Safely and Efficiently Programming a 64kB Computer

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MSR UW Summer Institute
August 2, 2017

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Securing the Internet of Things

- Secure Internet of Things Project
  - 5 year project (just started second year)
  - 12 faculty collaborators
  - 3 universities: Stanford, Berkeley, and Michigan
- Rethink IoT systems, software, and applications from the ground up

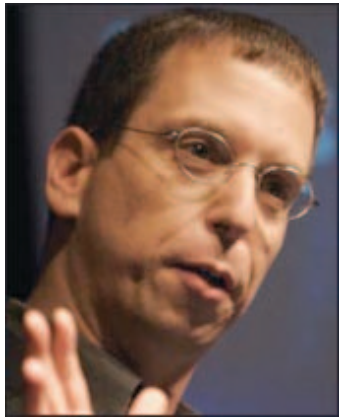
- Make a secure IoT application as easy as a modern web application

Team

Philip Levis
Stanford
Embedded Systems

Mark Horowitz
Stanford
Hardware

Christopher Ré
Stanford
Data Analytics



Dan Boneh
Stanford
Cryptography

Dawson Engler
Stanford
Software

Keith Winstein
Stanford
Networks

Peter Bailis
Stanford
Database Systems

David Mazières
Stanford
Security

Björn Hartmann
Berkeley
Prototyping

Raluca Ada Popa
Berkeley
Security

Prabal Dutta
Berkeley/Michigan
Embedded Hardware

David Culler
Berkeley
Low Power Systems

Steve Eglash
Stanford
Executive Director

Philip Levis
Stanford
Faculty Director

There's no such thing as a secure embedded OS today.

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Let's research why and write one.

Embedded Systems

"An embedded system is a computerized system that is purpose-built for its application."

Elicia White
Making Embedded Systems, O'Reilly

But the World is Changing…

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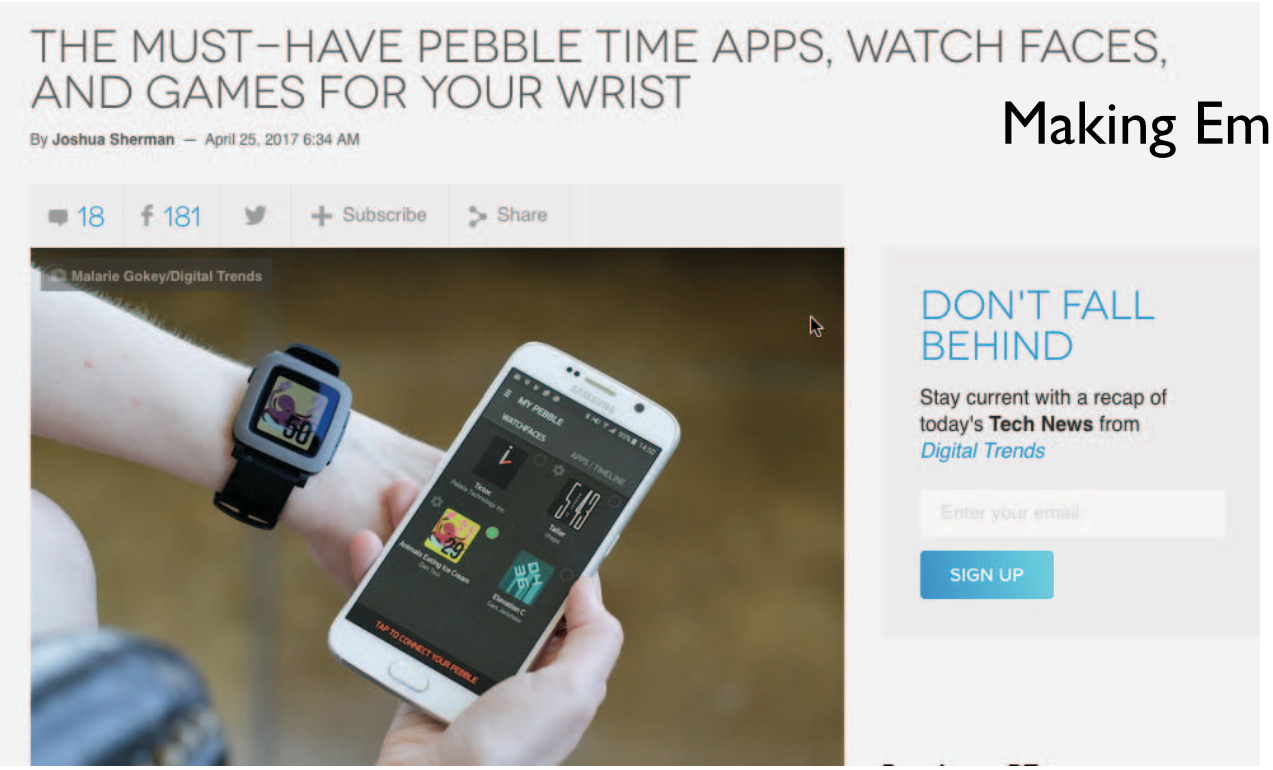
Elicia White
Making Embedded Systems, O'Reilly



