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LIGHT SPEED TRAP AHEAD

Once an abundant resource, the speed of light is now a crucial scarcity. Today the lightspeed limit is the key to immense new markets.

In the early years of the 20th century, the world of science confronted for the first time the full implications of the velocity of light as an unbreakable absolute. As Einstein saw it, the choice was stark. Physics either had to relinquish absolute light or abandon absolute time and space. Since exquisitely precise tests had repeatedly confirmed the absolute speed of light in all directions, regardless of rapid motions of the source or of the observer, Einstein instead boldly relativized space and time. The orderly Cartesian grid of classical theory collapsed and gave way to the baffling elastic mazes of general relativity. Measuring rods shrank and remote atomic timepieces slowed their vibrations from ultraviolet into red as the cosmos expanded from a big bang, black holes convulsed into infinite densities at the end of time, nuclear weapons exploded on cue, and undulating space-time geodesics emerged–least path straight lines swooning curvaceously in a succulent four dimensional continuum. Think of a cosmic Madonna visible through a prism at which mass becomes infinite, lengths shrink to zero, and clocks stand still.

That's the kind of thing we can expect today in the world of information technology as it collides with the speed of light barrier.

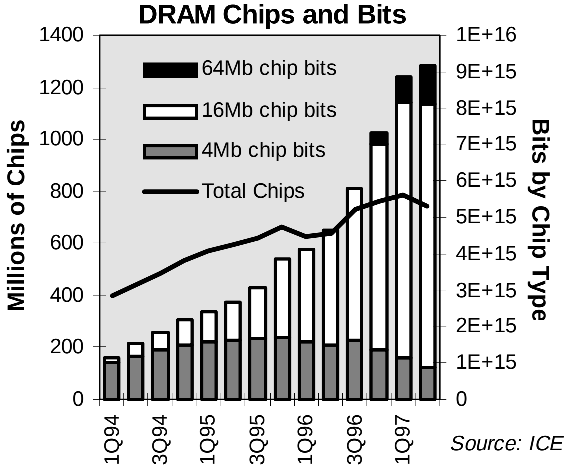
Don't laugh. Physics is at the heart of this technology. Physics is at the heart of the current rush to conglomeration among the leading semiconductor companies, from **Intel** (INTC) and **Chips & Technologies** (CHPS) to **National Semiconductor** (NSM) and **Cyrix** (CYRX). Physics is at the historic center of the entire microelectronics epoch.

At the same time as the relativity revolution early this century, quantum theory unveiled the inner structure of matter and upended the Newtonian assumptions of atomic solidity and determinism. Far from an unbreakable massy solid, the atom turned out to be as vacant in proportion to the size of its nucleus as the solar system is empty in proportion to the size of the sun. For an earthbound analogy, think perhaps of the mind of Al Gore. Electrons transpired as

The lightspeed limit requires creation of entire systems on a chip, overcoming the gap between processor speed and memory speed by putting the processor on the memory.

Chart 1

DRAM Chips and Bits



DRAM Advances with Micron

The DRAM market grew to $5,335 million in 2Q97 from $4,582 million in 1Q97. The 16.4% rise was realized despite a drop in unit shipments because of the continuing shift of production to higher priced, higher density 16 and 64 Megabit chips. Micron's production of some 30 million 16 Mb chips per month represents 20% of the 16 Mb market or 15.6% of the total bits shipped. Note: The two main kinds of memory chips are dynamic random access memories (DRAMs), which are relatively slow but which use single transistor cells to store bits in tiny capacitors, and static random access memories (SRAMs), which are as much as ten times faster but use between four and six transistors per cell. Cheap and dense, DRAMs overwhelmingly dominate the motherboards of computers, printers, digital televisions, and other devices. There are now as many as four megabytes (four million characters of memory, written 4MB) in a digital camera and 16MB in a typical PC. However, for historic reasons, memory chips themselves are described in megabits, (Mb), rather than megabytes (MB), with eight bits to a byte. -KE

baffling hybrid waves and particles that could not be fixed in time and space. Think of the views of Ross Perot. Photons emerged as paradoxically mass-less corpuscles of light stuck at a velocity of 186 thousand miles a second. Think of the original true to life version of *Speed*. Common sense departed physics, giving way to cosmic jokes. But by opening the interior of matter to manipulation, quantum theory ultimately allowed the creation of common computers on grains of sand and fiber optic lines of glass lasing photons around the globe.

Now, these miraculous quantum worlds of computers and communications are meeting a challenge from the lightspeed limit analogous to the upheaval of Einstein's physics. In much the way that absolute light overthrew the paradigms of physical time and space, so the light barrier is today subverting the established paradigms of time and space in information technology. In a siege of new alliances, buyouts and mergers, the industry is already transforming itself in relation to the luminal boundaries closing in upon it.

Once an abundant resource that enabled the miraculous pace of electronic processing and communications, the speed of light is now a crucial scarcity. It constrains the future shapes and solutions of computers and networks and puts today's architectures in jeopardy. From the lithographic gear that inscribes the circuitry on microchips to the "buses" that link microprocessors and memories at the heart of your PC, from the geosynchronous satellites that circle the globe and transmit digital television and data, to the fiber optic networks that connect distant cities on Internet backbones, the lightspeed limit has created a crisis of information systems.

Any crisis so fundamental opens large opportunities for engineers, entrepreneurs and investors. Today the lightspeed limit is the key to immense new markets in new microprocessor and memory architectures, in digital cameras and scanners, in wireless communications, in low earth orbit satellite systems, in network designs, and in semiconductor capital equipment.

