Towards a Safe and Sound Operating System

Martin Kröning, Jonathan Klimt, Stefan Lankes

E.ON Energy Research Center | RWTH AACHEN UNIVERSITY

Unikernels

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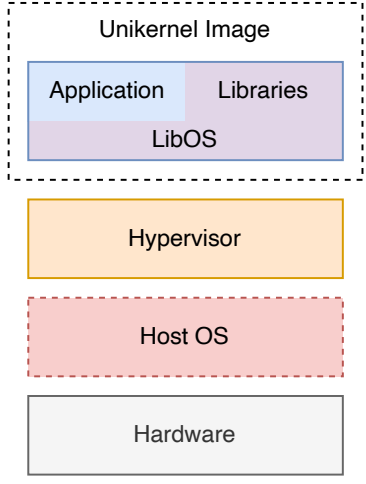
Unikernel Image
Application
Libraries
LibOS
Hypervisor
Host OS
Hardware

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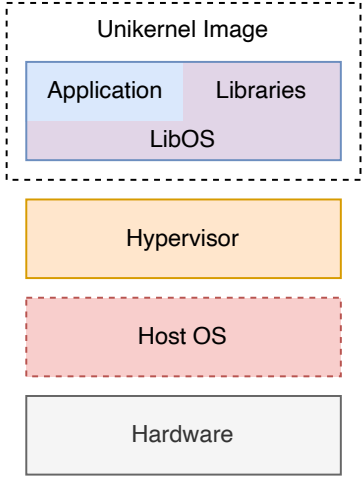
  - Tiny images



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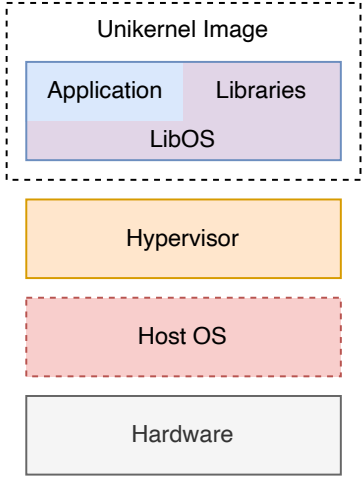

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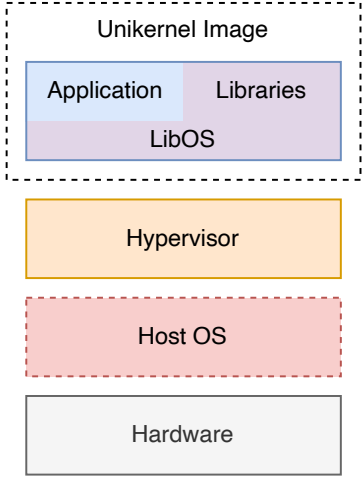

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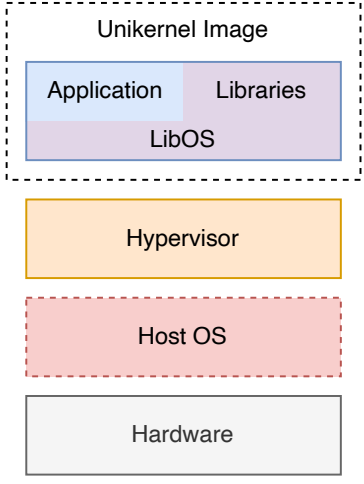

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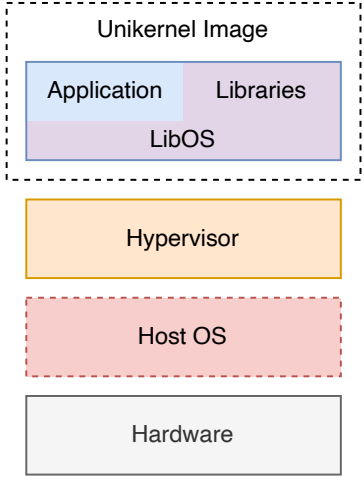
- System calls are just function calls



The Hermit Operating System

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Features

- Network (virtio, RTL8139)
- Multi-core support
- Easily configurable

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- Unikernel Project
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- Official tier 3 Rust target for Rust application
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Features