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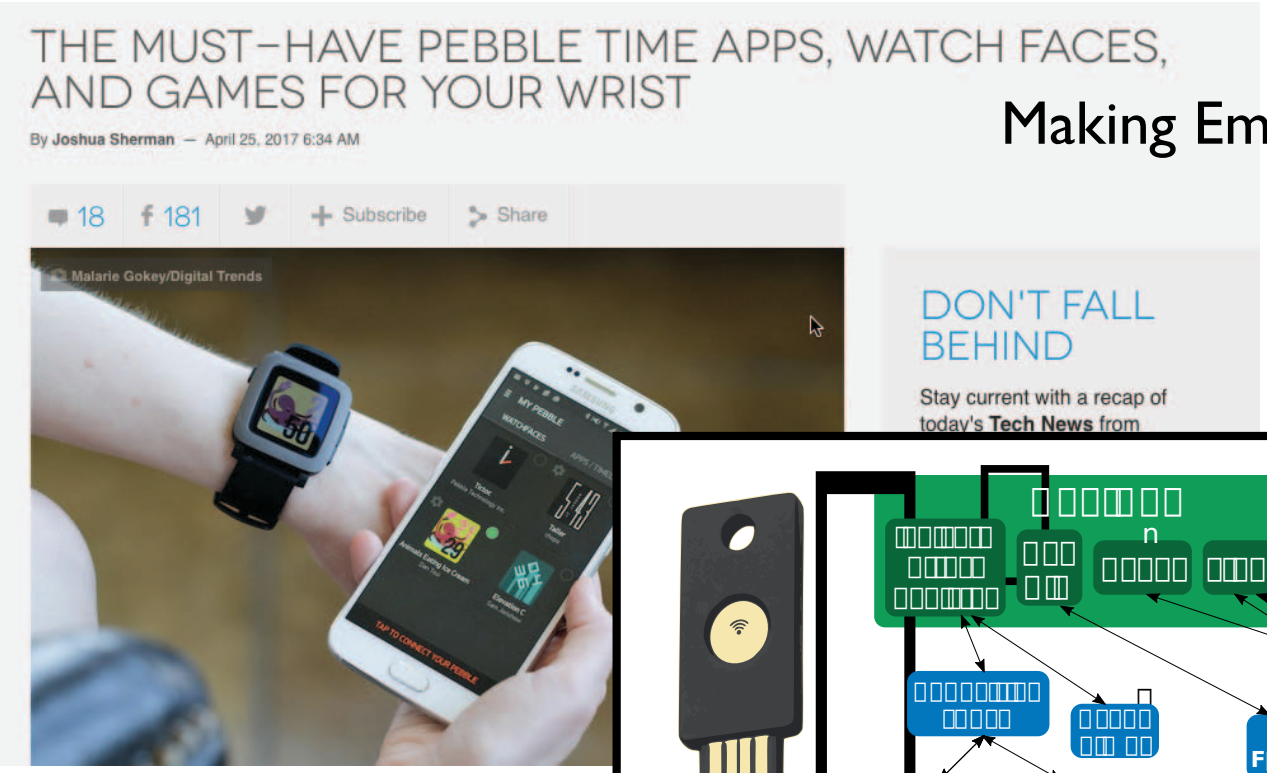

