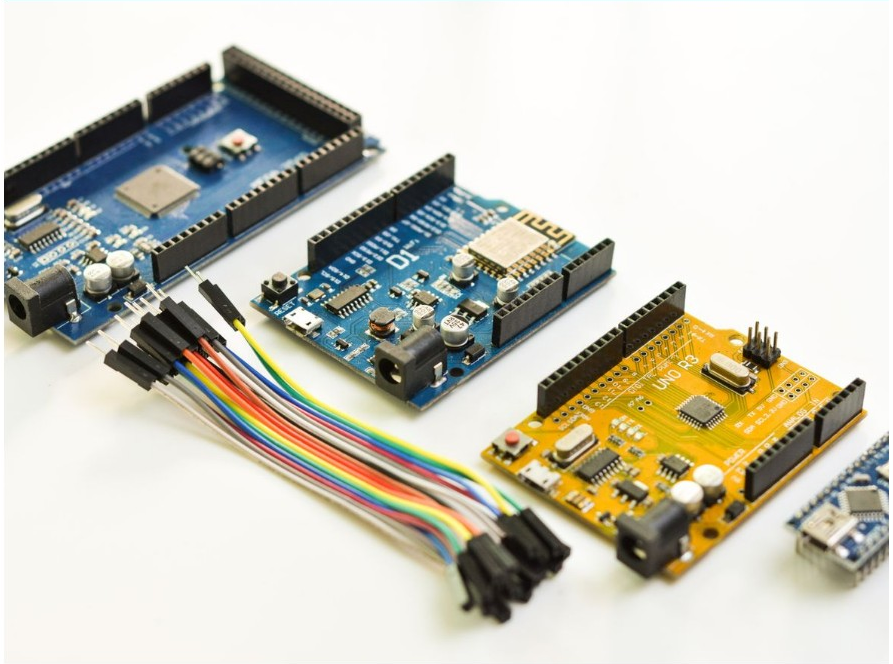

## EVEN FOR µC [2] [3]

[1] with an OS/std, since that provides `Arc<>`, `Mutex<>` etc.

[2] if the µC is single core

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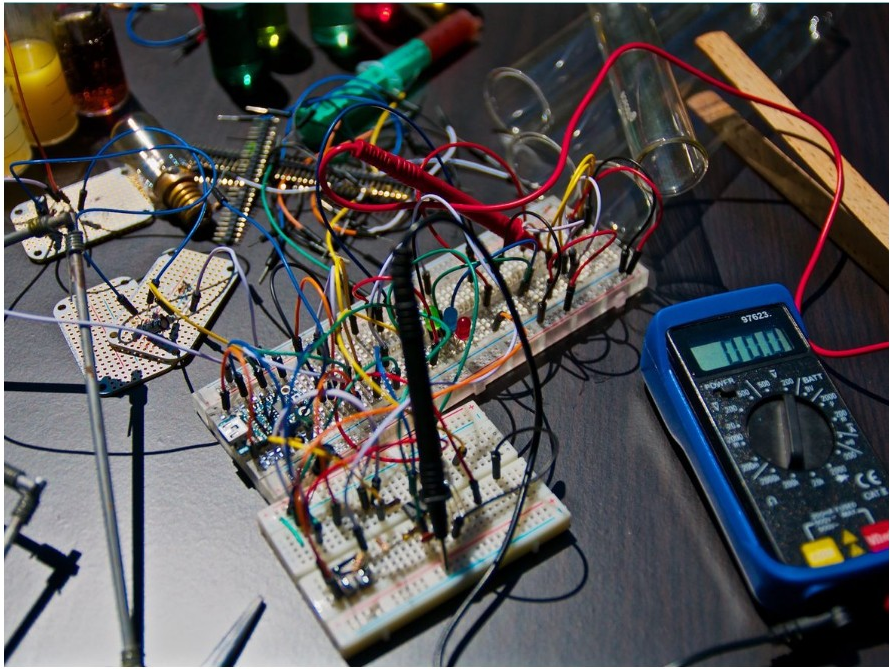


## EVEN FOR µC [2] [3]

[1] with an OS/std, since those provide `Arc<>`, `Mutex<>` etc.

