HPEC 2004 Panel Session:
Amending Moore's Law for Embedded Applications

The Second Path: The Role of Algorithms in Maintaining Progress in DSP

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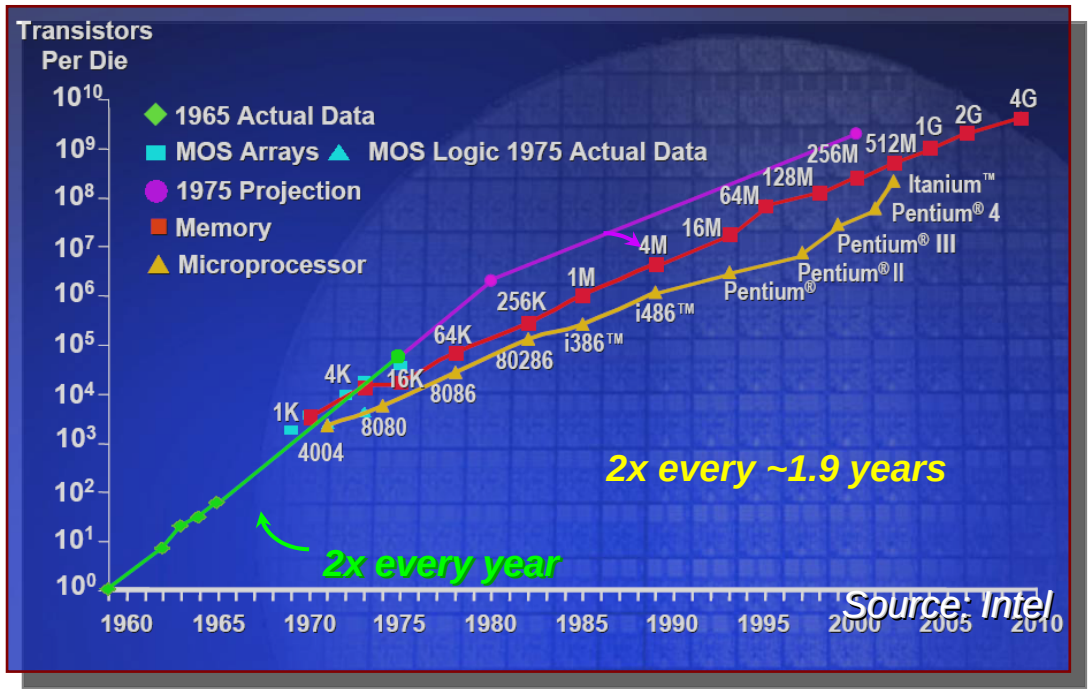
Digital Signal Processing is …

- **"… That discipline which has allowed us to replace a circuit previously composed of a capacitor and a resistor with two anti-aliasing filters, an A-to-D and a D-to-A converter, and a general purpose computer (or array processor) so long as the signal we are interested in does not vary too quickly."**
  - ***Prof. Tom Barnwell, Georgia Tech***

