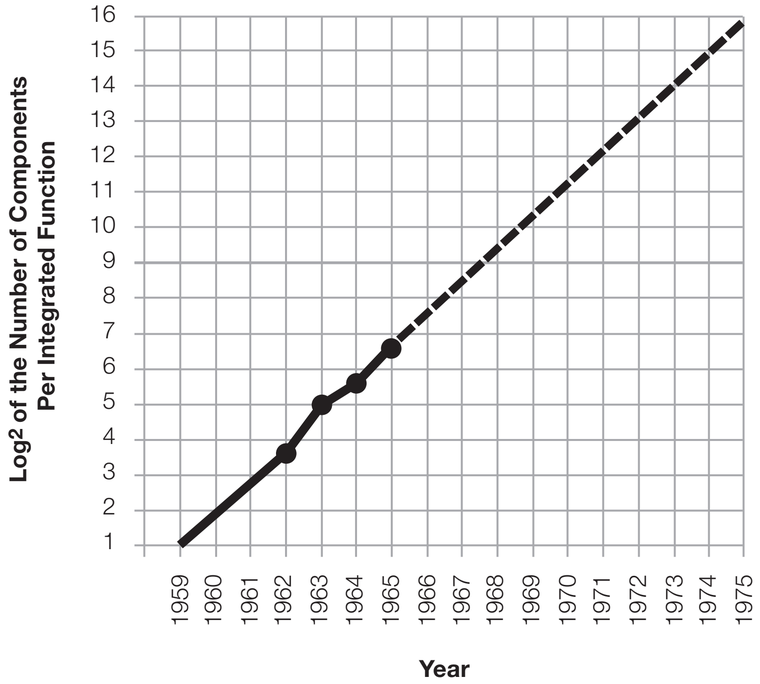
Challenges and Limitations

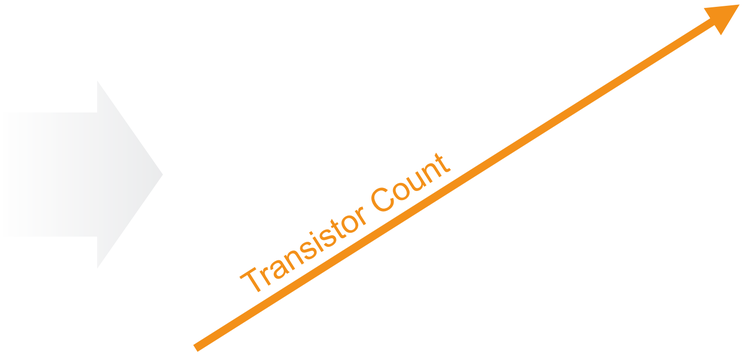
- What changes in the environment are affecting systems programs?
  - The end of Moore's law
  - Increasing concurrency – imposed due to hardware changes
  - Increasing need for security – the Internet
  - Increasing mobility and connectivity

Colin Perkins | https://csperkins.org/ | Copyright © 2020 University of Glasgow

The End of Moore's Law (1/2): Physical Limits



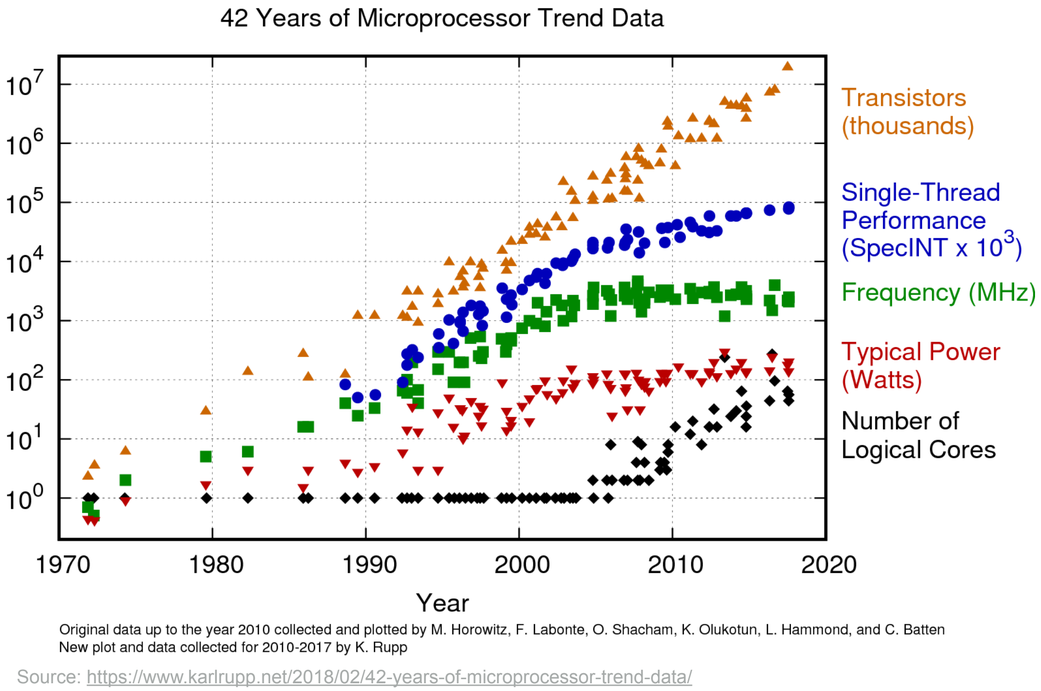
Source: Gordon Moore, "Cramming more components onto integrated circuits", Electronics, Vol. 38, Num. 5, April 1965.



