Arm **2018**

A Vision for Destruction of Post-Moore Disruption: How I Learned To Stop Worrying and Love Non-Von Neumann

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UCAR SEA, Boulder, CO

3 April

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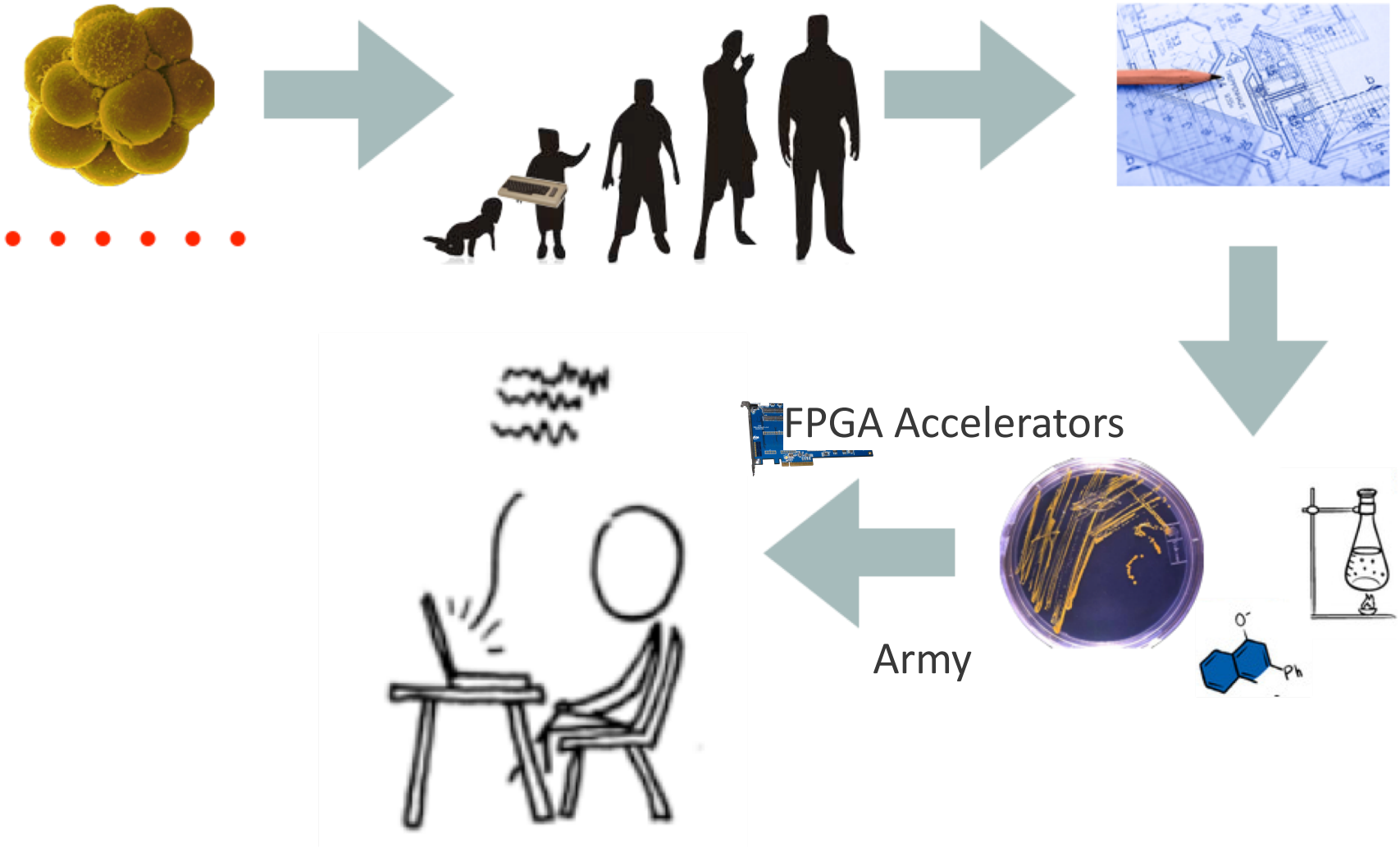
Disclaimer

- This is not a product presentation.
- Any changes to architecture must go through the standard architecture review board process.
- Nothing within this presentation should be taken as a direction of future architecture or product plans for Arm Inc/Ltd.
- Please ask questions related to the presentation, this should be a fun presentation!!

About Me

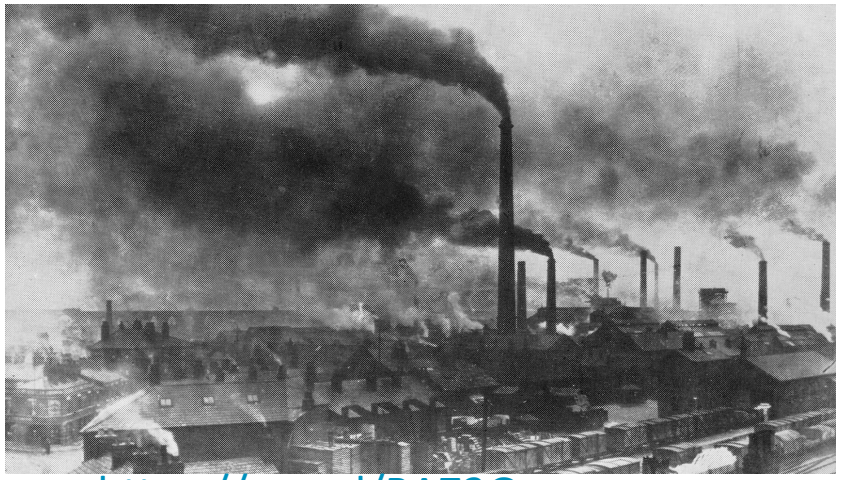


Natural Selection

Pale Peppered Moth

src: https://goo.gl/QJbLqG

19th Century London



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Bird Food

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Natural Selection

Pale Peppered Moth

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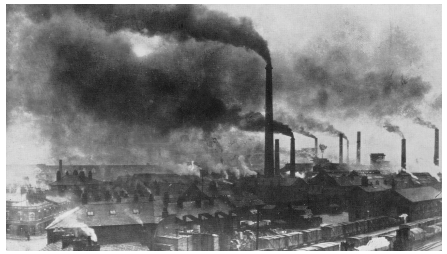

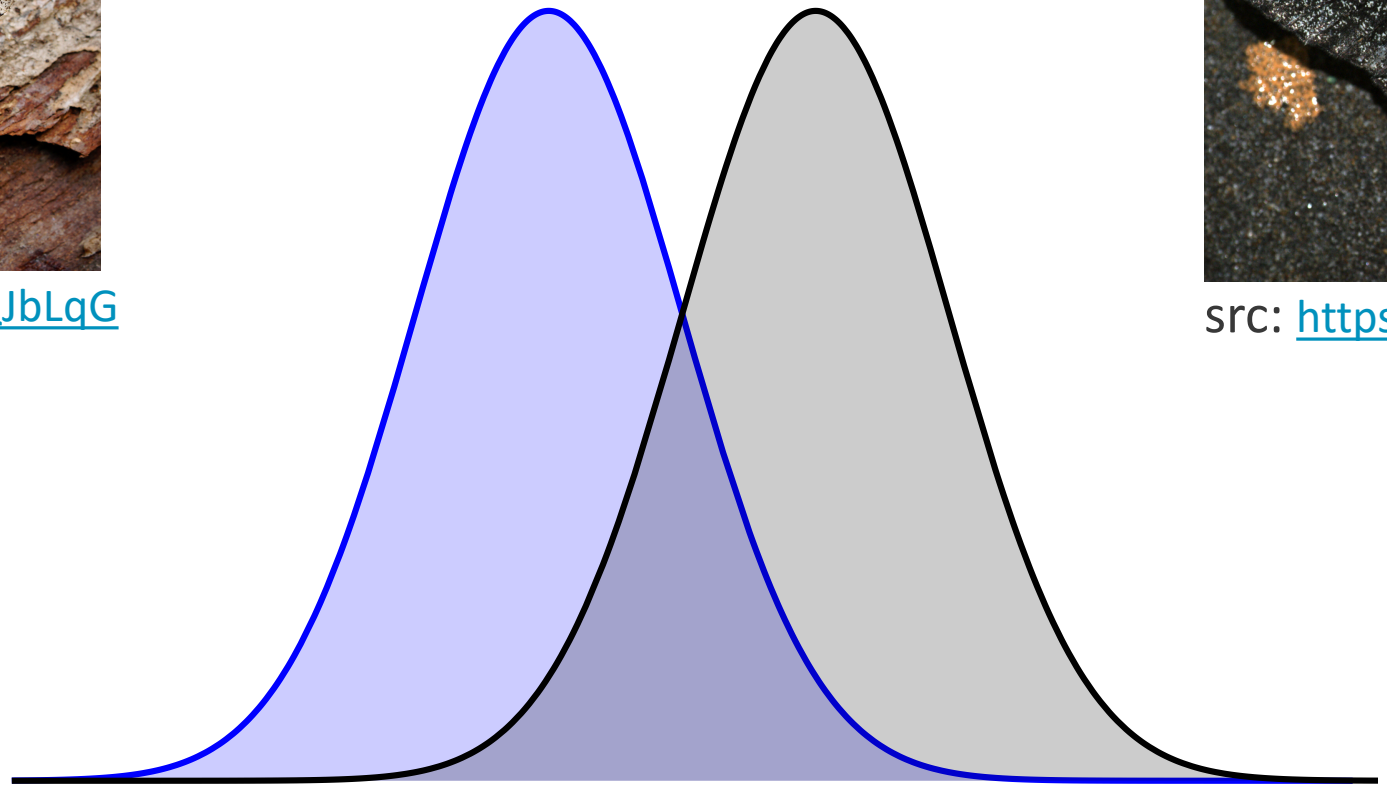

~~Pale~~ Peppered Moth

src: https://goo.gl/1BBZVG

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Natural Selection

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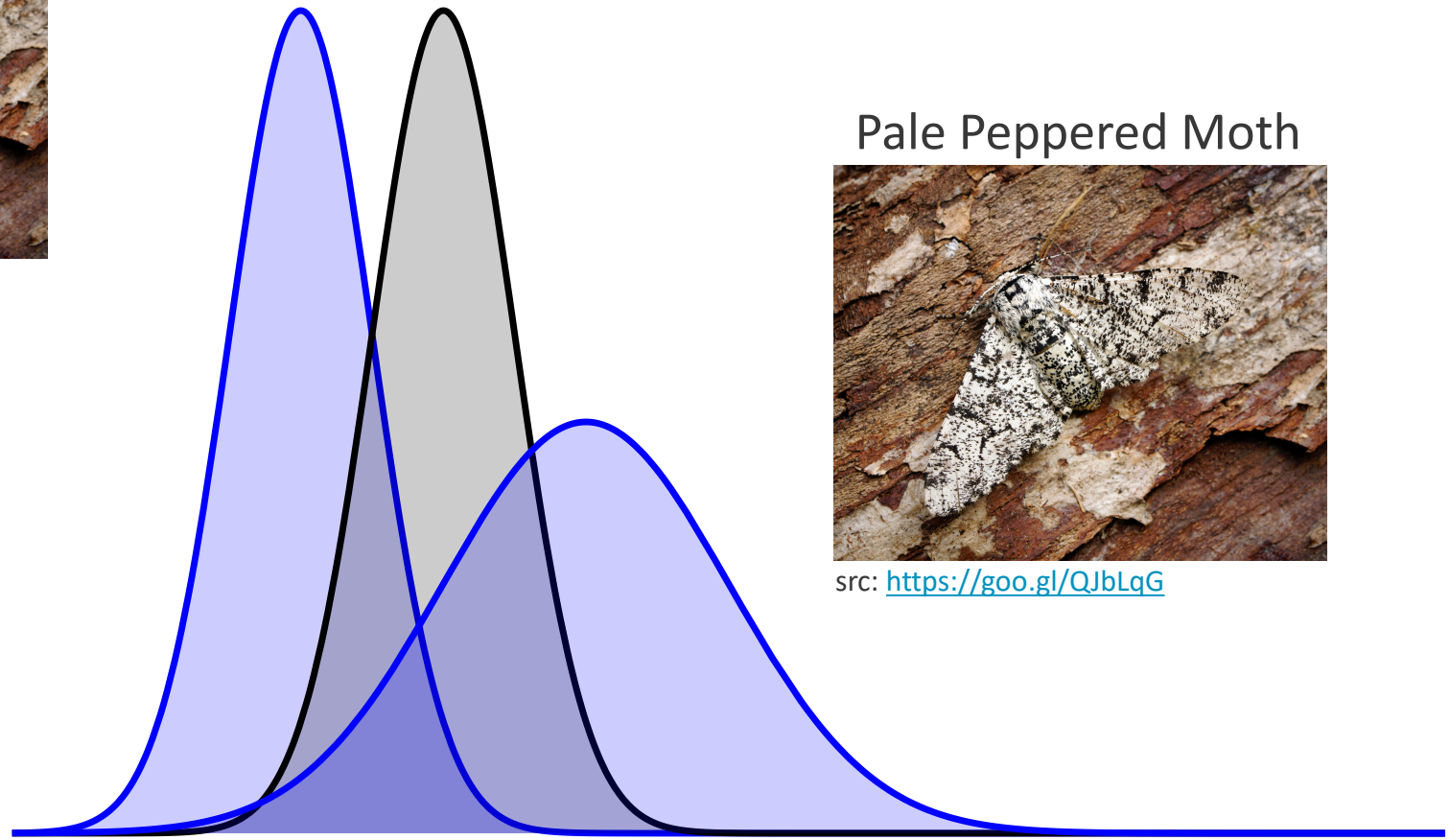
src: https://goo.gl/1BBZVG

