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BANDWIDTH ANGELS: A MILLENNIAL REVIEW

The computer age is over. That is the significance of the amazing Telecosmic run of the last year. Of the best stock market performers of 1999–an all time record year by every measure of wealth creation–the Telecosm list led the parade. While 63 percent of New York Stock Exchange companies and 52 percent of NASDAQ companies were down for the year, the date-adjusted GTR selection was up 268 percent, far ahead of any other major index.

Capturing first and second and six of the first ten on the Standard & Poor 500 and four out to the top eight in the NASDAQ 100, the Telecosm outperformed any previous technology list in memory, including the dot.coms of the year before. Breaking through with the global wireless standard for Internet access, **Qualcomm** (QCOM), the CDMA pioneer, was the runaway leader with a percentage rise of 2583, with **Sprint PCS** (PCS), the star in CDMA deployment, second at 343 percent. On the NASDAQ 100, **JDS Uniphase** (JDSU) rose 830 percent, **Conexant** (CNXT) 693 percent, and **Applied Micro Circuits** (AMCC) 649 percent. Since the great merger JDSU has gone from strength to strength, offering more highly integrated higher margin products, and further consolidating its position as the Intel of the Telecosm, with a string of lesser acquisitions giving it breadth and depth even its most elite, more narrowly focused competitors cannot challenge.

Capturing six of the first ten slots on the Standard and Poor 500 list, the Telecosm Companies outperformed any previous technology list in memory

On the S&P 500, the much maligned **National Semiconductor** (NSM) was an especially gratifying number 10 as its prowess in mixed signal devices and single chip systems was finally recognized. All the S&P top ten, except **Nextel** (NXTL), were clearly part of the paradigm and Nextel, though a TDMA retard, was otherwise exemplary of the onrush of wireless. The only true computer company on the list was **Sun** (SUNW), which built its business on the premise that “the network is the computer.”

In This Issue:

Bandwidth and now “storewidth” eclipse the PC paradigm. PCs remain important but peripheral. After a cataclysmic global run of thirty years, the PC revolution has stiffened into an establishment. So swiftly and subliminally did this silicon tide pass through the economy that many analysts missed much of the motion until it stopped. Then they mistook its dotage for dynamism. For it congealed so fast that its Mount Rushmore giants still walk and talk.

Contemplate the monumental frieze looming over the road ahead, which ends at a revolutionary shrine: Bill Gates of **Microsoft** (MSFT), Steven Jobs of **Apple** (AAPL), Gordon Moore and Andrew Grove of **Intel** (INTC). Still very much around, they beam from magazine covers, iconize companies, orate at Davos and Comdex, and publish books (Grove even writes them). Jobs launches new products in “insanely great” new tints and hues. Their totems tower over their time: Windows 2000, the Millennial operating system launched with 30 million lines of code and a record setting wild guess of 200,000 bugs; serried ranks of Pentium processors and support chips with scores of millions of transistors and insta-classical names, draining some 80 watts of power, enough to heat an igloo.

These Rushmore men, quick or dead, no longer shape the future. The trajectories of their companies are set in concrete source code, the DNA of an epoch that is over. Contemplating retirement, they manage portfolios more and more sodden with deductible good deeds of planetary angst and posterity preening, global whining, and pop science drivel. (For the answer to their complaints, turn to our colleague Peter

JDSU consolidates its position as the Intel of the Telecosm with a breadth and depth even its elite competitors cannot challenge

Huber's superb new book, *Hard Green.*) Computers no longer spearhead the economy. The action is elsewhere. The action is in the Telecosm.

Of course, the computer and the microchip remain enormously potent technologies. (So do the wheel, the steel mill, and the nuclear power plant). Gordon Moore's law, which dictates a doubling of microchip performance, or a halving of its cost every 18 to 24 months, is still in force. The process of ingraining intelligence into every aspect of our lives, mind into every machine, tool, or toy, continues at an accelerating pace. The displacement of matter by mind in the economy, already the most powerful economic event in recorded history–just now transpiring in economic data–has not yet begun to end.

The computer era–the age of the microchip, which I term the "Microcosm"–is ending not because it has failed, or even because it has been fulfilled, but because the Microcosm itself has given birth to a new era. It has enabled a new technology that is transforming culture, economics, and politics far more thoroughly than the computer age did. That is where you come in as subscribers to this report and subveners in the markets that guide funding for the Telecosm.

The computer era is falling before the one technological force that could surpass in impact the computer's ability to process information. That is communication, which is more essential to our humanity. Communication is the way we weave together a personality, a family, a business, a nation, and a world. The Telecosm will make human communication universal, instantaneous, unlimited in capacity, and at the margins free.

S & P 500 Ranking: 1999 Total Return (%)

Rank	Company	Total Return
1	Qualcomm Inc.	2618
2	Sprint PCS	343
3	Nextel	336
4	LSI Logic	319
5	Nortel Networks	304
6	Oracle Corp	290
7	Network Appliance	271
8	Yahoo Inc.	265
9	Sun Microsystems	262
10	National Semiconductor	217

Source: Standard & Poor

In the new economy, communications capacity, or bandwidth, replaces computer power as the driving force of technological advance. The telecosmic vision of nearly infinite bandwidth does for communications what Moore's Law did for computing: defines the direction of technological advance, the vectors of growth, the sweet spots for finance.