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Architectures

- x86-64 (primary)
- AArch64 (emerging)
- 64-bit RISC-V (upcoming)

Rust's raison d'être

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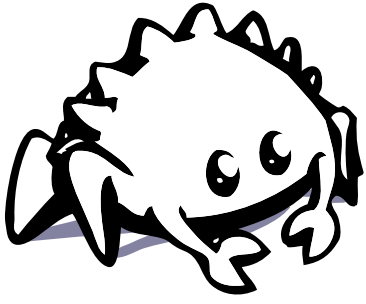
Memory Safety



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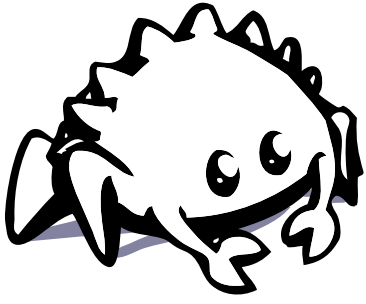

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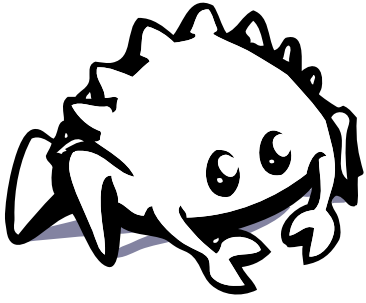

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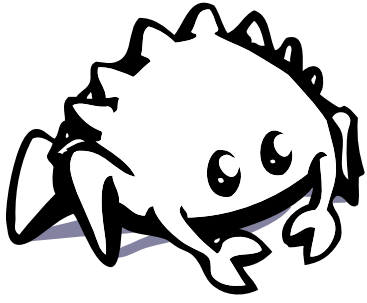

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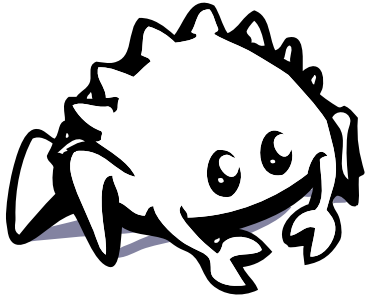

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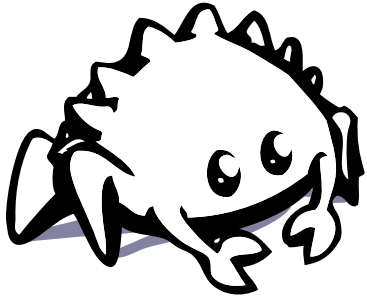
Could prevent 65 % of security vulnerabilities

(https://alexgaynor.net/2020/may/27/science-on-memory-unsafety-and-security/)



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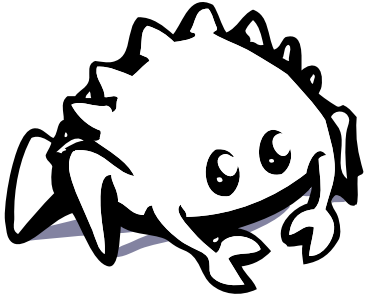

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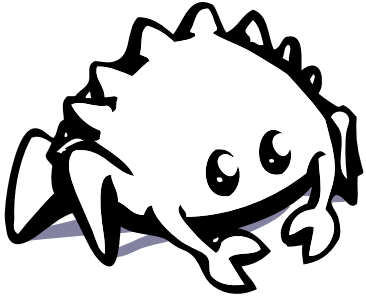

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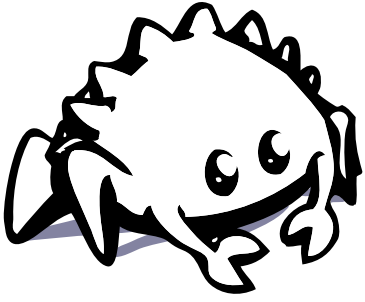

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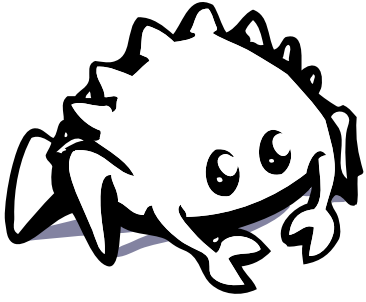