The most obvious and immediate manifestation of the crisis comes in the relationship between microprocessor speeds and memory access times. For the past twenty years, microprocessor clock rates have been advancing at an estimated pace of between 48 and 60 percent per year. As photolithography equipment employs ever shorter wavelengths of light to inscribe ever smaller features on chips, both the speed and density of processors increase. Memory densities also rise at the same rate. But memory access times have been improving at a pace of only seven percent per year, with some signs of a further flattening of the rate of advance. The result is that new microprocessors, such as 300 megahertz Pentiums or 600 megahertz **Digital** (DEC) Alphas, spend as much as 90 percent of their time in wait states, marking time during memory access.

The new Alpha under development for introduction in 1998 will run at a gigahertz, a billion cycles a second. That means a cycle every nanosecond and each cycle may process as many as three instructions. Yet depending on price, existing memory chips take between six and 60 nanoseconds to deliver data to a register on a processor.

Although the industry is full of announcements of improvements of memory technology, David Clark of MIT sums up the basic predicament: "You can increase memory capacity or memory bandwidth by throwing money at the problem," building new $2 billion dollar factories or multiplying the number of DRAM chips and thus the number of pins on the motherboard and expanding the number of lines or traces in the bus. "But memory latency (access time) is determined by the speed of light, and you can't bribe God." The lightspeed limit essentially rules that electronic signals move nine inches a nanosecond. As chips become denser, with smaller feature sizes and larger silicon areas, interconnect lines both on and off chip become longer and narrower, with hundreds of meters of infinitesimal wire on a single chip. With longer and narrower wires, resistance and capacitance slow the velocity of the signals even further, to some four inches a nanosecond, less than half of lightspeed in a vacuum. Today, as much as 80 percent of the delay in computer systems comes from interconnections, on and off chip. The gates to system speed are less and less at Intel, and more and more at connector companies such as **Molex** (MOLX) and **AMP** (AMP).

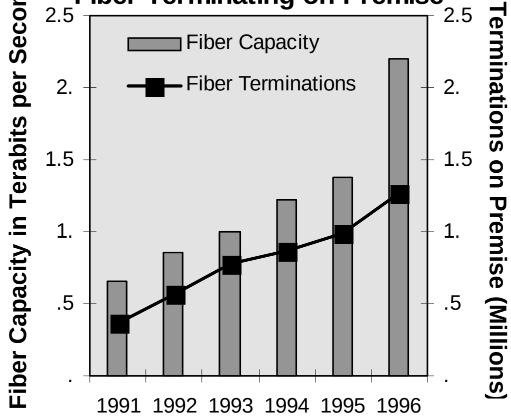
The usual answer to this problem is the creation of a complex hierarchy of on-chip and off-chip caches, which exploit propinquity–the likelihood that neighboring addresses will be accessed together. Often offering three tiers of caches, these systems couple expensive fast memories, chiefly static RAMs,

Fiber Bandwidth Expands

Lucent has continued to demonstrate the potential of wavelength division multiplexing (WDM) to further expand fiber bandwidth with the July 21, 1997 announcement of a 100-channel optical amplifier. By the end of 1996, the already abundant bandwidth of fiber optics moved significantly closer to the end user as the RBOCs (Regional Bell Operating Companies) moved to meet exploding customer demand for high bandwidth connections. Fiber's advance within the telco network from long distance trunk lines to inter-office connections and then into the local loop has continued with increasing fiber terminations on customers' premises. RBOC reports filed with the FCC in July confirm that not only are terminations increasing but the capacity of these fiber connections are dramatically rising (Chart 2). SBC's cancellation of Pacific Telesis' HFC (Hybrid Fiber Coax) network even appears to be a positive sign as Nynex bypasses HFC to bring fiber even closer to customers through its FTTC (Fiber to the Curb) buildout. Closer still to the end user, Mitsubishi Rayon Co., Toray Industries Inc., and Asahi Chemical Co. are producing low-cost plastic optical fiber (POF) for short distance, high bandwidth connections. Sony, NEC and Toshiba have announced intentions for using POF in their LAN systems. -KE

Chart 2

Fiber Terminating on Premise



Source: RBOC Reports to FCC

directly to the processor, and relegate cheaper but slower DRAMs to the back of the bus. Memory access logic transfers the most likely bits into the fastest memories, ultimately the memory registers on the processor itself. But for an increasing number of applications, including chip design tools such as CAE (computer aided engineering), the propinquity law doesn't work. The caches miss the crucial bits, and every cache miss means hundreds of instructions delayed.

Every computer today is 99 percent memory cells. The processor logic itself occupies less than one percent of silicon area. Silicon area is the best index of the cost of the device. Intel today gains some 75 percent of the profits in the semiconductor industry while incurring a tiny proportion of the silicon cost. Earlier this year Intel began dictating to the memory chip makers how they should accelerate their devices, mandating use of the **Rambus** (RMBS) technology for enhancing memory bandwidth. Most of the industry is grudgingly following the Intel signal. But the lightspeed limit suggests that this relationship will be reversed. In the future the dictation is going to go in the other direction, coming increasingly from the DRAM makers rather than from the microprocessor manufacturers.

The lightspeed limit requires getting the processor closer to the memory cells. That means real propinquity rather than virtual propinquity through off chip caches. That means creation of entire systems on a chip, overcoming the gap between processor speed and memory speed by putting the processor on the memory. Since systems are mostly made of memories and wires, it follows that many of the new hybrids will be built by companies that can make memories. That used to mean Japan and Korea and still does to a great extent. **Mitsubishi** and **Samsung** have both been leaders in integrated processors with as many as 16 megabits of on-chip DRAM cells. **Toshiba**, **NEC** (NIPNY), and **Fujitsu** are not far behind. **Texas Instruments** (TXN), one of GTR's original paradigm companies, is well situated to produce a variety of chips containing logic, digital signal processors, and other devices.