A millennial turn

Like all the twentieth century's most crucial passages, this millennial transition has its roots in physics. While the industrial age emerged from a mastery of the masses and energies of Isaac Newton, the computer age sprang from a practical grasp of the particles and paradoxes of the quantum theory of Erwin Schroedinger, Werner Heisenberg, and Albert Einstein. The heroes of the semiconductor industry took us step by step down quantum ladders toward the ultimate infinitesimal realms of atoms and ions, in the process multiplying transistors first by the thousands, then by the millions and tomorrow by the billions on a single sliver of silicon, enabling us to process, create, compute and reconfigure information at a speed and scale previously unimaginable.

Because the computer made the creation and manipulation of information the central activity of the economy this era has also been known as the information age. The great frustration of the computer era, however, has been the difficulty of communicating the information that we are told has become our most precious resource. Information is power, but information that cannot be readily moved is gridlock on the World Wide Wait. Immobile information makes our businesses larger, more static, and hierarchical than they need to be. It makes our economies less flexible, our jobs less fulfilling, our lives less luminous with opportunity.

The Telecosm launches us beyond the copper cages of existing communications, dissolves the topology of old limits, and brings technology into a boundless, elastic new universe, fashioned from incandescent oceans of bits on the electromagnetic spectrum.

At the heart of the Telecosm are lasers pure enough to carve a sliver of light into thousands of usable frequencies, gossamer glass threads carrying millions of times more information than copper cables thousands of times larger, fiber strands made of glass so pure that if it were a window you could see through 70 miles of it. In wireless technologies, the telecosm can even banish all the glass and unveil new cathedrals of light and air alone.

This is not futurism, for the science behind it is already history. The impact of the change, though, will exceed most of the dreams of technological futurists. Futurists falter because they belittle the power of religious paradigms, deeming them either too literal or too fantastic. Futures are apprehended only in the prophetic mode of the inspired historian.

The ability to communicate–readily, at great distances, in robes of light–is so crucial and coveted that in the Bible it is embodied only in angels. Distance is a fundamental premise of a material world. It fell not to the force of the telegraph, the telephone, the television, or the airplane. None of these achieve true action at a distance. Transmitting a few words, a few minutes of voice, even the few filmed spectacles that broadcasters deign to bounce around the globe, serves only to remind us how bound and gagged we are–how tied to the limits of time and space that angels traverse in an instant.

These gags and ties are now giving way. When anyone can transmit any amount of information, any picture, any experience, any opportunity, to anyone, or everyone, anywhere, at any time, instantaneously, without barriers of convenience or cost, the resulting transformation becomes a transfiguration. The powers it offers bring us back to the paradigms of paradise and its perils, prophets and their nemeses, infinite abundances and demonic scarcities.

Infinity and beyond

The concept of infinitude challenges us all, even the mathematicians and technologists among us. But the central event in technology over the last decade is a growing awareness that the information bearing power of the electromagnetic spectrum–its bandwidth or range of frequencies and wavelengths available to carry signals–is not severely limited, as previously believed, but essentially infinite. From AM radio signals through microwaves to visible light–a band of frequencies millions of times the bandwidth of our 56 kilobit modems–the spectrum can carry usable signals.

An infinitude of potential bandwidth implies the endless multiplication of spectrum use and reuse. Cellular technologies such as CDMA allow the reuse of all available bandwidth in every cell, the sharing of cellular bandwidth among many users, and the proliferation of local cells through the deployment of more antennas. The rise of Qualcomm is based on this potential of ubiquitous waves.

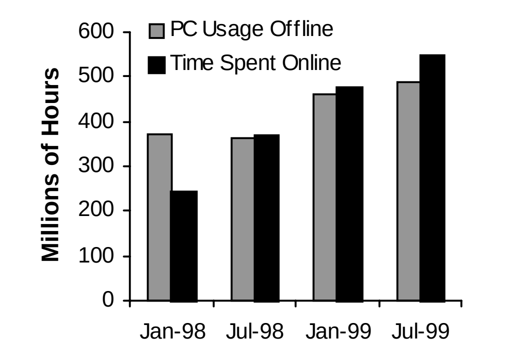

Chart 2
Weekly Household PC and Online Usage
Source: Odyssey L.P.

The most powerful of all spectrum reuse technology is fiber optics. Every fiber optic thread, the width of a human hair, can carry a thousand times more information on one path than all current wireless technologies put together. The basic measure of bandwidth is hertz or wave cycles per second. The bandwidth of currently used wireless spectrum, running from AM radio to Direct Broadcast Satellite, comes to a total of some 25 billion hertz (25 gigahertz), in scientific notation 25 times 10 to the 9th. The capacity of a fiber optic cable–incorporating some 864 individual fibers–is measured in petahertz–10 to the 15th waves per second. Petahertz signifies a million gigahertz.