src: https://goo.gl/yna3tH



Pale Peppered Moth

src: https://goo.gl/QJbLqG

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Selection on Computers

src: https://goo.gl/1dQoCZ

Speed

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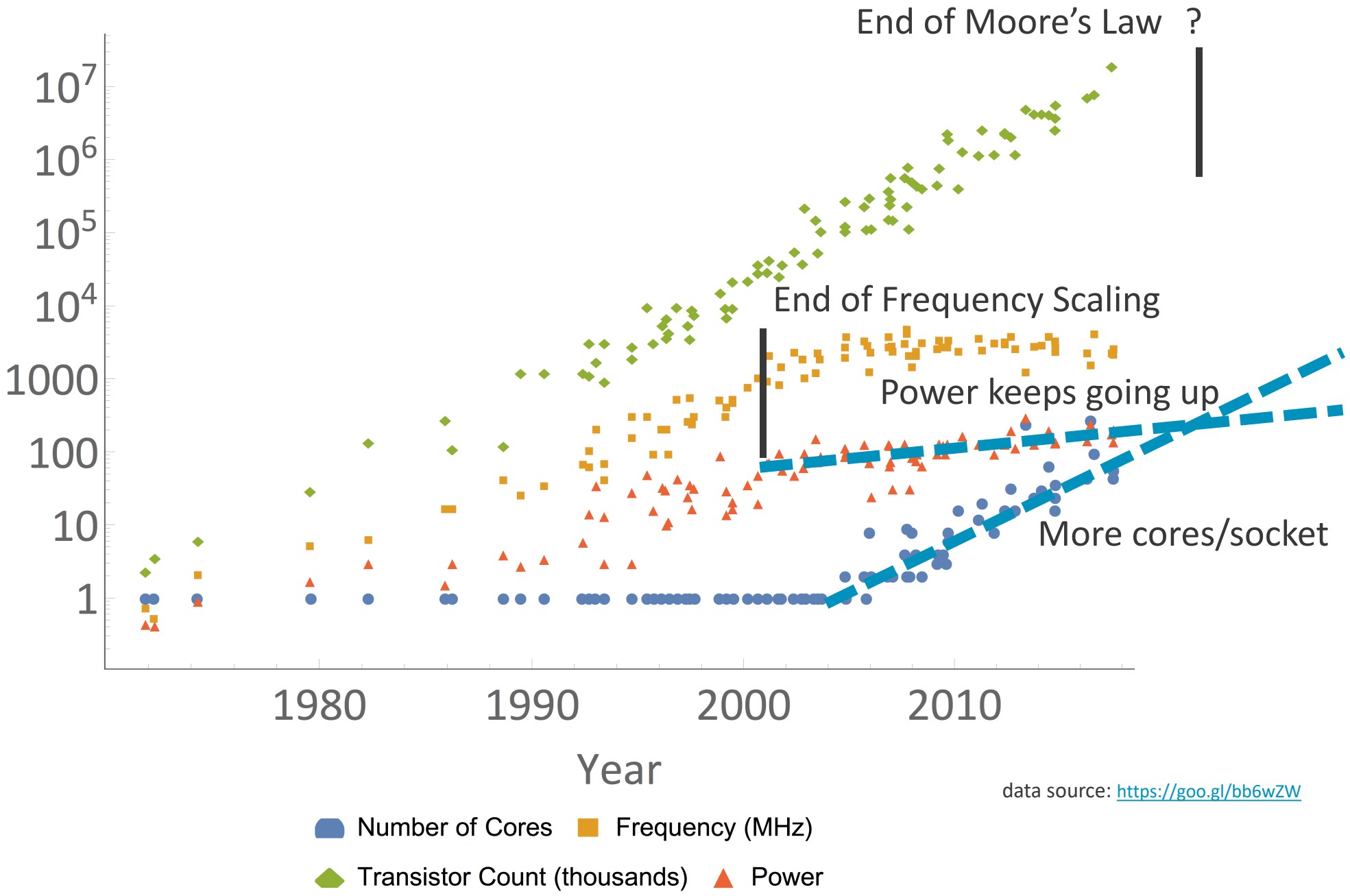
Energy Consumption

Ease of Use

Software Availability

Trends



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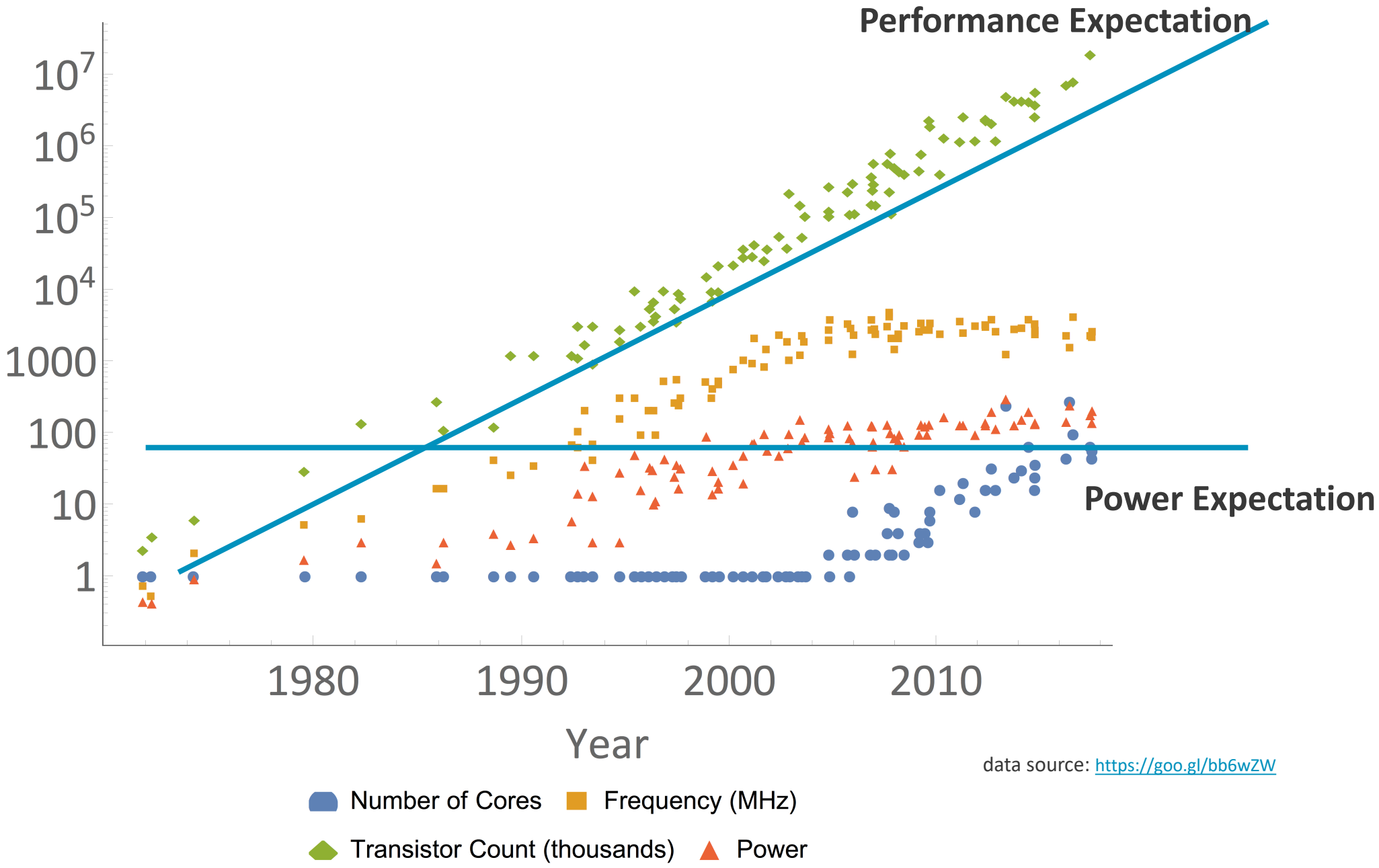
Trends



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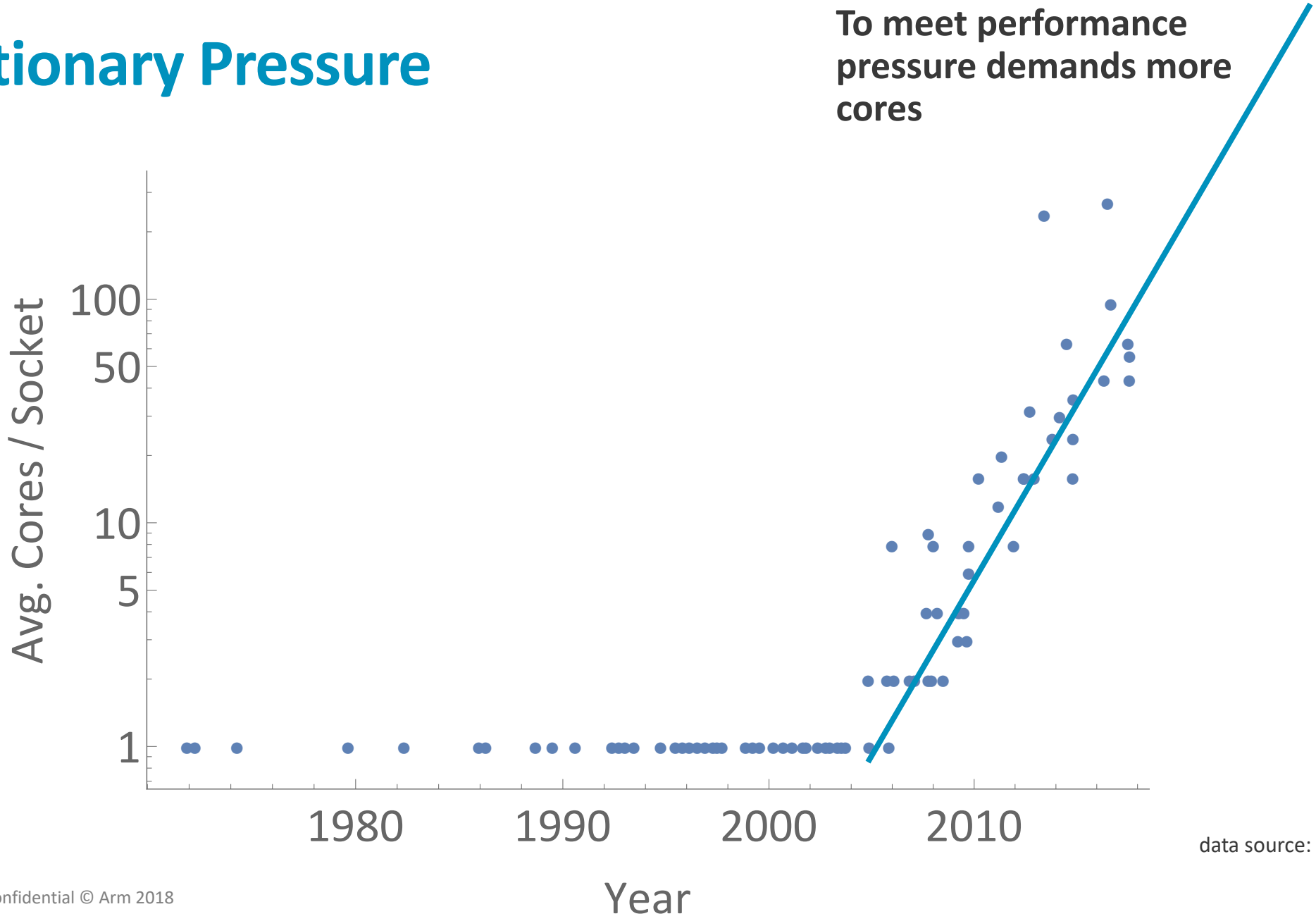
Evolutionary Pressure

To meet performance pressure demands more cores



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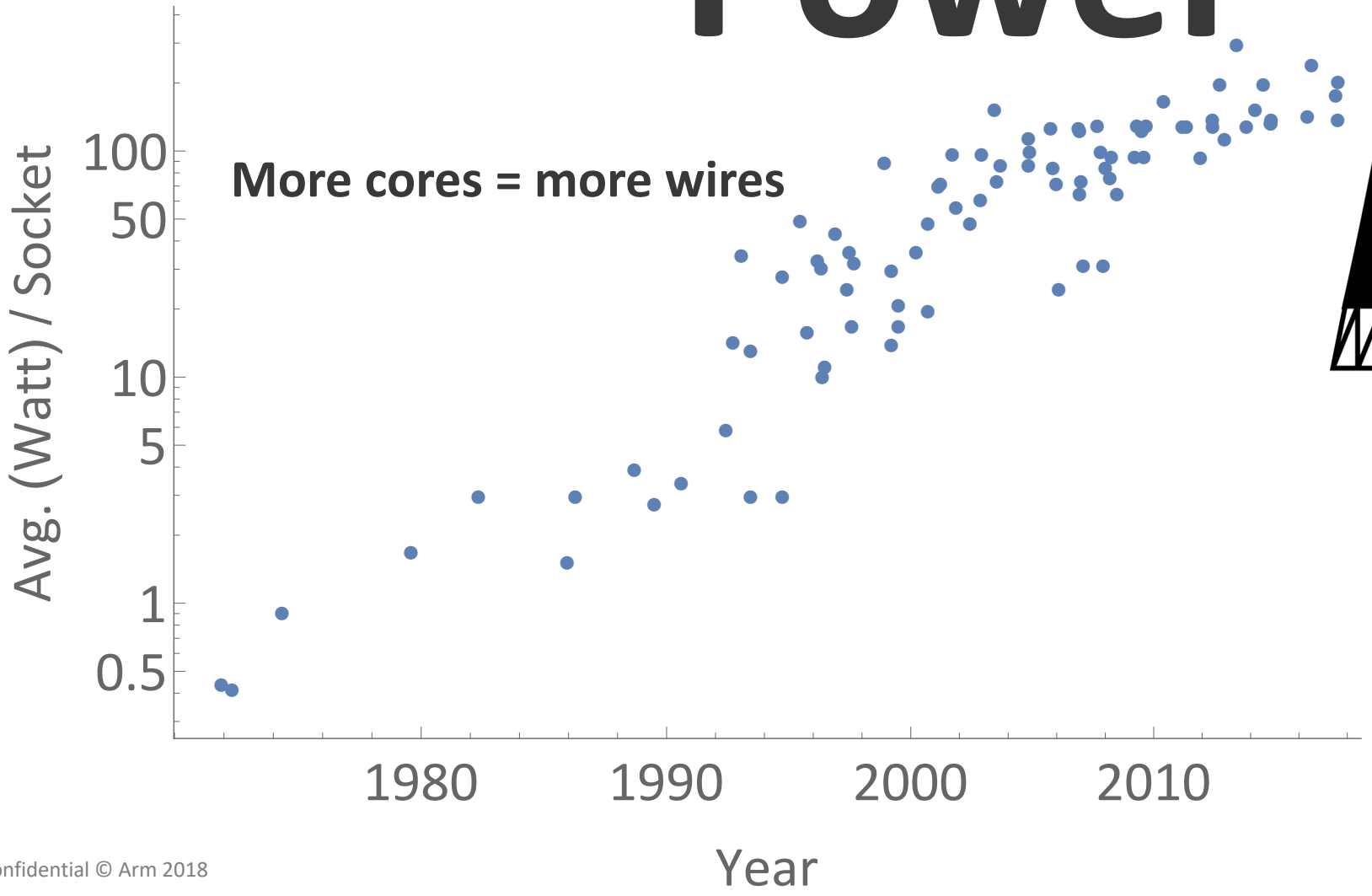
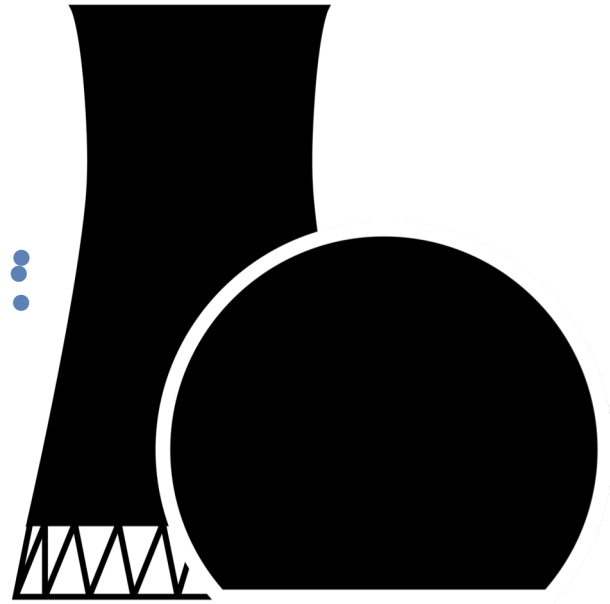
New Selective Pressure