In a shocking upset, however, **Micron Technology** (MU) of Boise, Idaho, just became the world's leading DRAM producer, with twice the marketshare of second place Samsung (see Chart 1). Although critics pointed out that Micron's lead comes from 16 megabit devices, rather than the current state of the art 64 meg chips, **Dell Computer** (DELL) announced that it has tested Micron's 256 meg samples and plans to use them in future products. Because Micron's DRAMs use fewer process steps and layers than the competition's, the company has been able to maintain gross margins as high as 49 percent during a period when Asian companies have been cutting back and Motorola announced that it is leaving the DRAM business entirely. The Micron breakthrough in a market long believed to be hopelessly lost to American companies is one of the great stories in the history of entrepreneurship. You can read their entire history in my book, *Recapturing the Spirit of Enterprise*, ICS Press in San Francisco.

All DRAM companies and some static RAM companies, such as **Cypress Semiconductor** (CY), with good design teams and understanding of computer logic, can now begin to escape the thrall of Intel. They can move into the lead in producing processor memory combinations for everything from digital cameras and network computers to digital phone-PCs and set top boxes.

In the central rivalry in current electronics, scores of companies are responding to the lightspeed limit by rushing to put systems on a chip. Brian Halla has sponsored two models of the one chip system, one at **LSI Logic** (LSI) under Wilf Corrigan and one at National Semiconductor, where Halla now serves as CEO. Today LSI Logic, with its role in the **Sony** (SNE) Playstation, **DirecTV**, and other popular consumer products seems to have the edge. LSI also will benefit from its recent alliance with Micron to embed DRAM cells in one chip systems. Micron and LSI jointly announced an unprecedented target product, combining 128 megabits of memory and 8.1 million logic gates. A key rule of semiconductor investing over the last 20 years is don't bet against Micron.

Showing design prowess and the power of its CoreWare system for integrating diverse functions on a single device, LSI recently introduced a $35 chip, DCAM-101, with a million transistors and a dozen subsystems that performs all the processing functions for a digital camera. With resolution up to 4 million pixels, the LSI device enables pictures that are some five times more dense than images from existing digital cameras on the market. Yet the LSI images are produceable at a rate of eleven snapshots per second, some 40 times faster than the competition. Suitable not only for Web page display and

As fiber networks span the globe, reaching hundreds of cities with broadband services, the market for local access facilities will boom. Covering the entire Earth's population at once, LEOs can command a potentially vast market.

Chart 3

Java Use Within The Enterprise

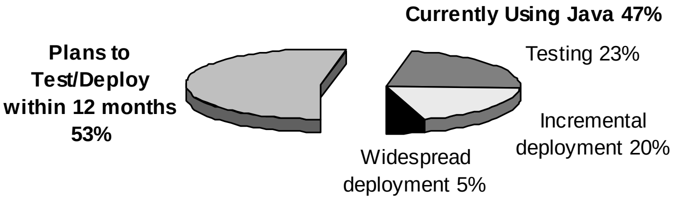


Chart 5

Network Computer Deployment Plans

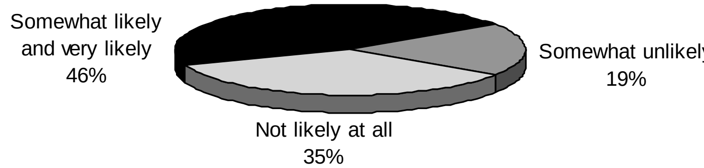


Chart 4

Java Developers in Demand

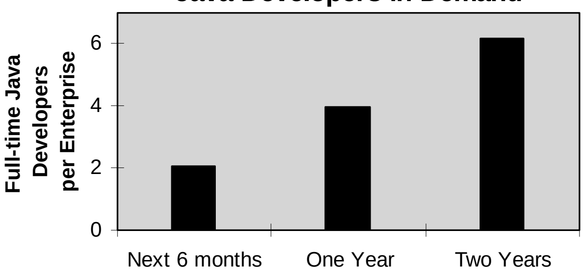
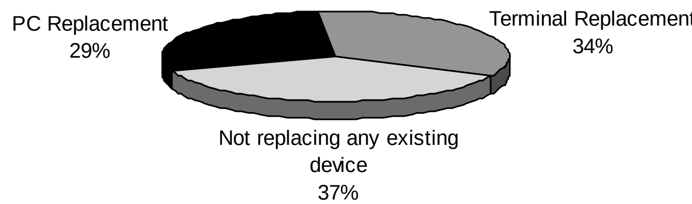