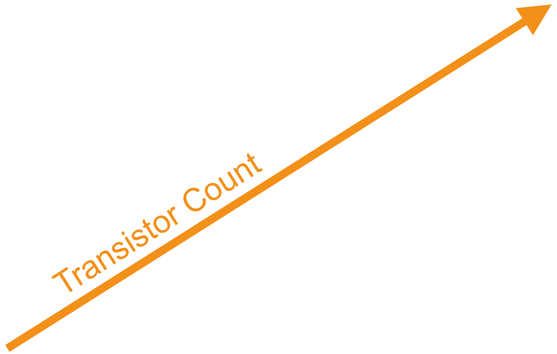
- Moore's law: advances in manufacturing double transistor count every two years

Colin Perkins | https://csperkins.org/ | Copyright © 2020 University of Glasgow

The End of Moore's Law (1/2): Physical Limits



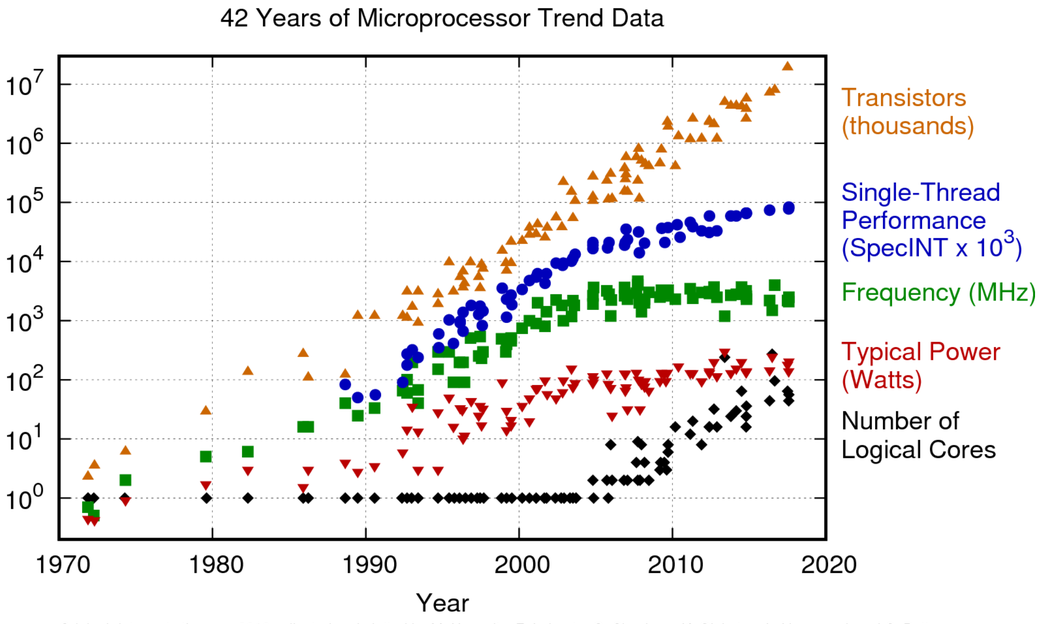
Source: https://www.karlrupp.net/2018/02/42-years-of-microprocessor-trend-data/