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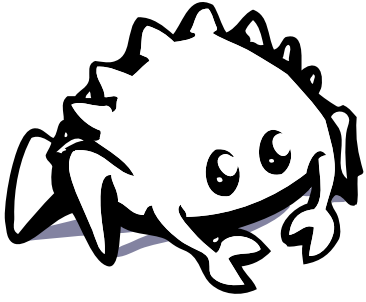

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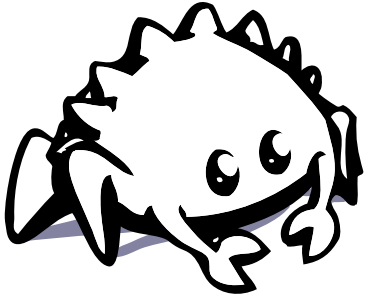

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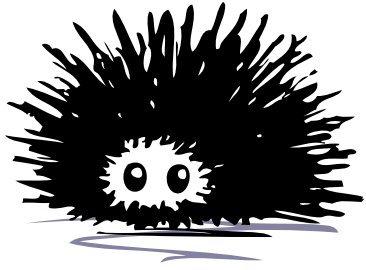
Removes some of safe Rust's restrictions:



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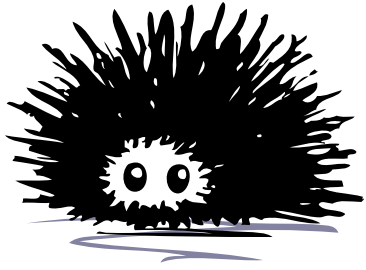

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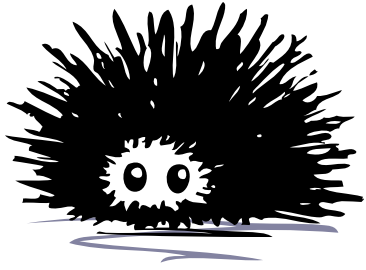

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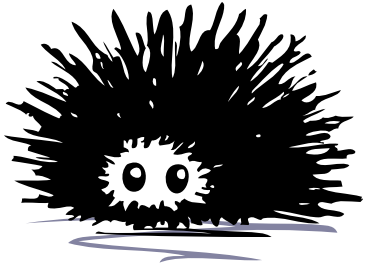

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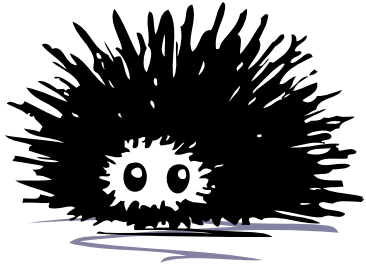

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Removes some of safe Rust's restrictions:

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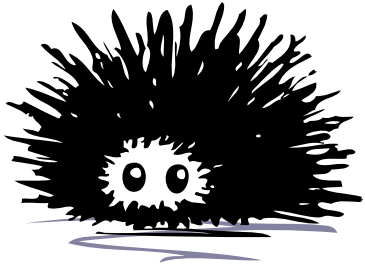
- Unsafe functions

How Rust Guarantees Memory Safety (cont.)



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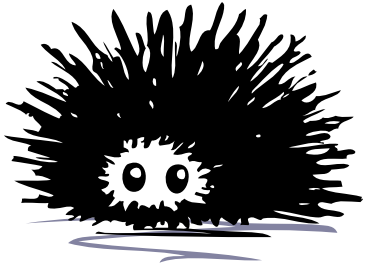

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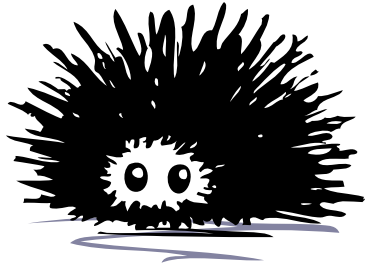