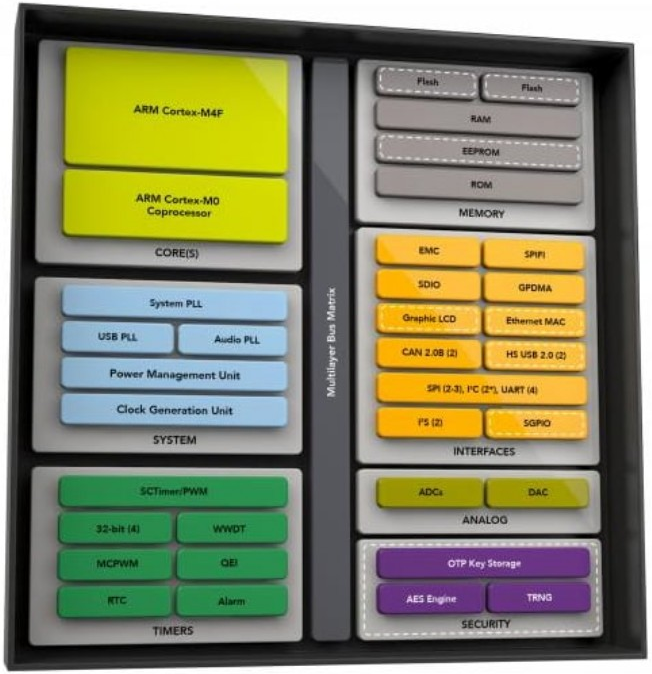
[2] if the µC is single core

[3] if you use a DSL (cortex-m-rt macros)

