

# The Decline of Computers as a General Purpose Technology

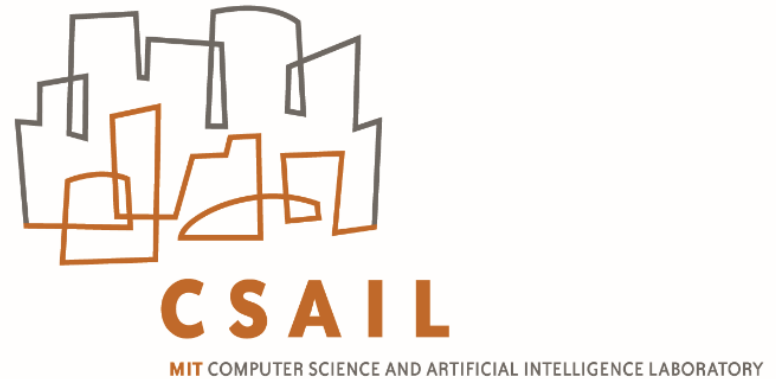
(Joint with Svenja Spanuth)



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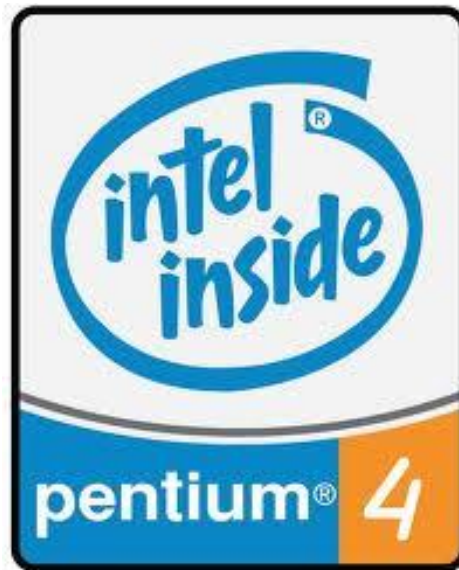
Technology and Declining Economic Dynamism Conference  
September 2020

# Context

- **History:** A large share of productivity improvement has come from:
  - Semiconductor industry
  - Implementations of I.T.
- **Declining Dynamism:** As Moore's Law comes to end (2004 – today) there has been a dramatic slowdown in computing progress
  - From doubling every 2 years to every 9
- **Asymmetric Effects:** The slowdown is fragmenting computing, making it less general purpose and decreasing the diffusion of its benefits