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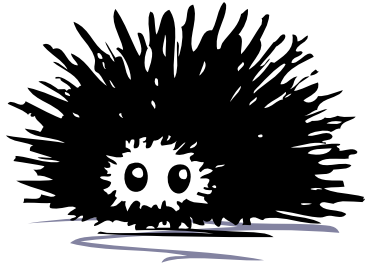

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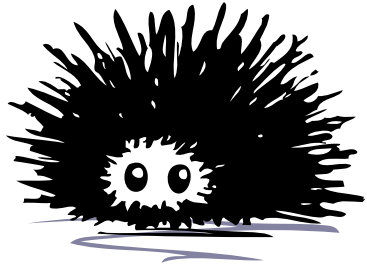

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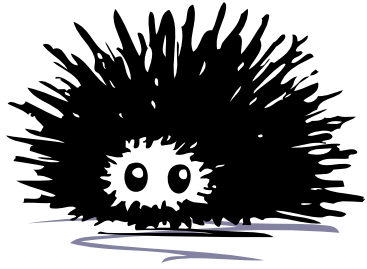

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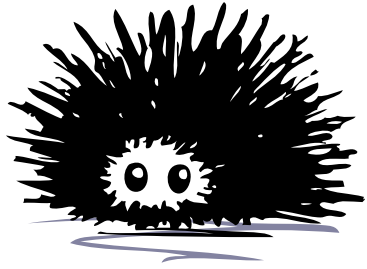

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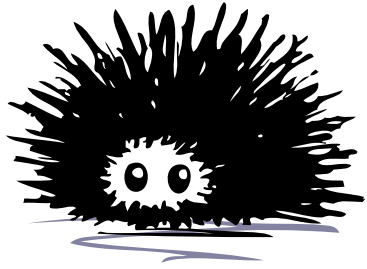
Soundness

- Unsafe Rust may never break safe Rust's invariants
- A *safe* Rust function must be *sound*



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- Hermit was sticking to C-isms
- Unsynchronized statics
- Aliasing `AND` Mutation (data races)

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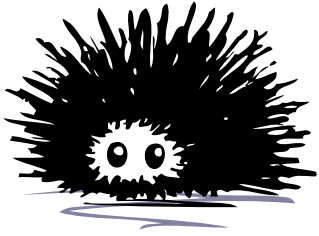
- Audit unsafe code from the bottom up
- Rework fundamentally unsound code
- Document safety invariants
- Publish modularized solutions
- Try to find more UB with tools

Unsynchronized Statics

```
static mut IDT: Idt = Idt::new();

fn init() {
    let idt = unsafe { &mut IDT };
    // Populate IDT entries
    // Load IDT
}
```



take-static

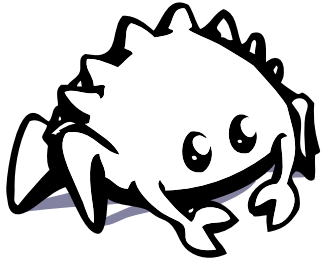
```rust
pub struct TakeStatic<T> {
    taken: AtomicBool,
    data: UnsafeCell<T>,
}

impl<T> TakeStatic<T> {
    pub fn take(&self) -> Option<&mut T> {
        if self
            .taken
            .compare_exchange(false, true, Ordering::Relaxed, Ordering::Relaxed)
            .is_ok()
        {
            Some(unsafe { &mut *self.data.get() })
        } else {
            None
        }
    }
}
```

Synchronized Statics

```
take_static! {
    static IDT: Idt = Idt::new();
}

fn init() {
    let idt: &mut Idt = IDT.take().unwrap();
    assert!(IDT.take() == None);
    // Populate IDT entries
    // Load IDT
}
```



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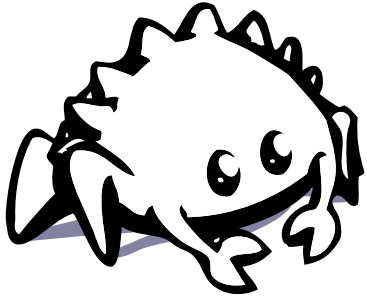

