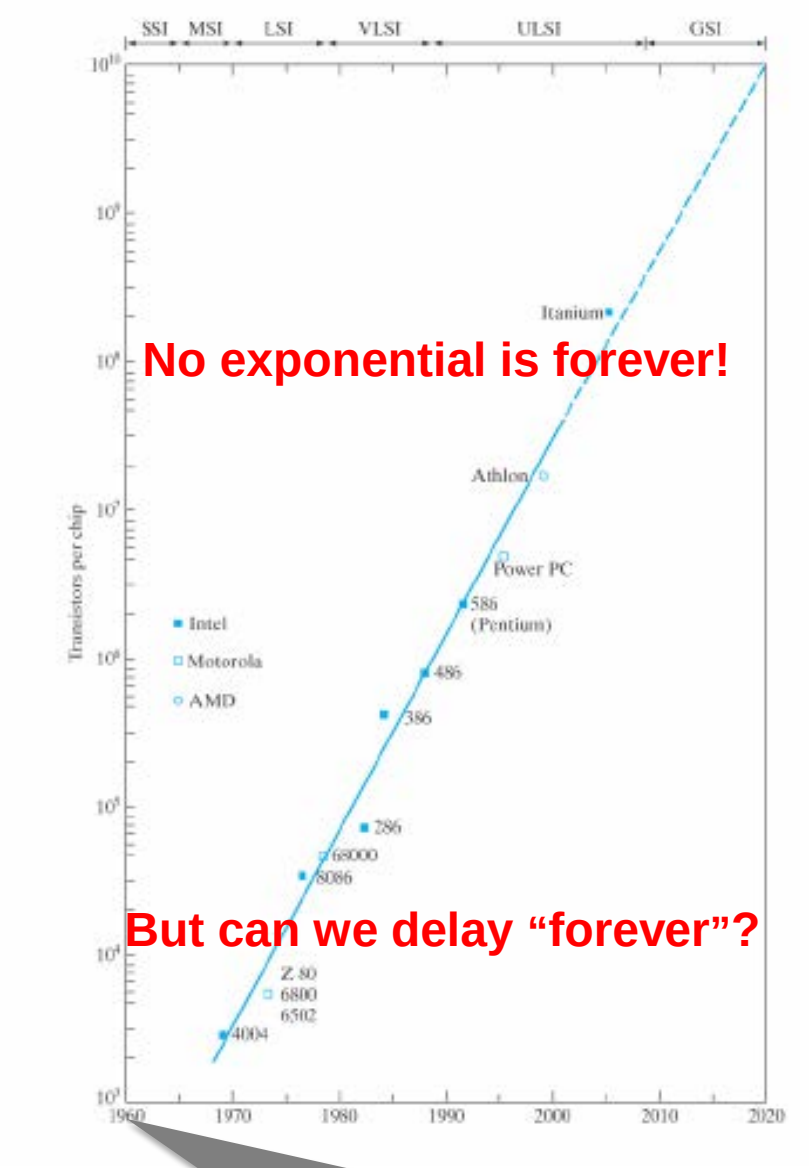
ITIF Panel: Future of Moore's Law:
Semiconductor Innovation & the High Tech Economy

# Microelectronics: The Beginning of the End or the End of the Beginning?

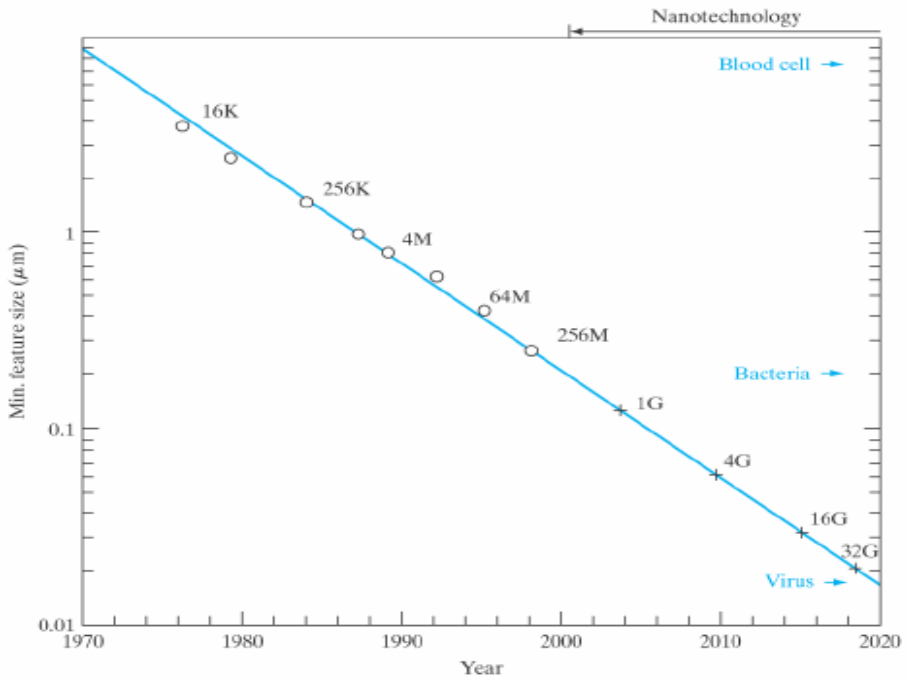
**Sanjay K. Banerjee**
**Director, Microelectronics Research Center**
**Univ. of Texas at Austin**