Power





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data source: https://goo.gl/bb6wZW

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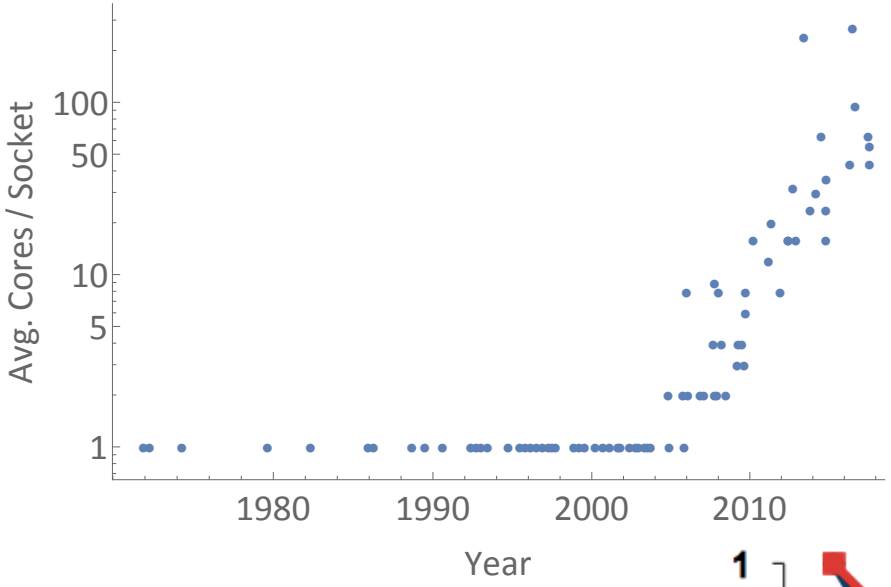
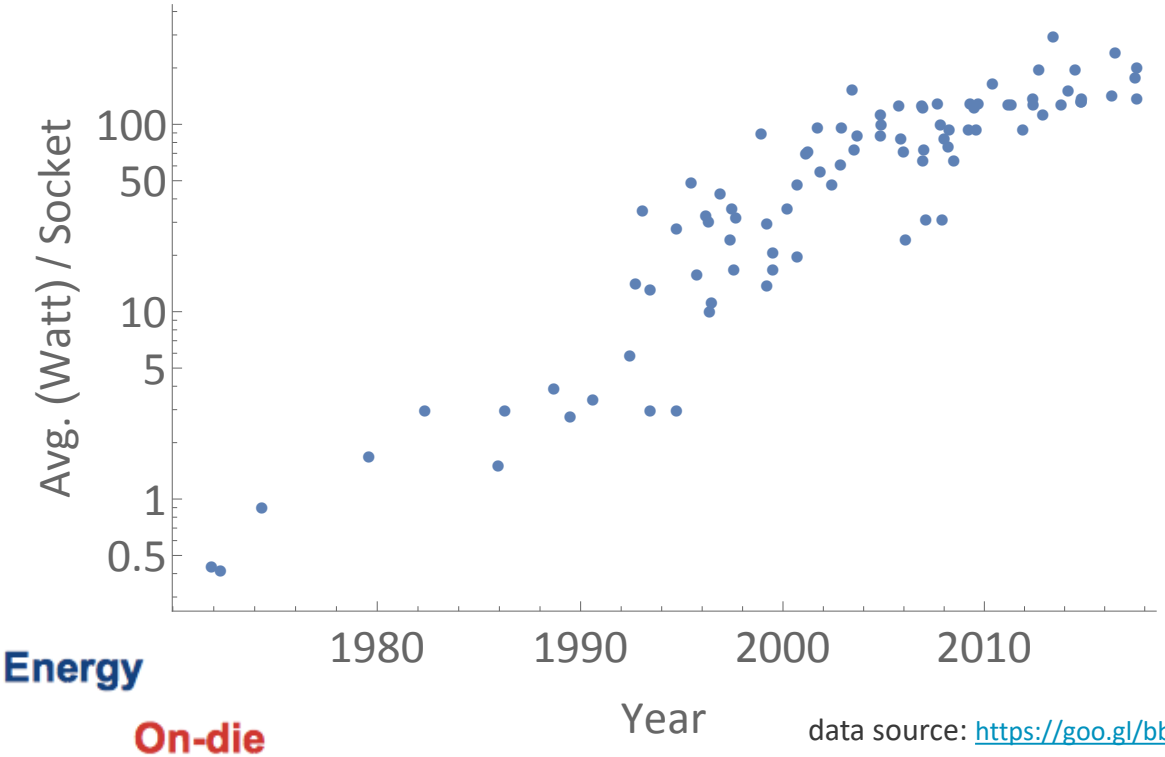
More Power!!





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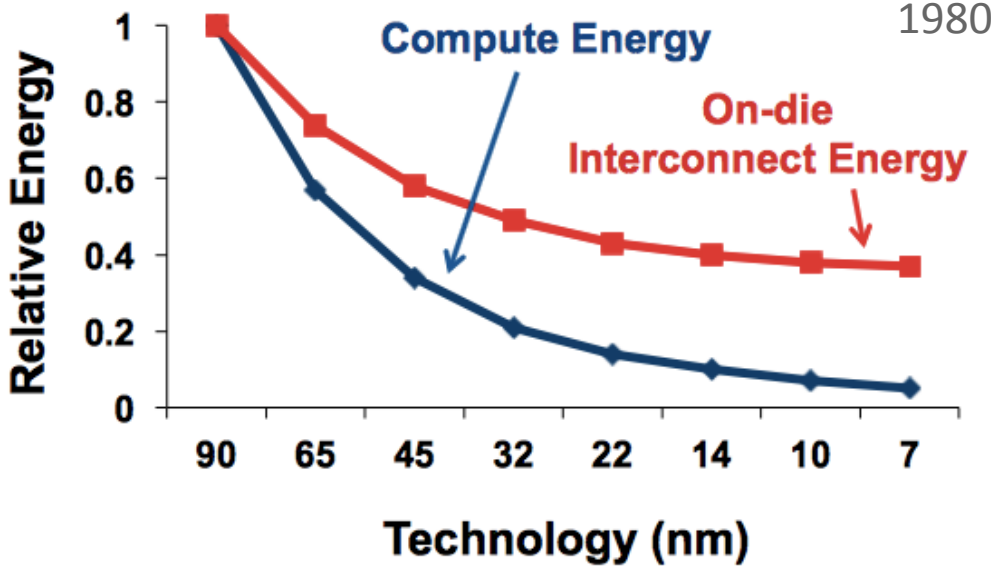

Source: Shekhar Borkar, Journal of Lightwave Technology, 2013

Selection on Computers

src: https://goo.gl/1dQoCZ

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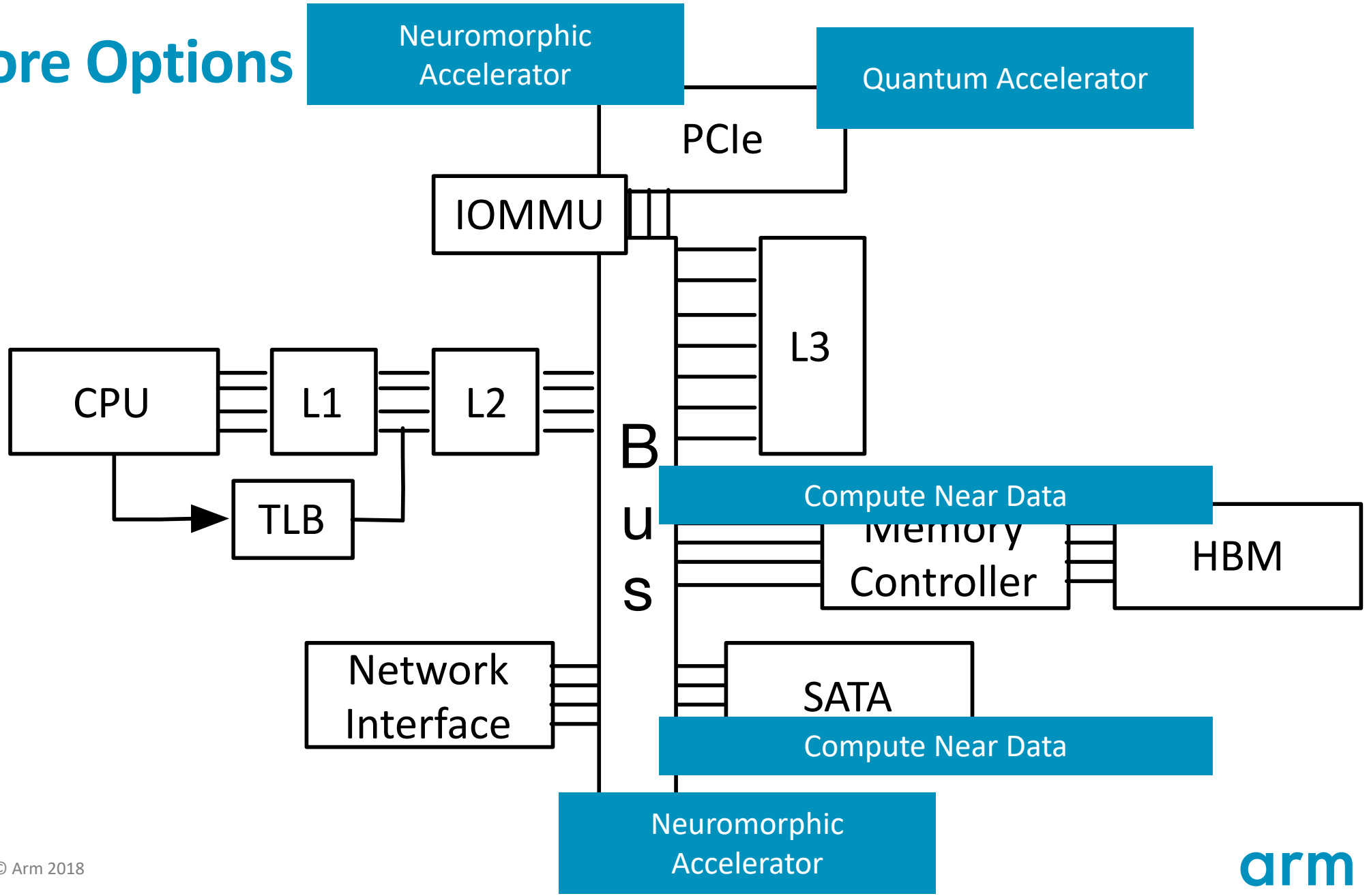
Speed