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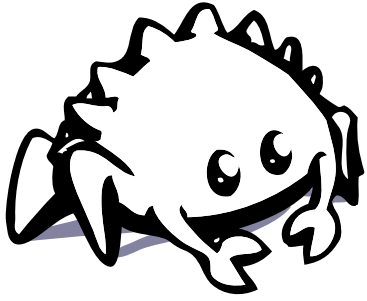
hermit-sync (github.com/hermit-os/hermit-sync)

Sound Bare-metal Rust-style synchronization primitives



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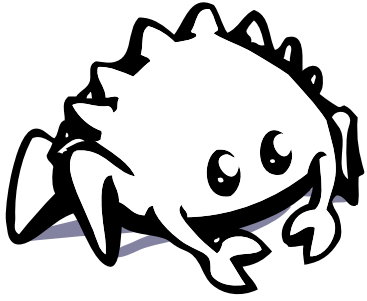

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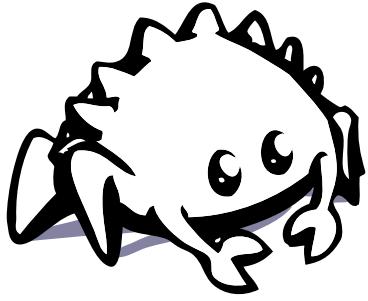
- `SpinMutex`
- `OnceCell`



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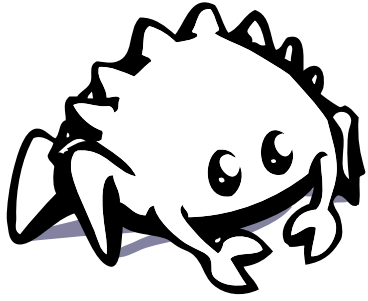
- `SpinMutex`
- `OnceCell`
- `Lazy`



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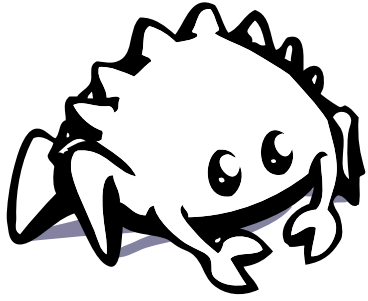
- `TakeStatic`



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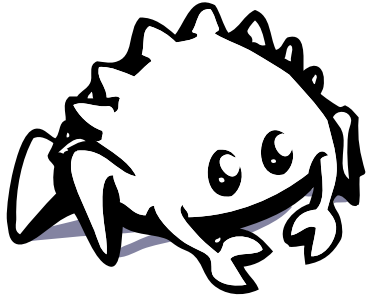

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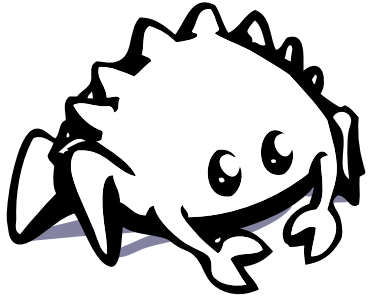

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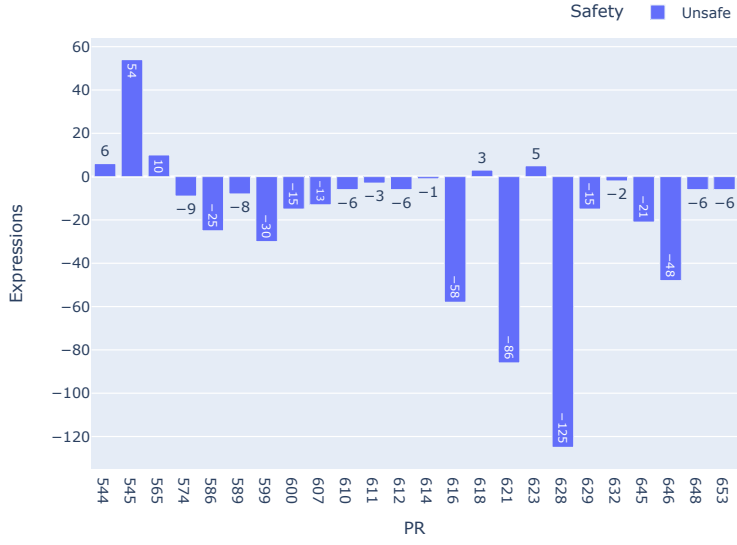