Chart 6

Network Computer Use In The Enterprise



Source: Zona Research

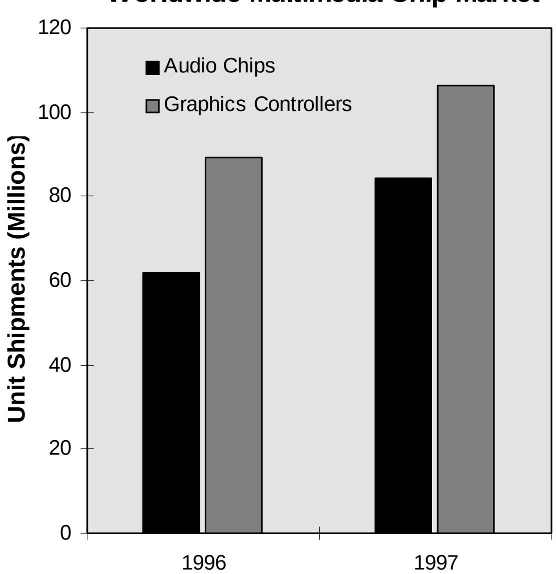
Java has been fully embraced by the enterprise. *That is the finding of the June Zona Research survey of enterprises with 250 or more computer users. Within the next 12 months, 100% of the organizations contacted will have begun the testing and deployment of Java-based solutions. Nearly 75% indicated Java will be used to extend existing applications, while 84% said their enterprises will develop new applications in Java. Nearly half, 47%, are already using Java. And of those currently using Java, 52% have moved beyond testing and are deploying Java within departments (42%) or across the enterprise (10%) (Chart 3). During the next 6 to 24 months, the share of the application development budgets allocated for Java-related activities will climb from 12.7% to 21%. Over the same period, based on man-months allocated to Java, the number of full-time Java developers will triple from an average of 2 to more than 6 (Chart 4). The share of enterprises employing more than 10 Java developers will increase from 6% to 22%, and those with greater than 50 will jump from just 1% in the next 6 months to 8% within 24 months. The factors motivating Java adoption included web browser linkage (cited by 72%), cross-platform compatibility (66%), and programmer interest and the ability to attract top programmers (62%). Although only 28% cited Java's ability to run on thin-clients or network computers (NCs) as motivating Java plans, that benefit is being realized by the 46% which are somewhat or very likely to be deploying NCs (Chart 5). NC plans include not only the replacement of aging terminals and more expensive PCs but also the expansion of computing and network resources to new users and uses (Chart 6). These findings compare with a Yankee Group study of the 100 largest US companies in January which found that 17% budgeted for NCs in 1997, 54% are piloting or evaluating NCs, and 65% plan purchases within 2 years.*

The multimedia chip market is expanding *faster than computer sales as an increasing percentage of PCs ship with advanced audio and video capabilities (Chart 7). Intel's purchase of Chips & Technologies highlights Intel's efforts to expand its hardware expertise beyond the CPU (central processing unit) into the essential subsystems at the same time it is attempting to use fast processors and advanced software to eliminate the need for non CPU components. In June, Intel outlined its efforts to use the computing power of Pentium II processors and advanced descrambling and video and audio decoding software to allow PCs to play back DVD (digital versatile disks) movies without the need for specialized off-CPU chips. IBM has also announced a software based DVD playback system. These software based approaches, however, dominate the CPU's resources and are not yet practical. Currently, the leading solution is provided by Chromatic Research's Mpact media processor. Chromatic's chip technology scored design wins with its adoption in new Gateway and Micron DVD PC systems. As DVD drives begin to appear in high-end PCs from Toshiba, IBM, Micron, Packard Bell-NEC and HP, Gateway announced in July that DVD drives utilizing the Mpact processor will be an option across its multimedia PC line. The highly successful launch of stand alone DVD players (Chart 8) with continued strong demand despite the restriction of software sales to 7 cities and a limited number of available titles, has encouraged Warner Home Video to increase titles and expand sales nationwide on August 26. Universal Home Video has also joined the list of studios who are coming off the sidelines to embrace DVD through the release of titles.*