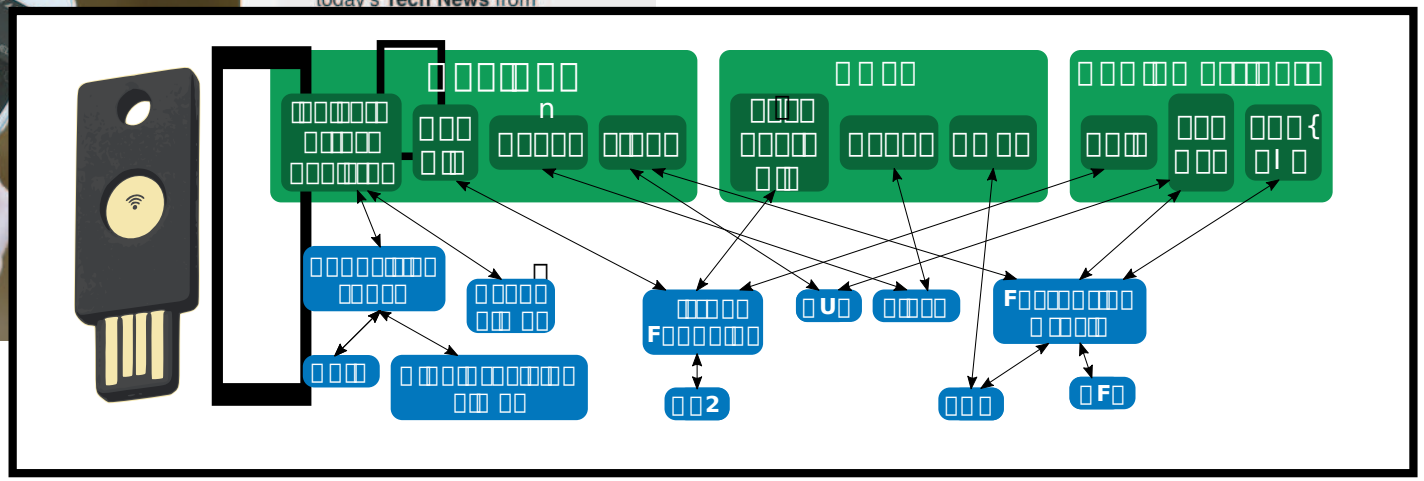

But the World is Changing…

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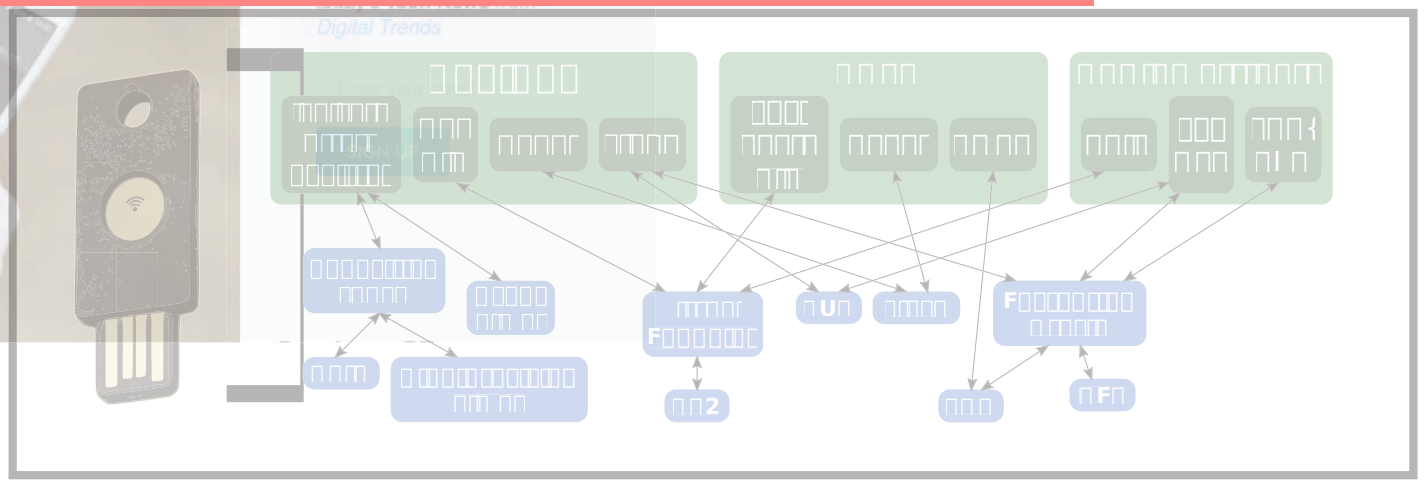
a White
O'Reilly

