Laws
That Are Governing
The Network

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THE NETWORK

- "The Network"
    - All digital networks worldwide
    - Includes the Internet
    - Includes the digital carrier networks
        - Local Exchange Carriers
        - Inter-Exchange Carriers
    - Includes trans-oceanic carriers
    - Includes all digital networks
        - Local area networks (LANs)
        - Metro area networks (MANs)
        - Wide area networks (WANs)

LAWS OF THE NETWORK

- Gordon Moore's Laws
  - Moore's 1st Law
  - Moore's 2nd Law
- George Gilder's Law of the Telecosm
- Network Intelligence
  - Peter J. Sevcik on Switched System Performance
  - David Isenberg and the Rise of the Stupid Network
- Observations in Satellite Systems
- Disruptive Technologies, a Need
- Conclusions

MOORE'S 1st LAW

- ## Moore's Law (The 1st Law)
  - Gordon Moore, Chairman Emeritus of Intel, predicted that chip complexity would double every device generation
    - Chip complexity is defined by the number of active elements on a single semiconductor chip
      - Now roughly comparable to performance as measured in millions of instructions per second (MIPS)
    - The device generation was assumed to be approximately 18 months, and still applies today
    - Valid now for three decades

MOORE'S 1st LAW PREVAILS

- Appears likely to be valid for several more device generations

	1975	1997	2003
Chip complexity (index to 1)	1	10	100
Feature size reduction, mm	2	0.25	0.08
Chip size increase, mm^2	30	150	600
Wafer diameter, mm	50	200	300
Facility automation, %	5	60	80
Die yield, % good	40	85	95
Line yield, % good	40	90	95
Operational efficiency	1	10	100
Equipment cost	1	10	50

MOORE'S 2nd LAW

- **Cost in fabricating chips** (factory cost) is also exponential in the opposite direction and is off-setting the gains in complexity
  - High-volume factories are now multi-billion dollar investments
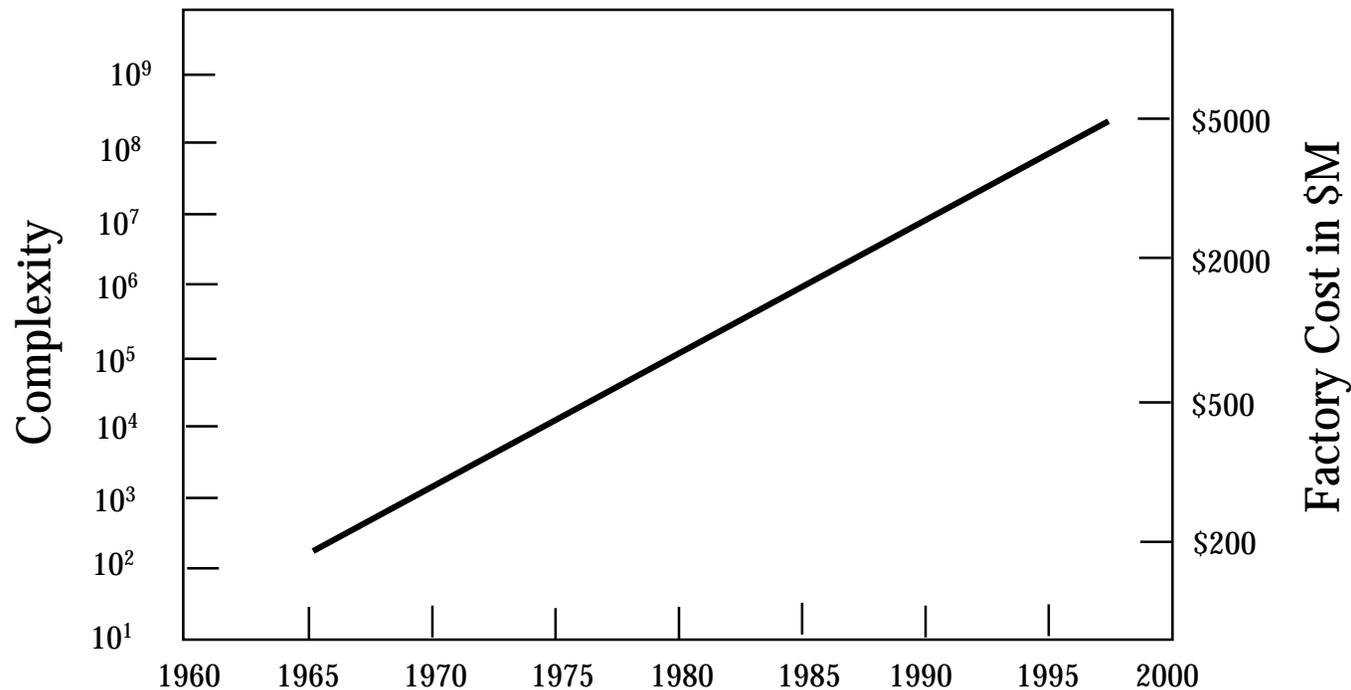
INERTIA BEHIND MOORE

