



Twists and Turns in Fiber Optics – What's Next?

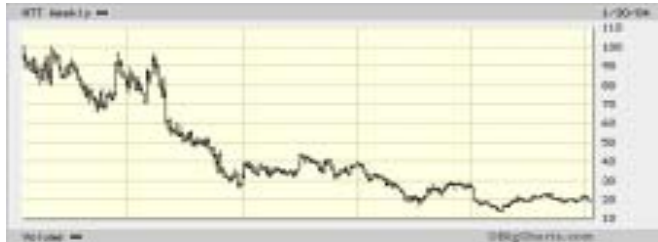
Pao-Lo Liu

Department of Electrical Engineering

University at Buffalo, the State University of New York

Telecom Market - It's a Wild Ride

AT&T (Core)



Verizon (Metro & Local)



Nortel (Equipment)



Lucent



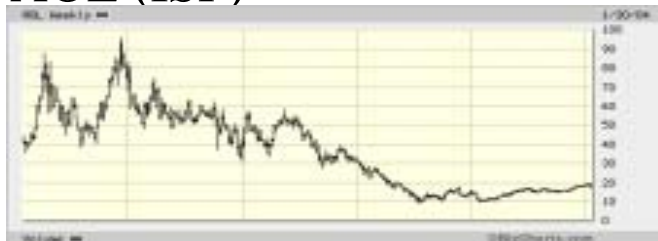
Corning (Sub-System)



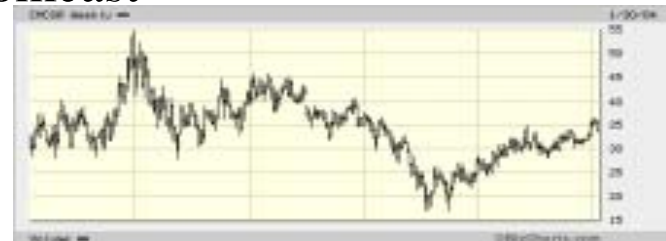
JDSU (Component)



AOL (ISP)



Comcast

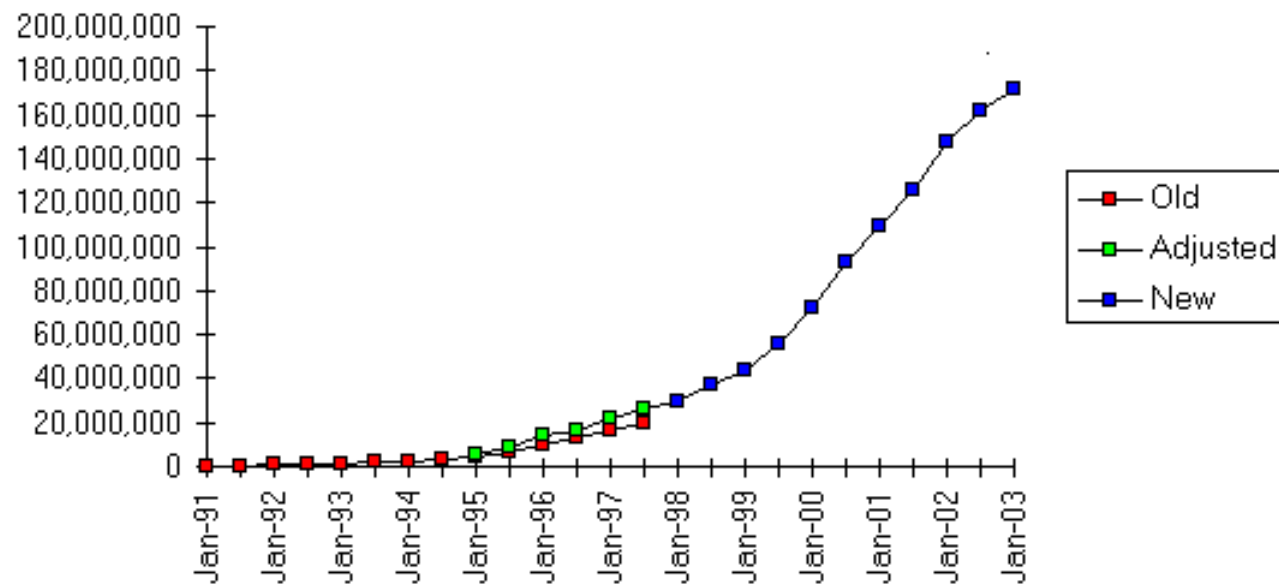


- Downturn is History
- Most Signs Indicate a Steady Recovery
 - 3-10 yrs to reach the peak again
- *Add Some Economics to the Engineering Curriculum*

What Happened?