These technologies together comprise the Telecosm. It makes bandwidth–information at enormous speed and almost infinite scale–the defining abundance of a new era, eclipsing even the still fantastic abundance of the computer age. It makes men into bandwidth angels.

Every new era is marked and measured by key abundances and scarcities. They shape the field of economics, the substance of business, the fabric of culture, and the foundation of life. As Japanese futurist Taichi Sakaiya has written: "Survival dictates that human beings…develop an ethics and aesthetics that favor exploiting fully those resources that exist in abundance, and economizing on items that are in short supply." That is how we exist. We do not breathe xenon or eat platinum. Abundances and scarcities are not merely economic phenomena; they help weave the texture of life.

Economists have traditionally focused on scarcity. Shortages, after all, are measurable and end at zero, thus making them suitable subjects for dissertations in the "dismal science." Abundances tend to end in a near zero price and thus escape economics altogether. As the price declines and their role in the economy becomes more vast and vital, their role in economic analyses diminishes. When they are ubiquitous, like air and water, they are invisible… "externalities." When they are, like the microchip, the product of human ingenuity they come as a surprise and thus escape analysis until their impact on the economy is so fundamental that they cannot be isolated for analysis. Yet abundances are the driving force in all economic growth and change.

Every economic era has a defining abundance, a critical resource or technology that is expanding in production and plummeting in price so rapidly that it appears virtually free compared to an array of competing critical resources for which it can be substituted. These abundances come to define the very character of their age, whether an age of "steam" or "oil" or an age of "information." Nations, companies, and individuals that exploit this "free" abundance gain market share against all rivals. The political leaders who accommodate them become the prime movers in global affairs. Their countries pioneer and prosper.

During the pre-industrial era in America, the scarcity was horsepower and the abundance was land. In the industrial age, horsepower–physical force, translated eventually into watts, or kilowatt-hours–abounded while land grew relatively scarce. Between 1660 and 1950, the cost of an effective kilowatt-hour dropped from thousands of dollars to some seven cents. We splurged on cheap horsepower–to clear farmland, to refine ores, to produce new farm equipment, to manufacture goods and capital gear, and to contrive armaments for capturing or defending land. And these activities defined the industrial paradigm.

Over the last 30 years, the era of the Microcosm, transistors became asymptotically costless. On a computer memory chip the price of a transistor, with support circuits, dropped from some seven dollars to a few millionths of a cent. Dropping at an

The central event in technology over the last decade is the growing awareness that the information bearing power of the electromagnetic spectrum is essentially infinite

A global economy designed to waste transistors, power, and silicon area and conserve bandwidth is breaking apart

average of 48 percent per year, a MIPS (millions of instructions per second) of computer power that cost several million dollars in 1960 sells for less than a dollar today. Thirty-five years ago, a chip factory could produce a few score transistors a day. Today, a single production line in a microchip wafer fabrication facility ("fab") can produce some 1.6 trillion transistors in twenty-four hours. We ended up "wasting" billions of them playing solitaire or singing Karaoke, brushing our teeth, warming a sandwich, or strumming guitars on music synthesizers. In this microcosmic era, every nation, company, and individual–from the oldest professions to the newest, whether you are a policeman, a farmer, a general, an architect, a prostitute, a software engineer, a fitness coach, an oil geologist, or a pharmacist–must use transistors to succeed.

Less noticed than the abundance of transistors but also important in shaping the technology of the era has been an implicit abundance of silicon area–the space available to accommodate the trillions of transistors. Filling up the multiplying expanses of computer backplanes and motherboards and daughter cards with increasing numbers of ever larger chips, silicon area has expanded dramatically. Every five years, the number of chips produced has approximately doubled, to some 285 billion units in 1999. With the average size of a chip rising some 50 percent during this span, total silicon area has been increasing 150 percent every half decade. Now at around 40 square kilometers of bare chips a year, the semiconductor industry could annually coat Silicon Valley itself, from San Jose to Palo Alto and across to Santa Cruz, with scores of layers of crystalline silicon meshed with microscopic aluminum and polysilicon wires and doped with enough exotic chemicals to be condemned as a toxic site by the Environmental Protection Agency.

An era's defining abundances relieve its critical scarcities. We use transistors to compensate for a shortage of human servants and–heretofore–broadband communications capacity. Think, for example, of the billions of chips devoted to making our telephone switches, modems, faxes, and "fast" Internet links function at all over narrowband telephone wires. It was in response to this basic problem that the transistor was invented in 1949 at **AT&T**'s (T) Bell Labs. The central rule of the Microcosm became: substitute cheap switches for expensive wires; abundant computation for narrow connections; intelligent processing for dumb but still expensive carrying capacity.

Microcosm upside down

But abundances can also create new scarcities. The plethora of cheap fuel created a dearth of roads and a need for pollution controls. The more recent glut of transistors–and the colossal streams of bits they shaped and sent–led to a shortage of the very communications capacity it was meant to enhance. While existing telephone bandwidth–maximized by resourceful electronic processing–was ample for voice communications, it became suddenly scarce when faced with a global abundance of computers generating data at a rate of megabits per second. The canonical abundance of one era creates a canonical shortage for the next.

