

# Reducing the Barrier to Post-Moore Era Hardware Innovation

DoE Energy-Efficient Computing for Science Workshop  
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**No Silver Bullet**  
**Essence and Accidents of Software Engineering**  
**– Fred Brooks, 1986**



# DARPA UPSIDE program (2012-2018)

## Unconventional Processing of Signals for Intelligent Data Exploitation

### Objective:

Exploit the physics of emerging devices, analog CMOS, and non-Boolean computational models to achieve new levels of performance and power for real-time sensor imaging systems.

### Approach:

**TA1: Image Application for Benchmarking:** Recreate a traditional image processing pipeline (IPP) using UPSIDE Compute models showing no degradation in performance.

**TA2: MS CMOS Demonstration:** Mixed signal CMOS implementation of the computational model and system test bed showing  $1 \times 10^5 \times$  combined speed-power improvement for analog CMOS.

**TA3: Emerging Device Implementation:** Image processing demonstration combining next-generation devices with new computation model.  $1 \times 10^7 \times$  (projected)

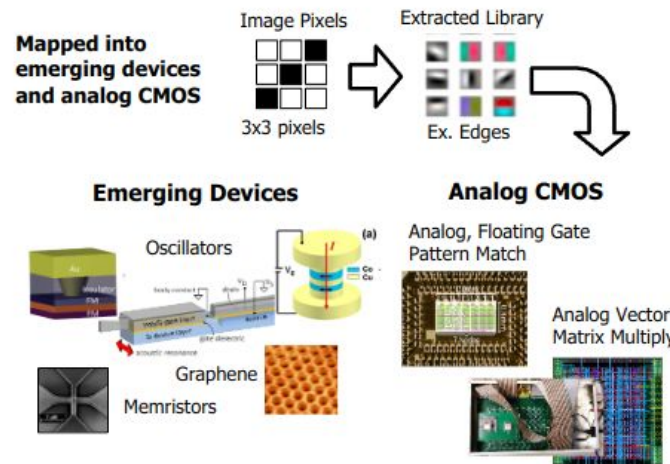
*Goal:* Demonstrate the capability and pathway toward embedded computing efficiency in ISR applications w/  $>1,000 \times$  processing speed and  $>10,000 \times$  improvement in power consumption

### Low-precision probabilistic computing algorithms



Detected Salient Pixels

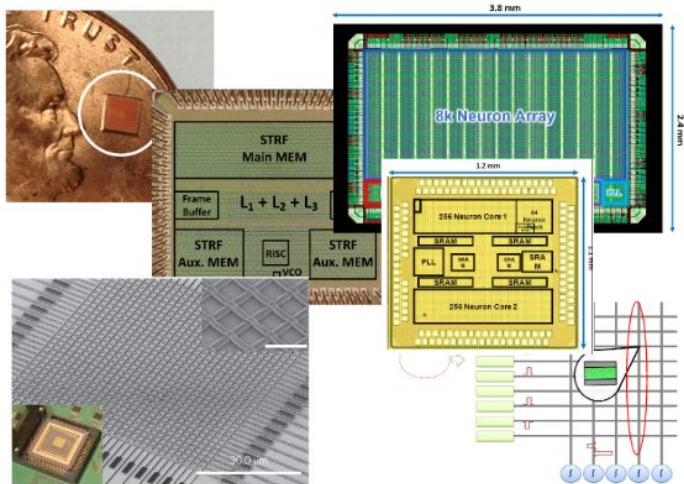
### Benchmarked using object classification and tracking applications