- Economic Boom in 1990's – Abundant Capital
- The Rise of the Internet
- Telecom Act of 1996
 - Regional Bell operating companies get into long haul
 - Inter-exchange carriers penetrate local loop
- Reality Check
 - RBOCs dominate with no real competitive local exchange carriers
 - Strong competition among IXC's
- Spectacular Technology Advances
 - DWDM, x100
- Business Planning
 - Build up supply while willfully disregard real demand

Internet Domain Survey Host Count



Source: Internet Systems Consortium, Inc. (www.isc.org)

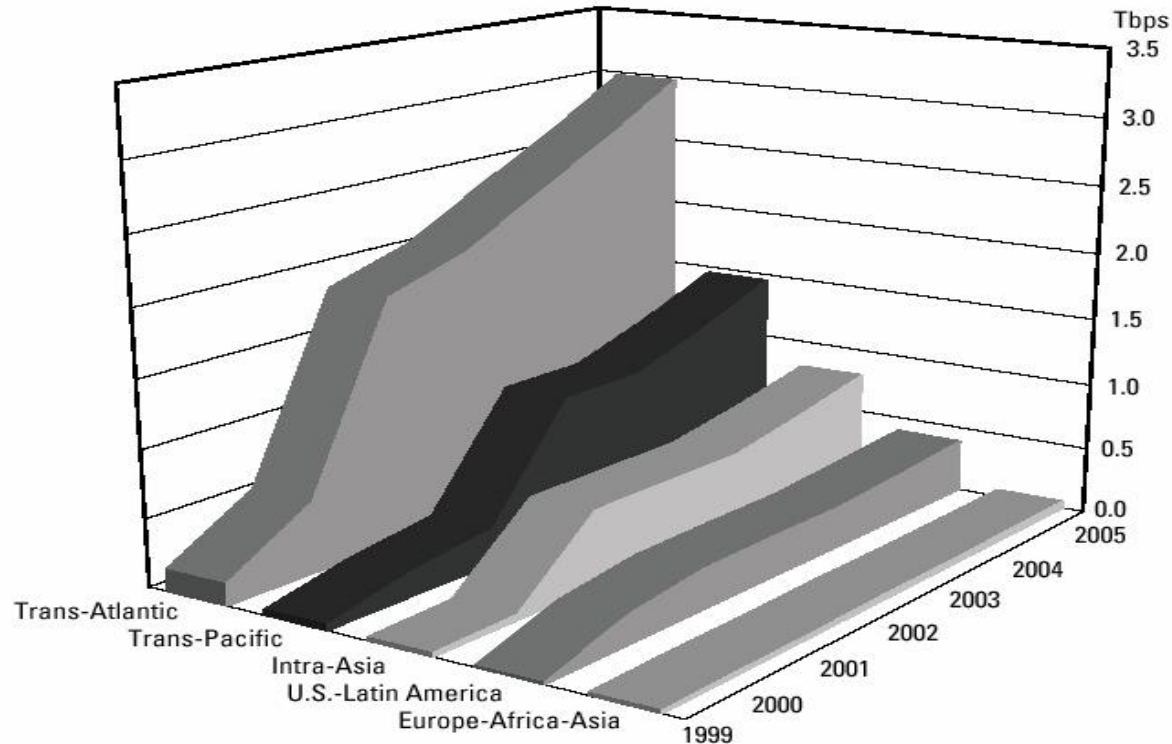
- Economic Boom in 1990's
- The Rise of the Internet
- Telecom Act of 1996 - Opportunities
 - Regional Bell operating companies get into long haul
 - Inter-exchange carriers penetrate local loop
- Reality Check
 - RBOCs still dominate; no real competitive local exchange carriers
 - Strong competition among IXC's
- Spectacular Bandwidth Increase
 - DWDM
- Business Planning
 - Build up supply while willfully disregard real demand

Michael Ching, an analyst of Merrill Lynch, states in his report:

“Carriers are only using about 2.7% of their total lit fiber capacity.”

Wall Street Journal, June 2001

Lit Submarine Cable Capacity Trends by Route, 1999-2005



Telegeography, Inc., 2003

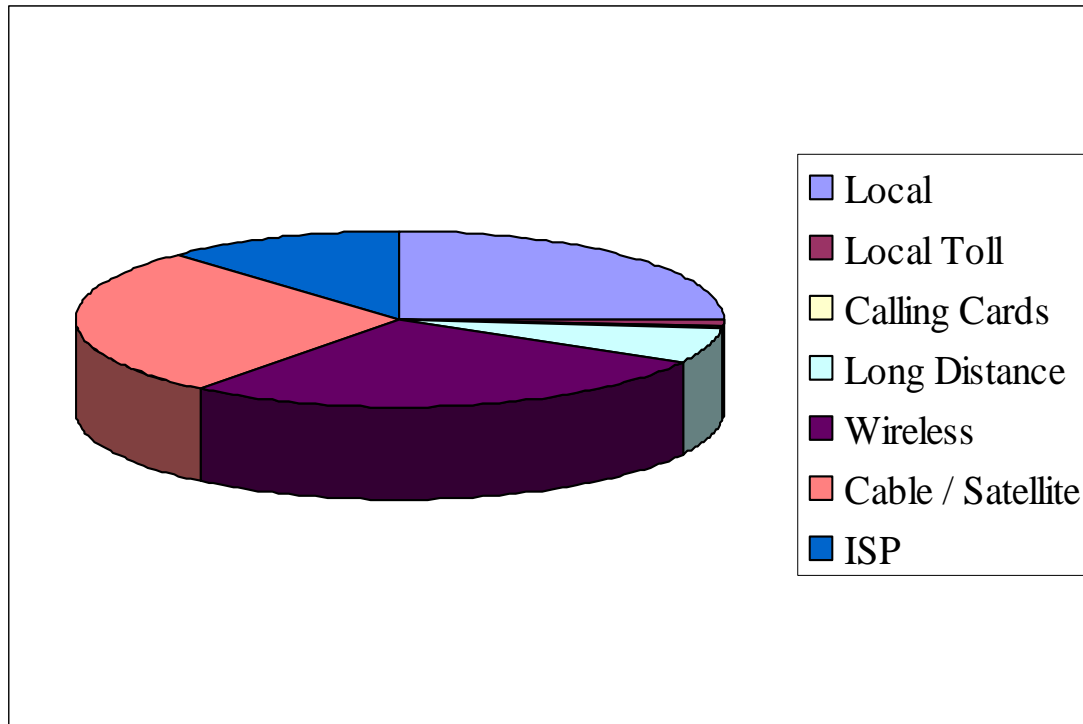
- Internet traffic NY-Washington, DC: 350 Gb/s
 - 64 DWDM channels of OC-192 in one fiber