And now, in the age of the Telecosm, all the defining abundances of the computer era–ever cheaper power, transistors, and silicon area–are becoming relatively scarce. And the crucial scarcity for which the transistor was meant to compensate–bandwidth–is the defining abundance of the new era. A global economy designed to waste transistors, power, and silicon area–and conserve bandwidth above all–is breaking apart and reorganizing itself to waste bandwidth and conserve power, silicon area, and transistors.

In the next era, the most common digital devices will be cellphones and smart cards–increasingly performing an array of computer functions–that must be powered by low power batteries or solar cells, technologies that double their efficiency over a span of decades rather than months.

Also scarce in these portable devices will be silicon area. Engineers must cram an ever increasing array of radio frequency, digital signal processor, and microprocessor functions within the constricted cavity and power budget of a handset. No longer can chips sprawl by the hundreds across PC backplanes and peripheral boards; cellphone computers will be based on single chip systems like those from National, **LSI Logic** (LSI), and **Atmel** (ATML), sharply economizing on power and silicon. **Xlinx**'s (XLNX) Programmable Logic Devices, now meet-

C-Cube, Broken Up, Heading for Storage

Our C-Cube, you may have noticed, has doubled since September. Under the terms of a C-Cube and Harmonic, Inc., deal, however, C-Cube is being broken up and the name will disappear. A supplier of optoelectronic gear for the cable TV industry, Harmonic will absorb C-Cube's rapidly growing DiviCom division in a deal worth some $2.5 billion. Chiefly a systems integrator for cable companies moving to digital video, in December alone, DiviCom won contracts with Time Warner and GTE, and broke through with a deal for deployment of an MMDS (wireless cable) system in China. Nevertheless, Harmonic is mostly an old paradigm cable equipment stock with surprisingly little interest in Internet and cable modem applications.

C-Cube's semiconductor company is a different story. It will gain independence and a new name at a time when C-Cube chip prospects are soaring. In addition to earlier success with decoder chips for the fast growing direct broadcast satellite (DBS) receiver market, C-Cube sold over 2.25 million DVD (digital versatile disk) decoder chips during the second and third quarters of 1999, while new markets emerge in recordable DVD players, digital VHS videocassette players (with JVC of Japan), along with new time-shift settop boxes using advanced real-time C-Cube MPEG CODEC (compression/decompression) chips. On December 20, C-Cube and Cisco announced the incorporation of C-Cube chips into Cisco's new Video-Over-IP networking product. The still nameless "C-Cube" microchip arm could emerge as a significant player in storewidth, enabling fast access to an array of digital video storage and delivery systems, from the Internet all the way to soon-to-be Internet ready direct broadcast satellites.

–Ken Ehrhart

ing or exceeding the capabilities of application specific chips and supreme in the rapidity and flexibility with which they can be programmed for specific applications, are crucial conservers of silicon area.

Similarly, coupling lasers and other communications devices to a fiber optic thread with a .8 micron core, a tenth of the width of a human hair, imposes severe restriction of space and power. These constraints become more acute when the fiber is laid on the bottom of the ocean under a pressure of 10,000 pounds per square inch. Led by **Global Crossing** (GBLX), companies that achieve prowess in this hostile environment will present rivals with major barriers to entry.

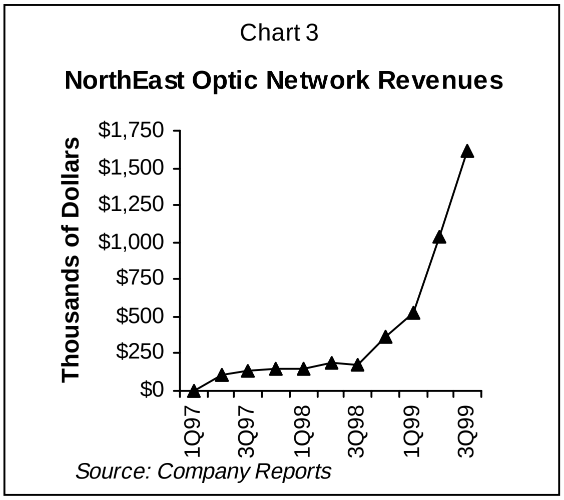

Chart 3

NorthEast Optic Network Revenues

Source: Company Reports

Fueled by solar energy, satellites also restrict power and silicon area. **Globalstar**'s (GSTRF) decision to use CDMA and keep most of the power-hungry electronics on the ground sealed its superiority over **Iridium** (IRID) and assures its Millennial future.

In the new millennium, with the price of digital transistors already down to millionths of a cent–virtually free already–their plummeting price will no longer spearhead the technology of the time. Crucial in the Telecosm, however, will be high frequency analog devices linking digital appliances to the real world of sounds and pressures, images and movements, and user interface inputs. Increasingly these analog digital converters, oscillators, low noise amplifiers, and high frequency transmitters will employ exotic materials such as silicon germanium, gallium arsenide, and indium phosphide in ever more complex combinations called heterojunctions and high electron mobility transistors. These transistors are millions of times more costly than the sturdy digital devices now being deployed by the billions on a single dynamic random access memory (DRAM) chip for your personal computer.