1985  
25 MHz



2002  
3 GHz

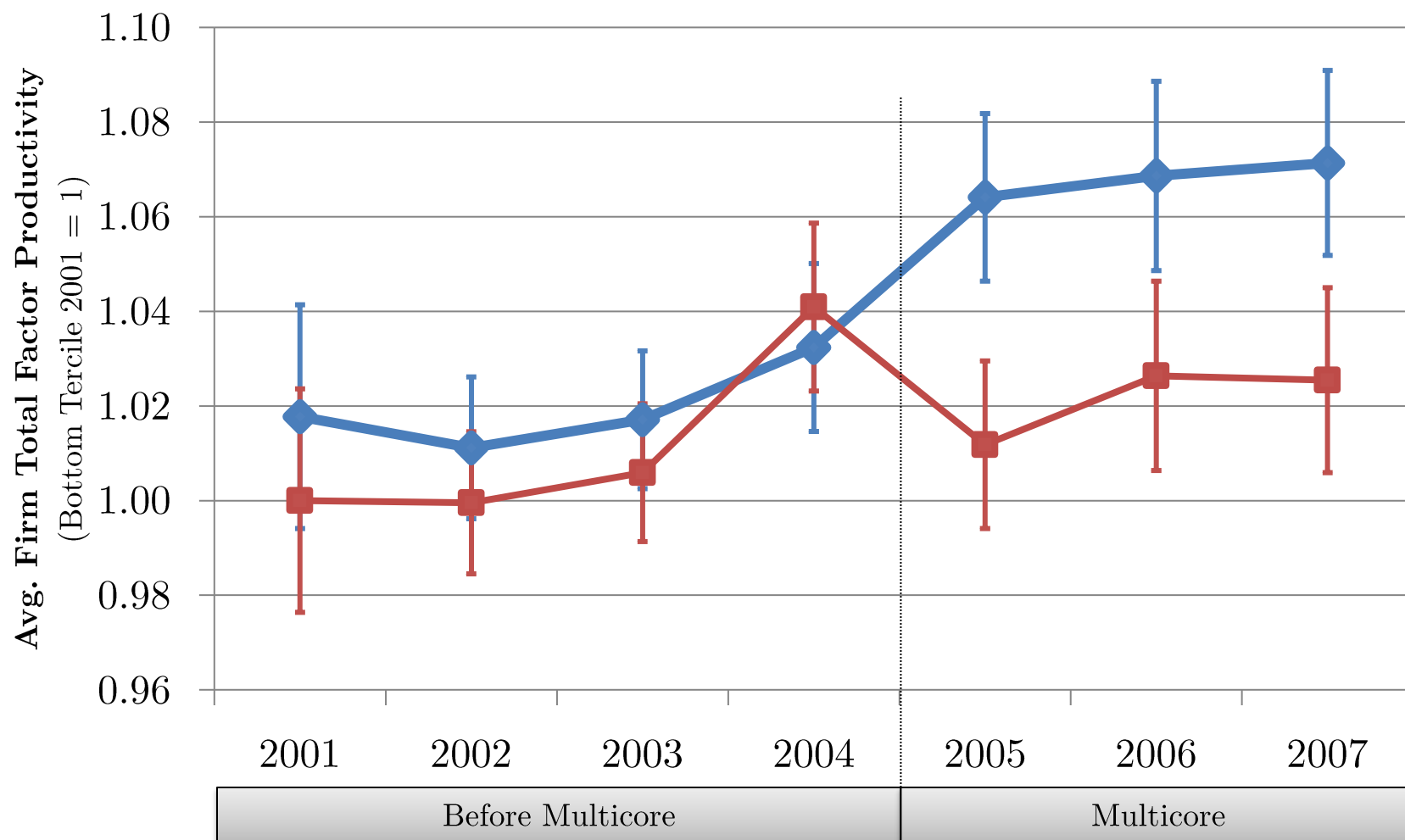


2018  
6 cores @ 4 GHz



2018  
~270 GHz

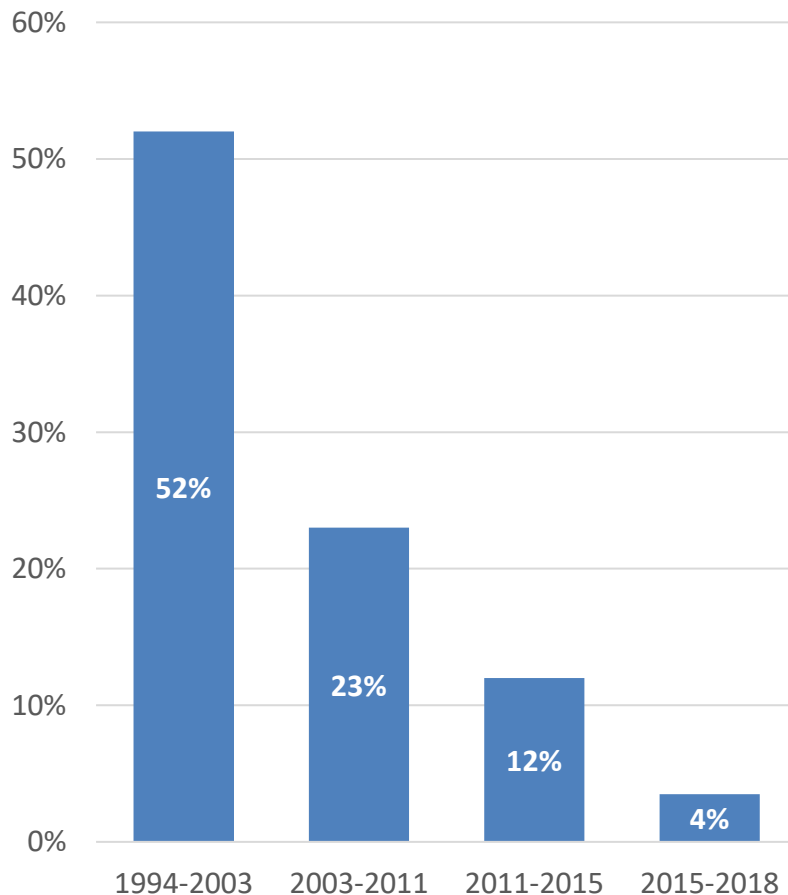
# Firm Total Factor Productivity (Thompson, 2017)