Results

- Lack of Differentiation in Services and in Quality of Services
- Fierce Price Competition
- Astronomical Telecom Debt
- Market Valuation Down
 - Terabit innovation turns into trillion dollar loss
- Capital Expenditure Down
- Industry Wide Slow Down and Loss of Talents
 - Optical MEMS switch
- *Establish a Roadmap*
 - *Build up Infrastructure with better planning*
 - *Coordination, cooperation among telecom providers*

Where are the Apples?

- Consumer Spending on Telecom



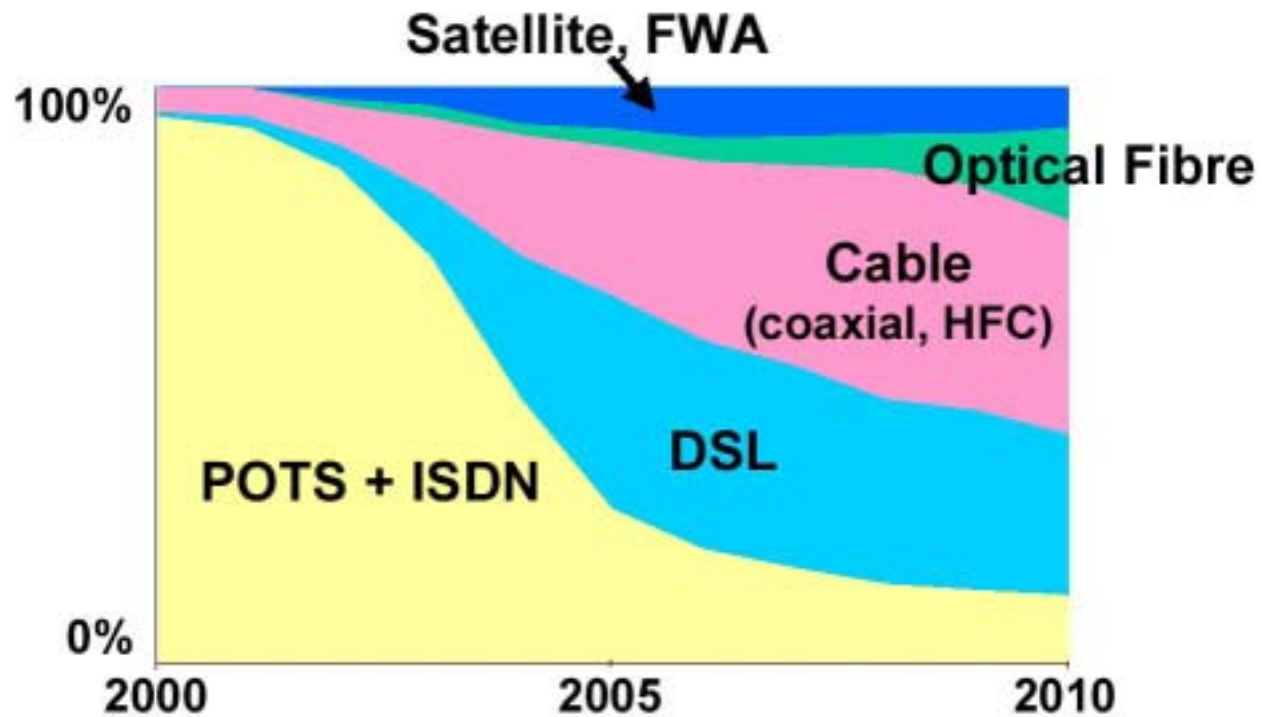
TNS Telecoms

- *More at the Retail Edge, Less in the Wholesale Core*

Status

- Internet Becomes a Necessity
- Data Surpass Voice and Growing
 - Packet switching will dominate
 - File transfer dominates streaming multimedia
- From Loop to Network
 - Optical Ethernet, VoIP
- From Managed to on Demand Services
- From Line to Wireless
- *Edge Access Problem*
 - *Last mile bottleneck*
 - *Digital divide*