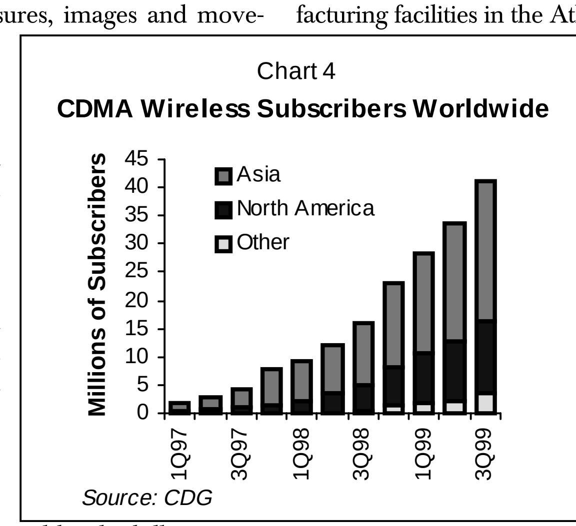

Chart 4

CDMA Wireless Subscribers Worldwide

Source: CDG

You will find the GTR focusing increasingly on low power technologies, whether silicon germanium microchips from Atmel and AMCC, mixed signal chips from National Semiconductor, **Texas Instruments** (TXN) and **Analog Devices** (ADI), or the low power phones that made Qualcomm the leading stock of 1999 and will make it a spearhead communications company for the Millennium.

Conexant's CDMA play

The critical analog function of a CDMA wireless phone for instance, is the management of extremely low-power signals to keep multiple shared frequency transmissions from drowning each other out. The leading manufacturer of the power amps that do this job is **Conexant** (CNXT), whose wireless revenues rose 34% sequentially last quarter, a reminder to acrophobic subscribers that there are other CDMA plays available for those experiencing vertigo on the Qualcomm heights.

As the year came to a close, Atmel enhanced its leadership in silicon germanium manufacturing by adding to its European Temic subsidiary an Hitachi 8 inch wafer fabrication plant in Irving, Texas, for the production of these devices.

Measured by the expansion of Internet traffic, the cost/performance of bandwidth is improving by a factor dwarfing Moore's Law. Doubling every three or four months, bandwidth is demonstrably advancing at a doubling rate at least four times the 18 month pace of the Microcosm.

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Nortel accelerates

Visiting **Lucent**'s (LU) giant fiber optic manufacturing facilities in the Atlanta suburbs in late 1999, and **Nortel** (NT) outside of Montreal in November, I saw evidence of a sharp further acceleration in the expansion of bandwidth. Nortel announced that it could put 80 wavelengths of light on a single fiber thread with each wavelength bearing 80 gigabits per second. On a state of the art 864 strand cable, that represents 5.6 million gigabits a second (a million gigabits is a petabit). But Lucent has demonstrated a thousand wavelengths on a single fiber, ten billion bits of information per second on each wavelength. With 864 fibers in each fiber cable, this adds up to a total of 8.6 petabits per second in a single fiber sheath.

One factor limiting the number of channels in a fiber is the restriction of signal transmissions to limited frequency ranges. Traditionally there are two usable frequency bands for WDM separated by a spike of signal attenuation loss, caused by water mol-

Nortel, already leading in high speed long distance transmission, brilliantly acquired Qtera, the leader with Corvis and Avanex in pushing transmission distance without costly electronic regeneration

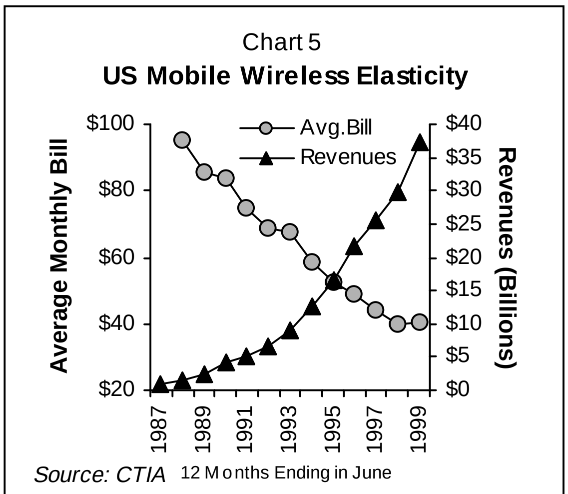
ecules introduced during the fiber manufacturing process. Lucent's ALLWave fiber eliminates this loss spike, widening the transmission window by some 60 percent, with an emerging possibility of over 2,000 channels per fiber. **NorthEast Optic Network** (NOPT) and **Metromedia Fiber Networks** (MFNX) are both pioneers of ALLWave fiber.

Eight petabits per second is a thousand times the total average telecommunications traffic across the entire global infrastructure as recently as 1997. Eight petabits represented the total Internet monthly traffic in 1996 when we began the GTR some three and a half years ago.