# Moore's Law




**No exponential is forever!**

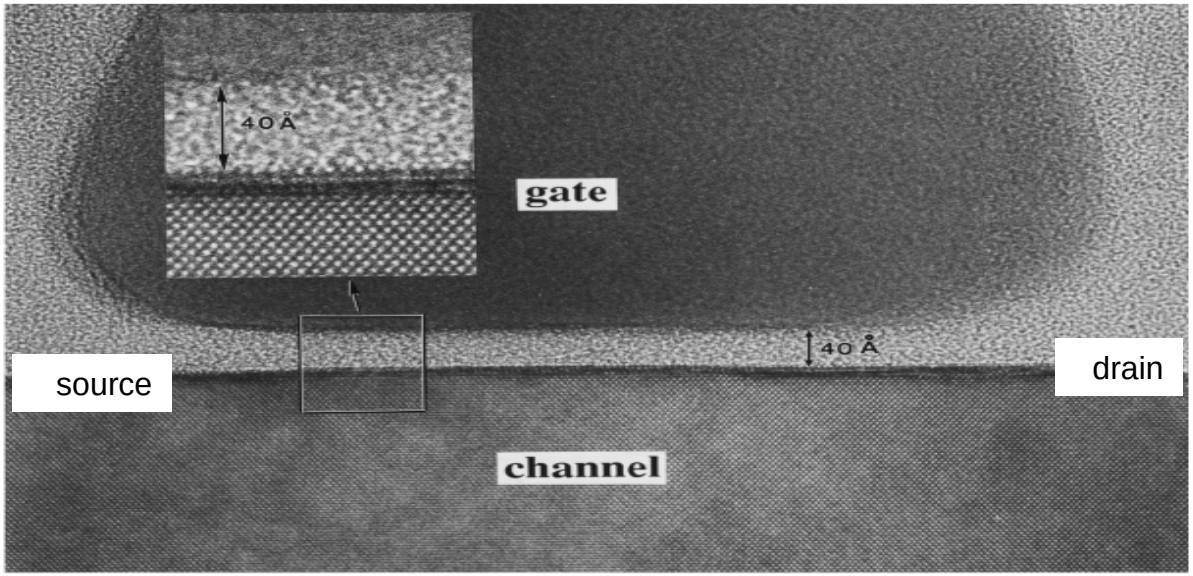
**But can we delay "forever"?**



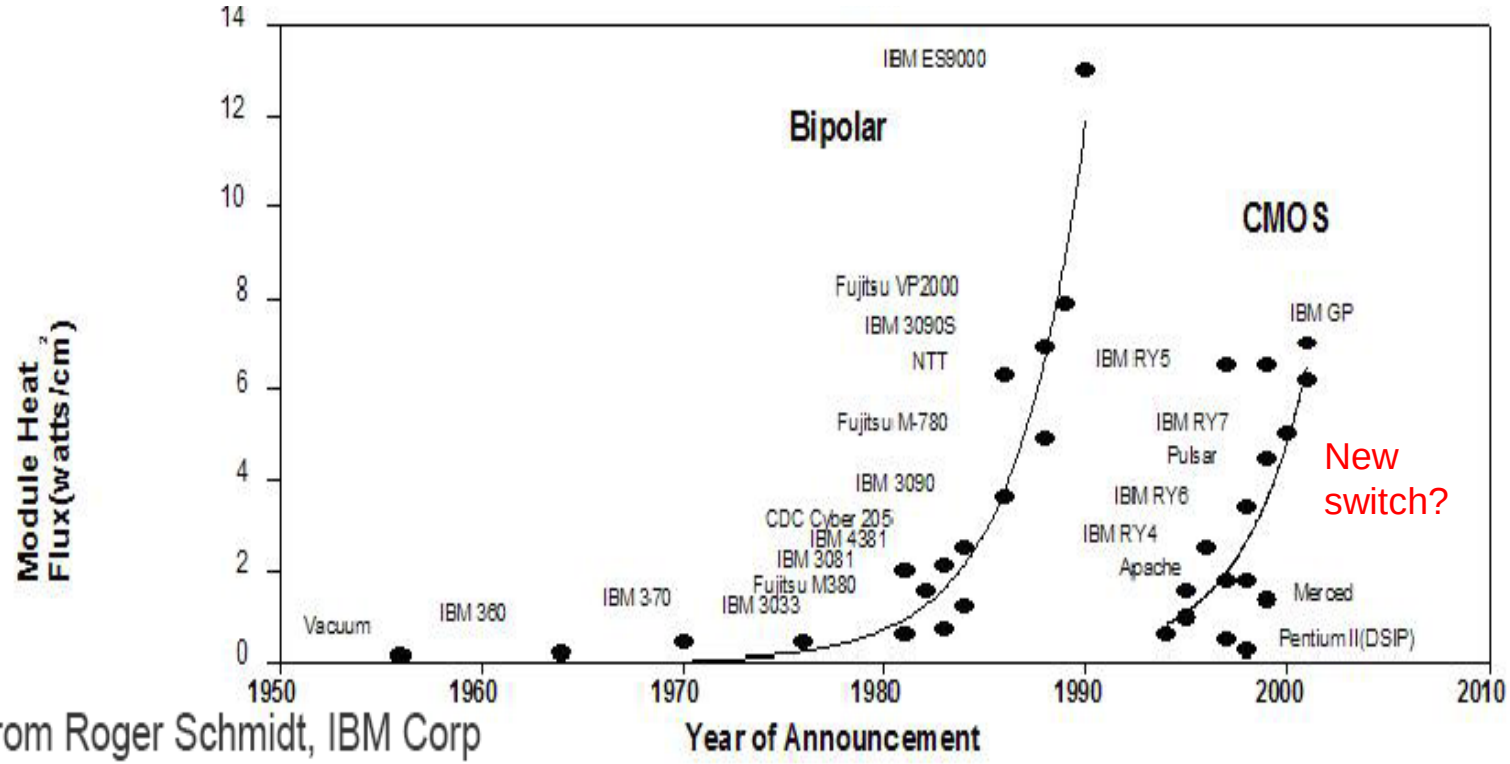

Invention of the IC by Nobel Laureate Jack Kilby of TI in 1958

# Societal Impact

- The $300 billion IC industry drives a $1 trillion electronics business, and has been the lifeblood of the Information Age for the past 50 years.
- Average person owns over a 100 billion transistors.
- 100,000 transistors would fit across, and cost less than a single grain of rice.



# The Other Energy Crisis!



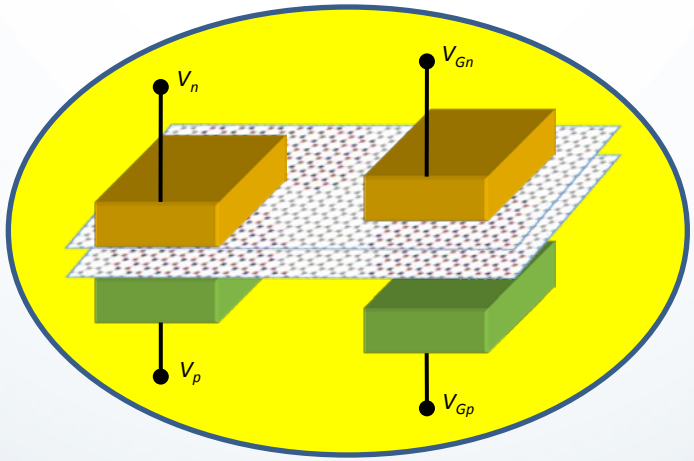

From Roger Schmidt, IBM Corp

# Strategic Paths to Innovation

- R&D investments in Tier 1 schools must increase to make us competitive with high tech powerhouses EU, Japan, …  and increasingly China.

- Example of successful partnership between Emerging Technology Fund of Texas, Texas Universities and Industry is the NRI South West Academy of Nanoelectronics at UT Austin, Dallas, Arlington, A&M & Rice:  funded by Intel, IBM, TI, Micron, Global Foundries and NIST.

- The Bilayer Pseudospin Field Effect Transistor could consume 0.1% of the energy of conventional transistors if it can be made.



# Opportunities for Transformation

## Things Natural



Dust mite

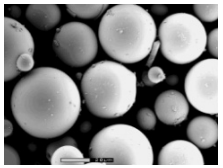
200 μm



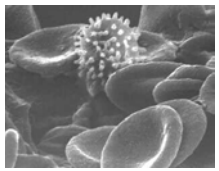
Human hair
~ 60-120
μm wide



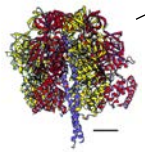
Ant
~ 5 mm



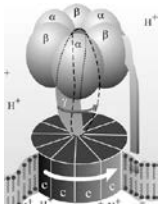
Fly ash
~ 10-20 μm



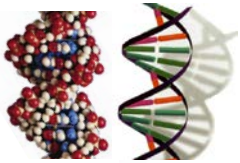
Red blood cells
with white cell
~ 2-5 μm