Energy Consumption

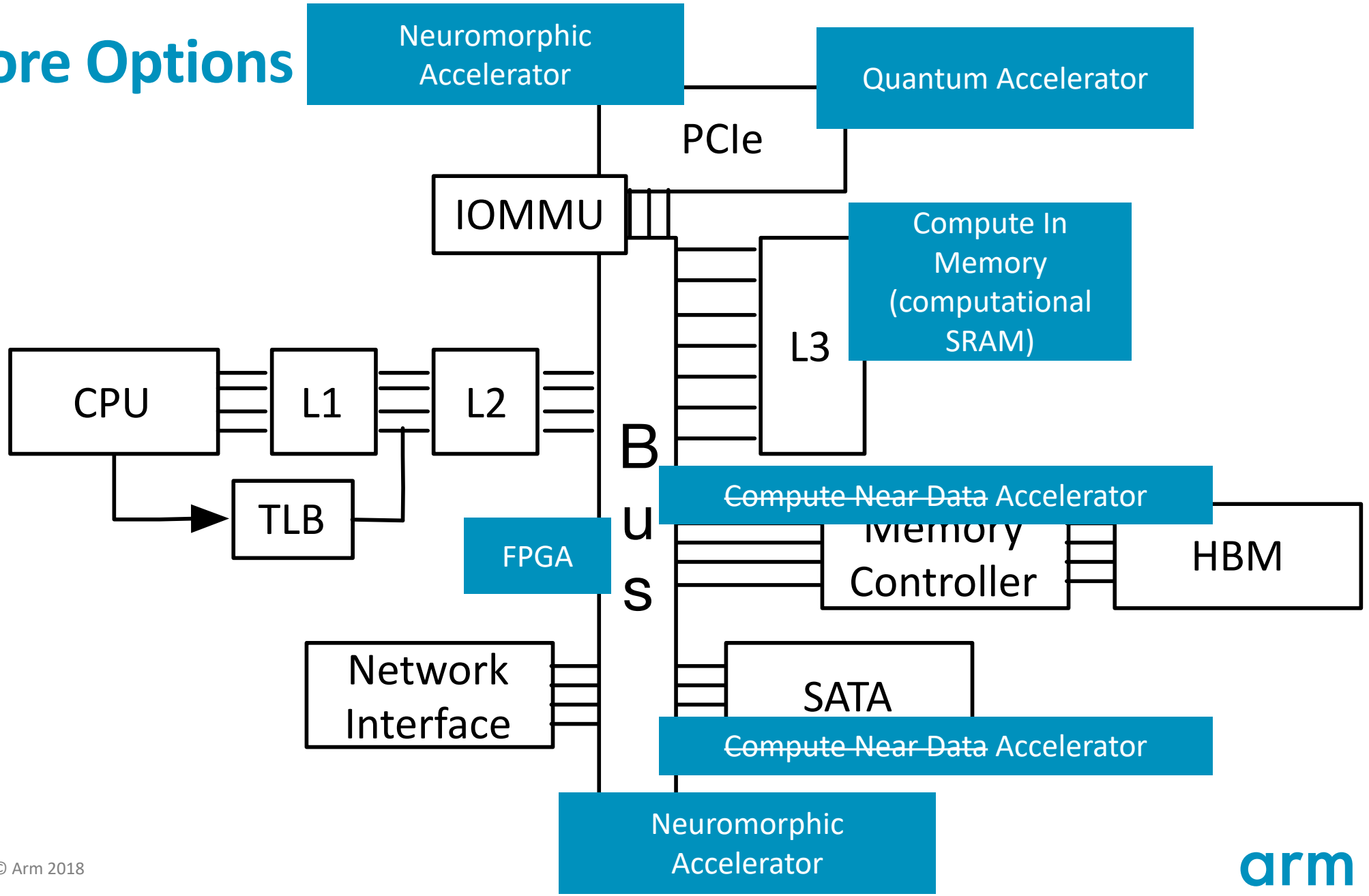
Ease of Use

Software Availability

Post-Moore Options

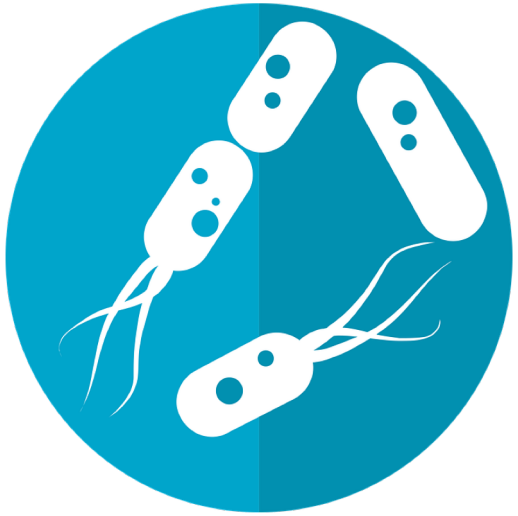


Post-Moore Options

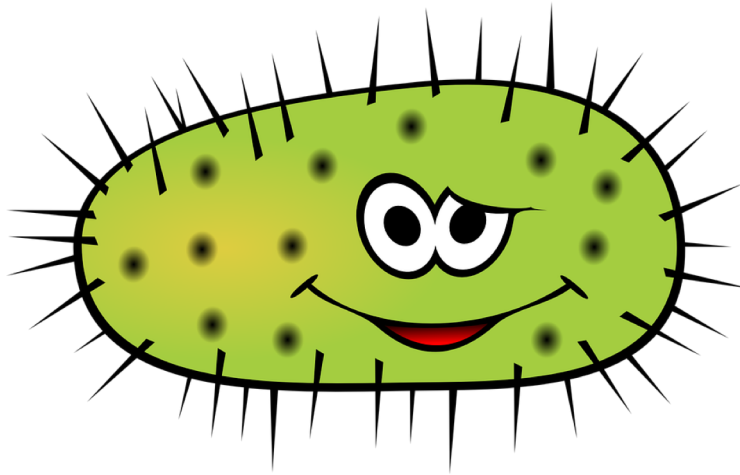


Evolutionary Pressure

Antibiotics



Bacteria



Pressure to select the resistant bacteria

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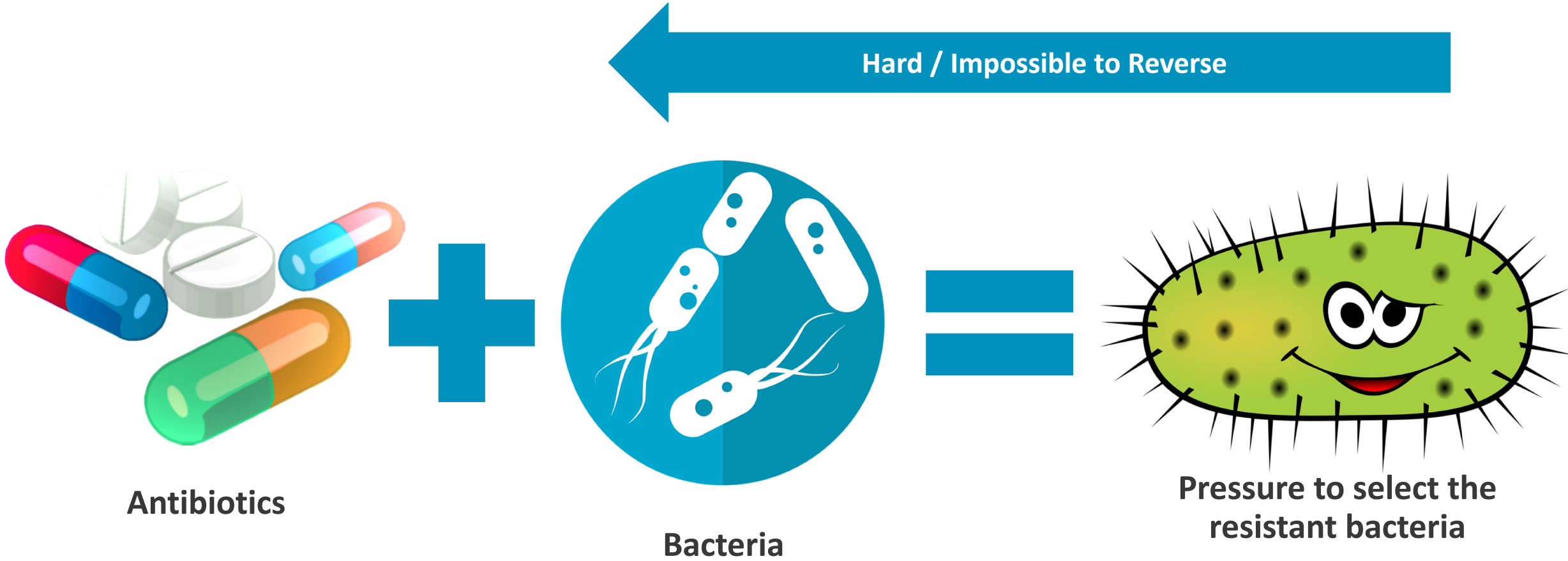
Evolutionary Pressure



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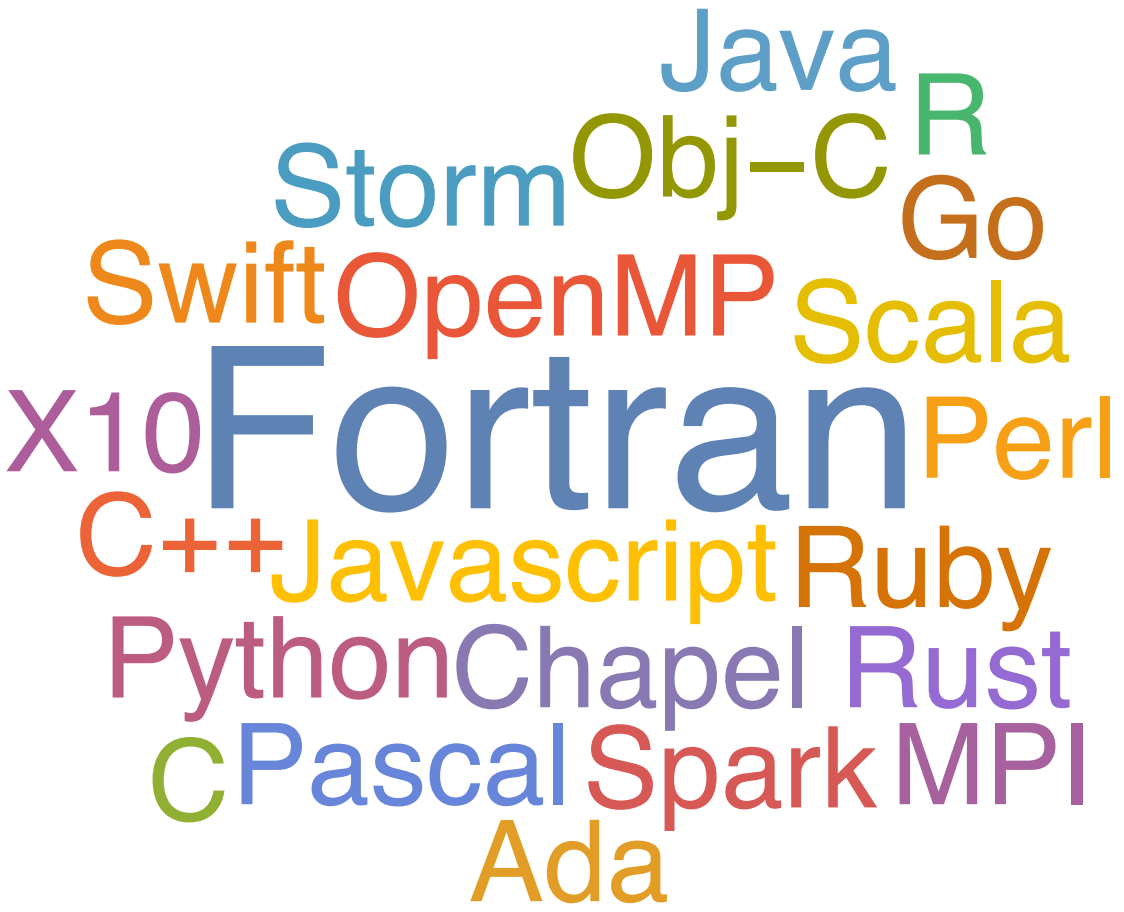
Many Language Options



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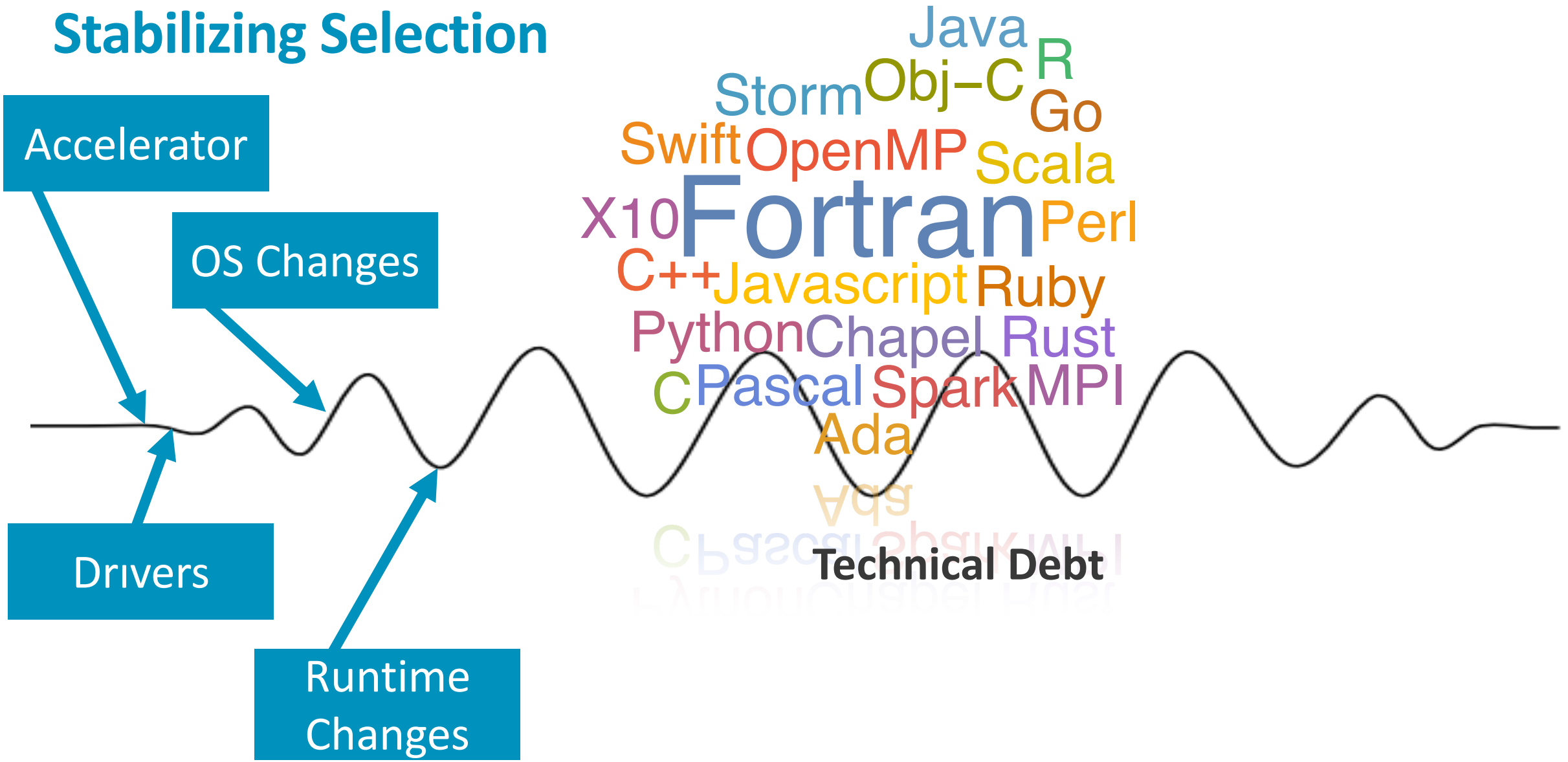
Stabilizing Selection