Avanex speeds out

Nortel has invested $400 million to expand its optical component manufacturing, and extend its traditional lead in high speed long distance transmission. Along the way it brilliantly acquired **Qtera**, the leader along with **Corvis** and **Avanex** in pushing the distance an optical signal can travel without costly electronic conversion and regeneration. Avanex, powered by the redoubtable Simon Cao –who maintains his record of more than one patent for every year of his luminous life–goes public in early February.

Having moved well beyond its core optical fiber business, **Corning** (GLW) has become a leader in optical components such as EDFAs (erbium doped fiber amplifiers). With its acquisition of **Oak Industries** whose Lasertron subsidiary makes pump lasers, Corning signals its intention to be a major producer of active as well as passive optical components.



Crucial as well to the bandwidth blowout is shedding the legacy of protocols, equipment, and expense still lingering from the days when fiber was no more than a point-to-point substitute for copper or microwave links interconnected by costly and elaborate electronics. The cumbersome layering of IP over ATM over SONET over WDM, becoming intolerable as the SONET toll heads toward $10 billion a year, is giving way to a simple stack of IP over WDM. Mesh network topologies enabled by real time lambda provisioning from **Sycamore** (SCMR), Avanex, **Xros**, Corvis, and Lucent via its WaveStar LambdaRouter, will more cheaply and efficiently replace legacy SONET rings.

Older carriers with a perceived advantage of large fiber deployments and large customer bases will find these legacies a burden in the struggle to reengineer their networks as well as their business plans. As the bandwidth bounty drives the price of landline voice to zero, new network competitors built from the ground up to play by Telecosm rules compete for the honor of cutting prices faster than their competitors. For Global Crossing and **Level 3** (LVLT), NOPT and Metromedia, **Williams Communications** (WCG) and **Enron** (ENE), there will be no fiber glut.

While we all wait for fiber to reach our curb, we can root for local telco deployment of ADSL (asynchronous digital subscriber line) technology to provide broadband last mile connections over existing twisted-pair copper phone wires. At the close of the September quarter, U.S. ADSL subscribers numbered nearly 300 thousand. Analog Devices has been a leader in ADSL and just announced shipment of their one millionth ADSL chipset. Texas Instruments, Conexant, Lucent and Nortel are other Telecosm Table companies with strong positions in this ascendant technology. **PMC-Sierra** (PMCS) has introduced breakthrough DSLAM (digital subscriber line access module) equipment that increases from some twenty to two-thousand the number of DSL ports that fit in a telephone rack.

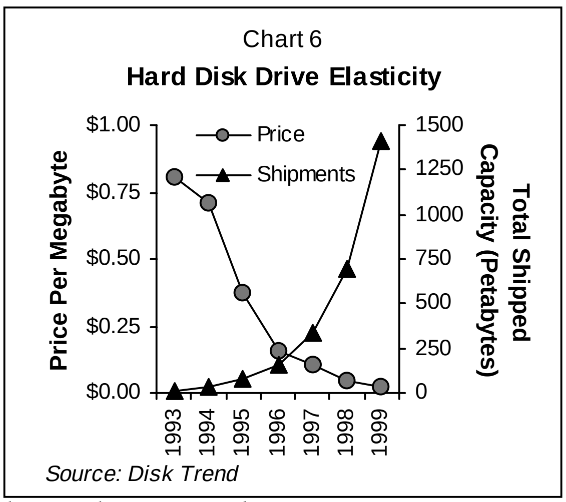
None the less, DSL lags far behind cable modems, which reached 1.4 million subscribers in North America at the end of the third quarter. **Excite@Home**, (ATHM) through its cable system partners, remains the market share leader. **Cox** (COX) has over 140 thousand cable modem subscribers, a four percent "penetration" of the homes passed by its service. **Shaw** (SJR), using **Terayon**'s (TERN) cable modems and headends, has more than nine percent penetration for 125 thousand subscribers. Yet in some Shaw communities and **Time Warner**'s (TWX) flagship Portland, Maine market, where service has been available and marketed for more than two years, penetration rates soar to 20 percent.

Broadcom (BRCM), which manufactures the vast majority of cable modem chipsets–and is diversifying with a range of broadband networking solutions including gigabit ethernet–is a Telecosm cable superstar. But the other major cable modem chip players are also found on our Table. TI, with its purchase of Israeli cable modem chip maker Libit, expands its analog, DSL and wireless offerings to cover the full range of modem technologies. Conexant can also offer its PC OEM customers a complete range of modem technology from analog and DSL to cable.

The most clearly differentiated offering, though, comes from Terayon. Its S-CDMA (synchronous code division multiple access) cable modem chips are superior in handling upstream noise, in data transmission through "drop-off areas" unusable for regular video broadcasts, and in flexibility for open access deployments. These advantages have given it a leading position in the Canadian, Japanese and European markets. In the U.S., the cable industries technical and standards body, CableLabs, adopted S-CDMA for inclusion in future cable modem standards, and CableLabs chief technical officer was apparently so impressed he has taken a job at Terayon.