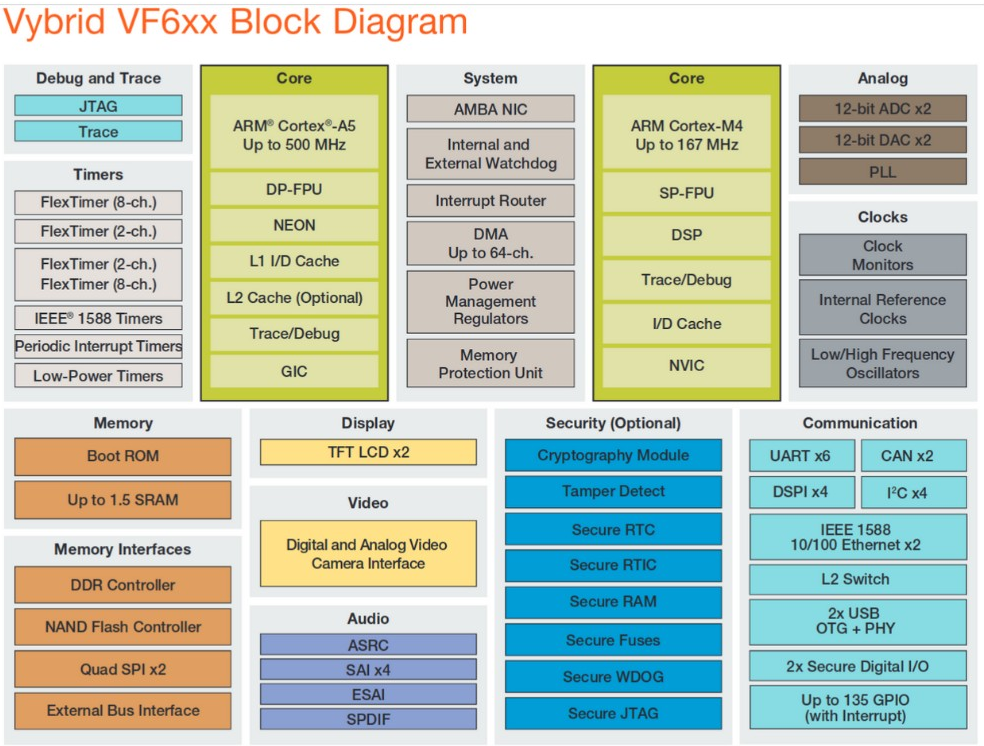
# UNCOVERED USE CASES

# MULTICORE - LPC34XX: M4 + M0

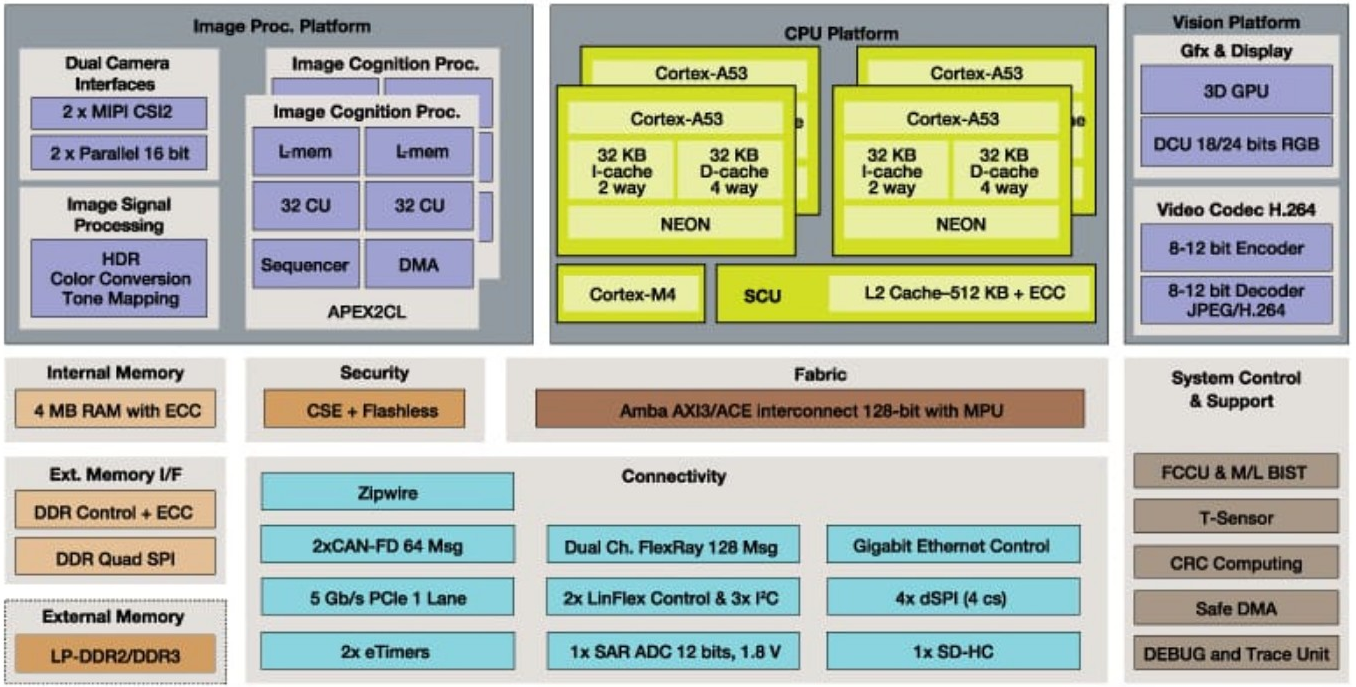
Cortex-M4 based microcontrollers which include a Cortex-M0 coprocessor



# MULTICORE - VF6XX: A5 + M4



# MULTICORE - S32V234: 4XA53 + M4



# IT WILL WORK... “ALL THE TIME, 80% OF THE TIME”

#[repr(packed), #[repr(align(N))]