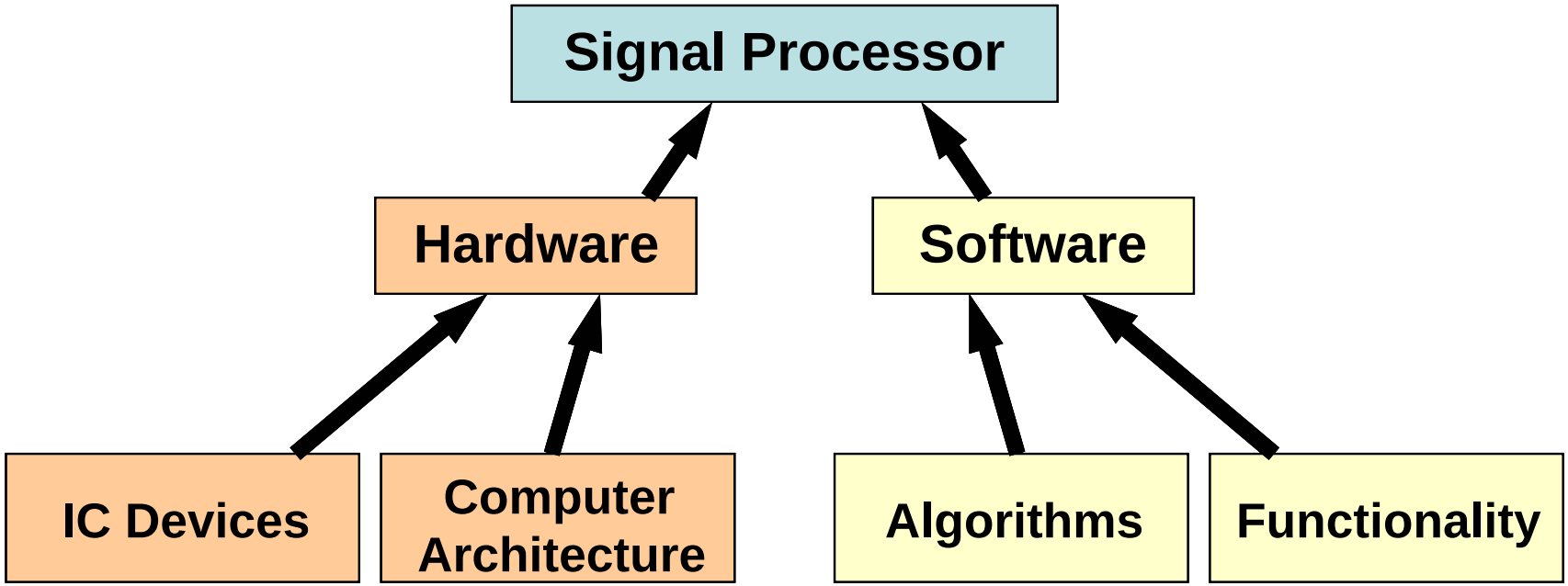
Reliance on Moore's Law

- **Doing our signal processing digitally has allowed us to grow our capability with Moore's Law …**



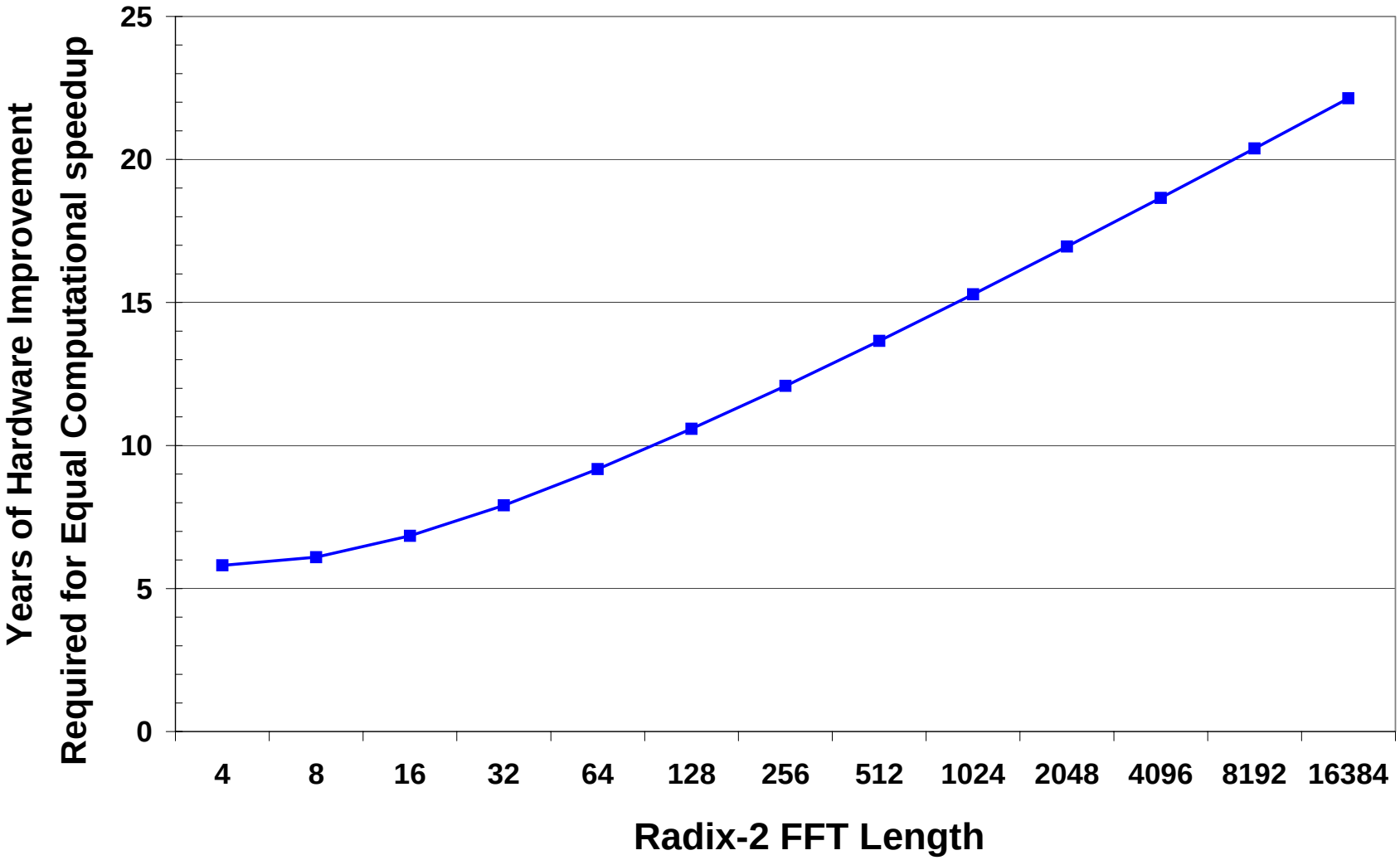
- **… but puts our rate of growth at risk if it begins to falter**