Terayon's window

The **AOL** (AOL) Time Warner Inc. merger reveals more about the two companies weaknesses than their strengths and deepens AOL's confusion about whether it is selling content or conduit. But it makes even more likely the dominance of the consumer broadband access market by cable for the foreseeable future. And it eases the "open access" political anxieties that have been the one cloud over cable's future, by giving AOL both its own broadband access opportunity and something more important to think about than hiring lawyers. Nevertheless the market will drive all the major conduit players toward open access, particularly benefiting Terayon's open access friendly S-CDMA system.



The Microcosm, characterized by the plunging price of computing power, and the Telecosm, characterized by the plunging price of bandwidth, meet in the realm of wireless. Within handheld wireless devices, the precision design of highly integrated circuits combining numerous functions into single, low-power systems–the ultimate microcosmic achievement–determines the limits of transmission bandwidth–the telecosmic yardstick–and the functionality of the connected devices.

Moving to this fertile crescent is **Motorola** (MOT). With the write-off of Motorola's $750 million commitment to the Iridium debacle the company may be cutting its losses and removing its most serious barrier to Telecosm status. The company has overcome its late entry to the digital handset business and is gaining market share. With trials of IS95B, (the 64kb version of the IS95 version of CDMA, typically 14 kb) Motorola is demonstrating a commitment to CDMA data, expanding the hopes for its already successful CDMA infrastructure business. Up-spectrum wireless has been a strong suit of the company. Motorola leads in cable modem market share and has broadened its cable offerings with its purchase of General Instrument. And Motorola's huge semiconductor intellectual property and design portfolio has been reorganized around the implementation of diverse single-chip systems for communications equipment, handhelds and other devices.

Storewidth 2000

Now for the year 2000, we move on to the storewidth paradigm. Combining bandwidth and storage, storewidth enables swift and reliable access to the ever expanding troves of content on the proliferating disks and cells–the repositories of the ever ramifying net. Increasing at a rate of more than 60 percent per year, the capacity of storage arrays of all kinds is rocketing ahead of the advance of computer performance, which is continuing its 33 percent annual pace. But storage facilities are lagging far behind the 300 percent annual pace of bandwidth. This differential between the expansion of storage and the speed of computers is prompting a drive to get the computer server out of the path and replace it with a cheaper and faster special purpose device widely termed network attached storage (NAS).

This interface is the domain of storewidth. So far coming to the fore are **Novell**'s (NOVL) directories and caching schemes, **Network Appliance** (NTAP) and **Procom** (PRCM) direct storage access tools, **Foundry** (FDRY) and **Alteon** gigabit ethernet switches, and **Akamai** (AKAM), **Digital Island** (ISLD), **Internap** (INAP), **Adero**, and @Home network access and caching management. In the coming year, we are going to be extending the telecosm to this frontier.

These markets represent the continuing dynamic convergence of Microcosm and Telecosm. DVDs, CDs and related storage gear all rely on the most advanced lasers, which according to the law of the Microcosm also turn out to be the cheapest lasers. Based on confining the energy of a single electron, the quantum well represents an ultimate computing and communicating unit. If Lucent's laboratory successes can be extended to the marketplace, quantum wells may soon be cascaded to create scores of minuscule lasers on a single device that will help drive the multiple colored bitstreams of Wavelength Division Multiplexing (WDM) ever deeper into local and enterprise networks.

Reduced to irrelevance by the bandwidth and storewidth explosions are all the conceptual foundations of the computer age. A new economy is emerging, based on a new sphere of cornucopian radiance–reality unmassed and unmasked, leaving only the promethean light.

George Gilder, January 13, 2000

The market will drive all the major cable conduit players toward open access, benefiting Terayon's open access friendly S-CDMA system