https://doc.rust-lang.org/reference/type-layout.html

# #[repr(packed)] == #pragma pack(1)

# #[repr(align(N))]


# WHAT'S MISSING

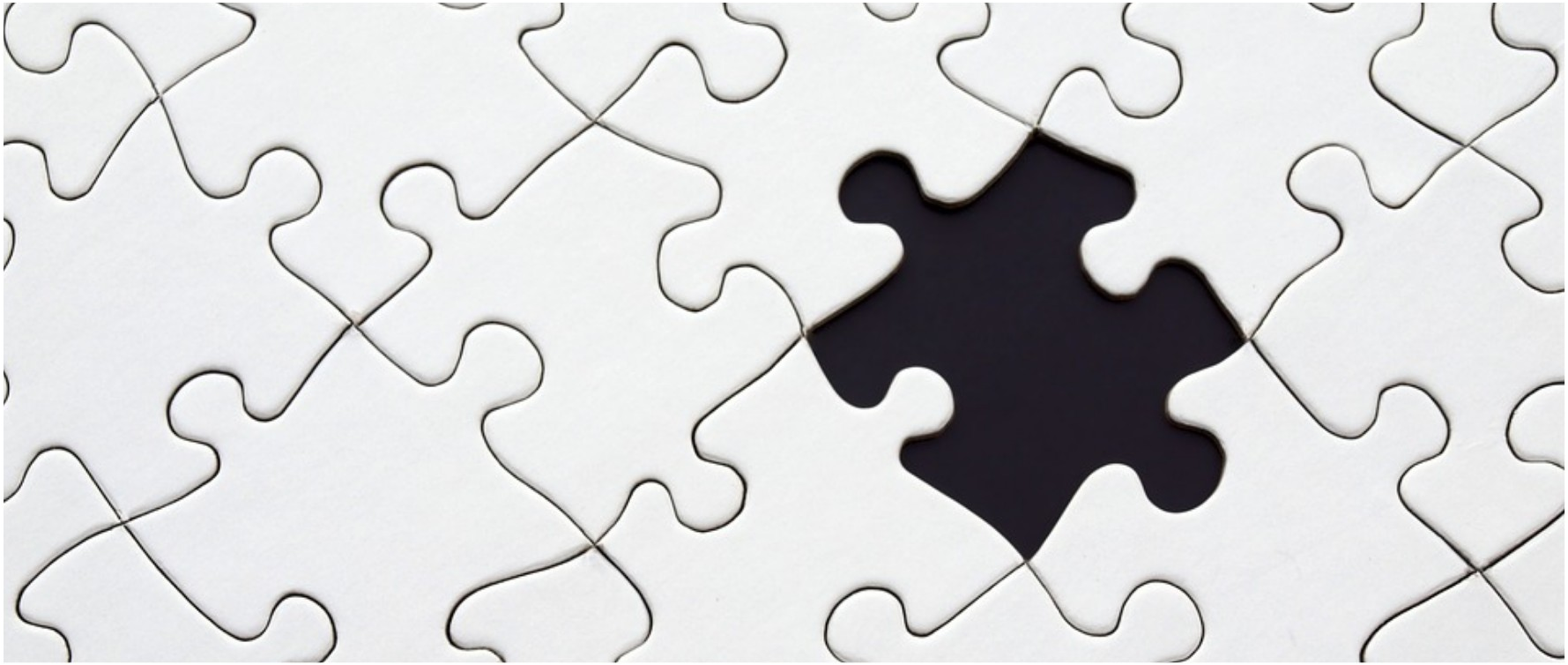
between #[repr(packed)] and #[repr(align(N))]

SHORT ENUM

PACK != 1

PACK && ALIGN

# EXTERN “C” STATIC(?) VARIABLE?



# “#DEFINE” != “CONST”

```
#define MY_CONST 1234U
```

```
const MY_CONST:u32 = 1234u32;
```

# MEMMAP.H MULTIPLE INCLUSION

https://www.autosar.org/fileadmin/user_upload/standards/classic/4-0/AUTOSAR_SWS_MemoryMapping.pdf

AUTOSAR

Specification of Memory Mapping
V1.4.0
R4.0 Rev 3

```
#define EEP_START_SEC_VAR_INIT_16
#include "MemMap.h"
static uint16 EepTimer = 100;
static uint16 EepRemainingBytes = 16;
#define EEP_STOP_SEC_VAR_INIT_16
#include "MemMap.h"
```

# NIGHTLY - “DAMNIT EVERYTHING REQUIRES NIGHTLY D:”

#rust-embedded: jamesmunns: [..]some stuff [..] is preventing me from making the BBQueue::new() function const. **I think it should be possible on nightly, but not possible on stable for now**

---

durka42: [..] you can **run `rustc --pretty=expanded` on nightly** to see the code that is generated

---

21:18 SpaceManiac darkstalker: yes, **with nightly feature 'specialization'**

**21:19 darkstalker damnit everything requires nightly D:**

21:20 SpaceManiac eddyp: the other reason is that **(IIRC) traits being known to have fields is a nightly feature**

21:21 eddyp may I quote darkstalker?