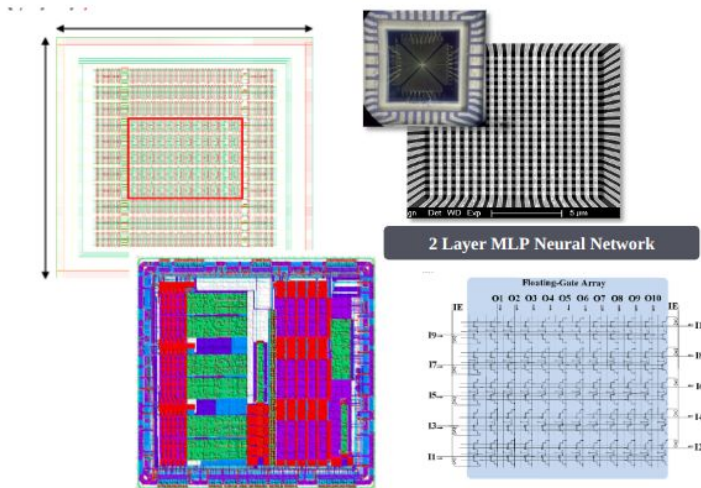
## Selected UPSIDE results

### University of Michigan



- Mixed signal processing (50TOPS/W)
- Sparse image reconstruction in memristors
- Numerous publications (Nature, ...)

### UCSB



- First memristor based multilayer perceptron
- Flash based 55nm analog computing (>10TOPS/W)
- Numerous publications (Nature, ...)

### Conclusion:

Fantastic work  
Analog>>Digital

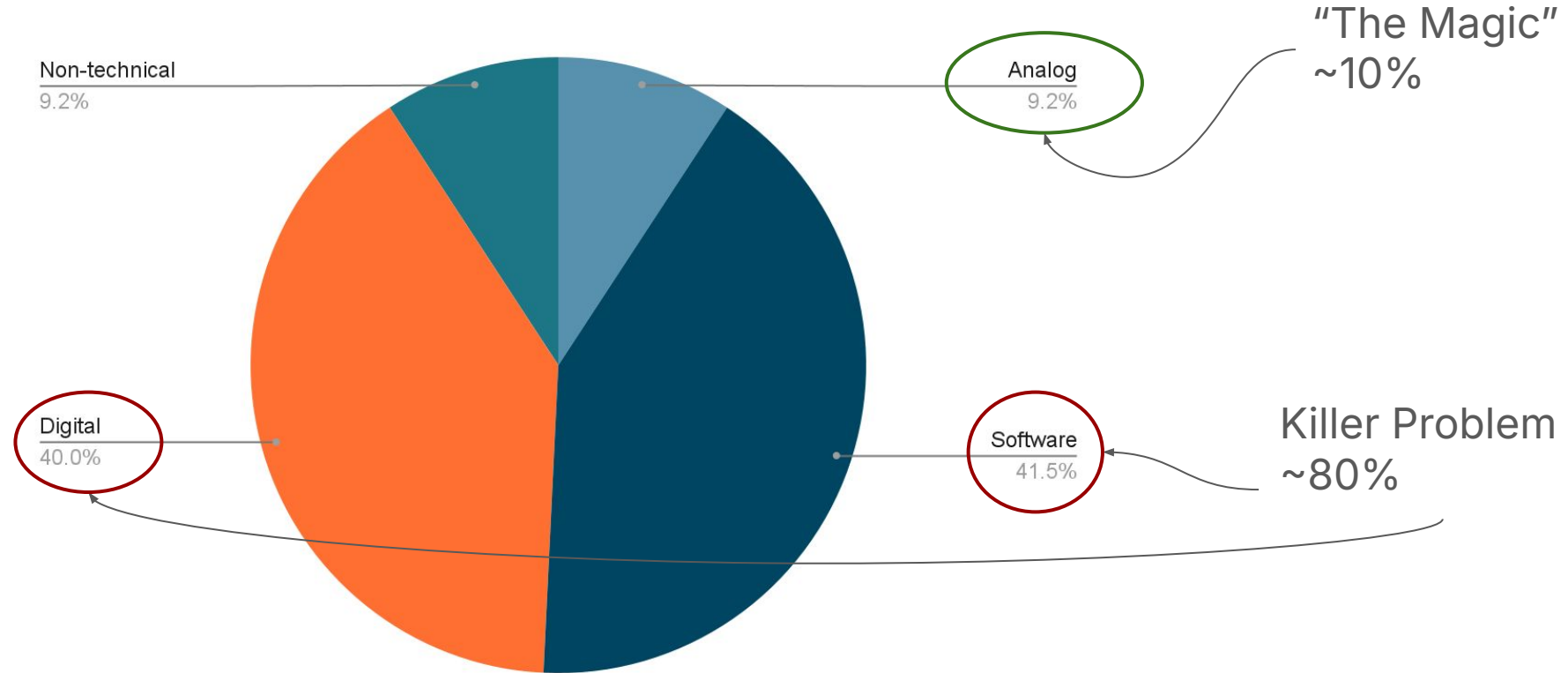
### But what about:

Applications?  
Speed?  
Integration?  
Scaling?  
Dynamic range?  
Manufacturing?  
Interfacing?  
Amdahl?  
Transition?  
Portability?