TELECOSM TECHNOLOGIES

ASCENDANT TECHNOLOGY	COMPANY (SYMBOL)	REFERENCE DATE	REFERENCE PRICE	DEC-99: MONTH END	52 WEEK RANGE	MARKET CAP.
CABLE TECHNOLOGIES/SERVICES						
Cable Modem Chipsets	Broadcom Corporation (BRCM)	4/17/98	12 *	272 3/8	46 1/4 - 289	28.365B
CDMA Cable Modems	Terayon (TERN)	12/3/98	31 5/8	62 13/16	25 3/4 - 75	1.370B
MICROCHIP TECHNOLOGIES						
Analog, Digital, and Mixed Signal Processors	Analog Devices (ADI)	7/31/97	22 3/8	93	24 3/8 - 92 1/4	16.225B
Silicon Germanium (SiGe) based photonic devices	Applied Micro Circuits (AMCC)	7/31/98	11 11/32	127 1/4	14 13/16 - 125	6.865B
Programmable Logic, SiGe, Single-Chip Systems	Atmel (ATML)	4/3/98	8 27/32	29 9/16	6 13/16 - 31 1/2	5.960B
Digital Video Codecs	C-Cube (CUBE)	4/25/97	23	62 1/4	17 1/4 - 65 3/8	2.526B
Linear CDMA Power Amplifiers, Cable Modems	Conexant (CNXT)	3/31/99	13 27/32	66 3/8	6 3/4 - 76 3/16	12.939B
Single Chip ASIC Systems, CDMA Chip Sets	LSI Logic (LSI)	7/31/97	31 1/2	67 1/2	15 5/16 - 71 3/8	10.039B
Single-Chip Systems, Silicon Germanium (SiGe) Chips	National Semiconductor (NSM)	7/31/97	31 1/2	42 13/16	8 7/8 - 51 7/8	7.343B
Analog, Digital, and Mixed Signal Processors, Micromirrors	Texas Instruments (TXN)	11/7/96	11 7/8	96 5/8	41 7/8 - 111 1/2	76.567B
Field Programmable Gate Arrays (FPGAs)	Xilinx (XLNX)	10/25/96	8 7/32	45 15/32	14 5/8 - 48 9/16	14.498B
OPTICAL NETWORKING						
Wave Division Multiplexing (WDM) Systems, Components	Ciena (CIEN)	10/9/98	8 9/16	57 1/2	13 1/2 - 74 9/16	7.946B
Optical Fiber, Photonic Components	Corning (GLW)	5/1/98	40 15/16	128 15/16	43 9/16 - 127	31.526B
Submarine Fiber Optic Networks	Global Crossing (GBLX)	10/30/98	14 13/16	50	18 15/16 - 64 1/4	39.738B
Wave Division Multiplexing (WDM) Components	JDS Uniphase (JDSU)	6/27/97	7 1/4	161 5/16	14 13/16 - 177 1/2	46.268B
Broadband Fiber Network	Level 3 (LVLT)	4/3/98	31 1/4	81 7/8	38 - 100 1/8	27.926B
Broadband Fiber Network	Metromedia FIber Network (MFNX)	9/30/99	24 1/2	47 15/16	16 1/8 - 49 7/8	11.161B
Broadband Fiber Network	NorthEast Optic Network (NOPT)	6/30/99	15 1/16	62 9/16	8 3/4 - 79	1.019B
WIRELESS TECHNOLOGIES/SERVICES						
Low Earth Orbit Satellite (LEOS) Wireless Transmission	Globalstar (GSTRF)	8/29/96	11 7/8	44	12 5/8 - 38 7/8	3.617B
Satellite Technology	Loral (LOR)	7/30/99	18 7/8	24 5/16	13 1/2 - 22 7/8	5.953B
Nationwide Fiber and Broadband Wireless Networks	Nextlink (NXLK)	2/11/99	20 7/16	83 1/16	11 13/16 - 91 1/2	11.054B
Code Division Multiple Access (CDMA) Chips, Phones	Qualcomm (QCOM)	9/24/96	4 27/32	176 1/4	6 5/16 - 185	29.074B
Nationwide CDMA Wireless Network	Sprint PCS (PCS)	12/3/98	15 3/8	102 1/2	17 5/8 - 114 7/16	53.011B
Broadband Wireless Services	Teligent (TGNT)	11/21/97	21 1/2 *	61 3/4	28 - 75 5/8	3.341B
INTERNET TECHNOLOGIES/SERVICES						
Internet Enabled Business Management Software, Java	Intentia (Stockholm Exchange)	4/3/98	29	31 1/8	17 1/2 - 35 1/4	0.744B
Telecommunication Networks, Internet Access	MCI WorldCom (WCOM)	8/29/97	19 61/64	53 1/16	44 - 64 1/2	100.400B
Directory, Network Storage	Novell (NOVL)	11/30/99	19 1/2	39 15/16	16 1/16 - 40 3/16	13.302B
Java Programming Language, Internet Servers	Sun Microsystems (SUNW)	8/13/96	13 3/4	77 7/16	20 3/4 - 83	121.000B
BROADBAND TELECOM TECHNOLOGIES/SERVICES						
Wireless, Fiber Optic Telecom Chips, Equipment, Systems	Lucent Technologies (LU)	11/7/96	11 25/32	75	47 - 84 3/16	235.600B
Wireless, Fiber Optic, Cable Equipment, Systems	Nortel Networks (NT)	11/3/97	23	101	24 9/16 - 110	137.500B

* INITIAL PUBLIC OFFERING

NOTE: This table lists technologies in the Gilder Paradigm, and representative companies that possess the ascendant technologies. But by no means are the technologies exclusive to these companies. In keeping with our objective of providing a technology strategy report, companies appear on this list only for these core competencies, without any judgement of market price or timing. Reference Price is a company's closing stock price on the Reference Date, the date on which the company was added to the Table. Since March 1999, all "current" stock prices and new Reference Prices/Dates are closing prices for the last trading day of the month prior to publication. Mr. Gilder and other GTR staff may hold positions in some or all stocks listed.

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Monument Mills • PO Box 660 • Housatonic, MA 01236
Tel: (413)274-3050 • Fax: (413)274-3031 • Email: gtg@gildertech.com

EDITOR: George Gilder
PUBLISHER: Richard Vigilante
DIRECTOR OF RESEARCH: Kenneth Ehrhart
TECHNOLOGY ANALYST: Jeff Dahlberg
MANAGING EDITOR: David S. Dortman
BUSINESS DEVELOPMENT: Mark T. Ziebarth

FOR SUBSCRIPTION INFORMATION TELEPHONE TOLL FREE:
(888) 484-2727
WEBSITE:
www.gildertech.com
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