21:26 darkstalker yes **it's true. all the cool things require nightly**

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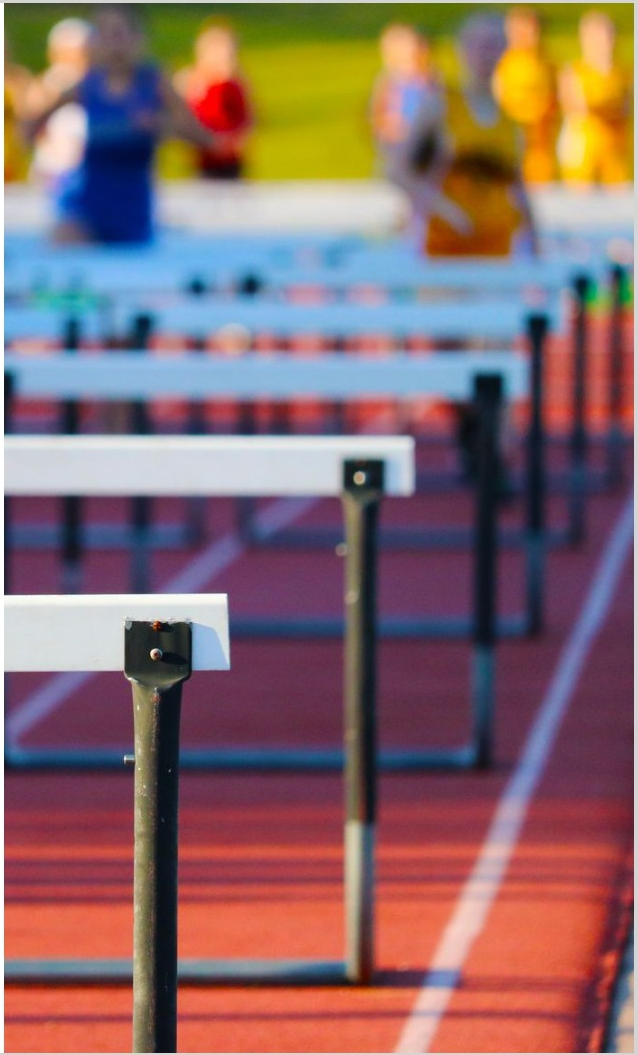


# ENGINEERS, MUCH LIKE OLD DOGS

NEW TRICKS ARE HARD

# HELLO, EMBEDDED RUST WORLD!

```
fn main() {
    println!(“Hello, world!”);
}
```

main.rs

```
fn main() {
    println!("Hello, world!");
}
```

main.rs

```
#![no_main]
#![no_std]

use core::panic::PanicInfo;

// The reset handler
#[no_mangle]
pub unsafe extern "C" fn Reset() -> ! {
    let _x = 42;

    // can't return so we go into an infinite loop here
    loop {}
}

// The reset vector, a pointer into the reset handler
#[link_section = ".vector_table.reset_vector"]
#[no_mangle]
pub static RESET_VECTOR: unsafe extern "C" fn() -> ! = Reset;

#[panic_handler]
fn panic(_panic: &PanicInfo<'_>) -> ! {
    loop {}
}
```

