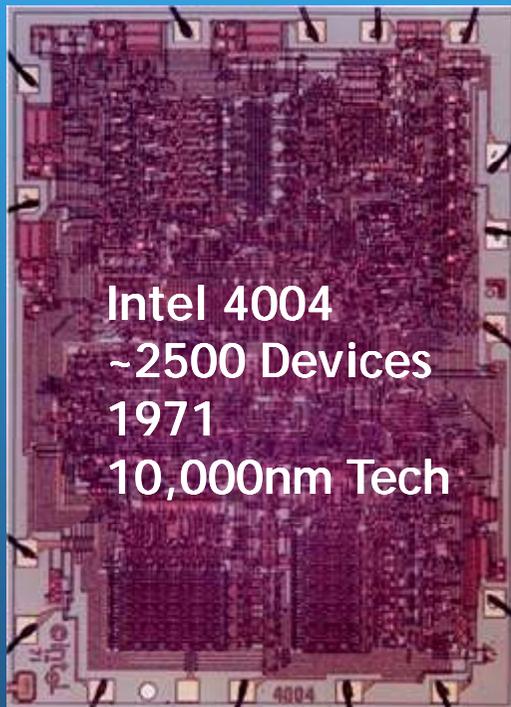


# The Light at the end of the CMOS Tunnel



Sani R. Nassif  
IBM Research - Austin  
[nassif@us.ibm.com](mailto:nassif@us.ibm.com)

# A Brief Retrospective



1971 ... 2011

10,000nm ... 20nm

$2^9$  (~500) reduction in feature size

$2^{18}$  (~65,000) increase in density

~18 process generations

And Still Going...

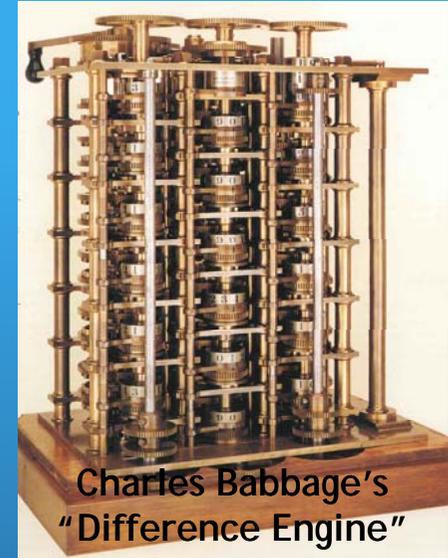
# The Result

- The world relies on electrical engineers to build all the various circuits on which our life runs.
  - Your phone.
  - Your laptop and desktop computers.
  - Your microwave.
  - The ATM at your bank.
  - The X-Ray machine at your airport.
  - The brake controller in your car.
  - Your heart implant.
- We expect these circuits to just “work”.



# Failure?

- As we make our systems ever more complex, failure becomes more and more possible.
  - Systems are a mish-mash of software, hardware, sensors, actuators, etc...
- Failure can occur because devices do not behave as expected, or external factors (noise), aging (metal fatigue), design (a software bug).
- **As we scale technology further, understanding and predicting device behavior is becoming more and more important to predicting potential failures!**



# Simulation and Prediction

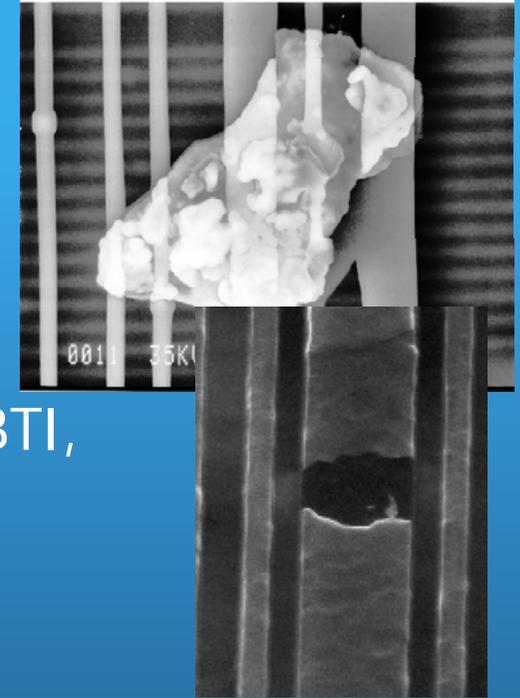
- Key to our understanding of failure is the notion that we expect our circuits to behave according to some **prediction**.
- This prediction is often arrived at using **circuit simulation**.
  - For example, using Spice.
- Simulation requires a **device model**.
  - Something like BSIM.
- In fact, we rely on models to an extreme degree!
  - We do not “crash test” our chips!
  - We do not build full-scale prototypes... First time right is an economic necessity.



# Why Semiconductors Fail

Variety of mechanisms:

- Defects...
- High Field effects: Hot Carrier Injection, NBTI, Metal Electro-Migration.
- Noise phenomena (local, or cosmic).
- Model/Hardware mismatch (lack of predictability).
- Big picture: a by-product of scaling... Small features mean:
  - Small contaminants can cause topology changes, and ...
  - A small "extra" charge can cause mistakes, and ...
  - Large fields, a  $V_{DS}$  of  $1V / 40nm = 250 \text{ KV/cm}$ , and ...
  - Increasing variability because of lack of averaging!



# Future Possibilities

- We want to make sure that Silicon Technology will continue to amaze and deliver.
- Silicon will be the substrate on which post-Si technology will be built.
- Our ability to confidently predict the behavior of Silicon Devices is the cornerstone!