Broadband Access Technologies

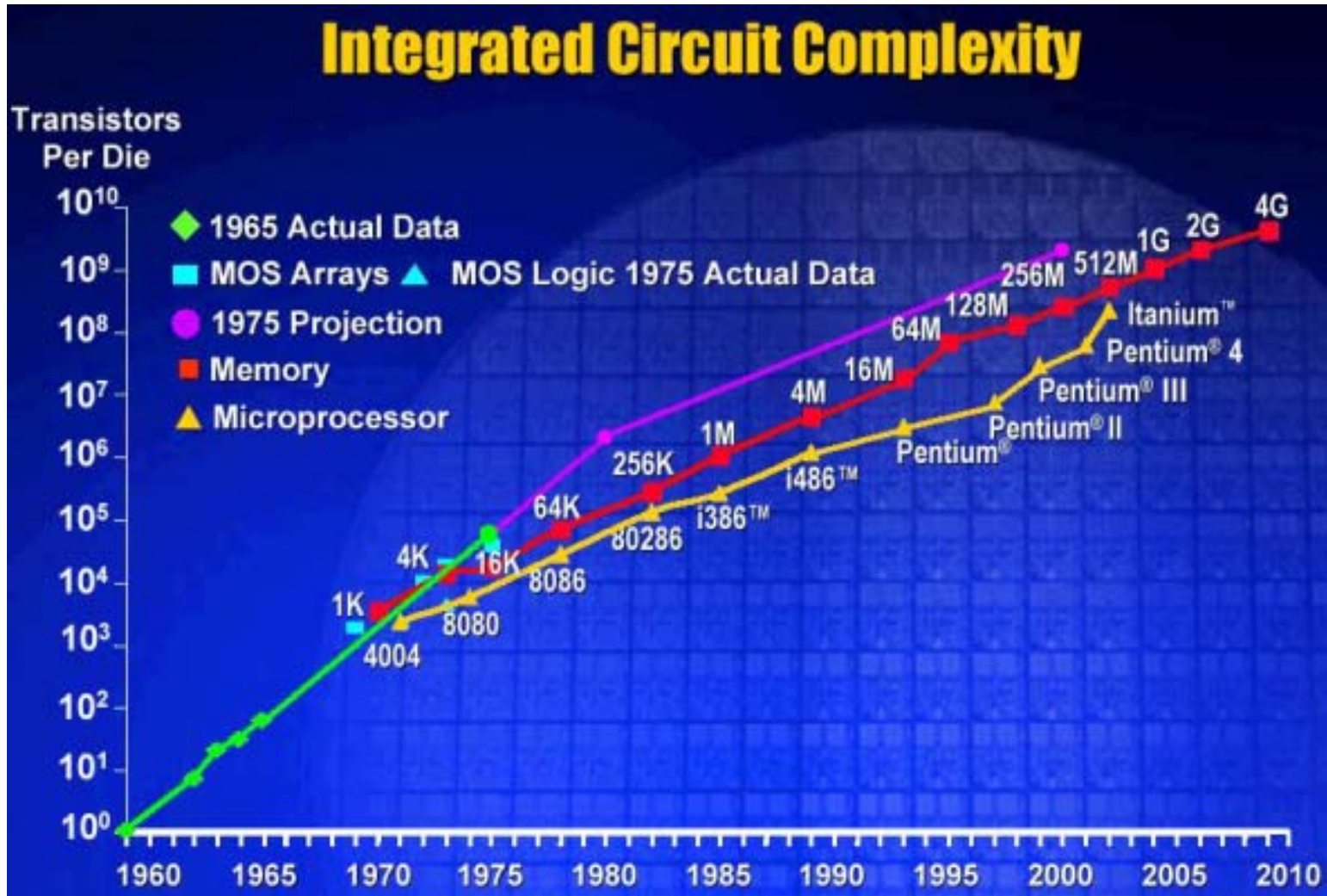


Paulo de Sousa, European Commission

Basic Principles

- Driving Force for Demand
 - People and Tools
- Telecom Infrastructure
 - Policy and Planning
- Winning Strategy
 - New Services and Quality of Services
 - Efficiency of Operations
- Commodity for Consumers
 - Cost
 - Marketing
 - Anticipation