Note: bars represent 1 standard error

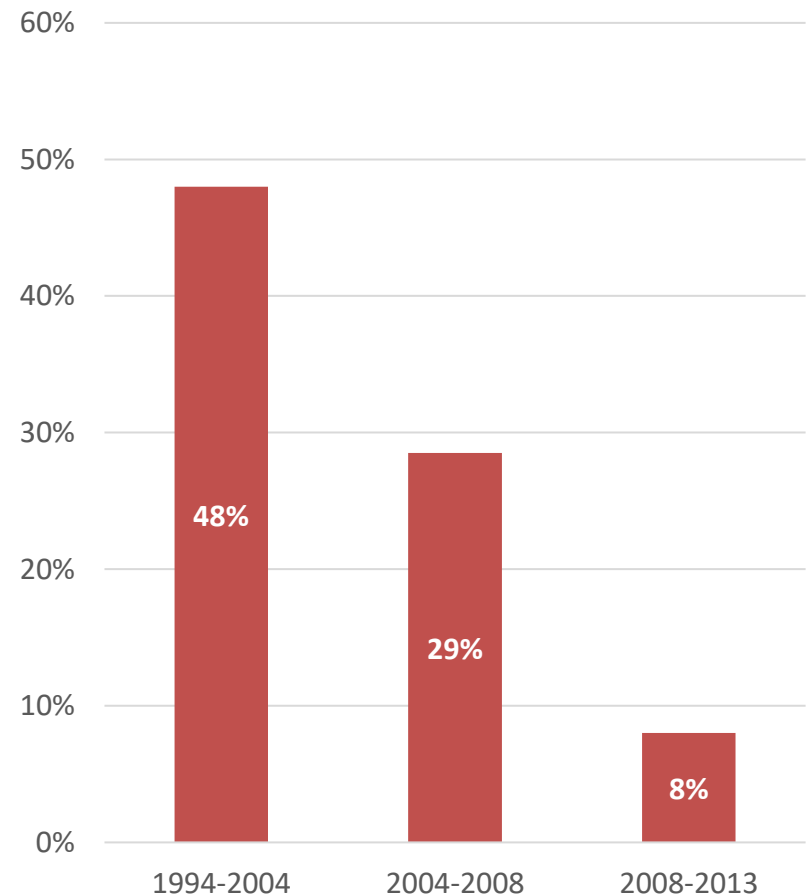
# Computing Performance Improvement is Slowing