-KE

Chart 7

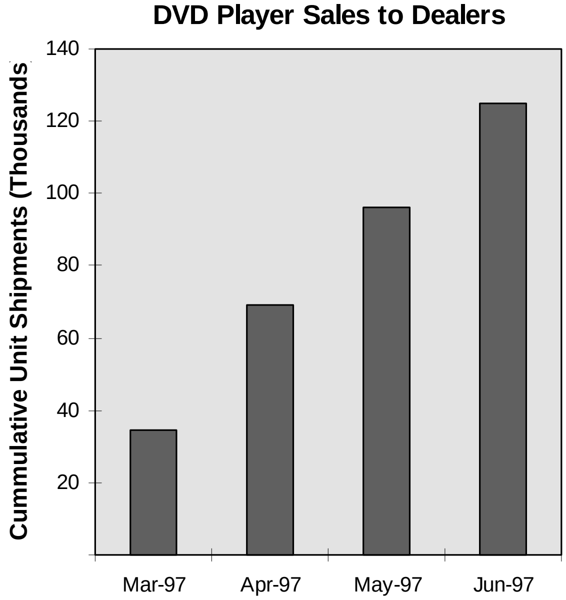
Worldwide Multimedia Chip Market



Source: Dataquest

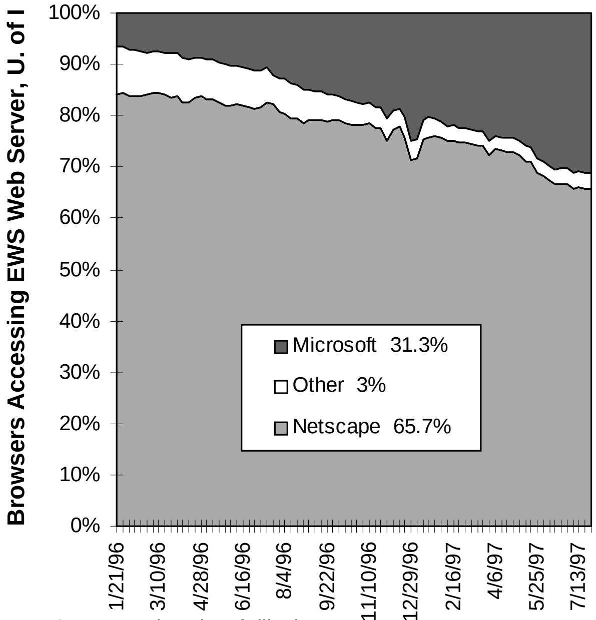
Chart 8

DVD Player Sales to Dealers



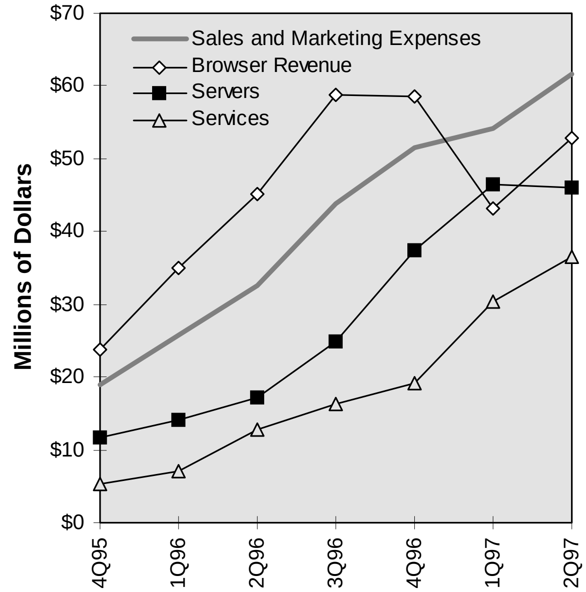
Source: CEMA

Chart 9
Web Browser Use



Source: University of Illinois

Chart 10
Netscape Revenues and Marketing



Source: Netscape

Microsoft's Internet Explorer 4.0 is designed to be a Netscape killer. *Integrating the web browser with the Windows interface, Microsoft has eliminated the distinction between surfing the web and browsing local files. No longer, they hope, is there a need for users to buy and install an independent browser application. Microsoft's success in giving away a browser which closely matches the functionality of Netscape's commercial product has resulted in the erosion since January, 1996, of Netscape's share of browsers in use from some 84% to 66% while Microsoft has climbed from 6.4% to 31% (Chart 9). During the same time Internet users have multiplied about 2.25 times, meaning Microsoft and Netscape have each captured about 50% of the market for new browsers. The impact of Microsoft's browser giveaway is clearly reflected in Netscape's bottom line. Netscape's browser revenues flattened from 3Q96 to 4Q96, plunged in 1Q97, and, despite the release of a new Communicator (replacing Navigator), rose in 2Q97 to less than the level of 3 quarters earlier (Chart 10). Netscape's server revenues are facing similar pressures, which became obvious in the 2Q97 figures. Netcraft's survey of web servers on the public Internet shows Netscape in 3rd place behind free public domain software available from the informal and non-profit Apache Group and Microsoft's Internet server which is offered free to users of Windows NT (Chart 11). Netscape's losing battle against Microsoft free product is demonstrated in their respective shares of new servers found by Netcraft in each month's survey (Chart 12). In Netscape's behalf, it must be said that Netscape is the overwhelmingly favorite choice among Fortune 1000 companies new to the web. And it is impossible using the Netcraft figures to gauge Netscape's share of the Intranet server market which is hidden by firewalls from the public Internet. From the evidence of Netscape's financials, however, in which browser, server and service revenues are each dwarfed by the climbing sales and marketing expenditures needed to offset the impact of free alternative products, Netscape is in need of new products and markets. Netscape's joint ventures NCI/Navio, with Oracle, and Novonyx, with Novell, offer some promise. Navio's lite version of Navigator has been adopted for use in NCs from NCI, HP, IBM, Tektronix, and Neoware, producer of the @workstation. Novonyx is raising expectations for Novell's renewed success in corporate networking and the possibility for Netscape to expand its own markets for messaging and groupware products. Netscape's newest browser version has mutated into Communicator with the addition of advanced messaging, groupware, and scheduling functions to compete in markets dominated by Lotus. Yet the risks remain great. On July 29, Lotus and Microsoft announced the planned close integration of Microsoft's browser into Lotus' products. Previously Lotus had shipped Netscape's Navigator with its products but switched to Microsoft after Netscape began aggressive pursuit of Lotus' customers with its Communicator suite. And, within a month, Lotus plans to ship a low-end Web server to compete directly with Netscape. Similarly, there is a risk that Navio's browser sales to NC manufacturers will suffer if they perceive Navio's merger with Oracle's NC producer NCI represents competition for their efforts. And Novonyx may require the revival of both Netscape and Novell to succeed. Clearly Netscape's technical expertise, the strikingly clear understanding they have demonstrated of what the Internet could offer and how it could transform both computing and business–the vision which had made Netscape a Telecosm Technology company–does not fully compensate for marketing inexperience and brutally aggressive competition.*

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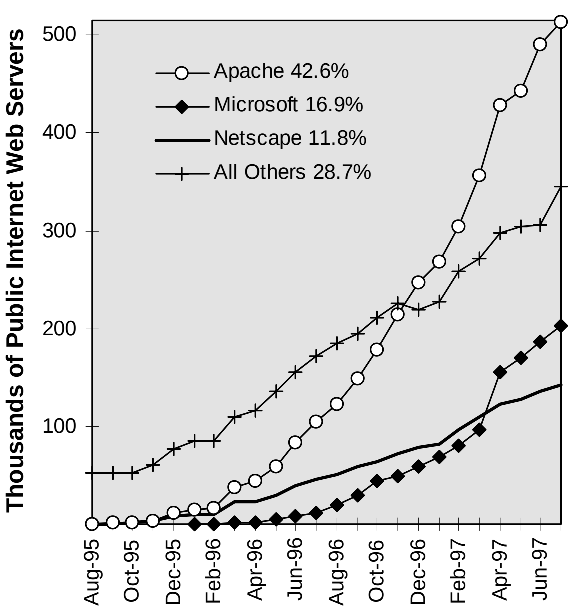
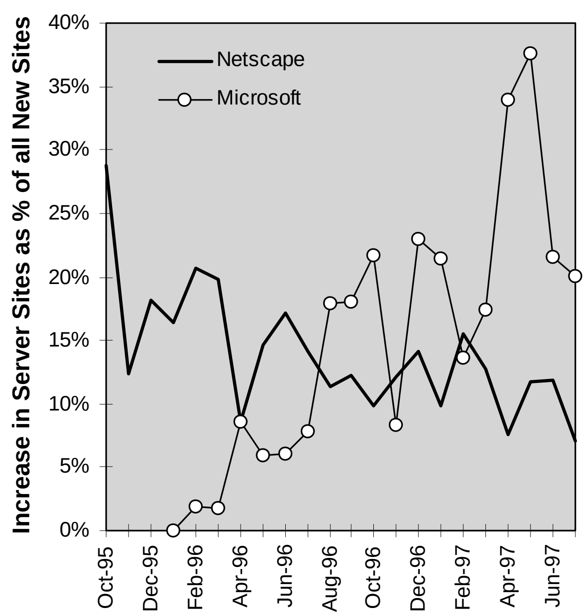
Chart 11
Web Server Software