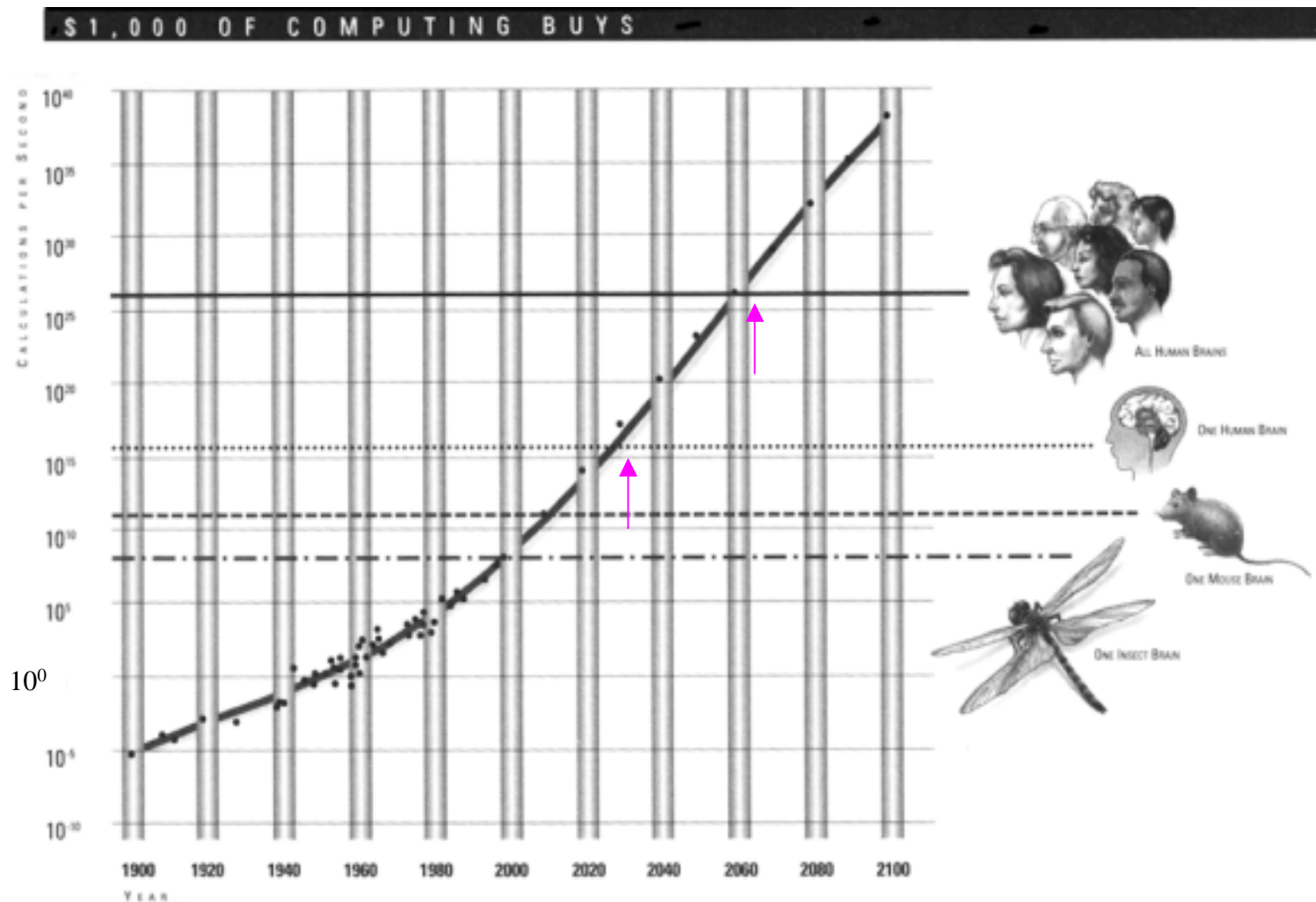
The Moore's Law



- *Systemic Growth*

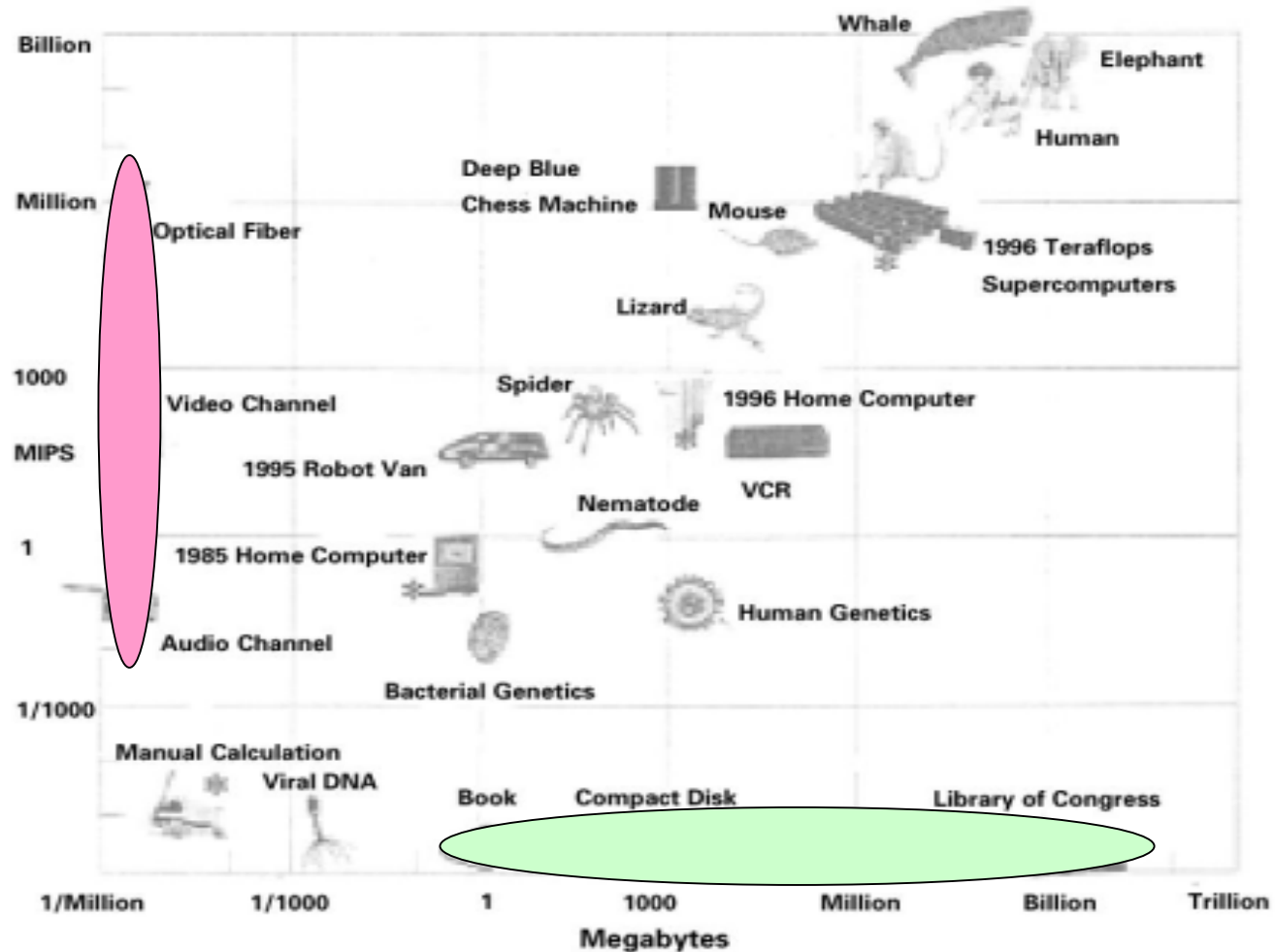
Gordon E. Moore

Future Outlook on Computational Power



R. Kurzweil, The Age of Spiritual Machines

Information Processing



- *Always Focus on the Future*

H. Moravec, Robot: Mere Machine to Transcendent Mind

Basic Principles

- Driving Force for Demand
 - People and Tools
- Telecom Infrastructure
 - Policy and Planning
- Winning Strategy
 - New Services and Quality of Services
 - Efficiency of Operations
- Commodity for Consumers
 - Cost
 - Marketing
 - Anticipation

- RBOC Siege, Telecom Attitude, Legacy Infrastructures, and Regulatory Quagmire
 - *Customer not the network is the asset*
 - *Bandwidth abundant not scarce*
 - *3-5 yr not 15 yr amortization*
- Keep Pace With Semiconductor
 - *Cost reduction*
 - *Performance enhancement*
- Partition of Technology
 - Fiber-to-the-X
 - Wireless
 - Cable
- Repartition of Business Boundaries
 - Merging of computing, communications, and entertainment

Cost of transistor in IC and bps in TAT



- RBOC Siege, Telecom Attitude, Legacy Infrastructures, and Regulatory Quagmire
 - Where is ISDN
 - Customer not the network is the asset
 - Bandwidth abundant not scarce