config

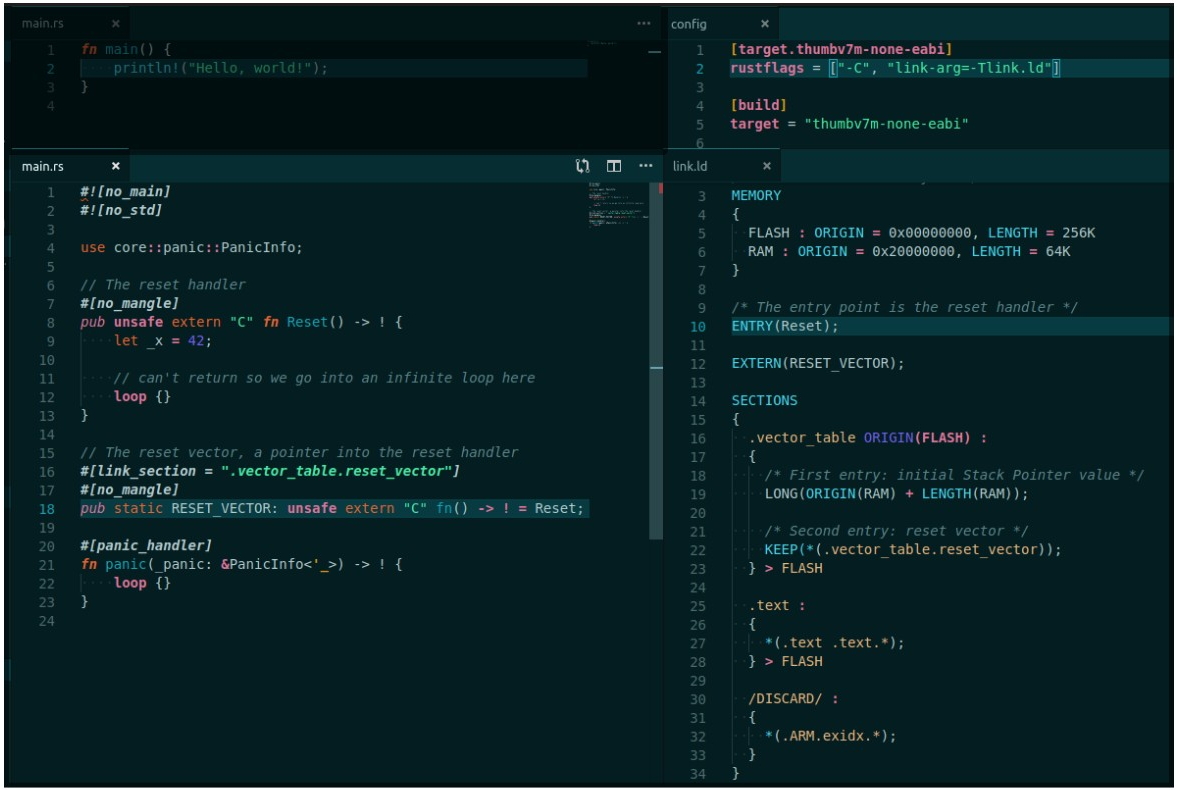
```
[target.thumbv7m-none-eabi]
rustflags = ["-C", "link-arg=-Tlink.ld"]

[build]
target = "thumbv7m-none-eabi"
```

link.ld

```
MEMORY
{
  FLASH : ORIGIN = 0x00000000, LENGTH = 256K
  RAM : ORIGIN = 0x20000000, LENGTH = 64K
}

/* The entry point is the reset handler */
ENTRY(Reset);

EXTERN(RESET_VECTOR);

SECTIONS
{
  .vector_table ORIGIN(FLASH) :
  {
    /* First entry: initial Stack Pointer value */
    LONG(ORIGIN(RAM) + LENGTH(RAM));

    /* Second entry: reset vector */
    KEEP(*(.vector_table.reset_vector));
  } > FLASH

  .text :
  {
    *(.text .text.*);
  } > FLASH

  /DISCARD/ :
  {
    *(.ARM.exidx.*);
  }
}
```

# HELLO, EMBEDDED RUST WORLD!

```
fn main() {
    println!(“Hello, world!”);
}
```



# MANAGERS

# INDUSTRY/MANAGEMENT: ADVERSE TO MONOCULTURE (OR OSS)

(unless is theirs)