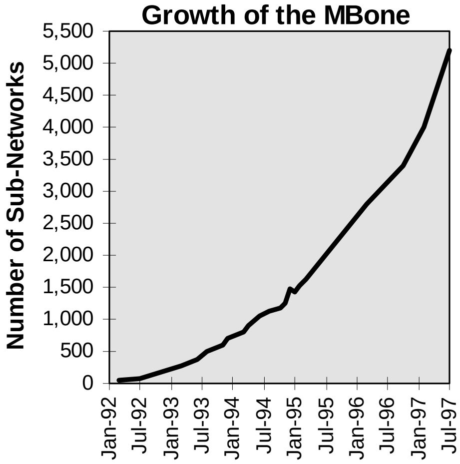
Source: Netcraft

Chart 12
Web Server Software Market Trends



Source: Netcraft

Chart 13



@Home is the first serious effort to address the speed of light problem in Internet access. @Home has woven together hardware and software in an elaborate system to bring favored Web pages close to the user.

@Home Commercializes Multicasting

The @Home Network's July 28, 1997 announcement of the first consumer trials of multicast streaming of audio and video content to its Fremont subscribers marks the culmination of efforts begun over 5 years ago to improve the efficiency of high bandwidth transmissions to multiple recipients over the Internet. The MBone (Multicast Backbone) was begun in 1992 to demonstrate and refine the technologies for IP multicasting and has now grown to encompass some 5,200 sub-networks (Chart 13). In contrast to traditional point to point "unicast" or broadcast data transmissions, in which separate data packets would be simultaneously sent to hundreds or thousands of users, bogging down servers and hogging bandwidth, multicast allows users to tune in to a single stream of data in which packets are each transmitted once from the server and leap frog from user to user–relayed from router to router and network to network–until they reach the last user. The effort is now led by the IP Multicast Initiative which includes over 70 member companies.

-KE

email dispatch, but also for printouts comparable for many purposes to an analog camera's slides, this device could ignite a huge new semiconductor market.

Under the terms of its July 30, 1997 license agreement with **Qualcomm** (QCOM), LSI can develop, manufacture and sell code division multiple access (CDMA) application specific integrated circuits (ASICs) to Qualcomm's subscriber equipment licensees for digital cellular, personal communications services (PCS), and wireless local loop applications around the world. LSI will profit from combining its CoreWare system on a chip technology with Qualcomm's leading CDMA wireless communications technology.

The ultimate systems on a chip must contain analog devices, transducers that interface with the real world–with network physical layers, voice inputs, light reflections, and wireless waveforms. Historically the world's analog leader, National Semiconductor has gained new state of the art analog to digital converters from its Comlinear subsidiary, which was acquired in 1995, and is now owner of leading edge microprocessors through its purchase of Cyrix. Halla is reconstructing the entire company around the concept of the system on a chip that also connects off the chip to the real world.

The demand for these devices is obvious. For the next decade, the largest markets in electronics will come from producers of the digital wireless communications devices that are rapidly becoming the most common personal computers. Some 50 countries around the globe are approaching a level of economic development that history shows will excite demand for billions of new telephones. Some 55 percent of the world's population has never made a phone call. There is no chance that this huge market will be served by wireline companies deploying rows of wooden poles across steppes and jungles and running backhoes through cities to entrench copper wires. While fiber optics will provide most of the long distance links and is moving closer to the home in developed countries (see Chart 2), the future of the local loop in global telephony is necessarily wireless.

The dominant wireless handsets will be based on complex systems on a chip comprising such functions as voice compression, modulation and demodulation, error correction, convolutional coders and Viterbi decoders, signal reception and transmission, frequency synthesis, and protocol processing. It will be full of National one chip systems, integrating radio receiver transmitters, phase lock loops that synchronize frequencies, comparators, operational feedback amplifiers, audio amplifiers, battery management controllers, low drop voltage regulators for low power, and analog to digital and D-A converters galore. These systems on a chip can only come from companies with full analog competence as well as digital capabilities. Few firms will qualify. High among the leaders, along with **Analog Devices** (ADI) and Texas Instruments, will be National.

Secreted among National's assets is a proprietary light speed technology that may bring the company into direct or indirect competition with LSI Logic in digital cameras. National last year purchased the rights to the CMOS photoreceptor invented by the legendary Carver Mead of Caltech and **Synaptics**. Under CEO Federico Faggin, the builder of the first microprocessors at Intel, Synaptics has used Mead's concepts to dominate the market in notebook computer touchpads and achieve a revenue run rate near $100 million.