 - 3-5 yr not 15 yr amortization
- Keep Pace With Semiconductor
 - Cost reduction
 - Performance enhancement
- Partition of Technology
 - Fiber-to-the-X
 - Wireless
 - Cable
- Repartition of Business Boundaries
 - Merging of computing, communications, and entertainment

Future Landscape

- No Partition Between Local and Long Haul Services
- No Partition Between Wireless and Wireline Services
- Telecom Infrastructure
 - Information Resource and Service Providers
 - Network Operators
 - Bandwidth / Pipeline Providers
- Telecom Equipment
 - System Providers
 - Subsystem Vendors
 - Component Manufacturers
- *More reorganizations until new business models emerge*

Basic Principles

- Driving Force for Demand
 - People and Tools
- Telecom Infrastructure
 - Policy and Planning
- **Winning Strategy**
 - *New Services and Quality of Services*
 - *Efficiency of Operations*
- Commodity for Consumers
 - Cost
 - Marketing
 - Anticipation

Basic Principles

- Driving Force for Demand
 - People and Tools
- Telecom Infrastructure
 - Policy and Planning
- Winning Strategy
 - New Services and Quality of Services
 - Efficiency of Operations
- **Commodity for Consumers**
 - Cost
 - Marketing
 - Anticipation

What's Reasonable?