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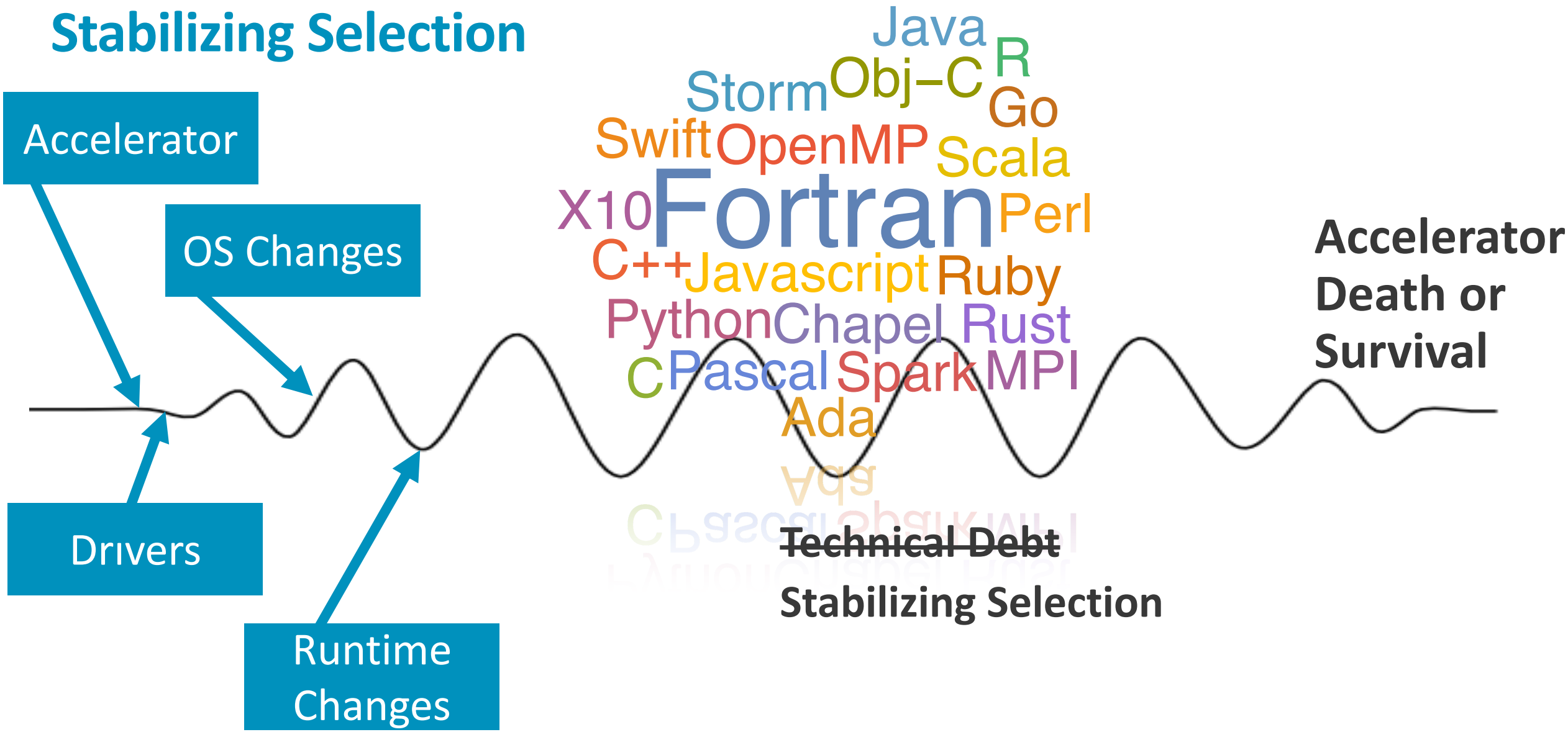
Stabilizing Selection



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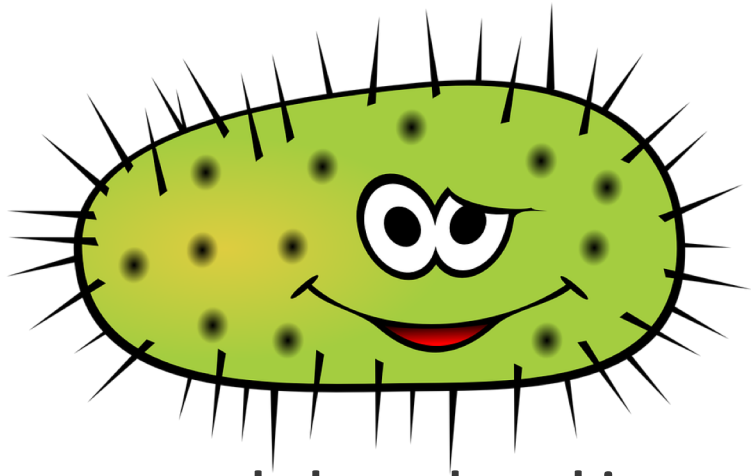
Why language interfaces stabilize

Evolutionary Pressure

src: https://goo.gl/1dQoCZ

Accelerator



e.g., unbalanced machine

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Hyper-optimized pressure

src: https://goo.gl/1dQoCZ

Accelerator

No memory system changes

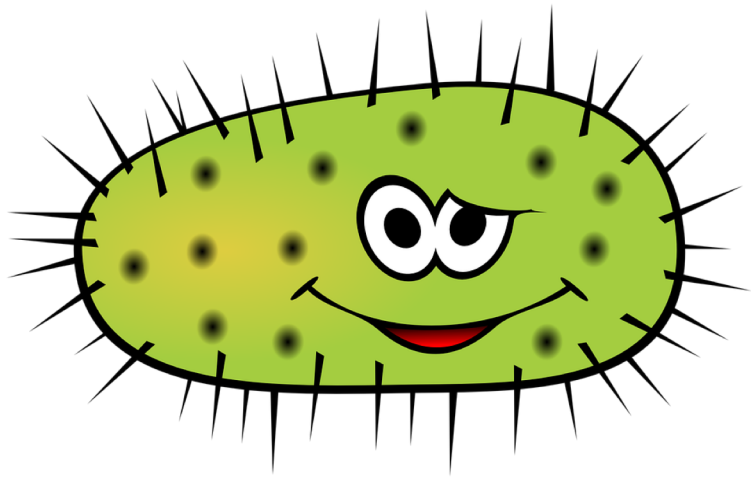
Only fully utilized at 20 FLOPS/B

Hyper-optimized pressure

src: https://goo.gl/1dQoCZ

Accelerator

No memory system changes



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Coevolution

src: https://goo.gl/1dQoCZ

Tune Code

```
_MM_TRANSPOSE4_PS(*((__v4sf*)b[4]) , *((__v4sf*)b[5]) , *((__v4sf*)b[6]) , *((__v4sf*)b[7]));
_MM_TRANSPOSE4_PS(*((__v4sf*)(b[4]+4)) , *((__v4sf*)(b[5]+4)) , *((__v4sf*)(b[6]+4)) , *((__v4sf*)(b[7]+4)));
row_swap((__v4sf*)(b[0]+4),(__v4sf*)(b[4]));
row_swap((__v4sf*)(b[1]+4),(__v4sf*)(b[5]));
row_swap((__v4sf*)(b[2]+4),(__v4sf*)(b[6]));
row_swap((__v4sf*)(b[3]+4),(__v4sf*)(b[7]));
```

Coevolution

```
_MM_TRANSPOSE4_PS(*((__v4sf*)b[4]) , *((__v4sf*)b[5]) , *((__v4sf*)b[6]) , *((__v4sf*)b[7]));
_MM_TRANSPOSE4_PS(*((__v4sf*)(b[4]+4)) , *((__v4sf*)(b[5]+4)) , *((__v4sf*)(b[6]+4)) , *((__v4sf*)(b[7]+4)));
row_swap((__v4sf*)(b[0]+4),(__v4sf*)(b[4]));
row_swap((__v4sf*)(b[1]+4),(__v4sf*)(b[5]));
row_swap((__v4sf*)(b[2]+4),(__v4sf*)(b[6]));
row_swap((__v4sf*)(b[3]+4),(__v4sf*)(b[7]));
```

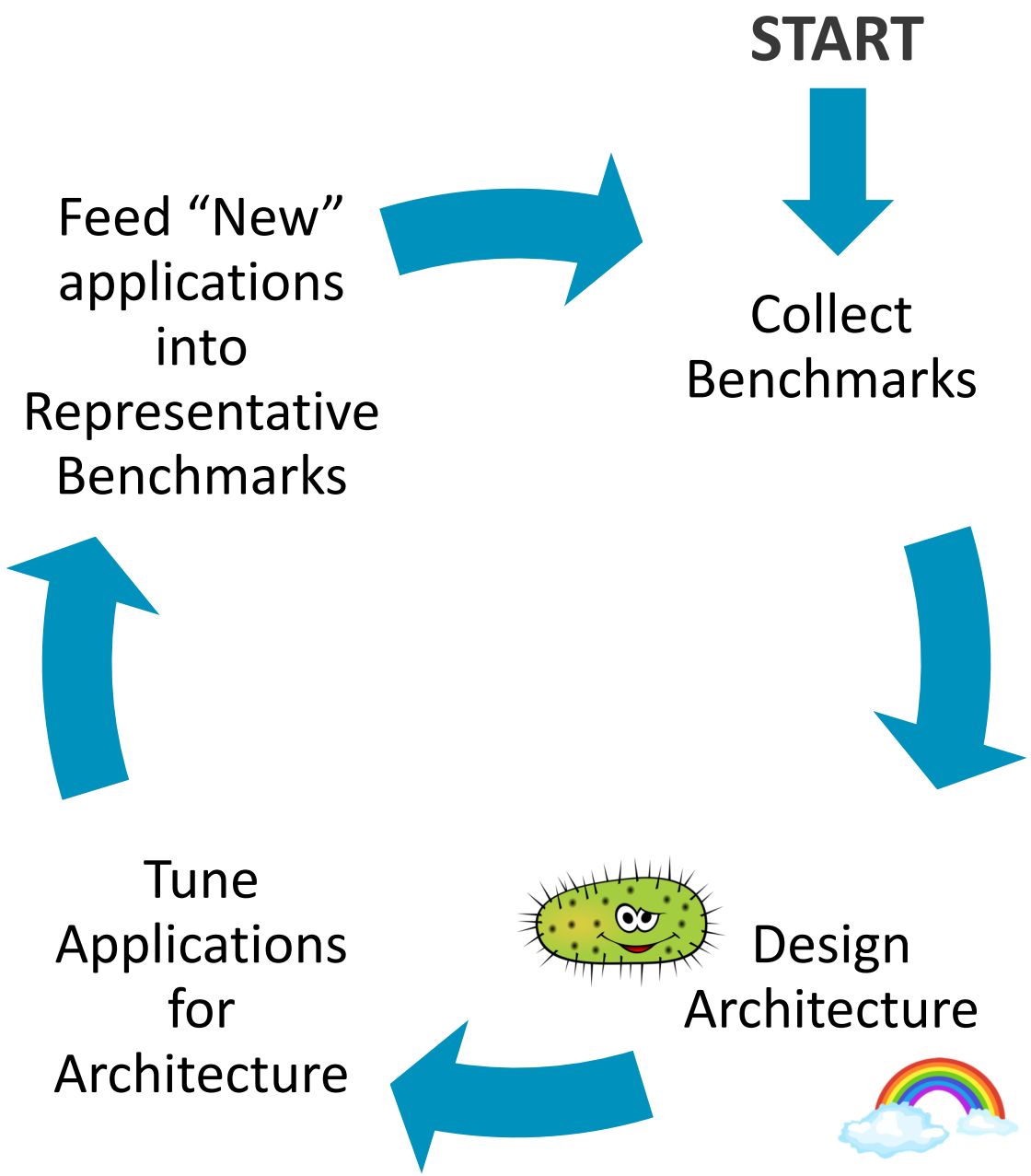
Gather workload requirements

Simulate Architecture

Environmental pressure yields almost identical architecture

src: https://goo.gl/1dQoCZ

Coevolution



- At some point we have to break out of the cycle.
- Cost of not doing so is getting more of the exact same architecture.
- Perhaps worse, architectures will evolve without much application input.

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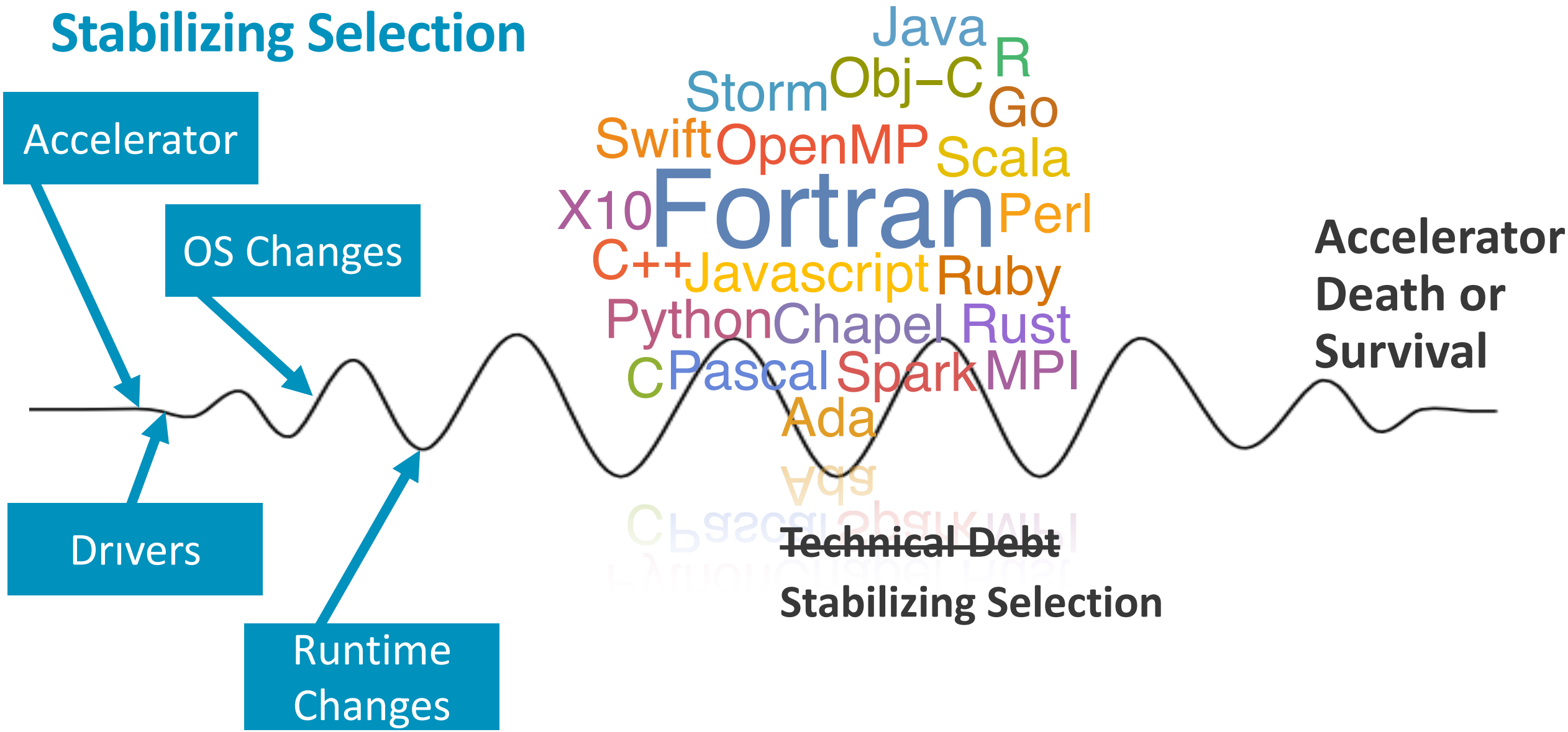
Stabilizing Selection