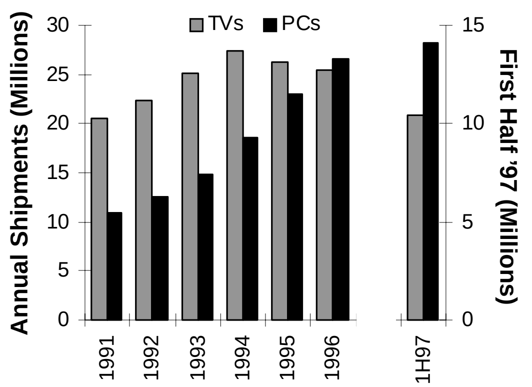
CMOS means complementary metal oxide semiconductor and it is the basic system employed by all semiconductor companies, from Intel to NEC, for digital logic devices such as microprocessors and memories. The usual problem of CMOS is called the bipolar latchup transistor, a parasitical device that can crop up between the complementary positive and negative transistors spread across a CMOS chip. Mead saw that this unwanted effect could be converted into an onchip phototransistor that could compete with the now regnant charge coupled devices (CCDs) used in existing digital cameras, scanners, and other light actuated appliances. Invented by outgoing **Apple** (AAPL) President Gil Amelio early in his career, charge coupled devices are inferior to the Mead concept because they require a specialized silicon waferfab manufacturing process. Built in an ordinary CMOS fab, the Mead devices not only exploit the bipolar parasitic but also use CMOS transistors operating below threshhold at power under .7 volts for further analog processing of the images. Incorporating digital functions as well, the Mead chip could make possible a true one chip digital camera, transcending the lightspeed limit by putting all the functions of the machine on a single silicon sliver where they never have to slow down for offchip pins and wires.

A second collision of established technology with the limits of light promises to decorate the troposphere with thousands of new satellites. Using geosynchronous satellites, 23 thousand miles up, users of telephones incur the lightspeed limit as the cause of an irritating half-second delay in international calls. If a half second is offensive for voice communications, which proceed at a leisurely pace of some 64 kilobits per second, it is an eternity for multimegabit data connections. Such Internet protocols as TCP-IP, which rely on acknowledgments, and data streams that require error correction, can suffer grave deterioration. As a result, **Globalstar** (GSTRF), **Iridium** (IRIDF), and **Teledesic** are launching low earth orbit satellites (LEOs) that are 60 times closer to the earth and perform with no more delay than fiber optics.

With booming worldwide demand for communications services, focused on the global Internet, LEOs can become worldwide carriers of last resort. Fiber optics and microwave are not competitors to the LEOs; they are complements. As fiber networks span the globe, reaching hundreds of cities with broadband services, and microwave links proliferate, the market for local access facilities will boom. Many areas lack basic infrastructure in the last mile. Others lack Internet connections, even in developed countries. With Internet traffic growing 200 fold over the last two and one half years, stress will mount on all the world's aging telecom infrastructure still optimized for voice. Covering the entire global population at once, low earth orbit devices can command a potential market limited chiefly by the ability of engineers to finance, build, launch, and maintain these complex systems.

Chart 14

US PC Shipments Dwarf TVs



Sources: Dataquest, IDC, CEMA

Most famous is Teledesic, the venture initiated five years ago by Craig McCaw and Bill Gates. It will ultimately field some 288 satellites interconnected in the sky with a space based packet network working at 60 gigahertz. The satellites will link to the ground at 17 and 30 gigahertz with phased array digital antennas based on millions of gallium arsenide circuits. At an estimated cost of some $9 billion, Teledesic is an awesome microwave technology based on the Star Wars concepts of the brilliant pebbles program.

Although Teledesic has often been derided as the pipe dream of two billionaires, it recently attracted a potential $100 million investment from **Boeing** (BA) for a 10% share and an imitative project from **Motorola** (MOT). Perhaps seeking a dazzling way to distract attention from its tormented Iridium venture, Motorola earlier this year requested approval from the FCC for a combined three way LEO and GEO system that would directly compete with Teledesic. Called Celestri, the $12.9 billion LEO system would complement the previously announced Millennium geosynchronous satellite scheme and a proposed LEO M-Star system. Together the triad could offer symmetric point-to-point connections at up to 155 megabits a second, bursty asymmetric services up to 16 Mbps, broadcast multimedia services, and interactive Internet applications galore. Motorola claims the ability to begin service by 2002 with a capacity of 80 gigabits per second, apparently about double the capacity of Teledesic. But the Motorola advantage comes from the huge downstream broadcast volumes possible from GEOs.

Combining 63 LEOs and 4 GEOs, the Motorola system will be more complex and hierarchical than the peer network that is being deployed by Teledesic. Since there is no reason that services offered by Teledesic could not be linked on the ground with GEO satellite broadcasts, the Motorola concept does not seem to offer any decisive advantage. The winner will be the customers for global communications and the company that can finance and launch the system first. Teledesic seems to have the head start.

However, the simpler and cheaper 48 LEO CDMA mobile system from GlobalStar, launched by **Loral** (LOR) and Qualcomm, may well have the most immediate impact. It offers the possibility of global roaming for the increasing millions of CDMA customers around the world. But GlobalStar lacks the broadband capabilities of Teledesic and the Motorola stunner.

All these LEOs attest to the imperious pressures of the lightspeed limit in an era of gigabit per second communications. The rise of the Internet, with its need for realtime feedback congestion control and error correction, has made even fiber optic delays troublesome. The speed of light means that it takes between 30 and 100 milliseconds for a message to cross the continent. Acceptable in voice communications, 30 milliseconds means scores of megabits in a one gigabit per second pipeline. The network backbones of **Sprint** (FON) and **MCI** (MCIC)now function as fast as 40 gigabits per second. This means more than a gigabit in the pipe.