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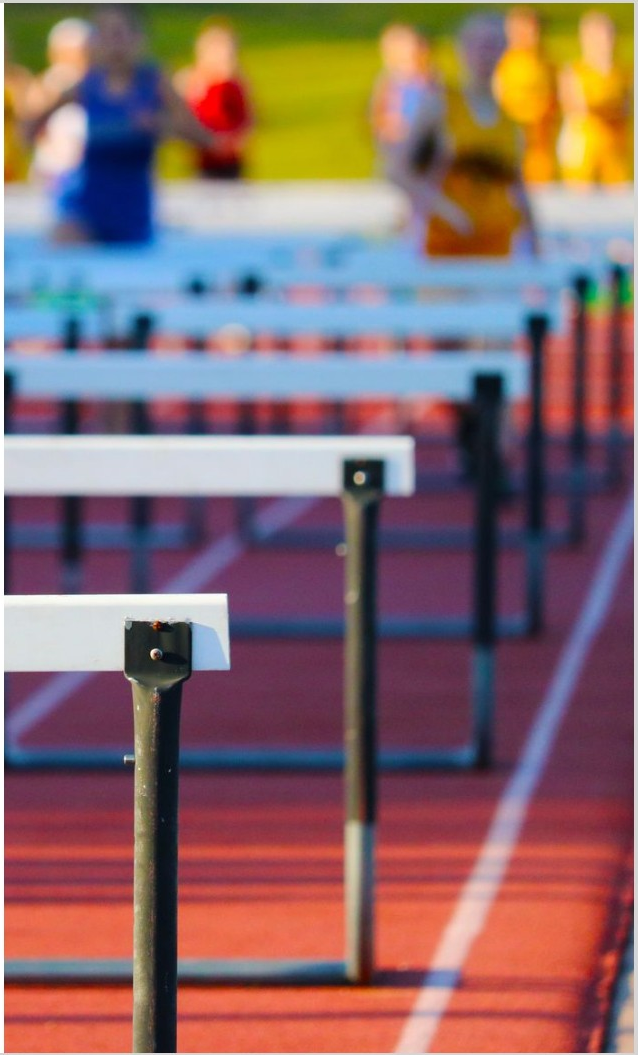
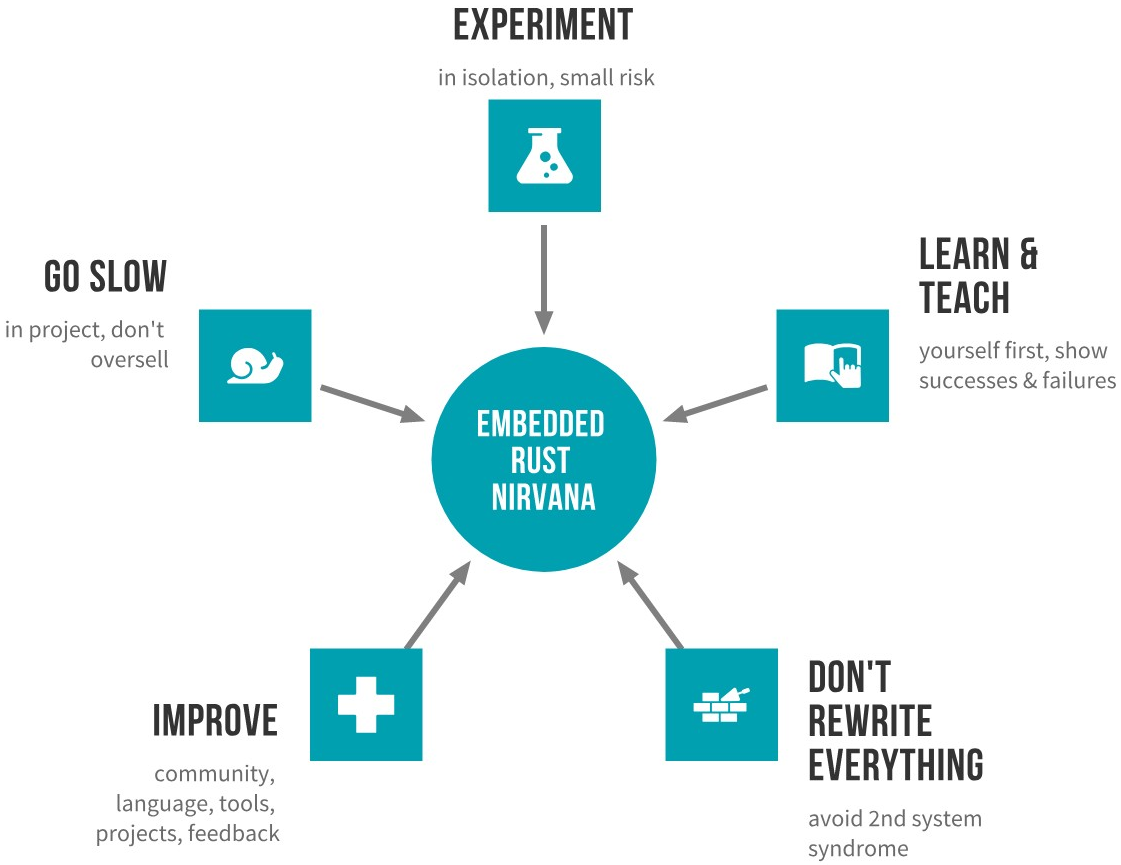