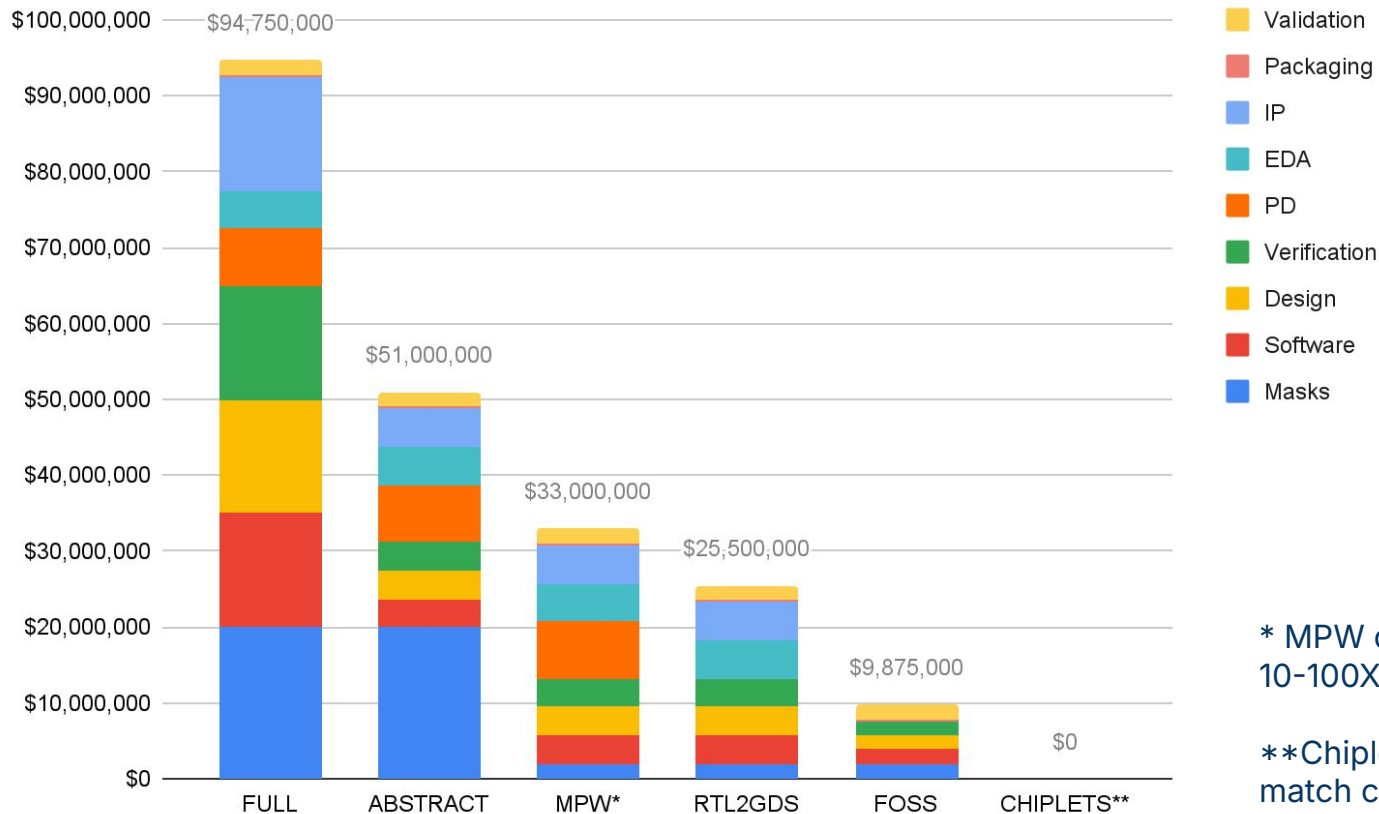
# Really Important Unanswered Questions

- **All non digital technologies:**
  - Amdahl, SW, general performance, system, HVM?....
- **Quantum:** What is the application?
- **Biological:** What is the application?
- **Analog:** How will you interface with digital & scale?