Elements Contributing to Embedded Processor Performance



The software side of DSP provides another path to exponential growth in capability

Moore's-Law Equivalent Years Required to Match FFT Computational Speedup

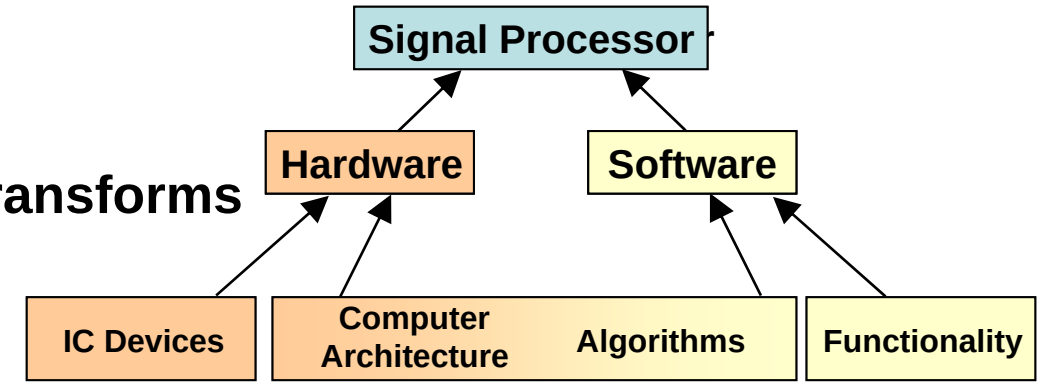


Different Character of Hardware (IC) *vs.* Algorithm Improvements

Improvement Metrics	*Hardware*	*Algorithms*
Regularity	Predictable	Unpredictable
Dependent variable	Time	Order complexity
Impact on applications	Incremental	Leap-ahead
Useful lifetime	3 years or less	10 years or more
R&D Cost growth	2x in 3 years	1.11x in 3 years