Microprocessor performance improvement



**Source:** Computer Architecture, A Quantitative Approach by Hennessy and Patterson

Microprocessor performance improvement per dollar



**Source:** Bureau of Labor Statistics

# Implication:

## Need for expensive software redesign

STATA

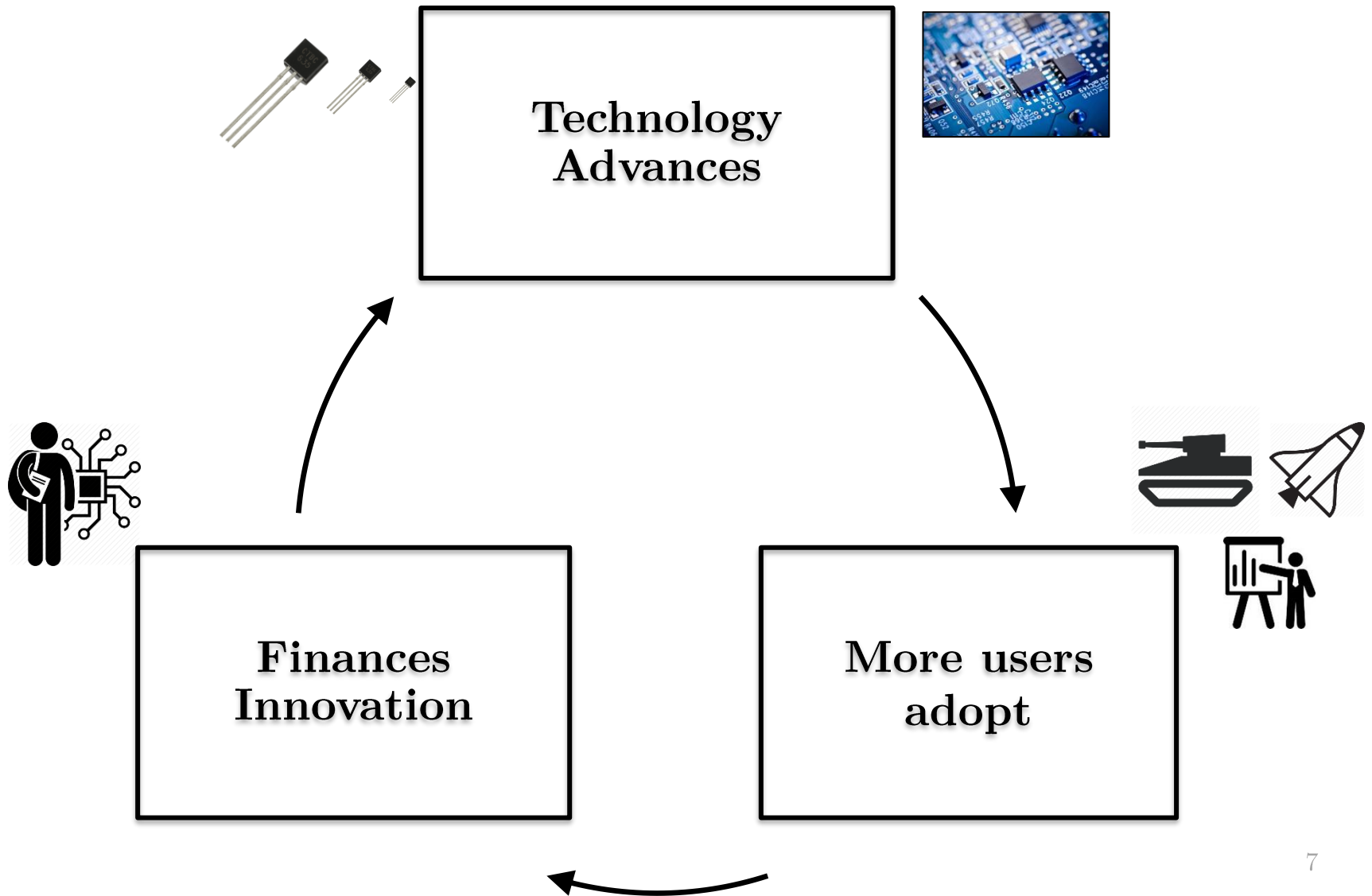


**Cost:** \$11/line of code

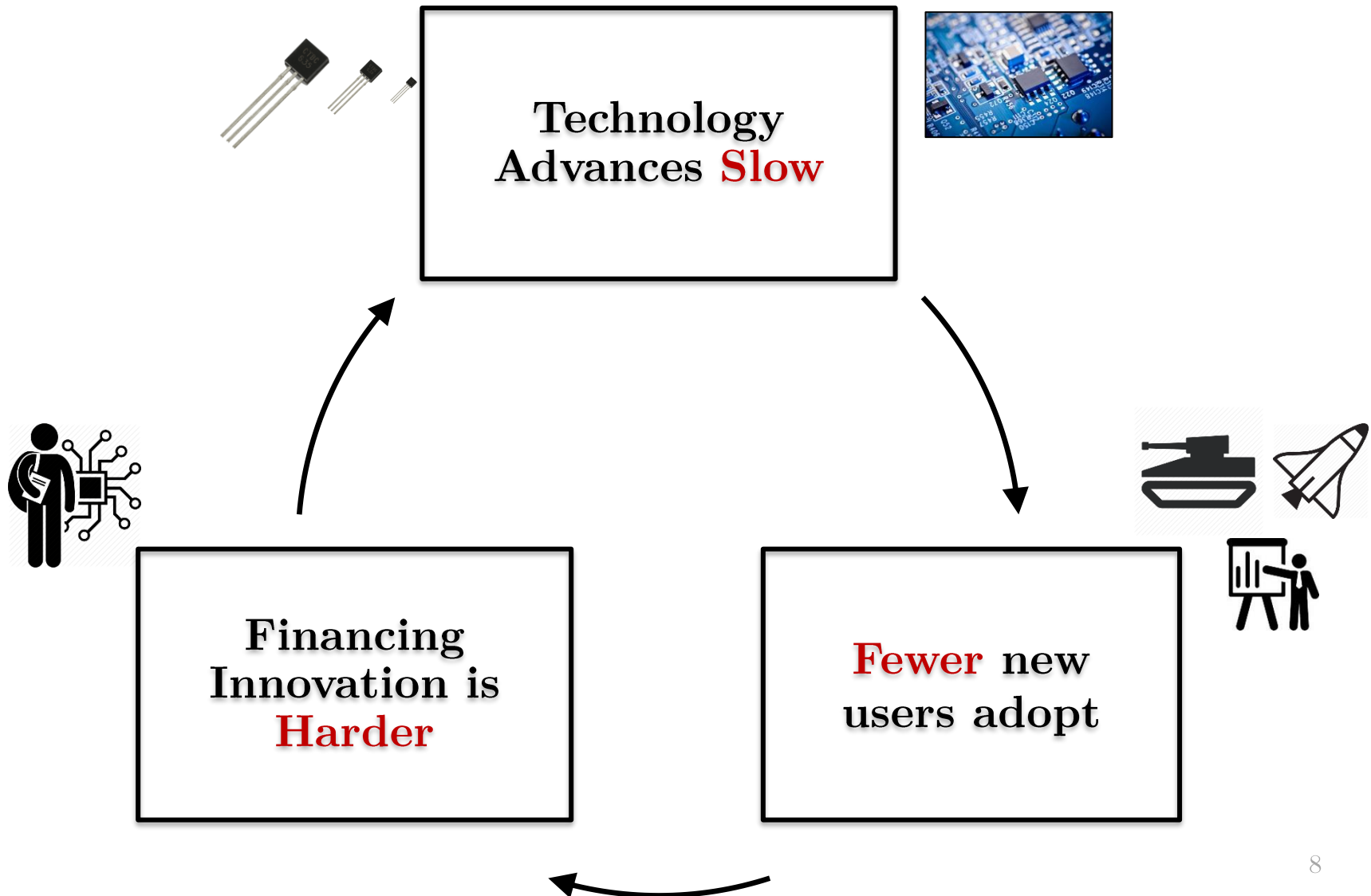
**Benefit:** Unclear, uncertain

# Virtuous Cycle of a General Purpose Technology

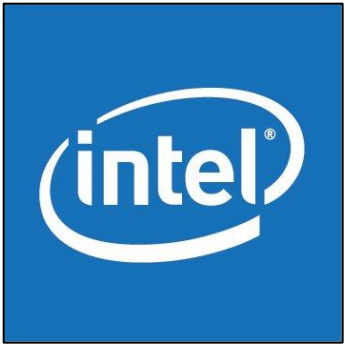
(Bresnahan and Trajtenberg, 1992)