- Data Traffic Growth
 - Software
 - CPU performance and disk capacity
 - *x10 / 3-5 yrs*
- Network Data Rate (Burst)
 - Memory and disk access
 - *1-10 Gb/s*
- Real-Time Applications (Streaming)
 - Digital video
 - *6-20 Mb/s per user*
- Consumer Spending on Telecom
 - *\$150/month (3% household income)*

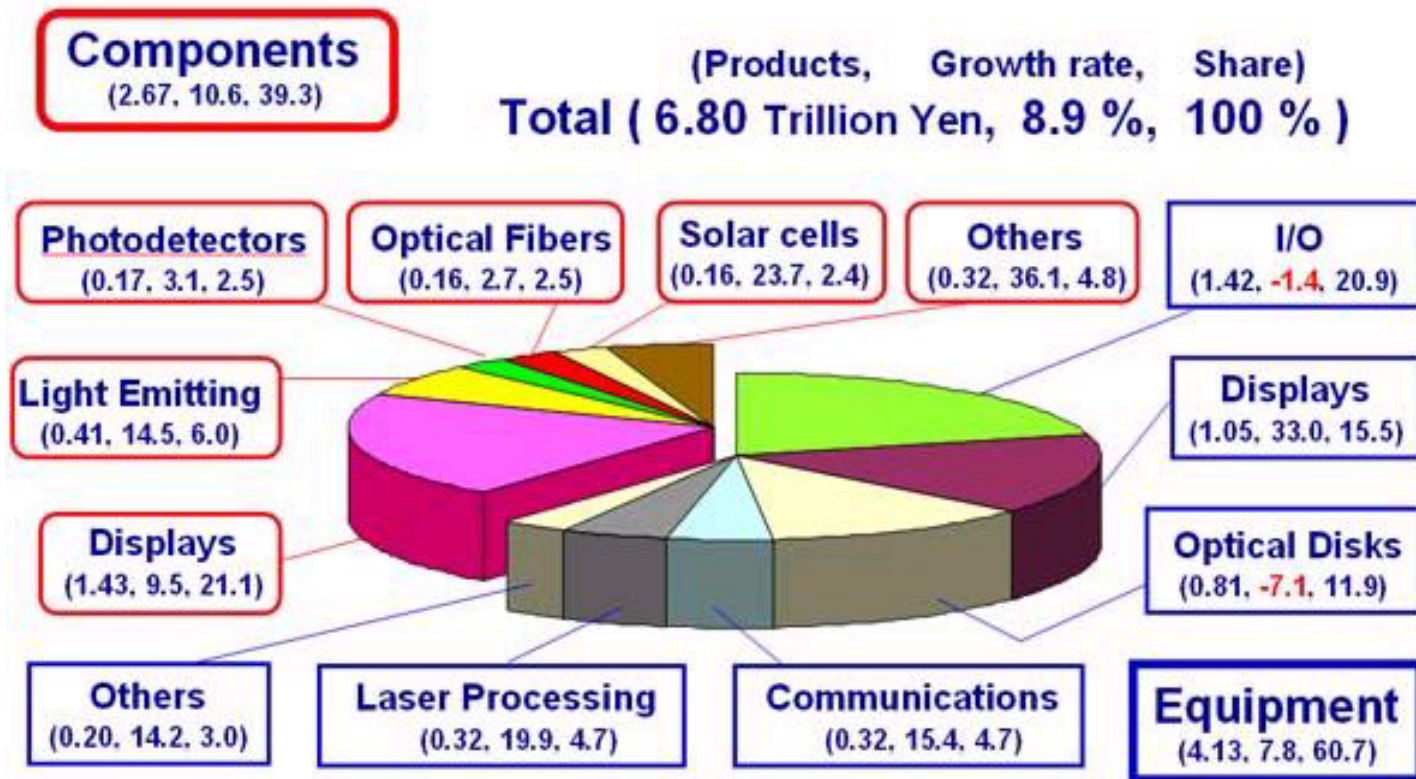
Opportunities

- Community Fiber Networks
- Ethernet / IP Equipment
- Personal Services
 - Virtual private networks for the general public
 - Personalized information delivery
- Security Enhancement
 - Eradicate virus, spam...
- Wireless Freedom
- Multimedia Immersion
- New Tools to Feed the Internet
 - Smart, ubiquitous devices
 - Software
- New System Architectures

More Opportunities

- Applications With Common Platforms
 - MEMS
 - Liquid Crystal
 - Sensors
 - Biomedical tools
- Integration

Optoelectronics



OITDA, 2003

Innovations in Photonics

- *Photonic bandgap and holey fiber*
 - Revolutionary changes in transmission and signal conditioning
- 40 G optoelectronics
- Ultra long haul systems with Raman amplifiers
- All optical switching
- *Organic and plastic optoelectronics*
 - Low cost fiber optics
- Optical coding
- Quantum cryptography and information processing
- Single photon devices