- Side note:
  - In 1974, Moore extrapolated the wafer size suggesting that by 2000 a wafer would be 57-inches in diameter - off by a factor of 10

- Important to note the impact of new technologies, materials, and processes allow structures on an atomic scale
  - New products and micromechanical devices in the labs include
    - Micro-refrigerators
    - Micro-turbines
    - Micro-motors

GILDER'S LAW OF THE TELECOSM

- **The law of the telecosm ordains that the total bandwidth of communications systems will triple every year for the next 25 years** - *George Gilder, Gilder Technology Report Volume II, Number 2, February 1997*

IMPRESSIVE FIBER GROWTH

Fiber Deployment by Telcos
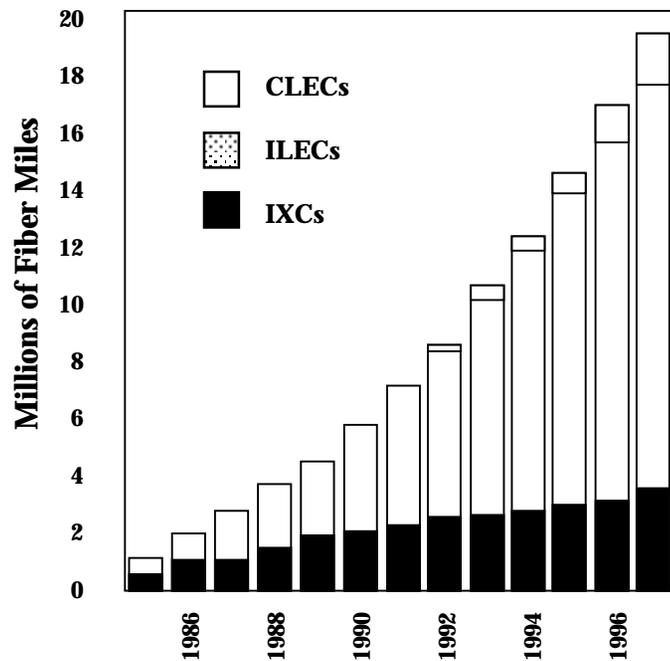
Source: FCC

Global Undersea Fiber Capacity
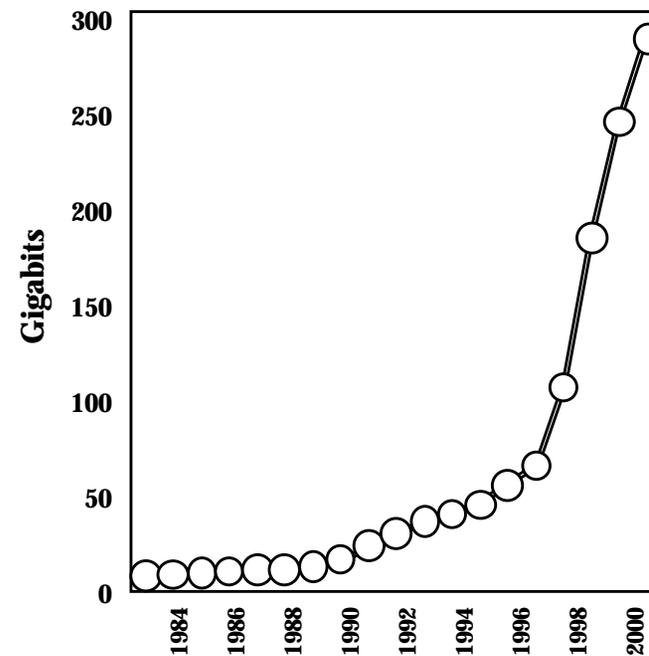
Source: GTG