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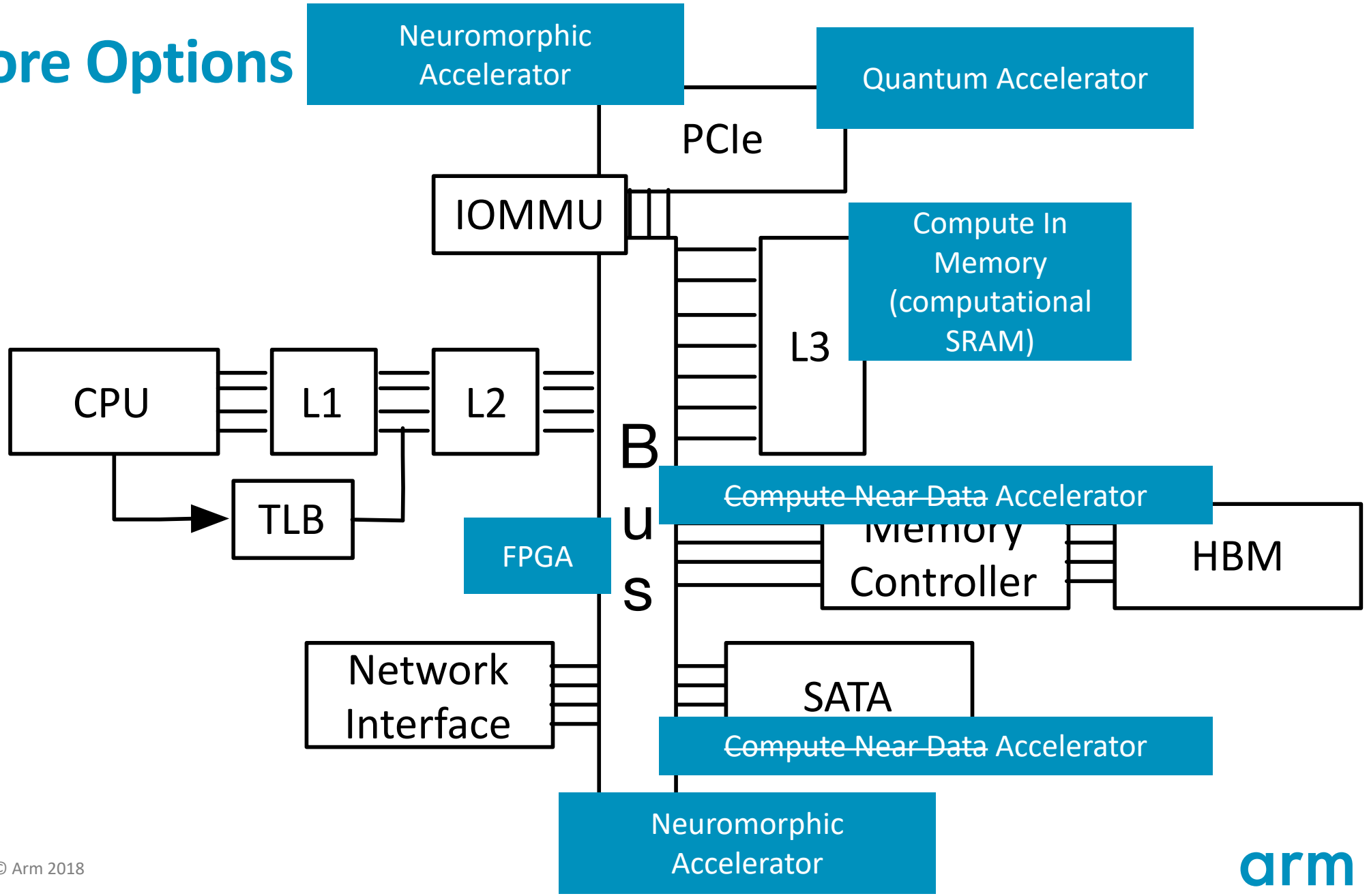
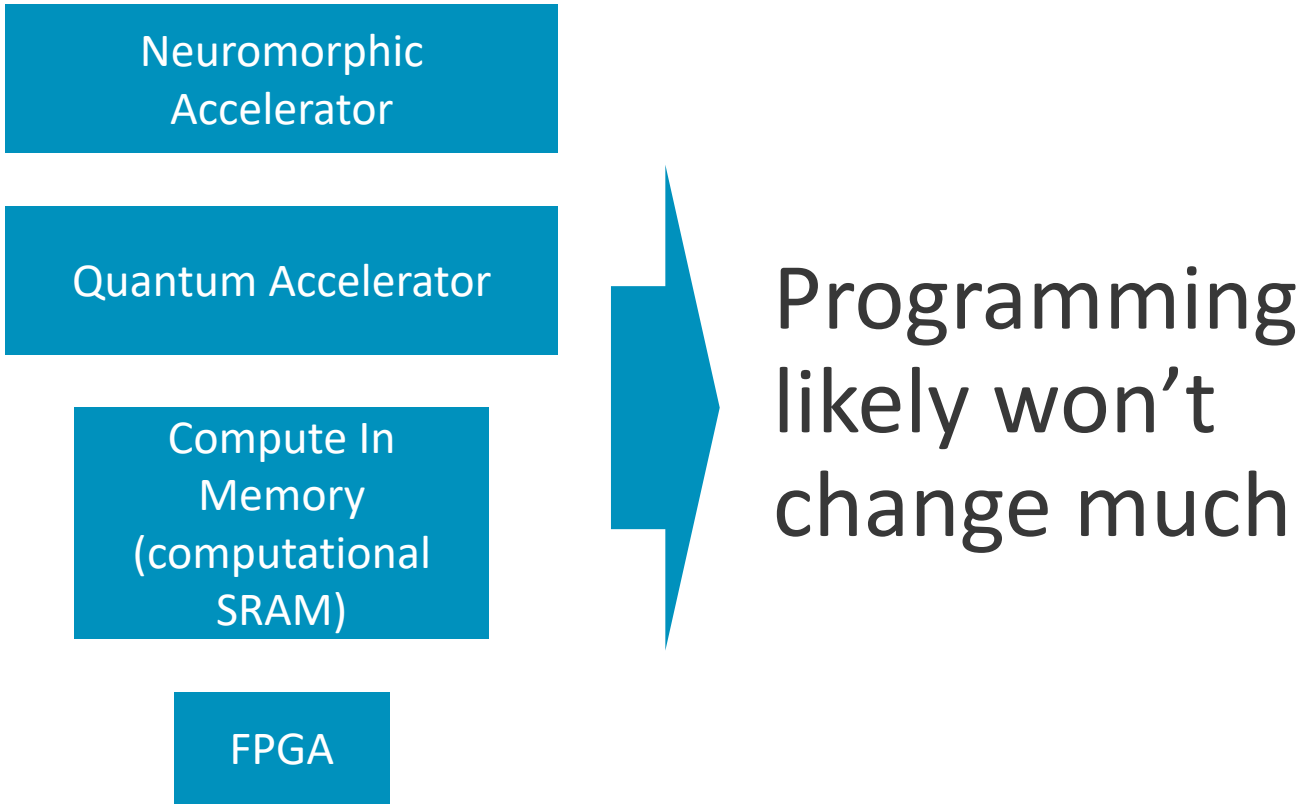
Post-Moore Options



Some disruption will minimize itself

- Stabilizing selection (technical debt)
  - Keeps rapid oscillations in hardware stack under control
  - Convergent evolution driven by software to hardware will drive similar solutions from multiple vendors (also potentially a bad thing…)
- How do we minimize cost of evolutionary changes while maximizing ability to introduce variation?



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Natural Selection

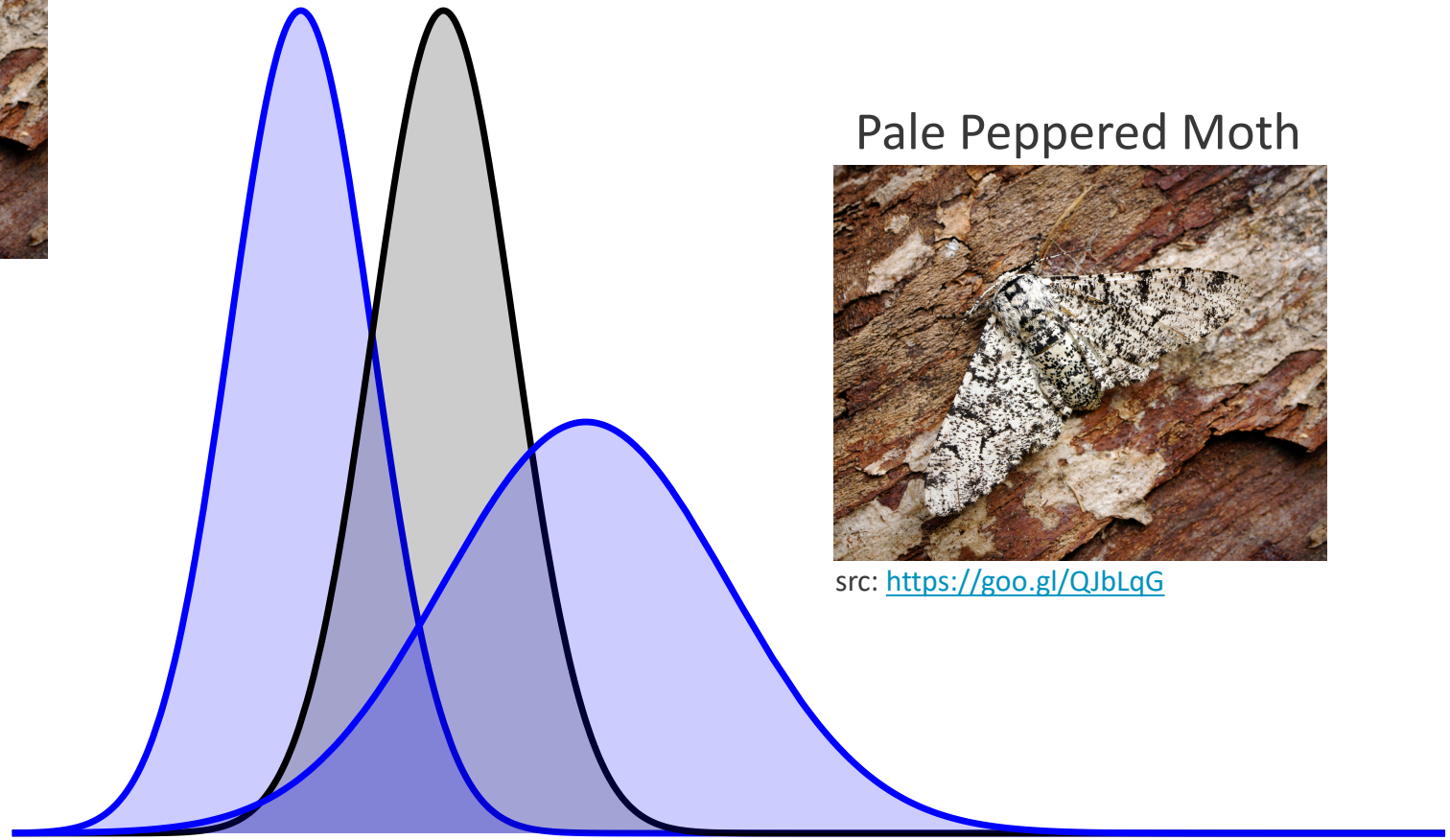
Pale Peppered Moth

src: https://goo.gl/QJbLqG

~~Pale~~ Peppered Moth

src: https://goo.gl/1BBZVG

src: https://goo.gl/yna3tH



Pale Peppered Moth

src: https://goo.gl/QJbLqG

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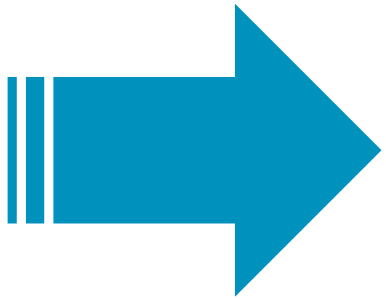
How to minimize disruption

~~Pale~~ Peppered Moth

src: https://goo.gl/1BBZVG

Pale Peppered Moth

src: https://goo.gl/QJbLqG



Moth…..

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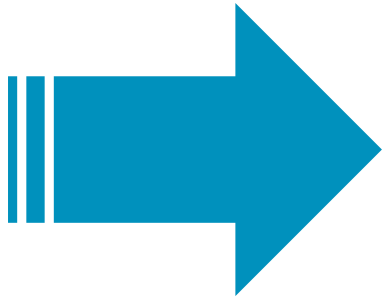
How to minimize disruption

Stable Digital Core

src: https://goo.gl/1dQoCZ



Neuromorphic Accelerator

src: https://goo.gl/1dQoCZ

FPGA

src: https://goo.gl/1dQoCZ

Quantum Accelerator

src: https://goo.gl/1dQoCZ

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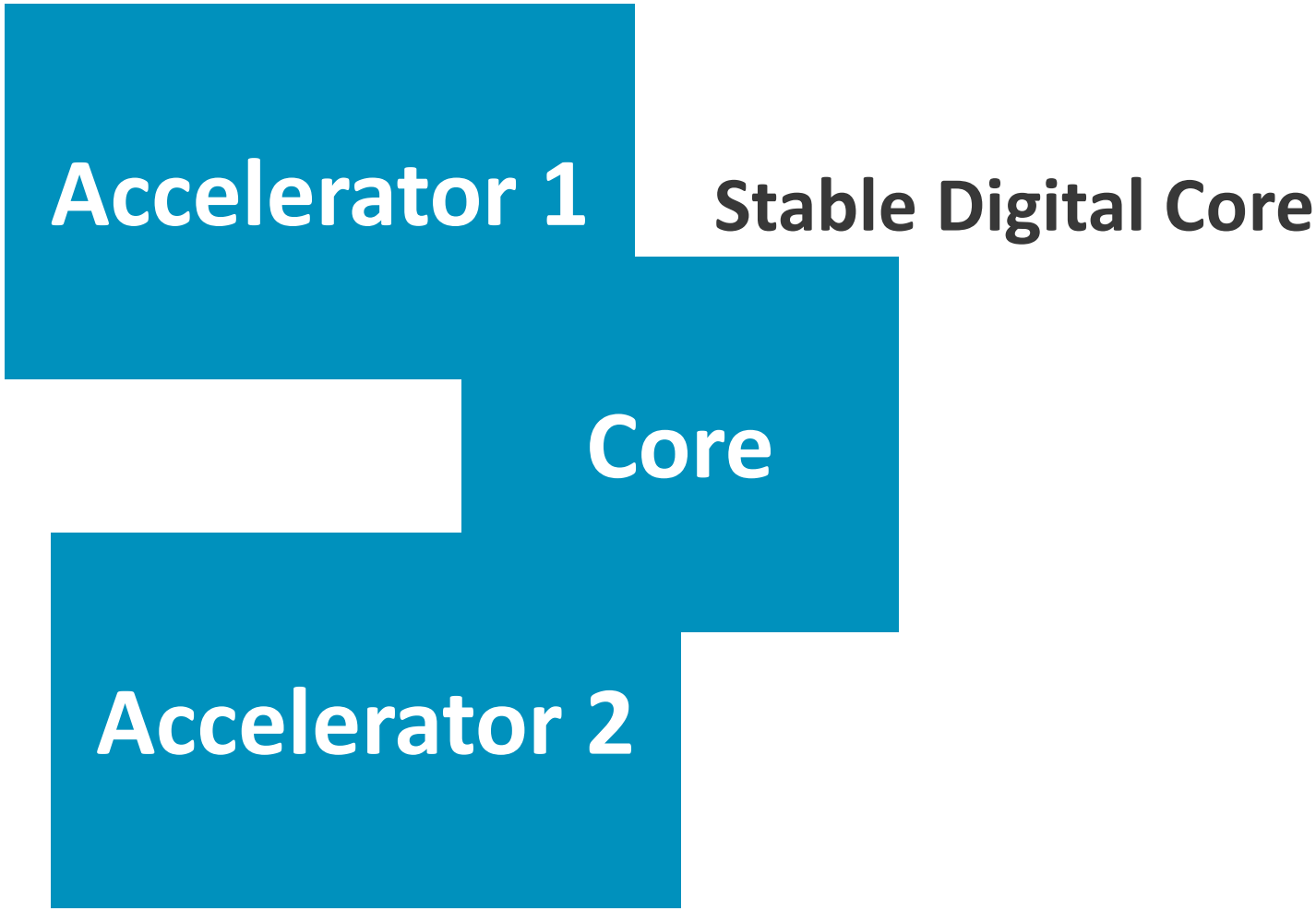
Common core: multi-part chip