# Fragmenting a General Purpose Technology



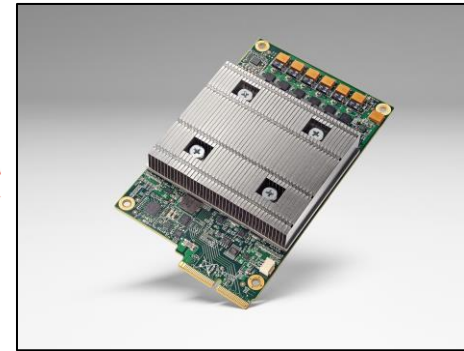
## Universal



Central Processing Unit  
(CPU)



## Specialized



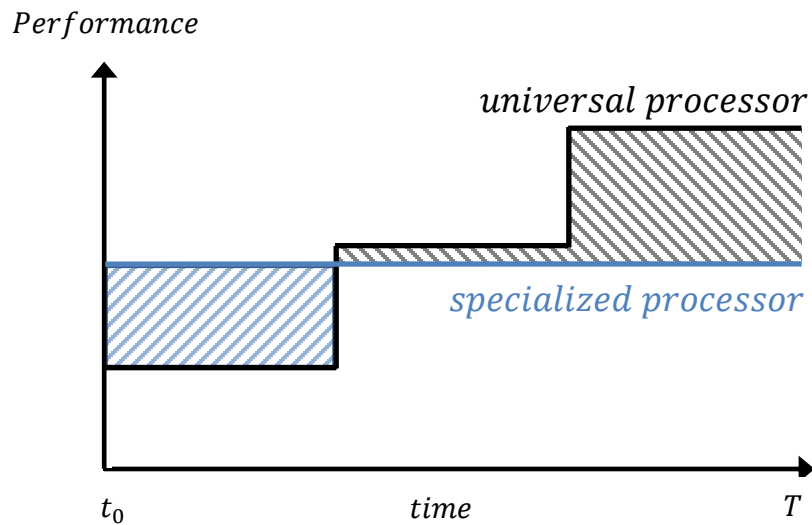
Tensor Processing Unit



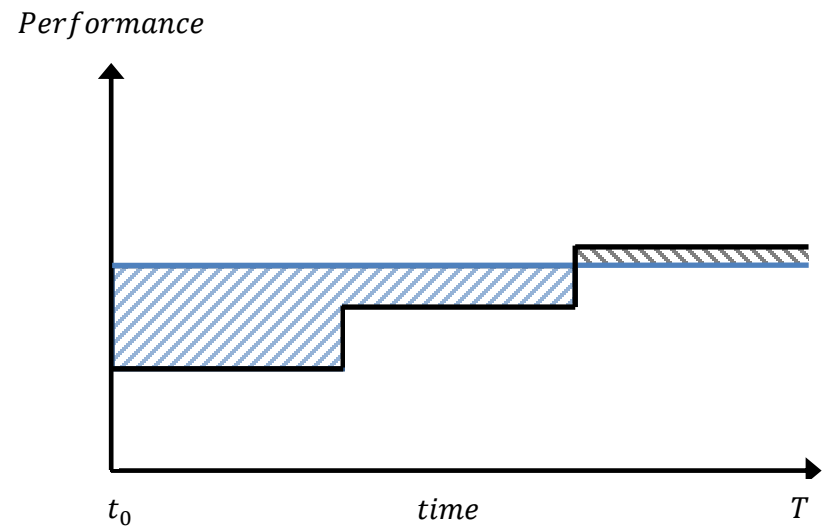
Cost: \$10Ms - \$100Ms

# Implications of Universal Processor Improvement Rates

Fast

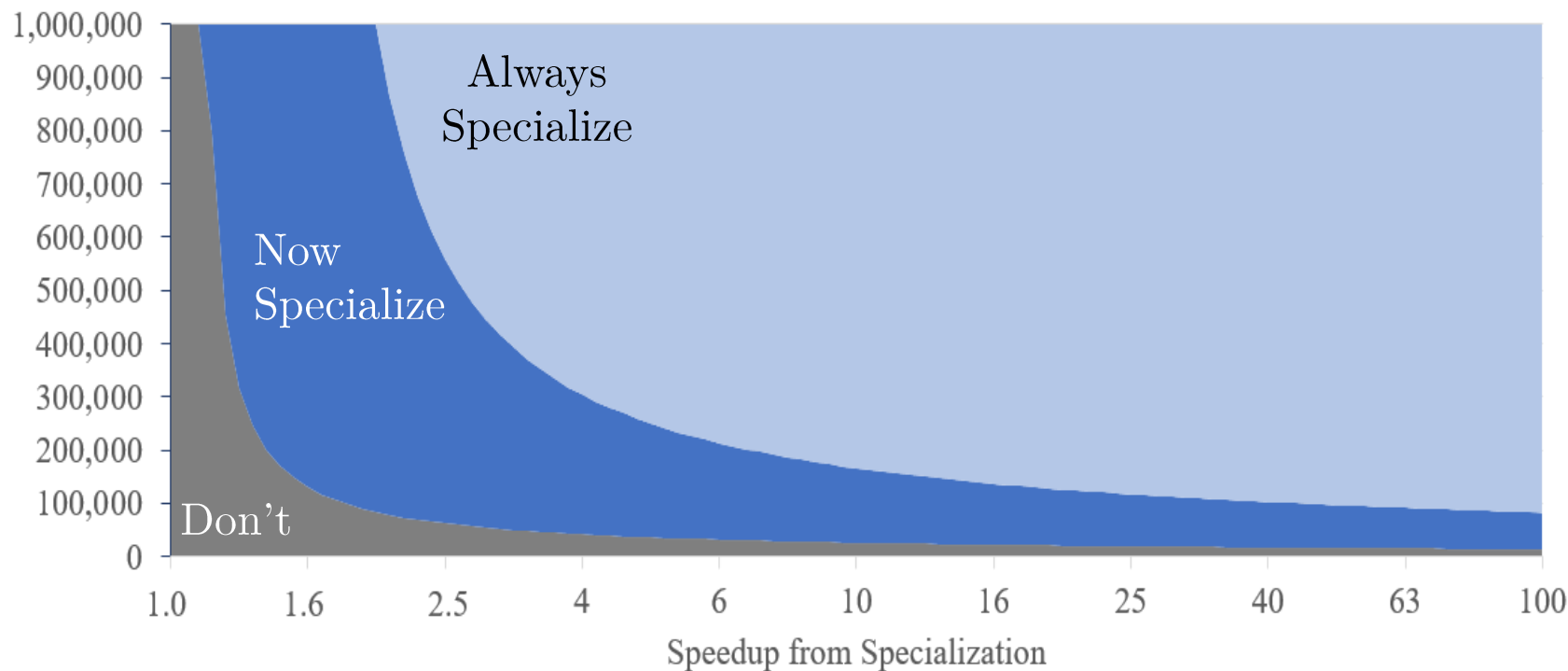


Slow