ADVANCES IN WAVE DIVISION MULTIPLEXING (WDM)

- WDM commercially introduced in 1996

- Now running 8, 16, and 32 λs

- Avanex now testing 800

- Lucent's "AllWave product objective is 3300 λs
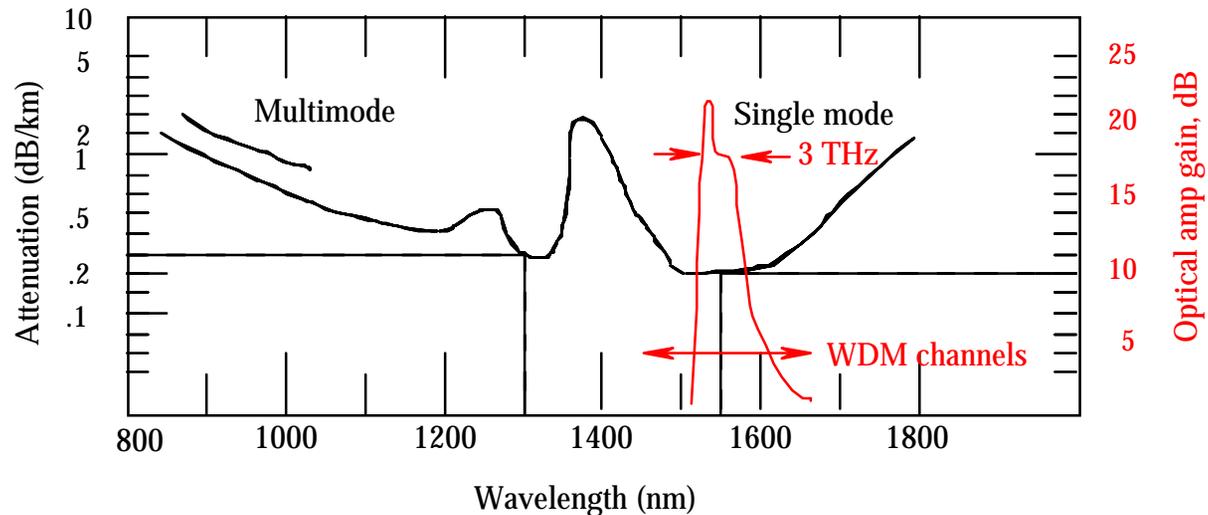
Visible light is between 400 to 700 nm.

MORE BANDWIDTH ON THE WAY

- Bundled fibers

- Moves toward lower noise & higher amplification efficiencies

  - Pre-Erbium doped fiber amplifiers (EDFAs) repeater spacing on the order of less than 100 km

  - EDFAs allow 400 to 600 km

  - Ramon amplifiers show promise of 10 Gb/s to 3,000 km

  - Ytterbium is another doping possibility

BUNDLED FIBER OPTIC TRANSMISSION SYSTEMS

32

27
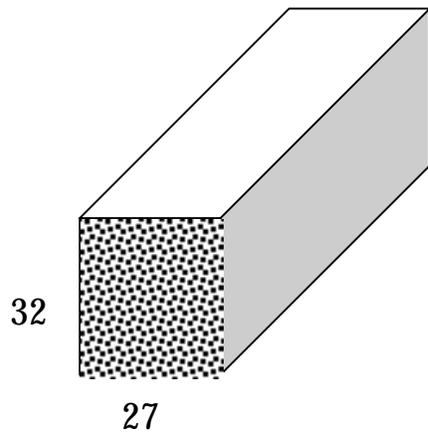
- Bundle of 864 SMF strands each with a core, cladding and buffer

- At 3,300 λs each

- Could contain 2.86 million λs

- At 10 Gigabits/ λ, that equals 28.6 Petabits/sec for this bundle

NETWORK INTELLIGENCE

- Network intelligence is moving to the network edge and away from the network core
  - **David S. Isenberg** in the Rise of the Stupid Network
    - Concept introduced April 1, 1996
    - Followed by internal AT&T publications and seminars
  - **Peter J. Sevcik's** Network Switching Laws were published a year later in the Business Communications Review, September, 1997
- Both weave the transition from centralized to decentralized network intelligence