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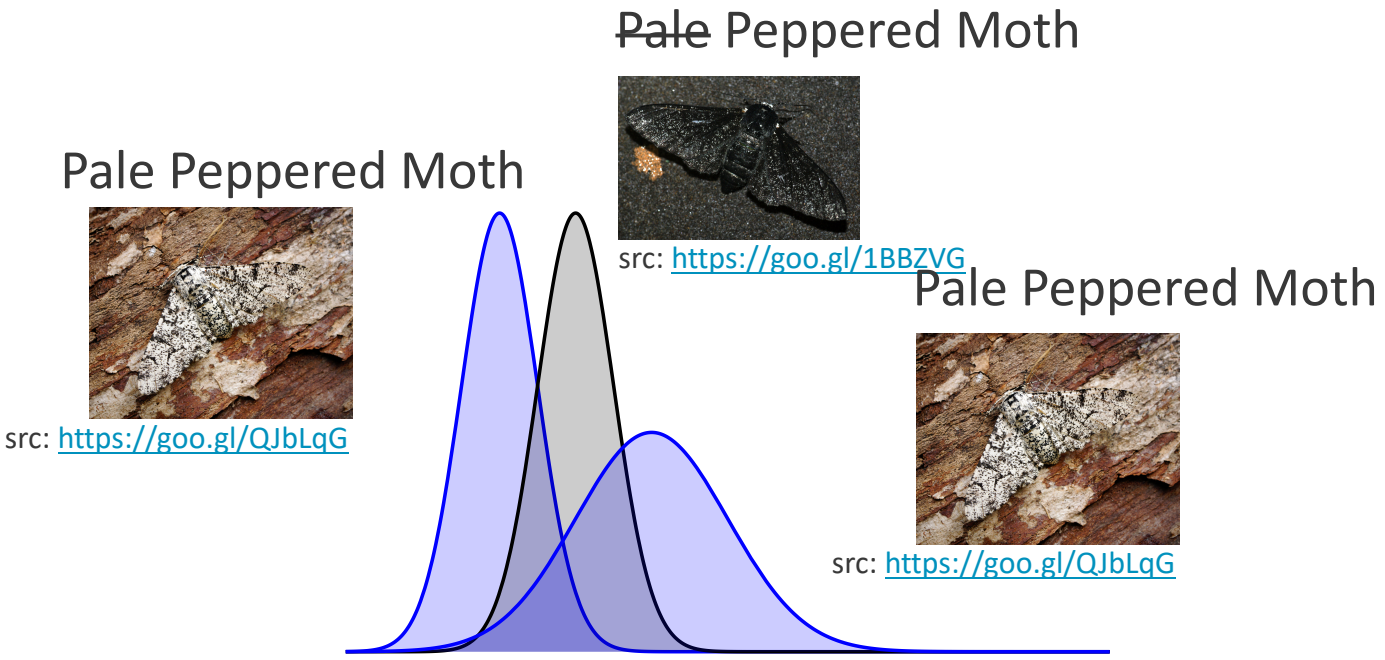
Minimize the cost of being eaten

- Enable faster integration of accelerators
- Enable easier integration of new memory technologies
- Enable code to run on multiple architectures more transparently
- Streamline virtual memory and security so accelerators are included natively
- Minimize data movement (tomorrow's talk)
- **Most importantly: re-enable portability**



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Folding (a.k.a. Manual Virtual Memory)

- Virtual memory started b/c of lack of available memory vs. storage
- Programmers wrote code that manually folded/unfolded to storage
- Huge controversy existed b/c all code at the time was written this way – Automatic folding hardware was ~25% slower than manual folding

"In ceasing to expend energy (item 1) **in a process whose main result is to make programs less fit to run on other machine configurations** (item 2), or **to run in company with other programs** (item 3), or to **run with temporarily reduced resources** (item 4), we do more than reduce costs; **we remove self-created obstacles** which today are impeding the development of needed types of systems"

- D. Sayre, IBM Yorktown Research (1969)

1970 - The Circle of Tech - “Self Created Obstacles”

Move In

Move Out

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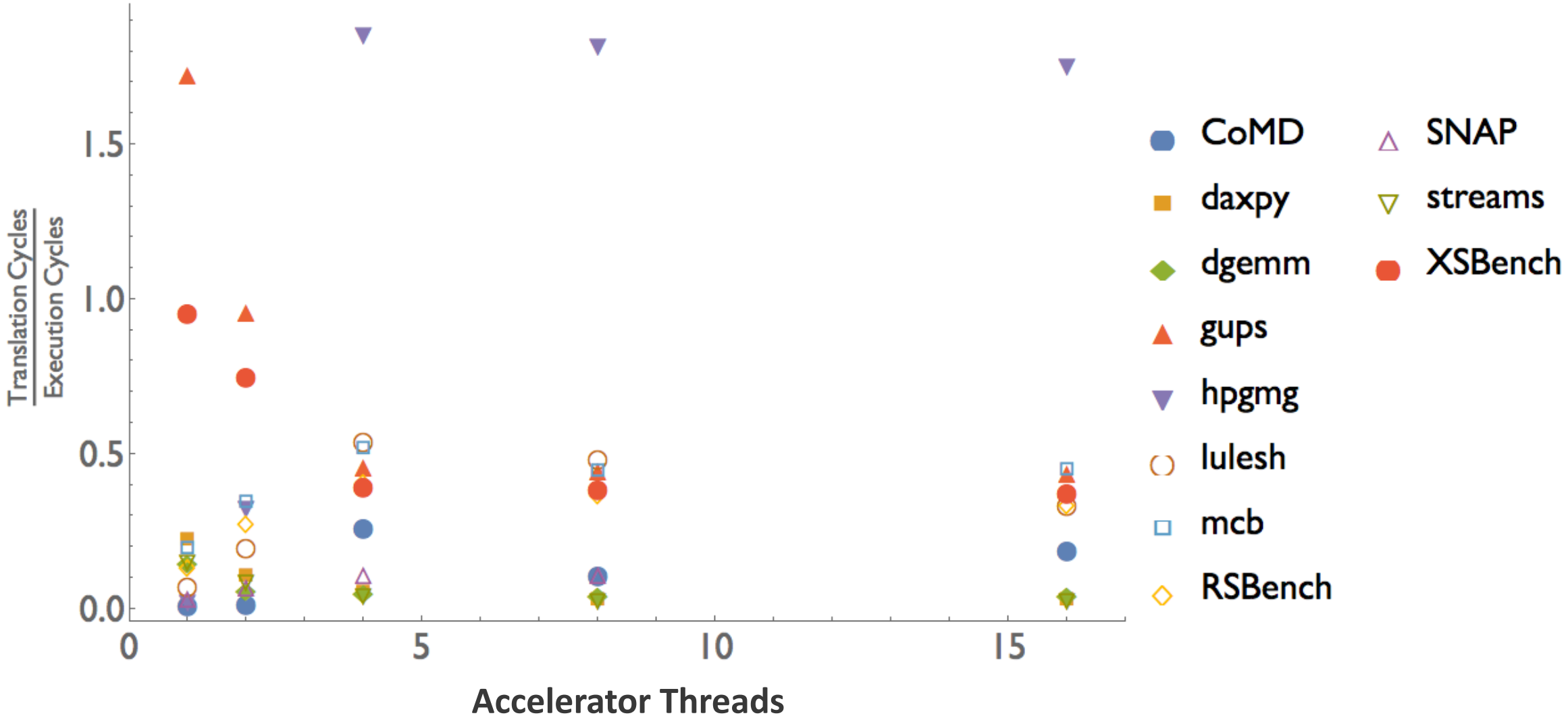
Constraining force: cost of extending virtual memory



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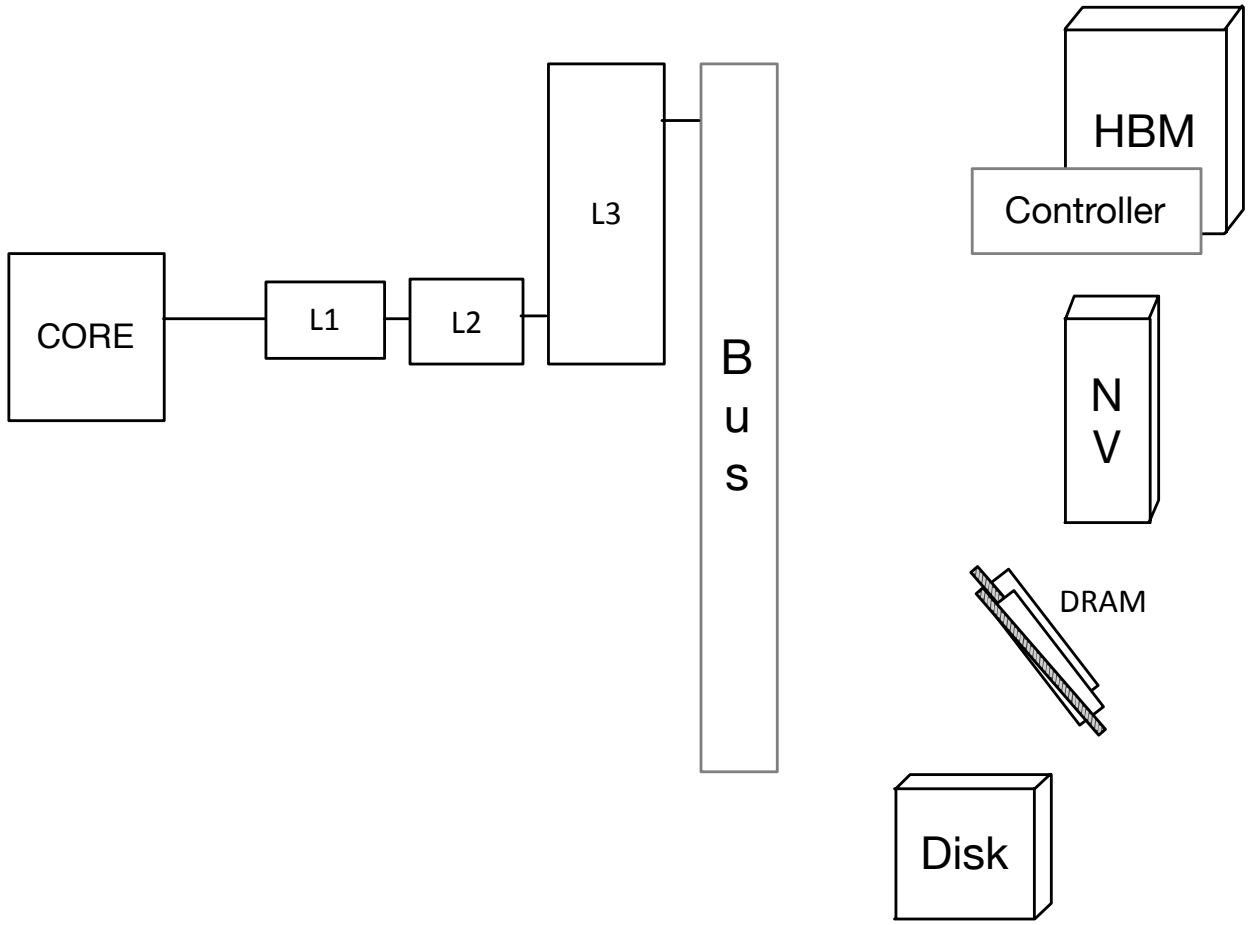
Memory Interface

Software Interface —?— Hardware Interface

- New memory technologies are perpetually 5 years out.
- Except when they're not.
- On the horizon, NV (various flavors), higher bandwidth DRAMs….How to interface with?