# Staff Count of a Failed Analog Computing Startup



# Chipleets: Best Path to Lowering the Barrier to Innovation

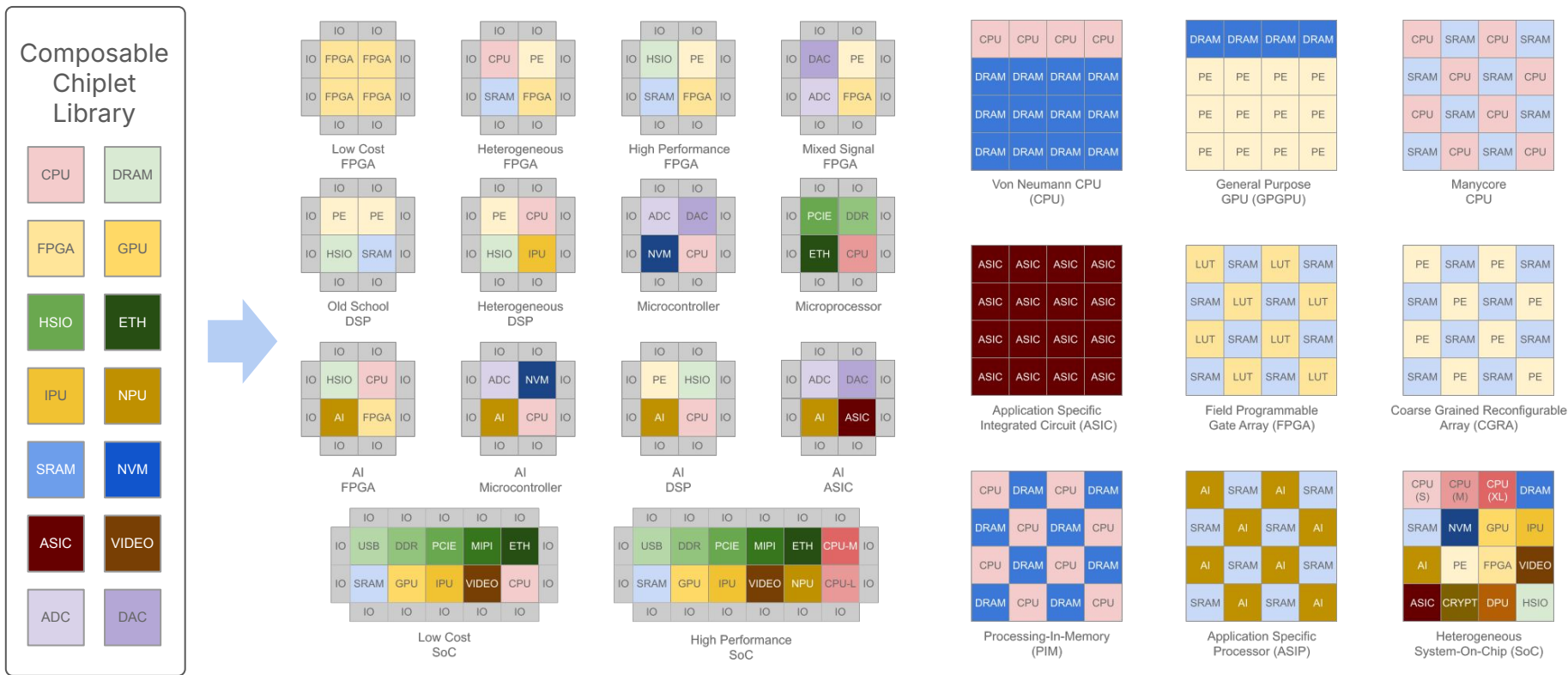


\* MPW drives up unit cost by 10-100X

\*\*Chipleets assume mix and match catalog



# Chiplets: The New Amino Acids of Silicon Systems




*"Finite investment, infinite possibilities"*



# Missing Chiplet Technologies

- Full-stack chiplet standards
- Open market chiplets
- Automated chip layout compilers
- Cost effective chiplet emulation
- Self service emulation infrastructure
- Silicon interposer access
- Automated high mix package assembly



What I have  
been  
working on  
since 2017...