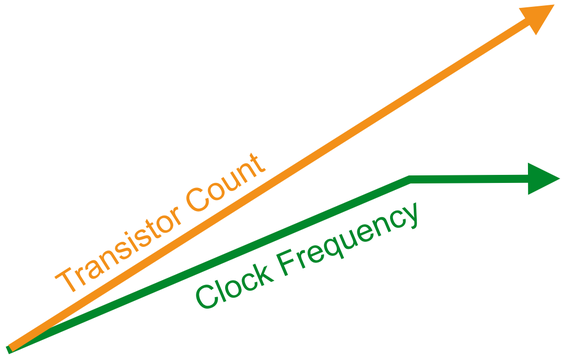
- Moore's law: advances in manufacturing double transistor count every two years
- But, rapidly approaching physical limits:
  - 10nm process → features ~40 atoms across
  - Transistors *will* stop shrinking soon

Colin Perkins | https://csperkins.org/ | Copyright © 2020 University of Glasgow

The End of Moore's Law (2/2): Dennard Scaling



Source: https://www.karlrupp.net/2018/02/42-years-of-microprocessor-trend-data/



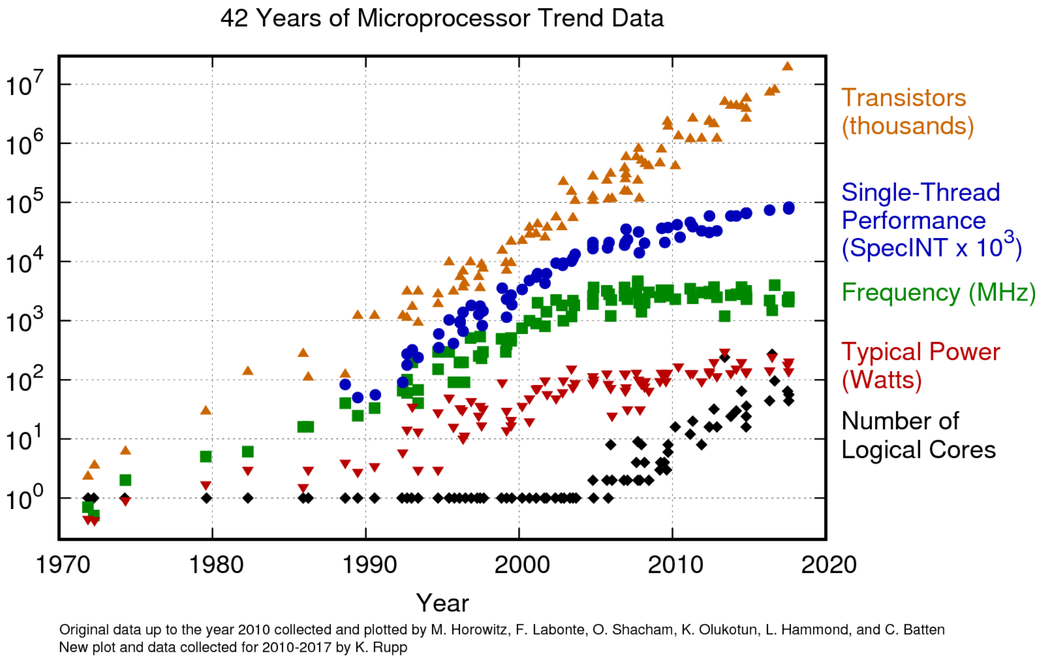
Power consumption $\propto C \cdot F \cdot V^2 + L$

- C = capacitance (transistor size)
- F = frequency (clock rate)
- V = voltage
- L = leakage

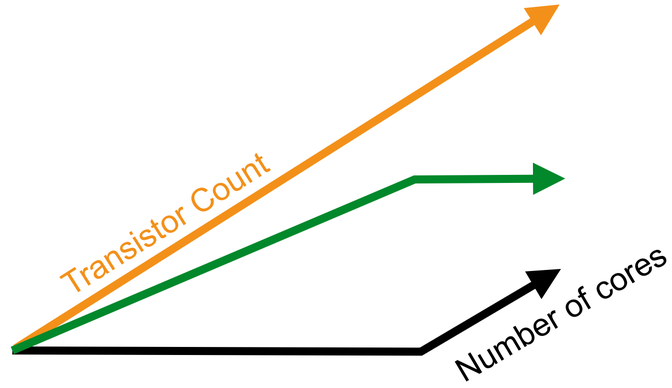
- Dennard scaling: smaller transistors reduce capacitance and voltage: frequency increase without increasing power consumption
- Scaling relation breaks down eventually, due to leakage, and clock frequency increase stalls