DAVID S. ISENBERG'S MESSAGES

- On April 1, 1996, Isenberg, a top scientific researcher at AT&T, sponsored an international conference titled: *What if minutes Were Free?*
  - So heretical and ridiculous that he chaired the event in a court jester's outfit.
- An internal paper on the subject was circulated at AT&T
- A year later, June 25, 1997 at 5:48 PM EST, Isenberg was allowed to release the electronic version - ***Rise of the Stupid Network***
  - He wrote in his cover e-mail: "Here is my attempt at entropy gradient reversal at AT&T. . .
  - . . If you want EXPLICIT frontal exposure of the Critical Issues, or language that is commensurate with my thinking, you'll have to read between the bits."

ISENBERG'S SIMPLE PREMICE - THE MIPS OF A TELEPHONE VERSES THE PC AND END USER IS SHIFTING POWER TO THE EDGE OF THE NETWORK
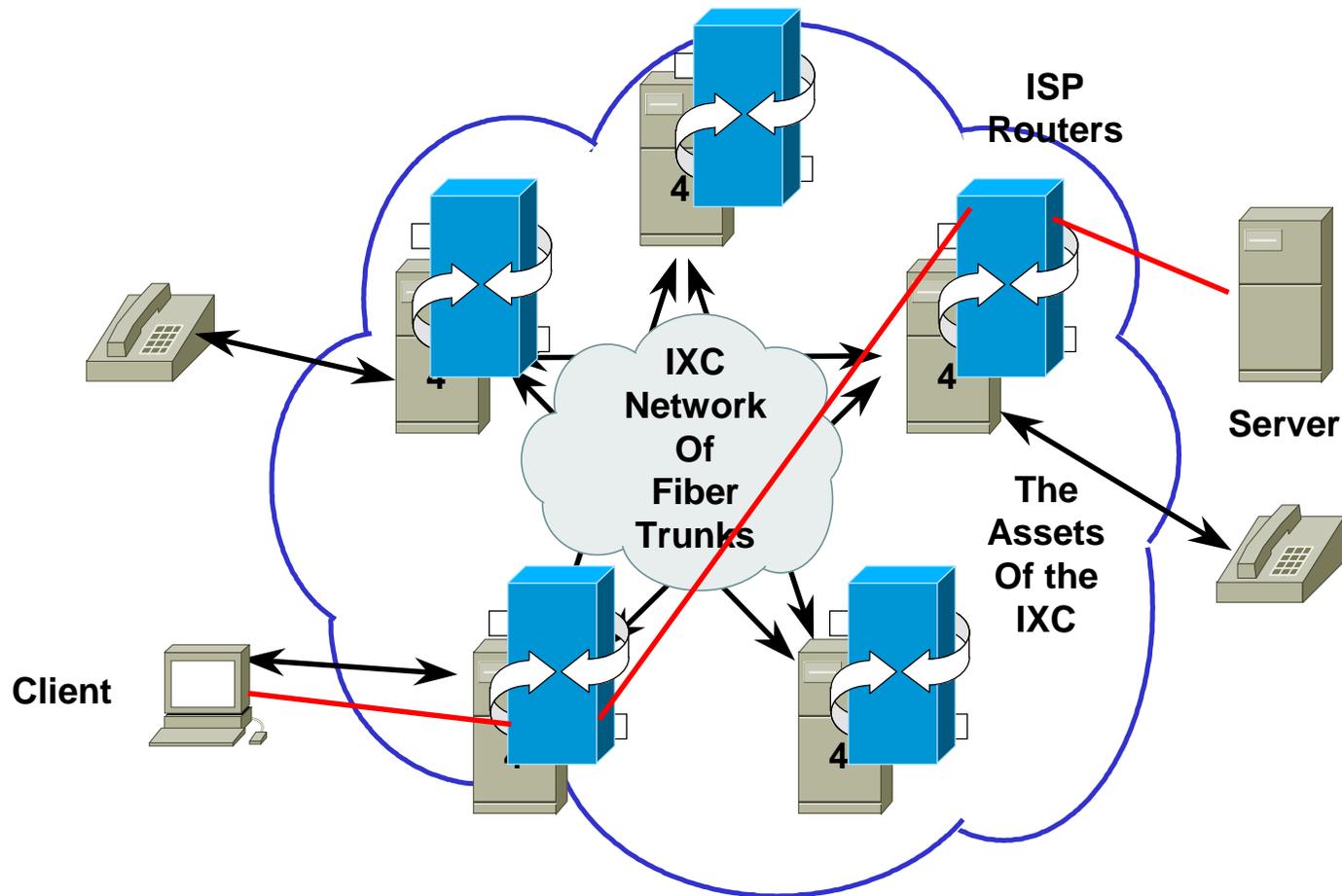
SEVCIK'S NETWORK SWITCHING LAWS