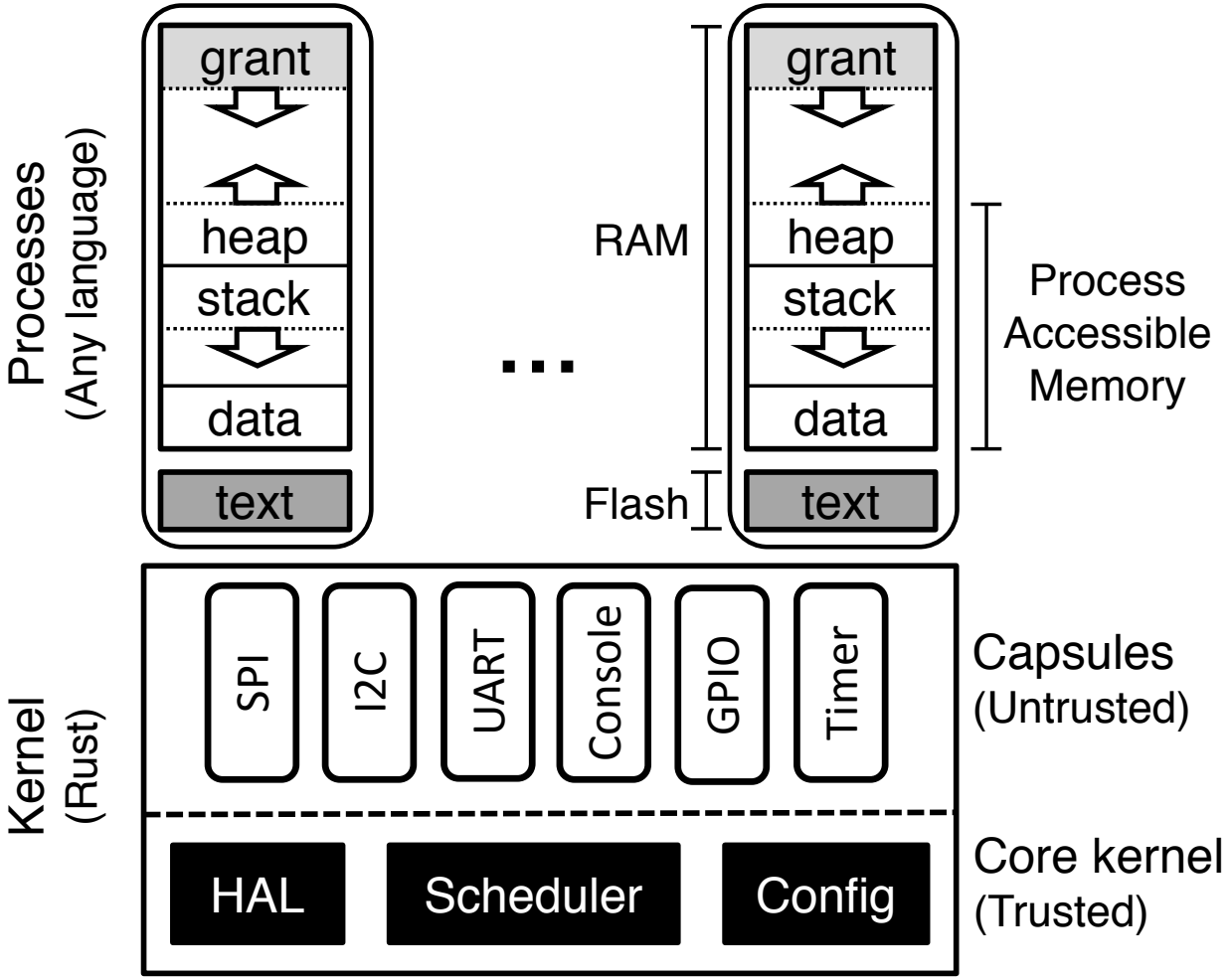
A new class of embedded devices, that act as platforms supporting loadable programs within a particular application domain.