# Hardware field is mostly failing at collaboration!

**awesome-opensource-hardware** Public

Pin Unwatch 69 Fork 167 Starred 1.8k

main 1 Branch 0 Tags

Go to file Add file Code

**aolofsson** Removing recommendations to avoid bias 2c4e221 · last week 127 Commits

File	Commit Message	Time
repos	Adding ability to clone all repos	2 years ago
.gitignore	Adding clone all repos script	2 years ago
LICENSE	Adding clone all repos script	2 years ago
README.md	Removing recommendations to avoid bias	last week
clone.py	Adding clone all repos script	2 years ago

**awesome-opensource-hardware**

A curated list of awesome open source hardware tools, generators, and reusable designs.

- Categorized
- Alphabetical (per category)
- Requirements
  - link should be to source code repository
  - open source projects only
  - working projects only (not WIP/rusty)
- One tag line sentence per project

**About**

List of awesome open source hardware tools, generators, and reusable designs

Readme MIT license Activity 1.8k stars 69 watching 167 forks

**Releases**

No releases published [Create a new release](#)

**Packages**

No packages published [Publish your first package](#)

**Contributors** 27

+13 contributors

- <https://github.com/aolofsson/awesome-opensource-hardware>

- **450+** open source repos
- Amazing growth in 10 years
- Limited collaboration

## Recommendation:

- Identify the gaps
- Fund the boring stuff
- Don't rely on students for critical infrastructure.
- Enforce standards/discipline
- Learn from DoE HPC SW success?

# Walking the walk...

- **Hardware Compiler:**

<https://github.com/siliconcompiler/siliconcompiler>

- **Target Agnostic Libraries:**

<https://github.com/siliconcompiler/lambdalib>

- **Virtual PDKs:**

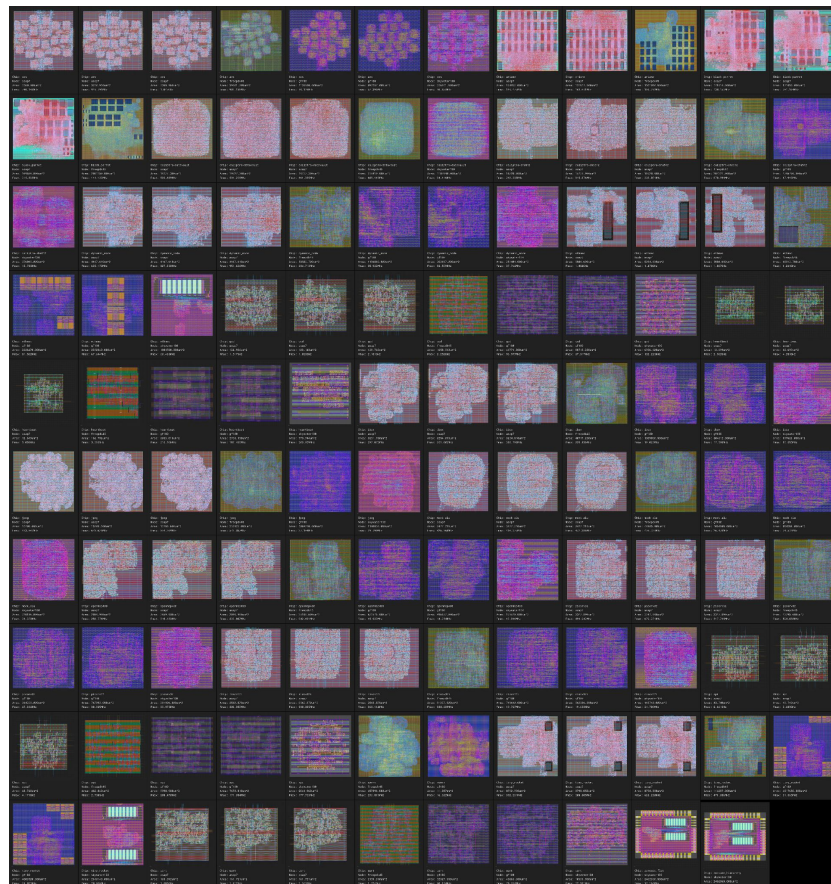
<https://github.com/siliconcompiler/lambdapdk>