Results

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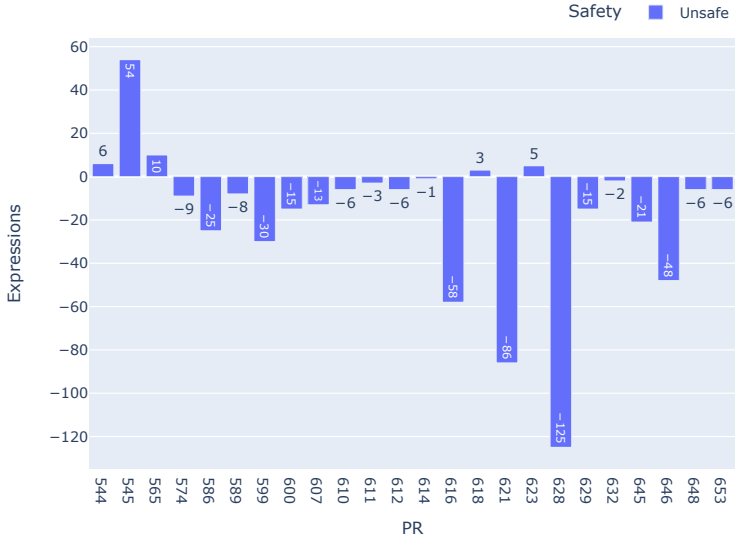
- Removed more than 400 `unsafe` expressions.



Results

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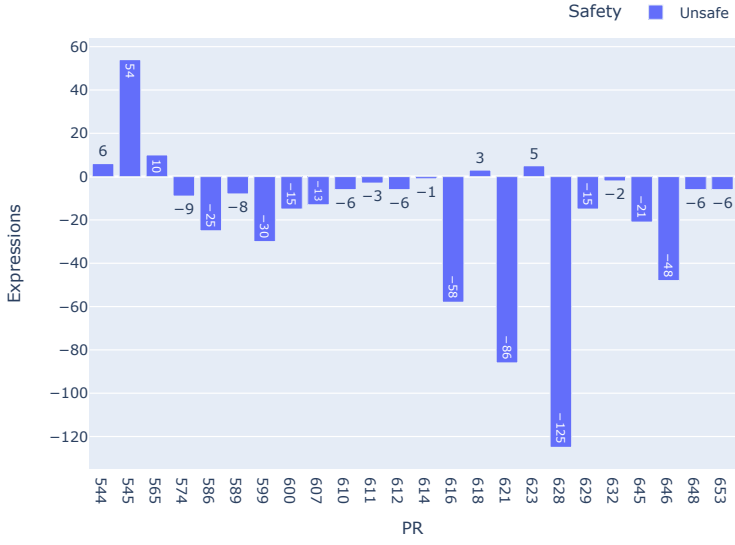
- Removed more than 400 `unsafe` expressions.
- Solved *real* memory safety issues.



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- Continue discussing libraries with the Rust OS-dev community.
- Continue discussing fundamental soundness issues with Rust's operational semantics team (T-opsem).
- Research running Hermit on *Miri*.

Acknowledgements

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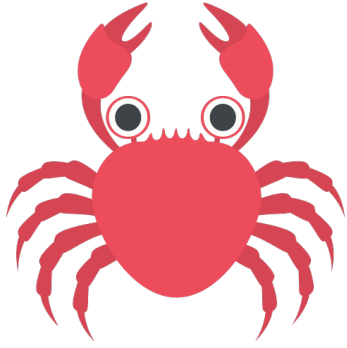
History of Hermit

HermitCore (2015)

- Unikernel *and* Multikernel
- Runs side by side with Linux in HPC clusters
- HermitCore occupies some cores
  - Like a hermit crab ;)
- Lightweight HermitCore computes
- "Heavyweight" Linux drives hardware



History of Hermit (cont.)

RustyHermit (2018)

- Rust is modern and exciting
  - Rewrite it in Rust (RIIR)
- One true toolchain
  - Easy cross-compilation
- Vibrant community
  - Easy dependencies through central registry
- Recently rebranded as *Hermit*