Tock Operating System

- Safe, multi-tasking operating system for memory-constrained devices
- Core kernel written in Rust, a safe systems language
  - Small amount of trusted code (can do unsafe things)
    - Rust bindings for memory-mapped I/O
    - Core scheduler, context switches
- Core kernel can be extended with *capsules*
  - Safe, written in Rust
  - Run inside kernel
- *Processes* can be written in any language (asm, C)
  - Leverage Cortex-M memory protection unit (MPU)
  - User-level, traps to kernel with system calls

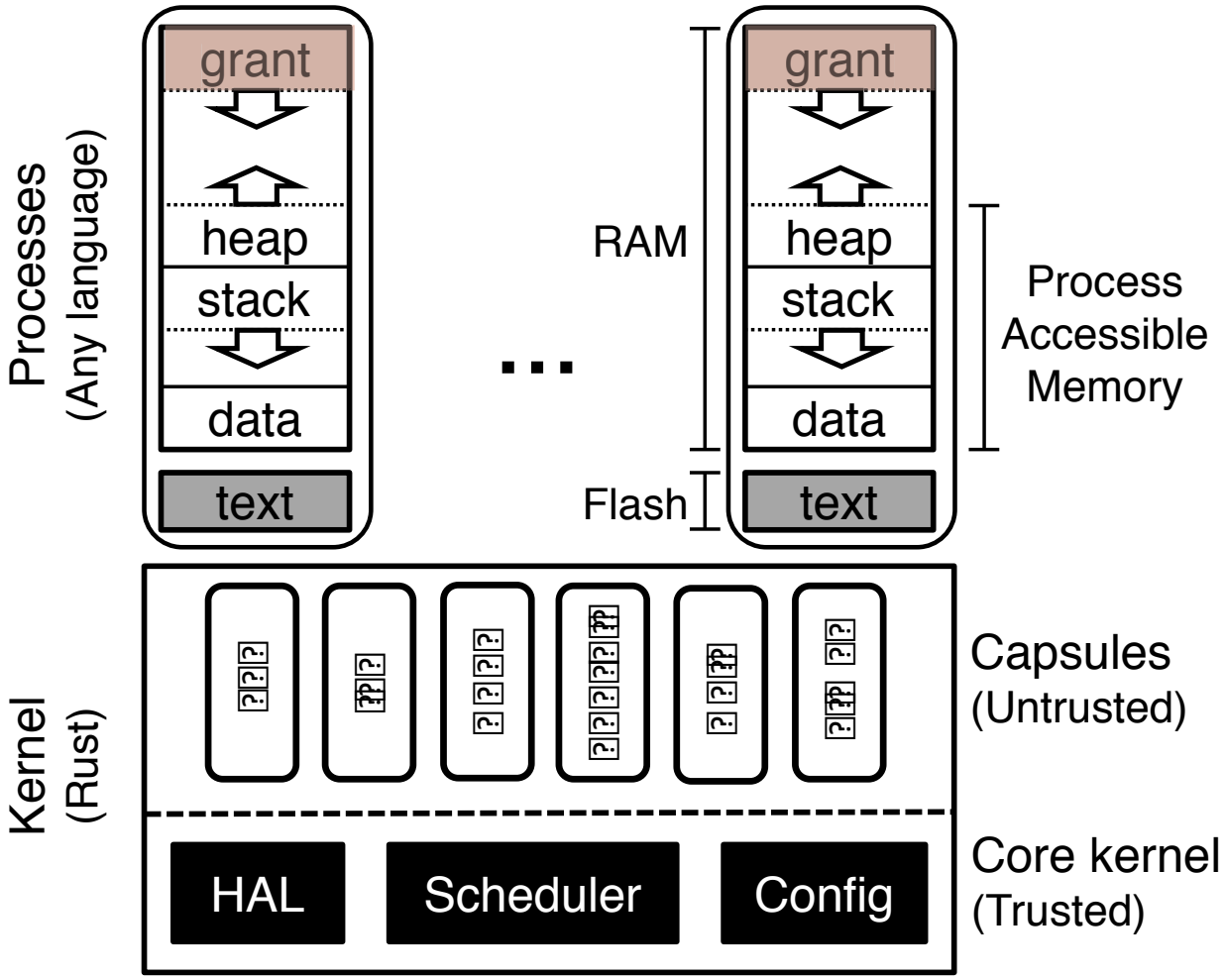
Tock Architecture



Challenge: System Calls

- System calls need to dynamically allocate memory
  - Create a timer, kernel needs to keep timer's state
  - Enqueue a packet to send, kernel needs reference to packet
- For dependability, kernel has no heap
  - Otherwise a process can exhaust kernel memory
  - Fragmentation