- **Universal Memory Interface:**

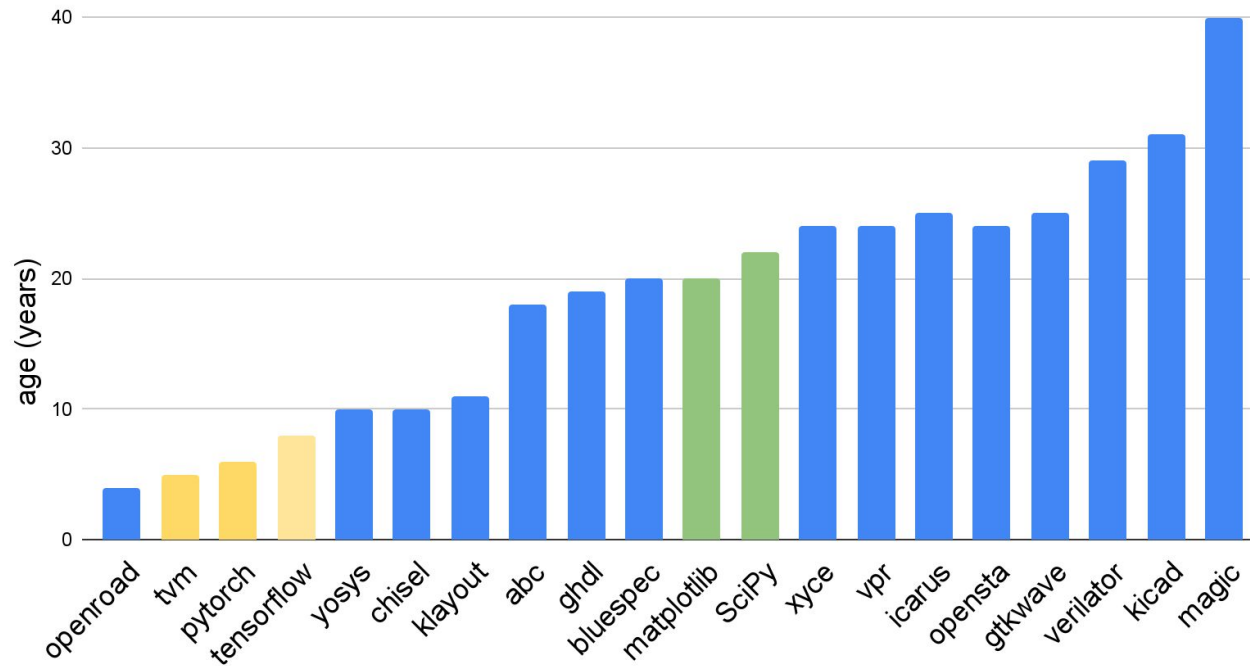
<https://github.com/zeroasiccorp/umi>

- **Digital Twin Distributed (Chiplet) Emulator:**

<https://github.com/zeroasiccorp/switchboard>



# Infrastructure Must be Built to Last!



- Build to scale (LLVM inspired)
- Plan for 10 years
- Developer redundancy
- Ensure long term funding
- Make wise choices!
- Leverage others

# List of “Boring” Unsolved Infrastructure Problems

- High quality open source digital **IP** (see DARPA POSH, 2017)
- Automated **RTL2GDS** flows (see DARPA IDEA, 2017)
- Common chiplet **standards** (see DARPA CHIPS, 2017)
- ML hardware **compilers** (see DARPA RTML, 2019)
- Common CMOS+X **test** vehicles (see NATCAST TVIP)
- **Packaging** infrastructure, non existent (see NAPMP)
- High quality open source **analog** IP, currently at zero (?)
- Open source analog circuit **data** sets for EDA/AI (?)
- Creating the RISC-V equiv for ..AI, analog, fpga,... (?)
- Proxy **PDKs** for analog and digital to get around NDA (?)
- Standard **packaging** MPW infrastructure (?)
- Standard free and fast **MPWs** (3 month turn, not 12)