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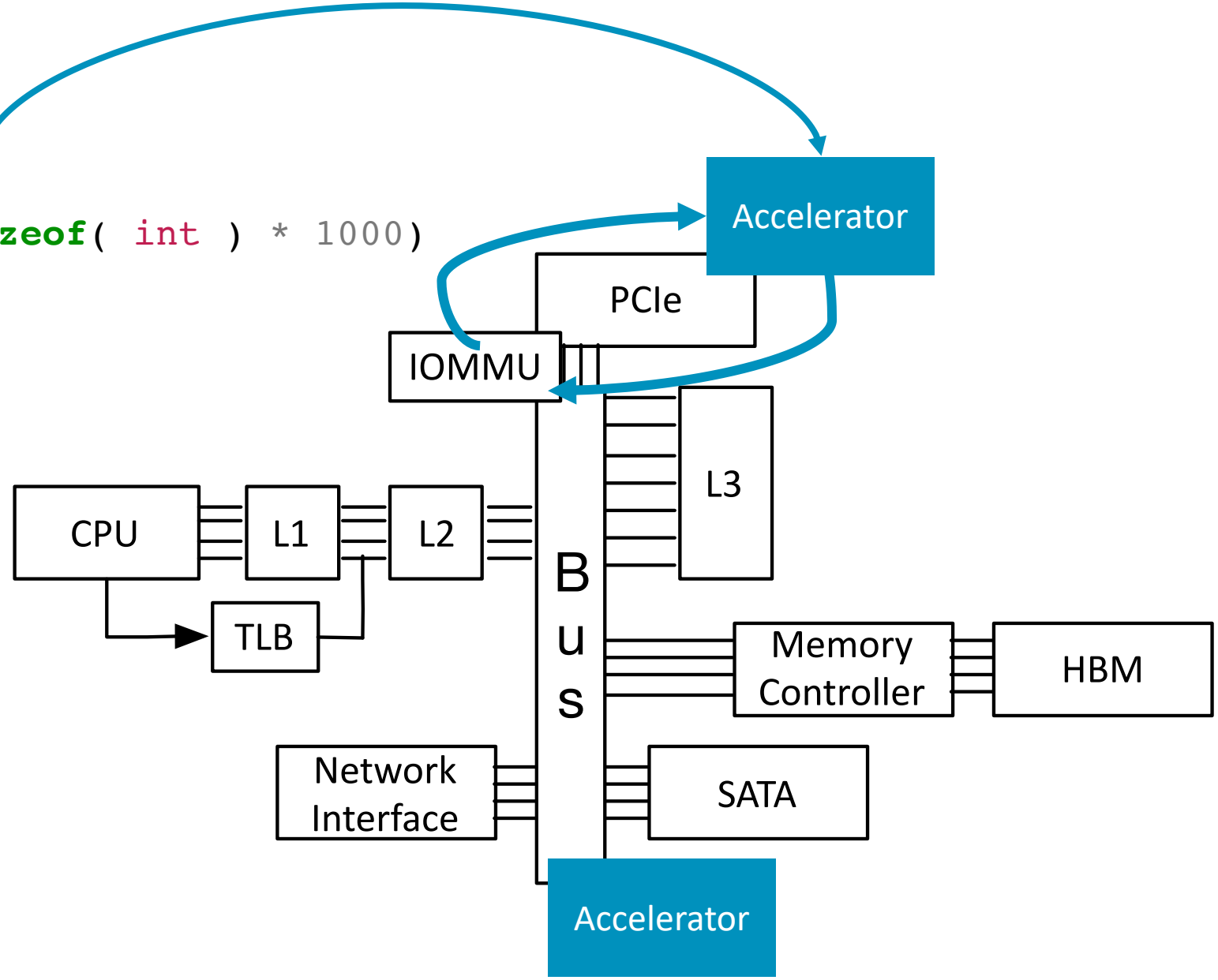
Virtual Memory

```
auto *foo(
        (int*) malloc( sizeof( int ) * 1000)
    );
```

- Plug accelerators into VA space as 1st class citizens.
- Can hide underlying memory interface
- We must develop a better virtual memory that accepts accelerators more easily.
- CCIX, GenZ, etc. are a step forward
- Co-design needed for further dev



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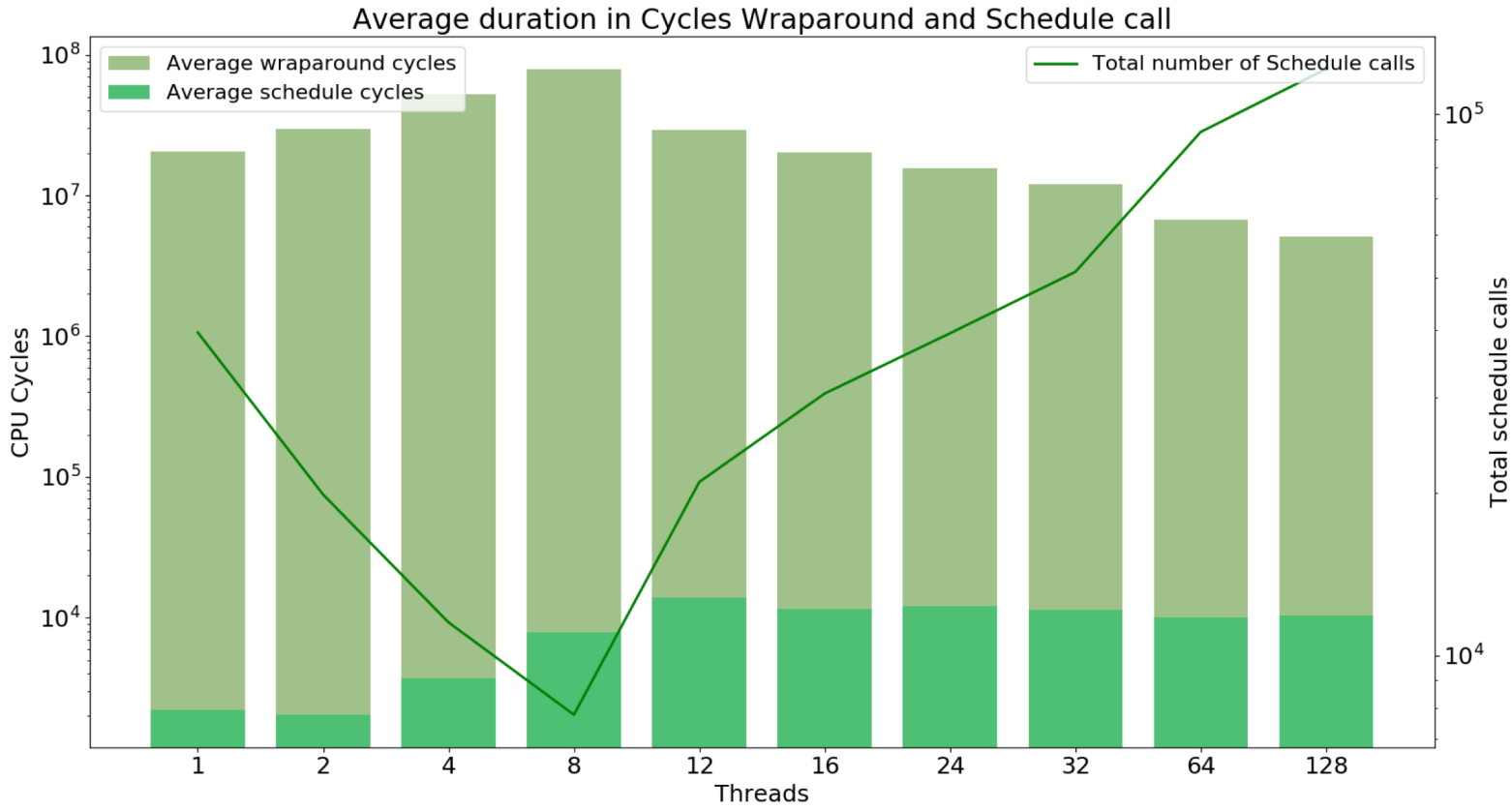
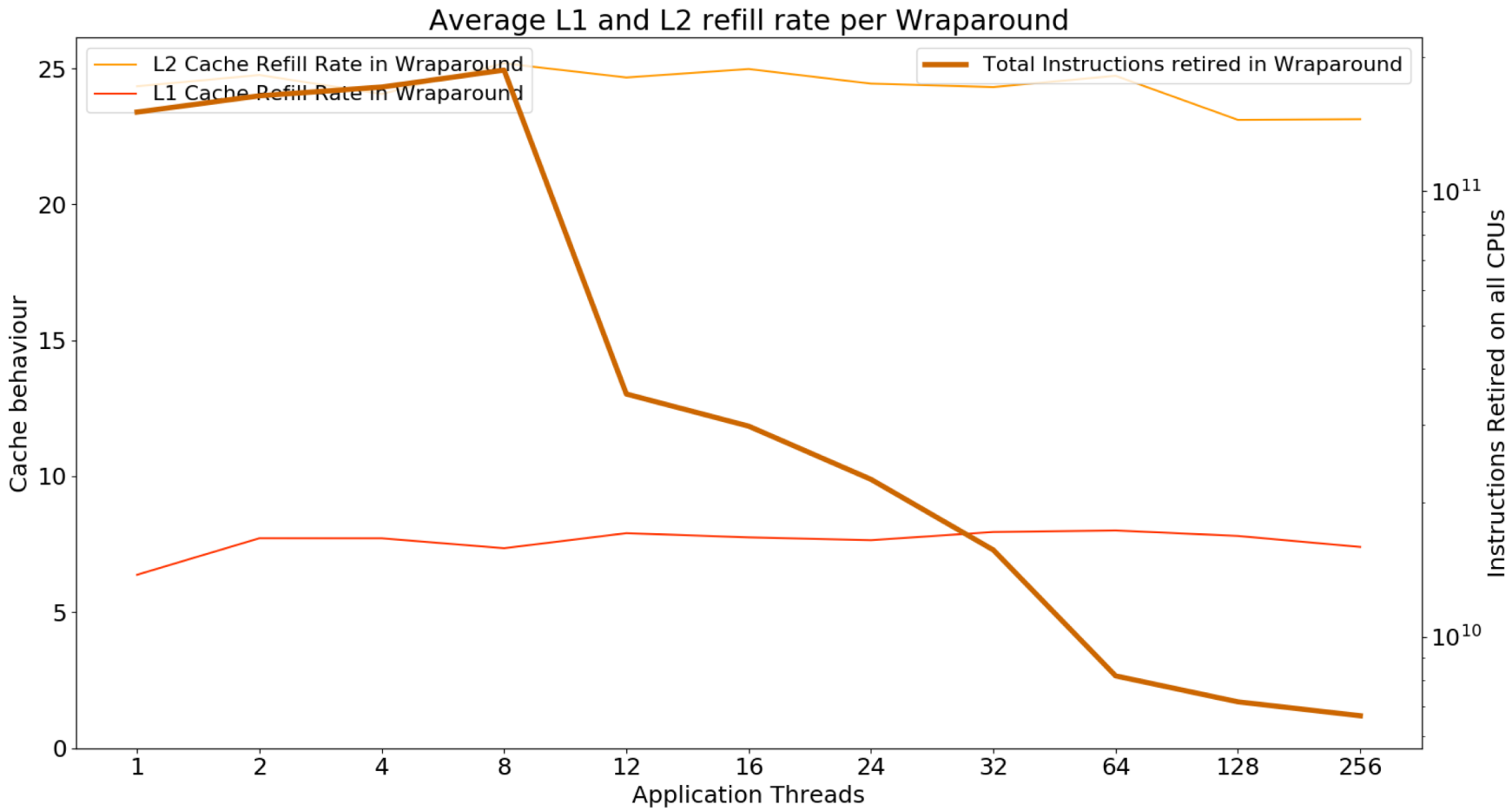
Example: current context swap behavior

- Newer NV tech enables access in 100-2000 cycle range
- Reduce context swap overhead (currently Linux overhead for swap is 2000—5000 cycles) to enable hiding of intermediate latencies.



Secondary context swap behavior

- Future systems must reduce data movement cost
- Current overhead is relatively constant for swap, directly impacts application performance



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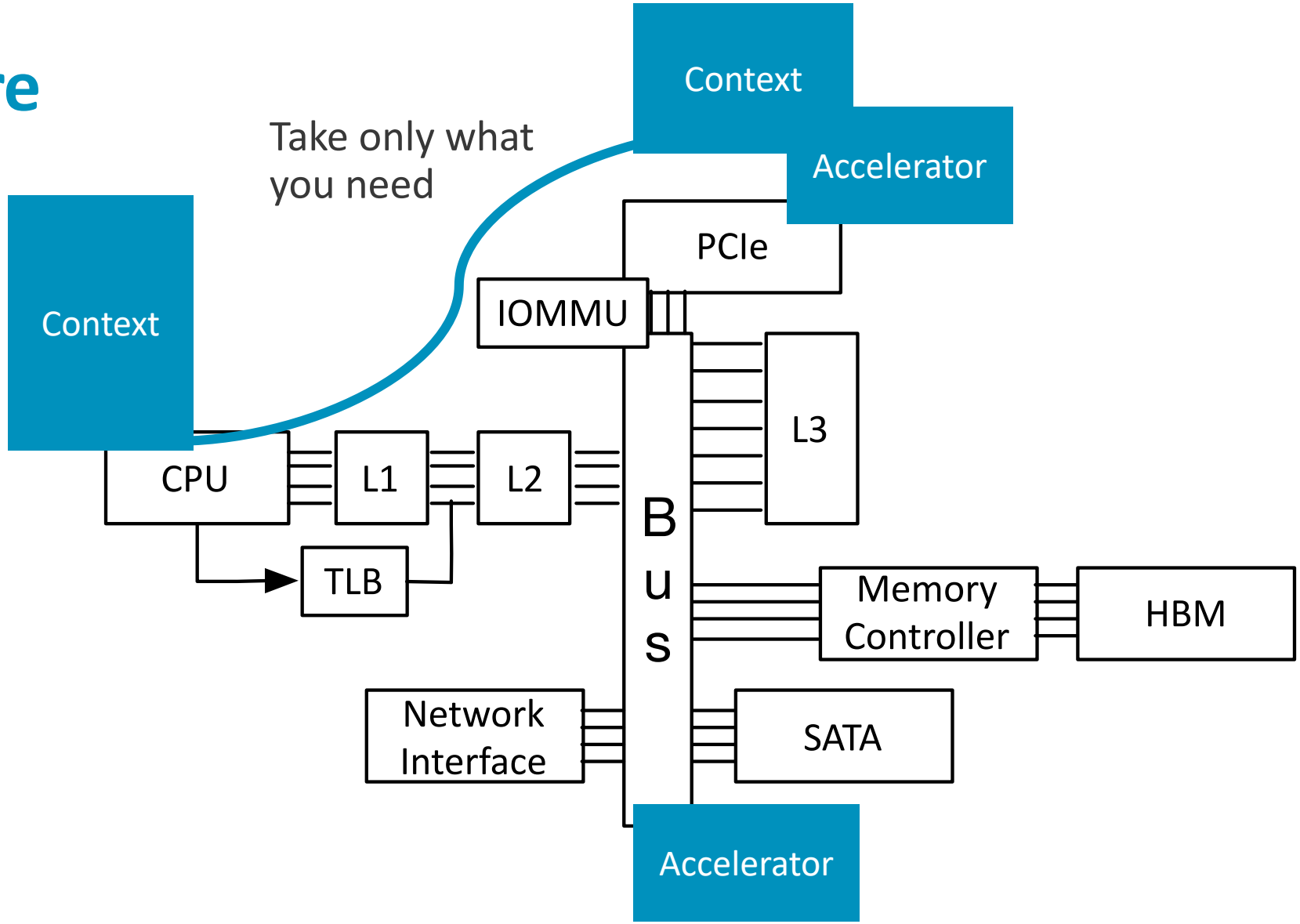
Context Architecture

- Reduce/remove drivers from accelerator offload mechanism
  - Enable standardized exception formats
  - Enable simple state transference.



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Conclusion

- We will see some serious attempts at disruption over next 5—20 years
- Many disruption will die quickly b/c of our technical debt
- Providing a better hardware/software abstraction can enable faster evolution while reducing destabilizing impact to software of technology disruption.
- Better interfaces are needed for:
  - Virtual memory
  - Context migration
  - Exception handling
- Slides will be available at: http://www.jonathanbeard.io/media
- Feel free to Tweet me @jonathan_beard
- Thanks for listening!