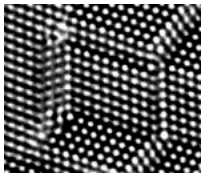
~10 nm
diameter



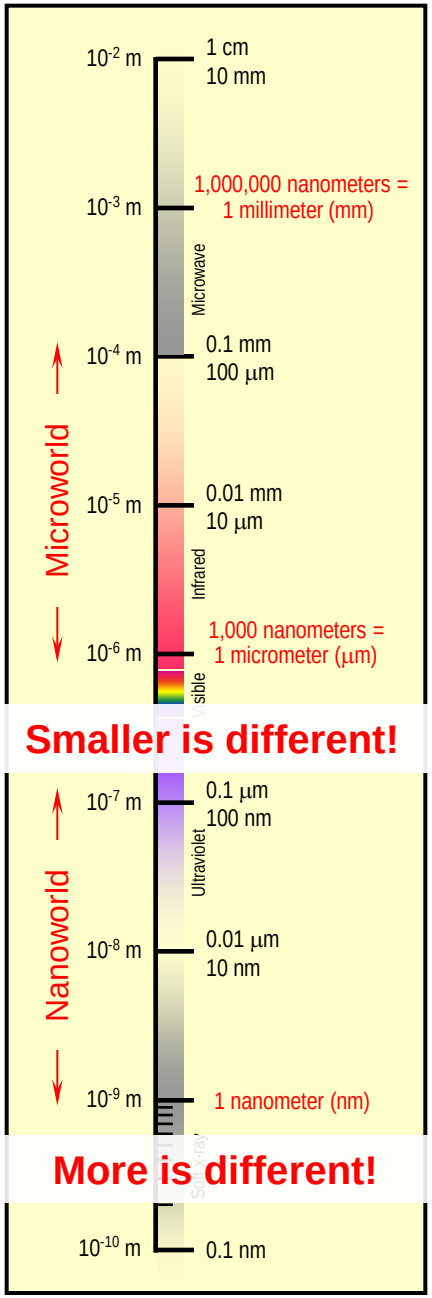
ATP
synthase



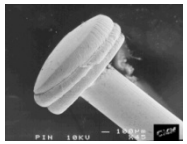
DNA ~2-1/2 nm diameter



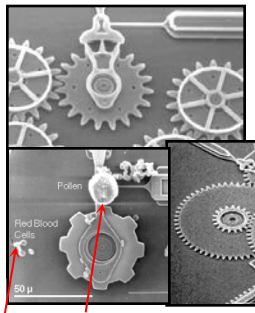
Atoms of silicon
spacing ~tenths
of nm




## Things Manmade

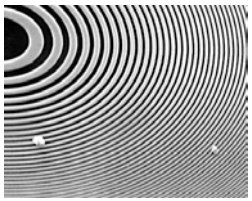


Head of a pin
1-2 mm

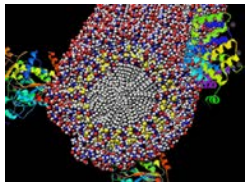



MicroElectroMechanical (MEMS) devices
10 -100 μm wide

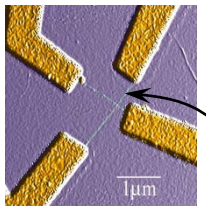
Pollen grain
Red blood cells



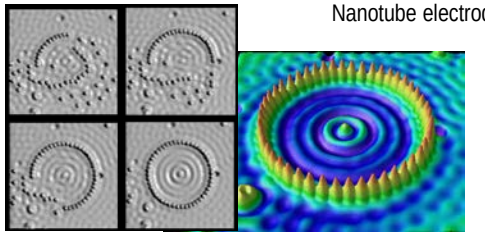
Zone plate x-ray "lens"
Outer ring spacing ~35 nm



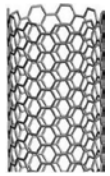
Self-assembled,
Nature-inspired structure
Many 10s of nm



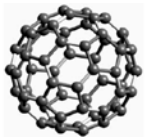

Nanotube electrode



Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm



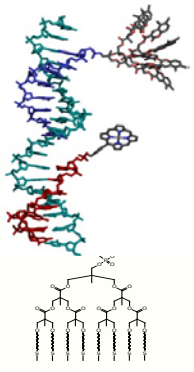
Carbon nanotube
~1.3 nm diameter



Carbon
buckyball

~1 nm
diameter

### The Challenge





*Fabricate and combine nanoscale building blocks to make useful devices, e.g., a photosynthetic reaction center with integral semiconductor storage.*

Office of Basic Energy Sciences
Office of Science, U.S. DOE
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