# Specialization is more attractive now that CPUs are improving slowly

Volume needed to be worth designing a specialized chip



CPU ↑ @48%/y  
CPU ↑ @8%/y

2x
1,000,000
81,000

10x
167,000
27,000

Summit  
Supercomputer uses  
this many specialized  
accelerators *itself!*

100x
83,000
15,000

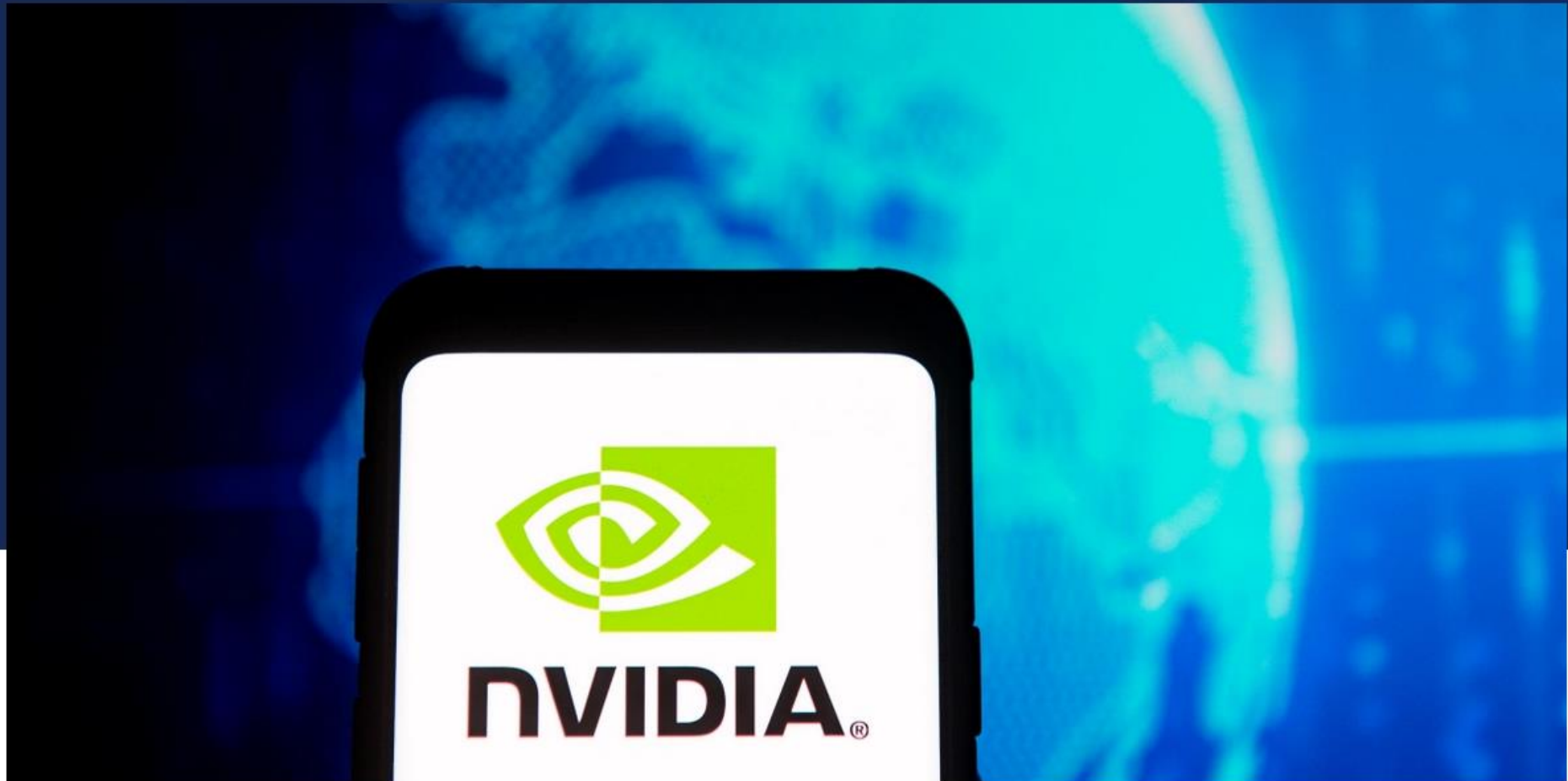
# Nvidia overtakes Intel as most valuable U.S. chipmaker