- Sevcik published his work in the Business Communications Review, September, 1997, page 33, titled *"Why Circuit Switching is Doomed"*
  - Short and sweet quantitative material that fell in line with Isenberg's findings
- **Sevcik's Network Switching Laws**
  - Successful new switching technologies double their performance/cost ratio twice as fast as the previous technology.
  - As switches improve their performance/cost ratios, they also shed processing functions to satellite processors (severs) or directly to end stations.
  - A steep performance/cost improvement trajectory is more important to the success of a switching technology than its initial performance or cost relative to its competitors.
- *Side note: "Personally, I never bet against compounding." Peter Sevcik*

MOST INTERESTING GRAPH
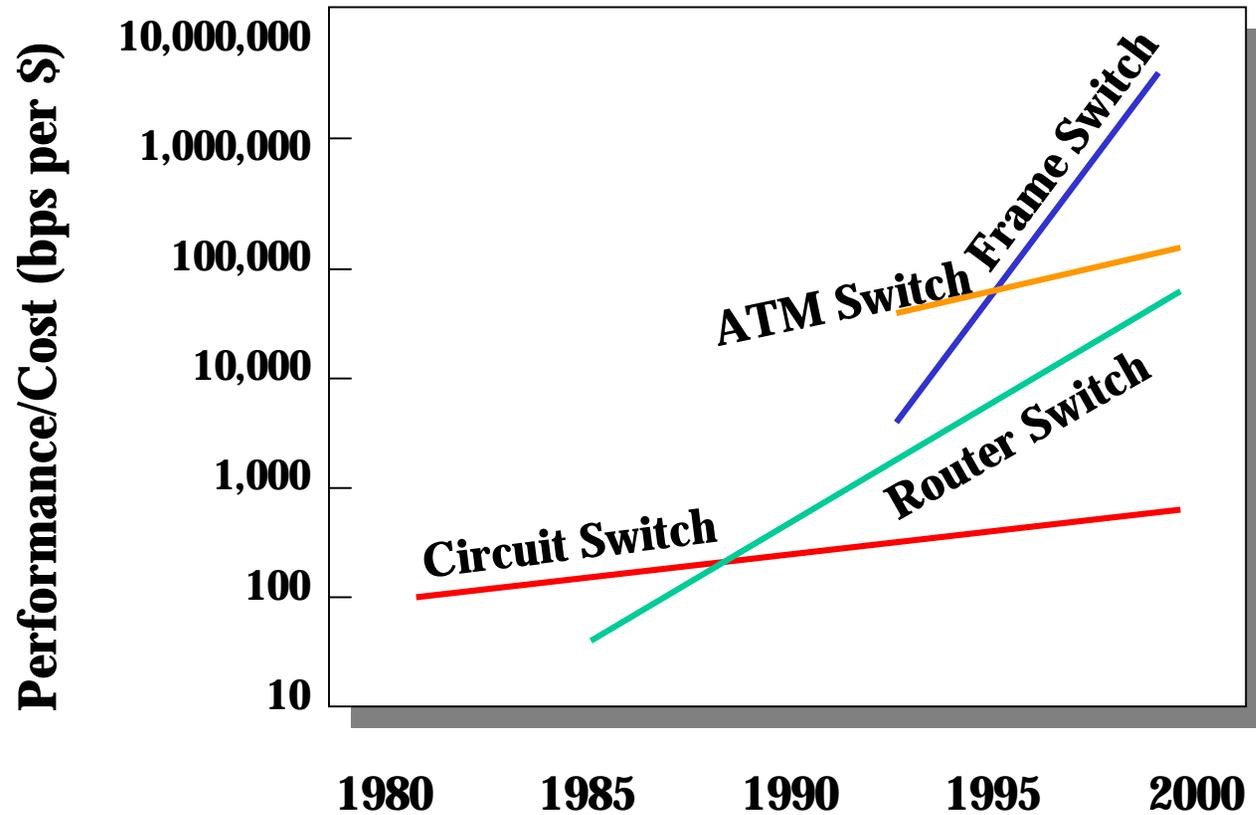
Peter J. Sevcik
"Why Circuit Switching is Doomed"
Business Communications Review, September, 1997