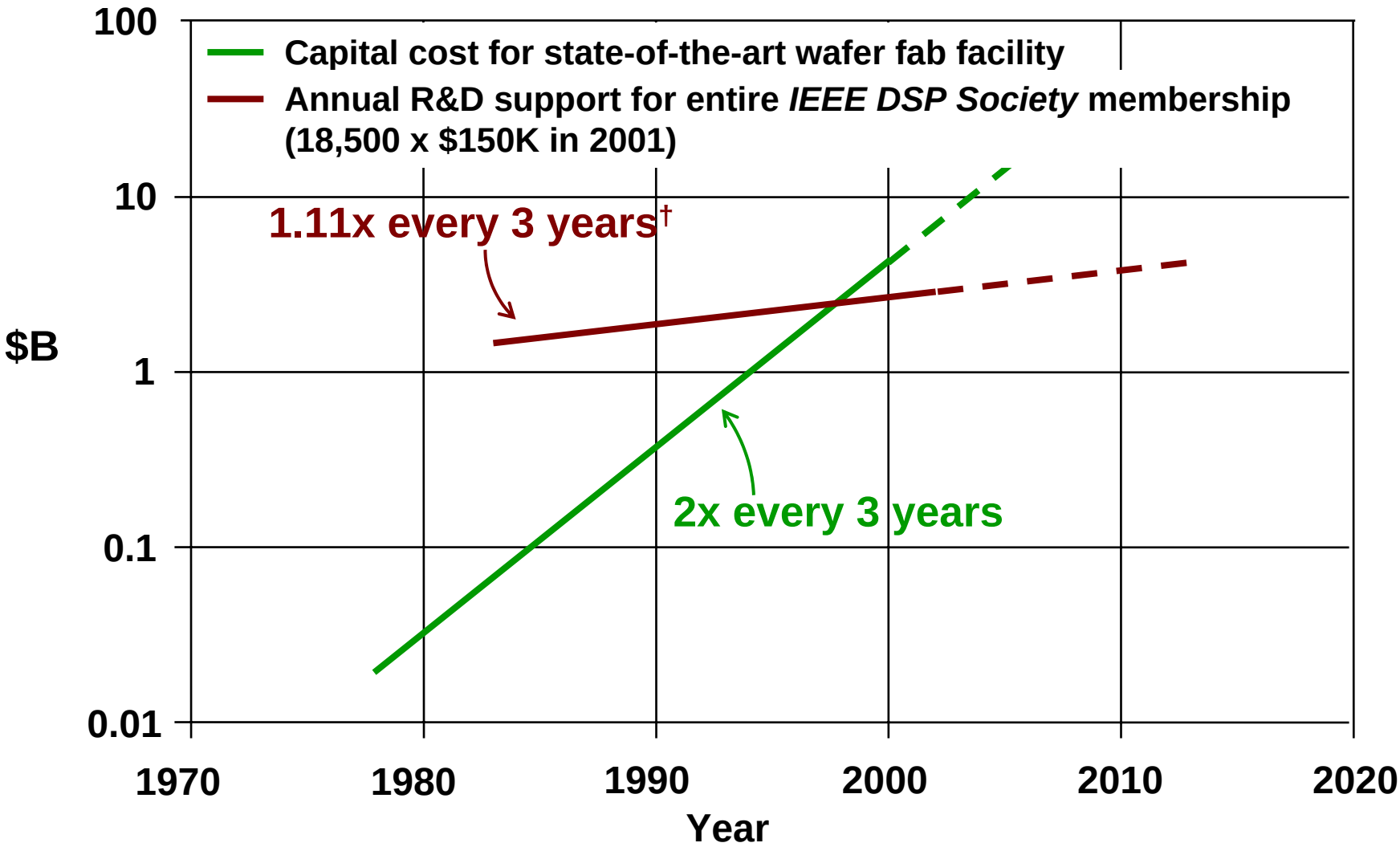
Types of Algorithm Contributions

- **Improved efficiency of existing functionality**
  - **Quicksort, FFT:** $N^2 \rightarrow N\log N$
  - **Fast multipole algorithm:** $N^2 \rightarrow N$
- **Architecture-aware implementations**
  - **FFTW: discrete Fourier transforms**
  - **ATLAS: linear algebra**
  - **SPIRAL: DSP algorithms**



- **Entirely new Functionality**
  - **Creates capability not achievable with any amount of hardware speedup**
  - **Example: voice recognition using parametric modeling and HMMs instead of vocoders and 1960s pattern recognition**
  - **Wavelets, quantum signal processing, nonlinear techniques, knowledge-based and cognitive techniques, *etc.***

Wafer-Fab Capitalization Cost Compared to Annual DSP Algorithm R&D Costs



† *Salary inflation rate based on US Bureau of Labor and Statistics Median Engineering Salaries 1983-2003*

Algorithms Provide …

- **The other half of implementation speedup**
- **Entirely new functionality**
- **Non-exponential cost growth**
- ***A way forward if hardware speedups slow!***