More Innovations in Photonics

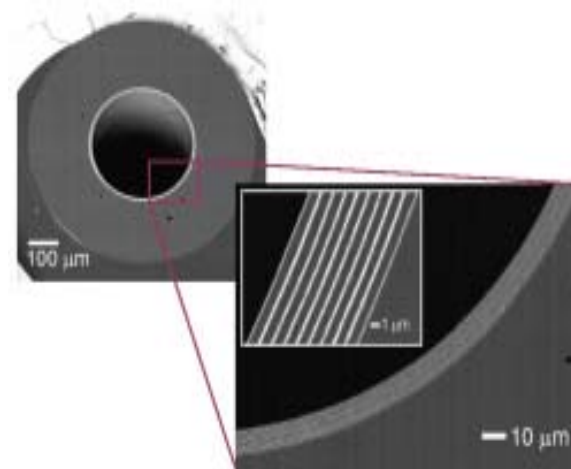
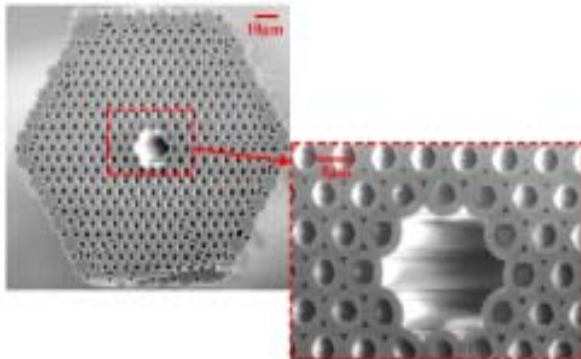
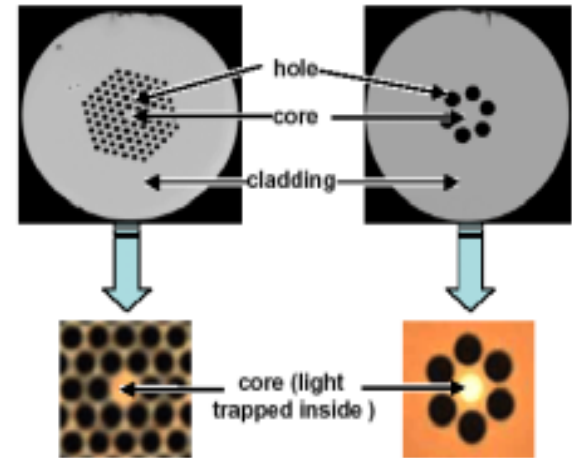
- Negative index and subwavelength optics
- Bose condensation and slow wave
- Resonance enhancement

Nano Technology

- Single quantum devices
- Manipulation and manufacturing at the atomic level
 - Self assembly
 - Nanometer lithography
 - Sub-wavelength optics
- Metamaterials
- Faster and numerous devices
 - More bandwidth and processing power
 - In tandem, fault tolerant, neuron-like operations
- Omni-Science
 - Convergence of science disciplines

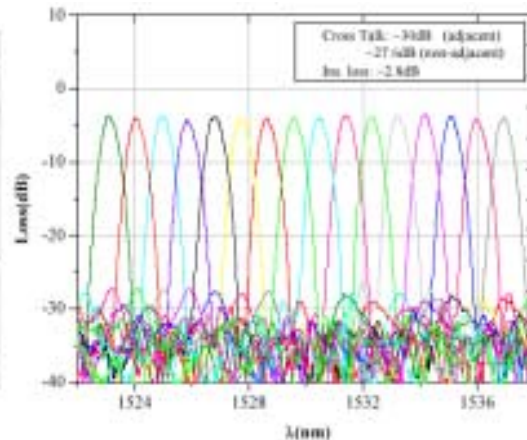
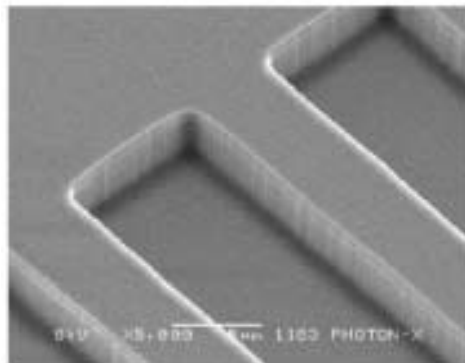
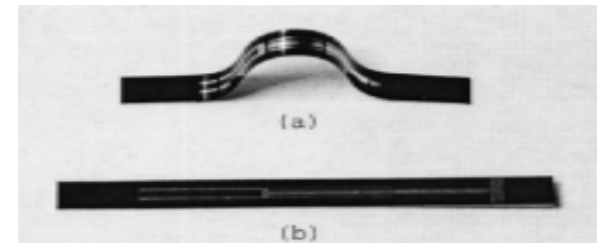
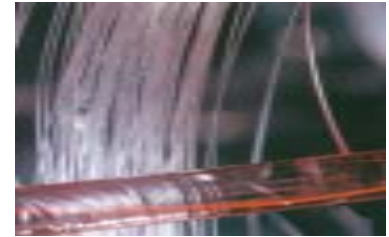
Photonic Bandgap and Holey Fiber

- 3D Periodic Structure With Novel Optical Properties
- Holey Fibers
 - single-mode over a wide range
 - reduction in bending loss
 - versatile dispersion
 - control of non-linearity
 - polarization-maintenance



Organic and Plastic Optoelectronics

- Common platform
 - Molded micro-optic arrays in LCD display panel
 - OLED
 - Organic transistors
 - Flexible electronics and optoelectronics
 - Fiber and waveguide devices
 - Electrooptic modulators
 - Self aligned nano structures





Conclusion

- There is still a lot to be gained in optical communications
 - From tera to petta
 - From grand to dollar
 - From backbone to home
 - From engineer to layman
- The success of optical communications should not be measured by the dollar amount alone but by the impact it brings to the people and society.

“Chaos often breeds ‘new forms of’ life.” - Henry B. Adams

Thank you!