ELECTRONIC VERSES OPTICAL SWITCHING

- More support for dumbing down networks
  - Micro Electro Mechanical Systems (MEMS)
    - Lucent Technologies' WaveStar™ LambdaRouter™ of 256-inputs to 256-outputs
  - Bubble Matrix
    - Agelent Technologies' Champagne
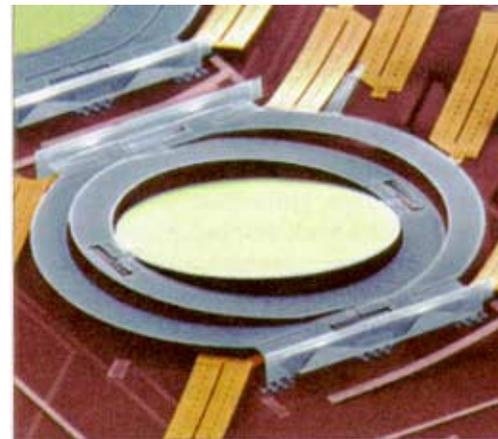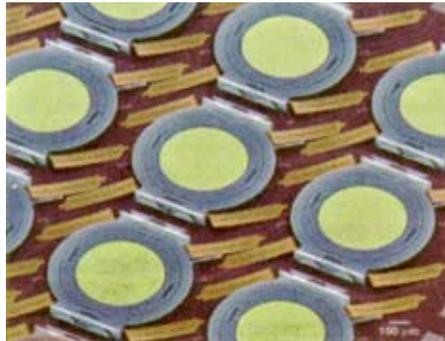
ARE SATELLITES KEEPING PACE?

- Research conducted by Victoria L. Miralda at the University of Colorado - Spring Semester, 2000
  - Satellites may be an aberration in the data
  - Some data - commercial payloads deployed

	GEO Commercial	LEO Commercial	Total Commercial Payloads
1995	18	4	22
1996	24	1	25
1997	28	59	87
1998	22	82	104
1999	22	54	76