Funded by **Kleiner-Perkins**, **TCI** (TCOMA), **Cox** (COX), **Comcast** (CMCSA) and other cable companies, and beneficiary of a billion plus IPO in mid July, **@Home** (ATHM) is the first serious effort to address the speed of light problem in Internet access. @Home has woven together hardware and software from **Sun** (SUNW), **Silicon Graphics** (SGI), **Cisco** (CSCO), Sprint, **Oracle** (ORCL), **OSI** (OSII), **Tivoli** (TVLI), **Netscape** (NSCP) and **Teleport Communications Group** (TCGI) in an elaborate system of servers, caches, mirrors, and replicators to bring favored Web pages close to the user. The direct connection to the home comes over cable in a hybrid fiber coax system that is currently available to only some 2 million homes but that will be extended, according to current plans, to as many as

As PCs are now outselling TVs by some 40 percent in units, the triumph of the PC and the net approaches as fast as @Home and its rivals can deliver these new digital capabilities to the home.

ASCENDANT TECHNOLOGY	REPORT(S) Volume: No.	COMPANY (SYMBOL)	Reference Price	Price as of 7/31/97
Cable Modem Service	I: 2, 3 II: 7, 8	*@Home* (ATHM) +	19 1/2	19 1/2
Erbium Doped Fiber Amplifiers, Telecommunications Infrastructure, Wave Division Multiplexing (WDM)	II: 2, 3, 4, 7	*Alcatel* (ALA)	16 3/4	27
Analog to Digital Converters (ADC), Digital Signal Processors (DSP), Silicon Germanium	II: 3, 7	*Analog Devices* (ADI)	22 3/8	31 1/2
Java Thin Client Office Suite, Rapid Application Development (RAD)	II: 6, 7	*Applix* (APLX)	4 1/2	6 1/16
Digital Video Codecs	II: 5	*C-Cube* (CUBE)	23	24 1/8
Erbium Doped Fiber Amplifiers, Wave Division Multiplexing (WDM)	II: 2, 7	*Ciena* (CIEN)	23 *	56 1/8
Low Earth Orbit Satellites (LEOS)	I: 2 II: 1, 3, 4	*Globalstar* (GSTRF)	21 3/4	32
Single Chip ASIC Systems, CDMA Chip Sets	II: 8	*LSI Logic* (LSI) +	31 1/2	31 1/2
Telecommunications Equipment, Wave Division Multiplexing (WDM)	II: 1, 2, 7	*Lucent Technologies* (LU)	47 1/8	84 7/8
Single Chip Systems	II: 8	*National Semiconductor* (NSM) +	31 1/2	31 1/2
Internet Software	I: 1, 3, 4 II: 1, 4, 6, 7, 8	*Netscape Communications* (NSCP)	53	36 11/16
Code Division Multiple Access (CDMA)	I: 1, 2 II: 1, 3, 4, 7, 8	*Qualcomm* (QCOM)	38 3/4	46 1/4
Java Programming Language, Internet Servers	I: 1, 2, 3, 4 II: 1, 5, 6, 7, 8	*Sun Microsystems* (SUNW)	27 1/2	45 11/16
Servernet System Area Networks (SAN)	I: 1, 7	*Tandem Computers* (TDM) **	9 1/2	29 3/8
Optical Equipment, Smart Radios, Telecommunications Infrastructures	I: 1 II: 1, 2, 3	*Tellabs* (TLAB)	29 1/8	59 7/8
Digital Signal Processors (DSP), DRAM	I: 2, 3, 4 II: 5, 8	*Texas Instruments* (TXN)	47 1/2	115
Wave Division Multiplexing (WDM) Modulators	II: 7	*Uniphase (UNPH)*	58 3/4	68 1/4
Code Division Multiple Access (CDMA) Testing Gear	II: 1, 2, 7	*Wireless Telecom Group* (WTT)	10 3/8	11 3/4
Field Programmable Logic Chip	I: 3	*Xilinx* (XLNX)	32 7/8	47 3/8

+ New Addition ** To be acquired by Compaq * 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.

20 million over the next five years. It is also possible that the **Terayon** CDMA modems, which operate at speeds up to 60 megabits per second in non-upgraded facilities, will become widely available.

At the end of July, @Home announced an alliance with **Progressive Networks** to deliver streaming real time audio and video over the Internet to personal computers (see Chart 13). Thus the video gap between the capabilities of PCs and TVs is quickly closing. As PCs are now outselling TVs by some 40 percent in units (see Chart 14), the triumph of the PC and the net approaches as fast as @Home and its rivals can deliver these new digital capabilities to the home.

Finally, the lightspeed limit will determine the future interplay between the laws of the microcosm and the telecosm that have governed the evolution of the technology. The law of the microcosm is a centrifuge. It tends to drive intelligence to the edges of networks. Based on the power delay product in semiconductor engineering, which relates switching speed of transistors to heat dissipation, the law of the microcosm ordains that any increase “n” in the number of transistors on a typical chip will result in “n” squared performance gains. Smaller transistors closer together not only yield more processing logic and memory capacity; they also run faster, cooler, and cheaper.

This law has resulted in an exponential slope of improvement in the cost-performance ratios of single chip systems and microprocessors. Thus it has fueled the ever more widely distributed reach of personal computers. Many analysts now predict a return of more centralized systems and even propose a revival of the mainframe computer.

The speed of light limit, however, converges with the chip density curve to assure that the law of the microcosm will continue to distribute ever more cheap intelligence through the world economy, with no significant trend toward recentralization. The speed of light dictates that one chip systems remain limited in size to reduce the length of interconnections. It resists the centralization of networks. As with @Home, hubs and servers will be dispersed and localized across the Internet mesh.

The law of the telecosm will not rescind the waves of emancipation in the global economy fueled by the microcosmic spread of intelligent systems. Instead, the lightspeed limit will enforce a new era of liberation technology.

George Gilder, August 3, 1997

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