  - Cleaning up after process failures
- How does the kernel handle system calls if it has no heap?

System Call Insight

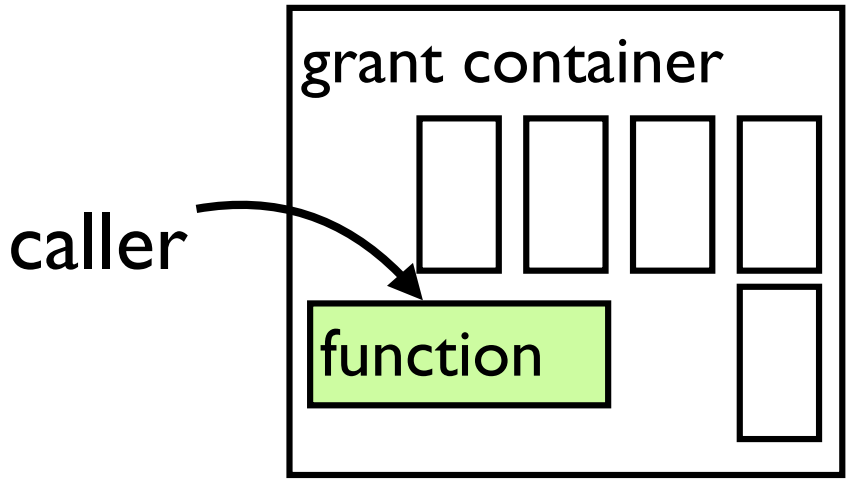


- Processes given block of memory
- Dynamically allocated when process loaded
- Kernel can allocate memory from process

Memory Grants

- Each process has a growable container of *grant memory*
- Kernel can allocate objects from the grant block
- References to objects cannot escape the block
  - Process failure/crash does not lead to dangling pointers
- Users pass a function to the container with `enter`

```
self.apps.enter(appid, |app, _| {
    app.read_buffer = Some(slice);
    app.read_idx = 0;
    0
}).unwrap_or(-1)
```



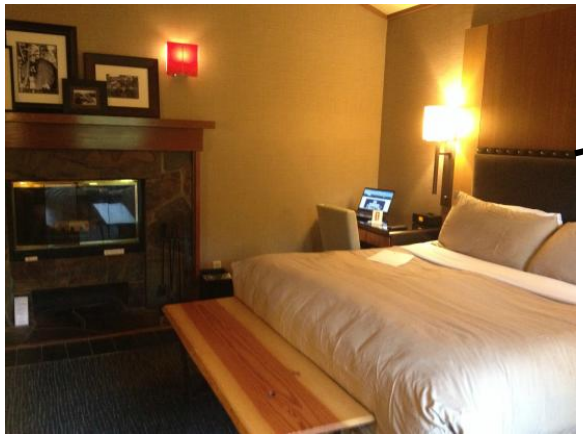
Programs to the Edge

Firmware

lua

python

C



Application programming model
Application-to-application authentication
Network security policies
20-year cryptography/software update