AST: Commercial Space Transportation: 1999 Year in Review

SATELLITE LAUNCHES SEEM TO DOUBLE EVERY TEN YEARS
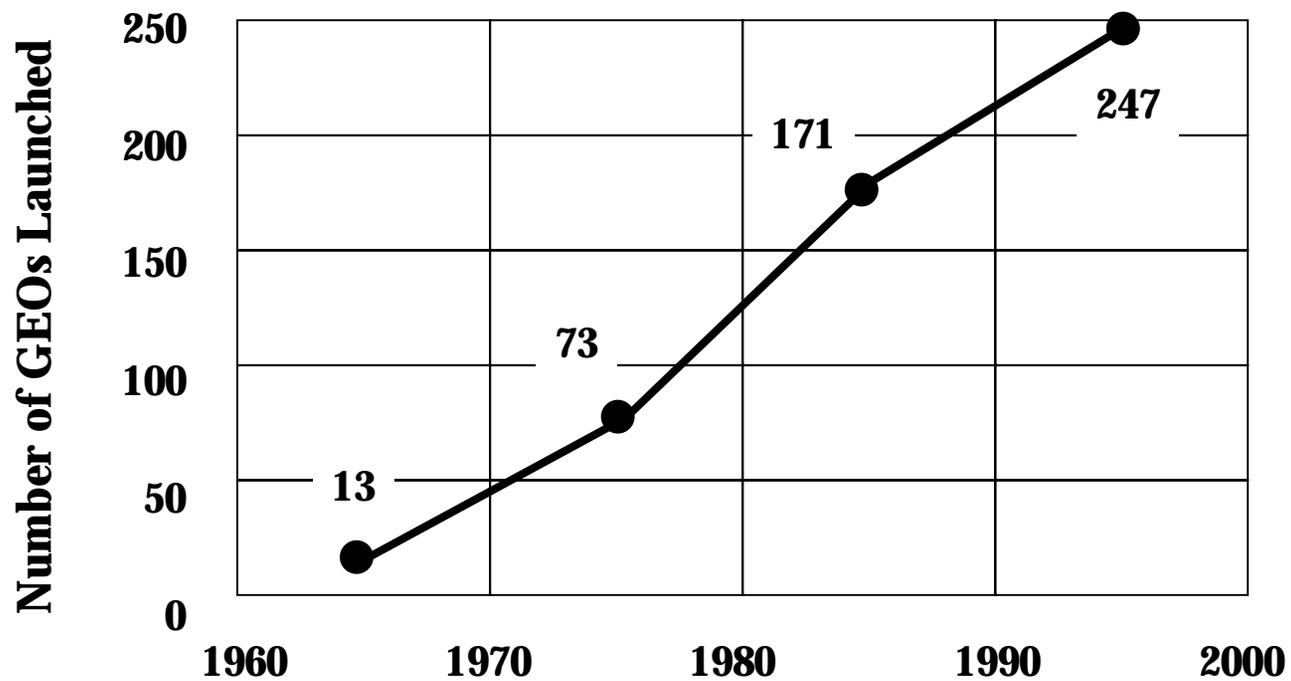
ROLL-UP OF RAW ORBITAL BANDWIDTH CURRENT AND PROJECTED
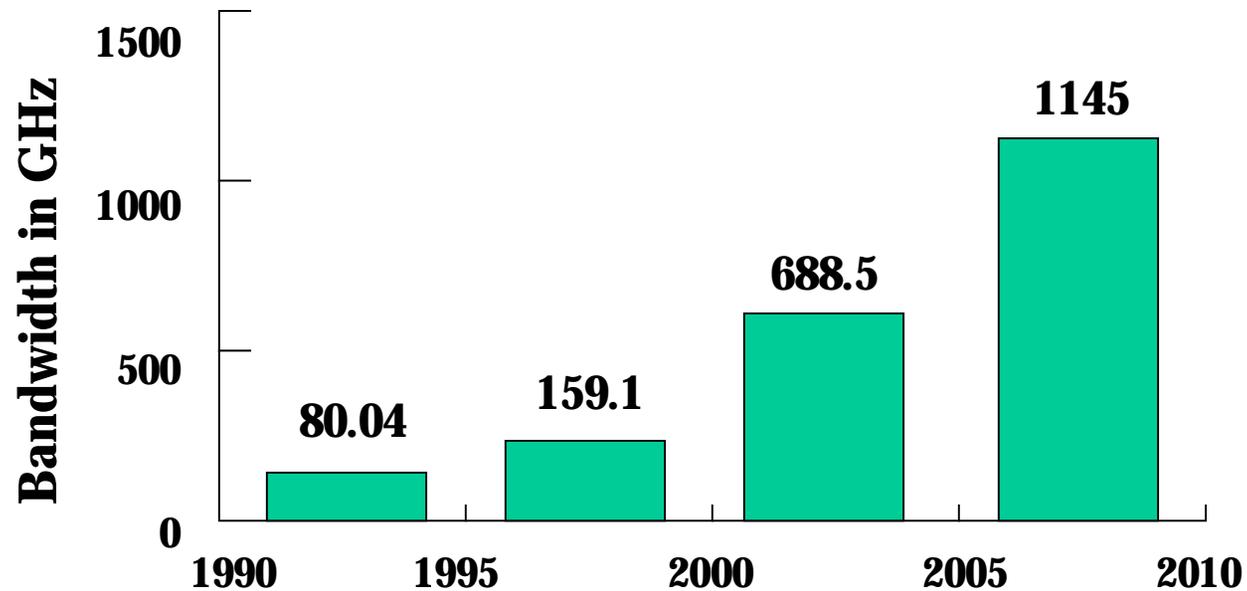
LAW OF THE SPACECOSM

- LEOs will be capable of tripling capacity approximately every 5 years and GEOs every 8-10, depending on the multiple factors of the Spacecosm. The average time to triple satellite bandwidth capacity will be on average 7 years.