Colin Perkins | https://csperkins.org/ | Copyright © 2020 University of Glasgow

Increasing Concurrency



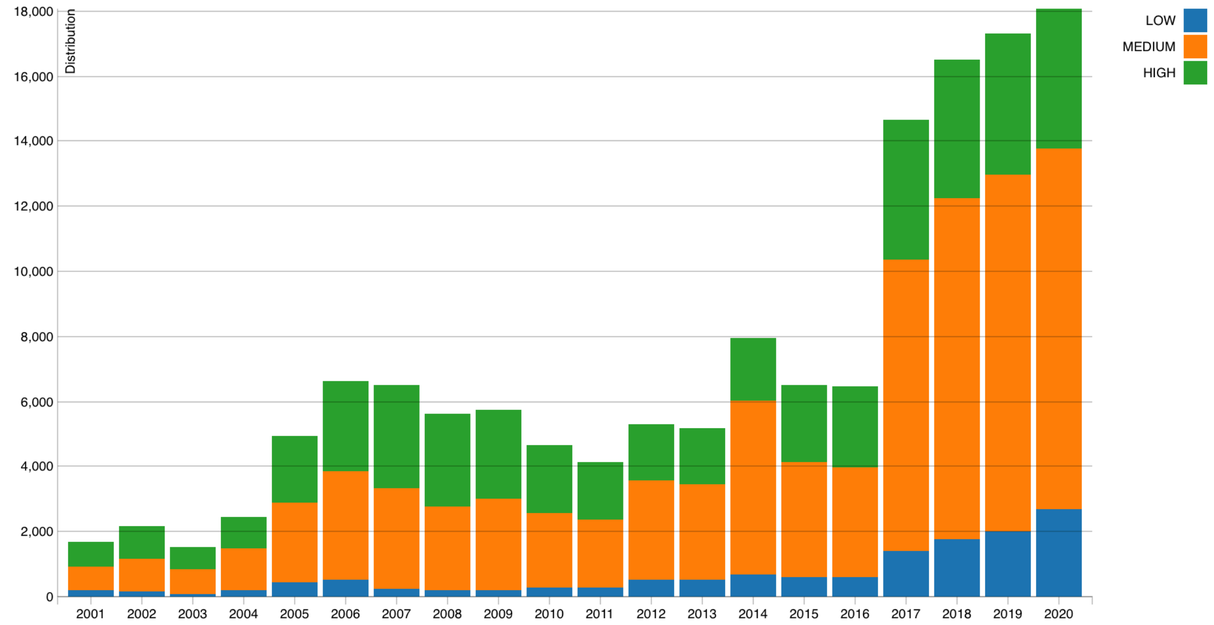
Source: https://www.karlrupp.net/2018/02/42-years-of-microprocessor-trend-data/



- Breakdown of Dennard scaling limits clock frequency, but Moore's law gives more transistors → used to increase number of cores
- Concurrency related problems become more severe:
  - Performance with correctness, avoiding race conditions and deadlocks

Colin Perkins | https://csperkins.org/ | Copyright © 2020 University of Glasgow

Increasing Need for Security



Source: https://nvd.nist.gov/general/visualizations/vulnerability-visualizations/cvss-severity-distribution-over-time

Number of security vulnerabilities reported per year – US National Vulnerability Database

- Weaponisation of the Internet
- The combination of C and Unix has not proven easy to secure
- **Most** vulnerabilities due to weak typing and lack of memory safety

Colin Perkins | https://csperkins.org/ | Copyright © 2020 University of Glasgow

Increasing Mobility and Connectivity

- Computing increasingly implies mobile devices
  - Always on – but constrained by limitations of battery power
  - Always connected – by increasingly heterogenous networks

- Do we have the APIs, tools, and programming models to make effective use of such devices?

Colin Perkins | https://csperkins.org/ | Copyright © 2020 University of Glasgow

Systems Programming

- What is systems programming?
- The state of the art
- **Challenges and limitations**
- Next steps in systems programming

Colin Perkins | https://csperkins.org/ | Copyright © 2020 University of Glasgow