Reuters

July 10, 2020 2:43 AM

Enterprise

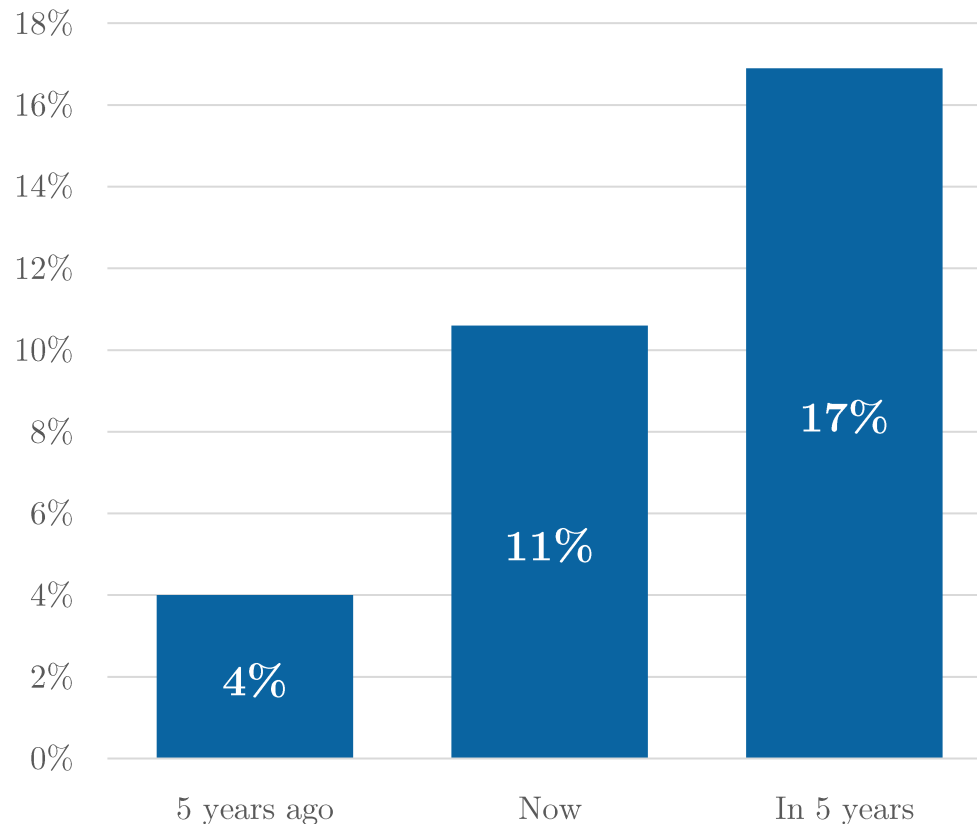
f t in



# Specialized Chip Usage

(Survey of Advanced U.S. Computing Users)