Victoria L. Miralda, "Will Satellite Communications Keep Pace With Internet?" Research Thesis, University of Colorado at Boulder, Interdisciplinary Telecommunications Program, Boulder, CO, April 14, 2000

A CASE FOR DISRUPTIVE TECHNOLOGIES

- A disruptive technology is one which defies projections by introducing a step function in the trend that it supports
  - Marc Andreessen's Mosaic Browser given Ted Nelson's hyper-text and Tim Berners-Lee hyper-linking
  - Breakthrough of the semiconductor industry from traditional Al+Si vrs CU+Cu
  - Wave Division Multiplexing (WDM)
  - And so on . . .

CLIENTS AND SERVER DEMANDS WILL NOT SLOW DOWN
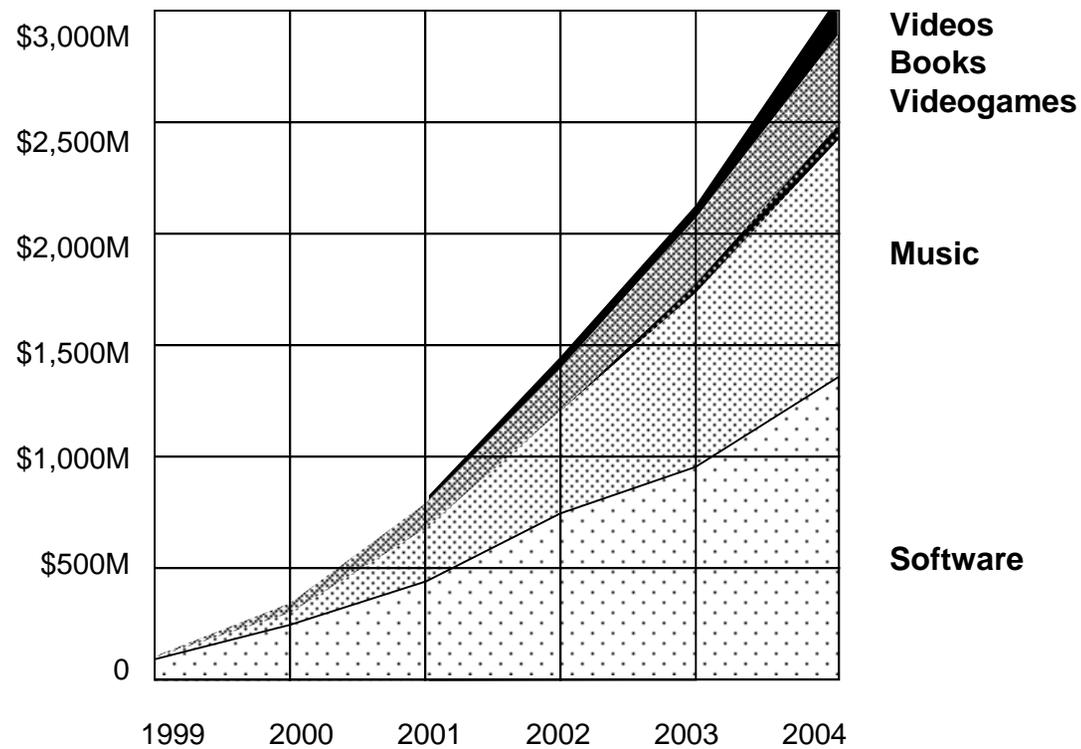
Digitally downloaded product sales forecast, 1999 to 2004

CONCLUSIONS

- The laws of the network seem to be holding firm
- Such projections have and will continue to appear radical and even preposterous
    - "Here is my attempt at entropy gradient reversal at AT&T. Of course, everyone knows that reversing the entropy gradient is absolutely impossible, and that if you show even the vaguest threat of succeeding, the threatened world throws you out on your ear." - David S. Isenberg
- But, disruptive technologies can be counted on - **the final law of the network**
- Let each and every one of us be a part of this wonderful ride