# LEGACY SOFTWARE

Sometimes you feel like taking a shower after touching it...


CONCLUSIONS

# WHAT CAN YOU DO?



# WHAT CAN THE (EMBEDDED) RUST COMMUNITY DO?

# STABILIZATION (BEYOND CORTEX M)

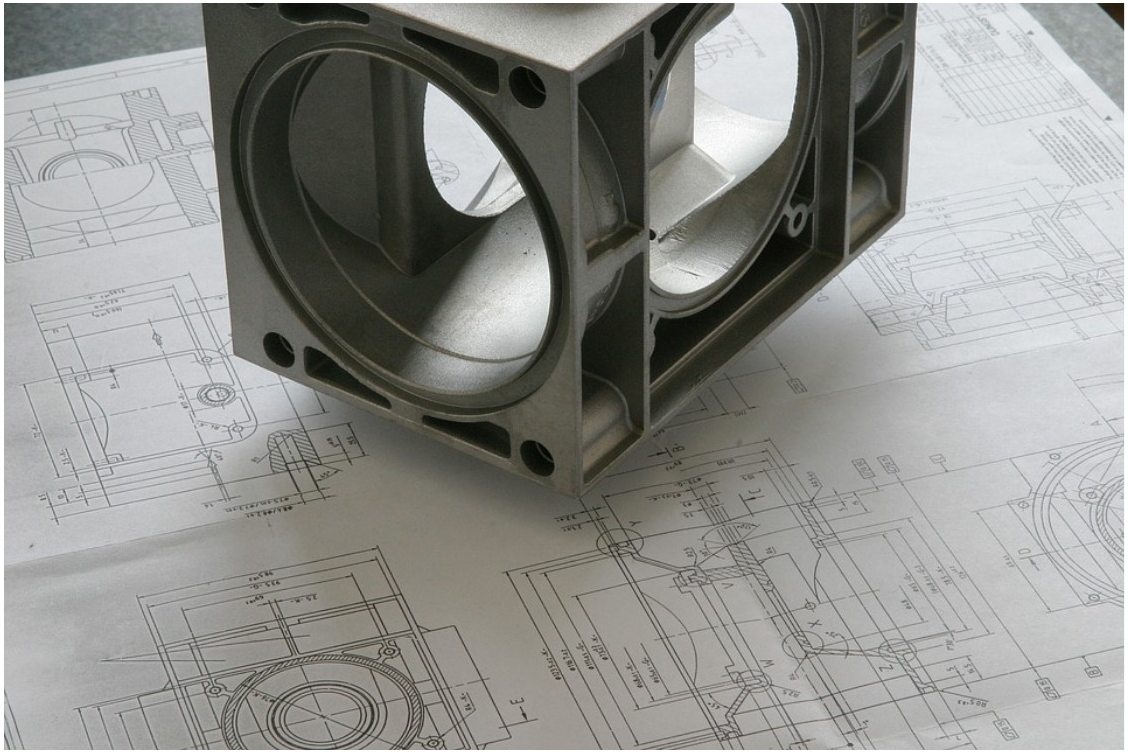
ASM INTERFACE - NOT JUST ARM

# SAMPLES

HOPEFULLY, LESS CREEPY THAN THESE >>>


Provide more std-like examples: Sema4<> mutex?

# NO FORMAL SPEC



# WE NEED ALTERNATIVE RUSTC IMPLEMENTATIONS

Mutabah's Rust Compiler - https://github.com/thepowersgang/mrustc - might be an easier entry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