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  - Small amount of trusted code (can do unsafe things)
    - Rust bindings for memory-mapped I/O
    - Core scheduler, context switches
- Many new system design and research challenges
  - Writing a kernel in a type safe, not garbage collected language
  - Memory isolation and allocation
- Come learn how to use it!

Thanks!

https://www.tockos.org/

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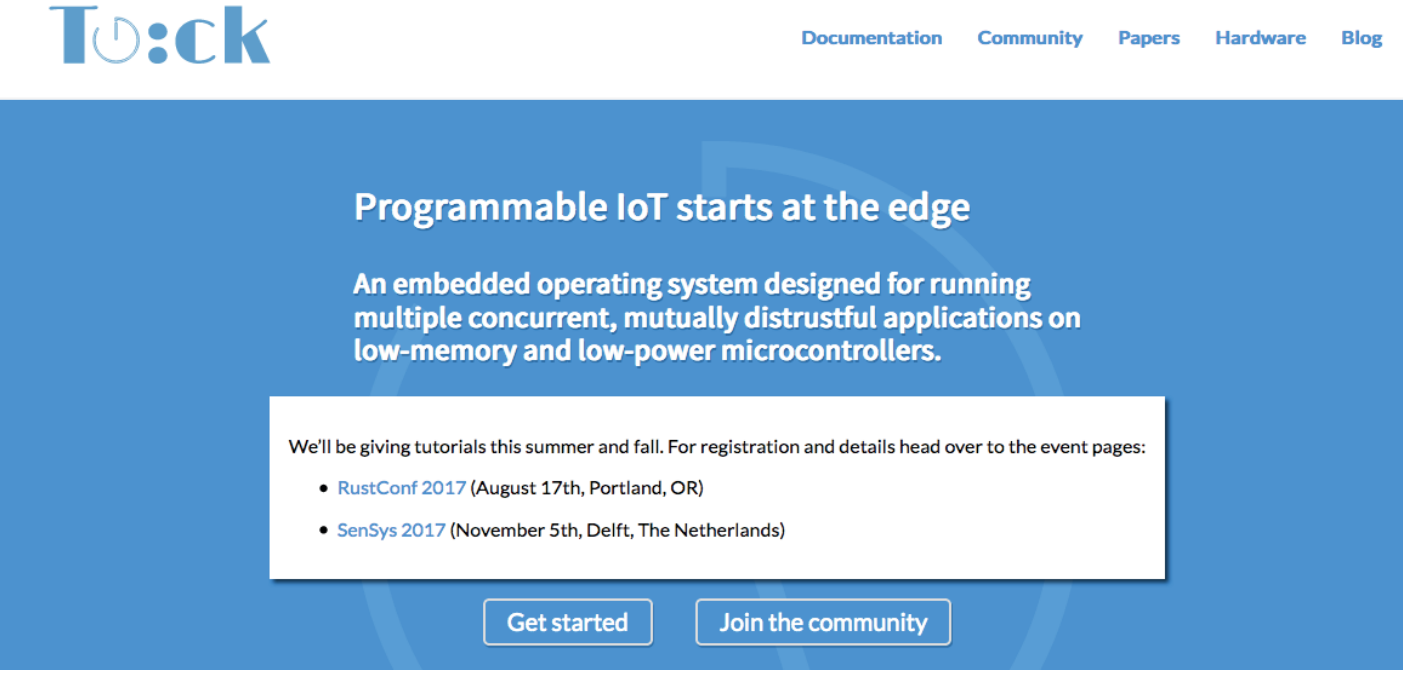

↑ Amit will be on the job market this year - help me make him smile!