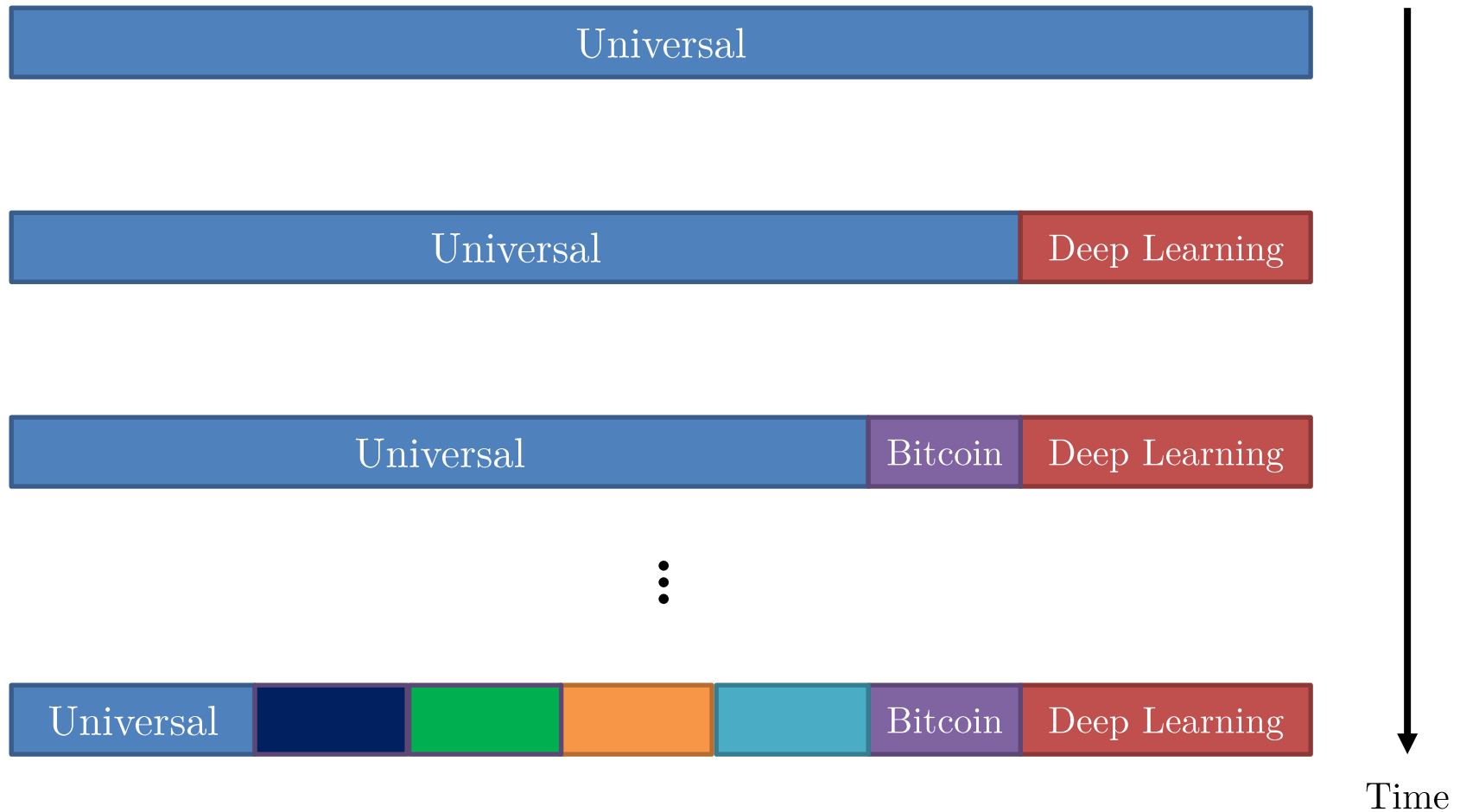
## Share of Computing



## % of Developer Workforce (Median Organization)

- 1-5% Designing new specialized chips
- 6-10% Re-engineering software for specialized chips
- 6-10% Re-engineering software for parallelism

# Computing is Fragmenting



# Implication:

## Old Model:

Rising Tide lifts all Boats



## New Model:

Fast and Slow Lane



# Summary

- The end of Moore's Law is providing a widespread negative shock to I.T. productivity
  - Requires software investment to take advantage of multicore
- The slowdown in general purpose chips has made specialized chips more attractive
  - Creates a new barrier to entry to using I.T. effectively
  - Cost of specialized chips is *rising*, which will make this effect stronger
- As computing fragments, the diffusion of benefits that come from Computers being GPTs will continue to fall

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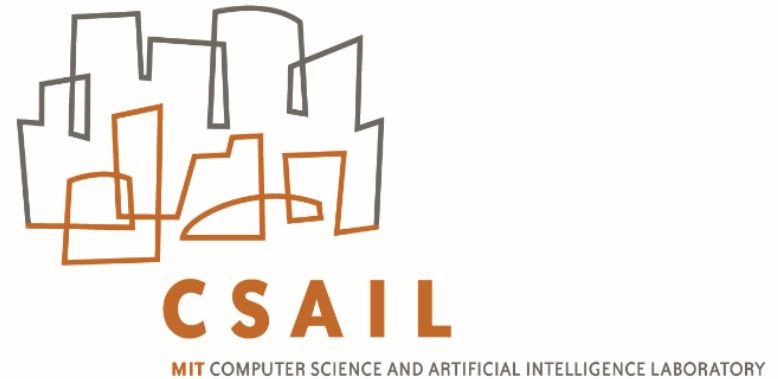
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