GILDER TECHNOLOGY REPORT

January 2005 / Vol.X No.1

Wide and Weak

NetLogic has a slew of design wins for a custom layer 3 and 4 processor that will complement the packet shufflers from Intel and others, until EZ takes over with 7 layers

Inside:

One of the more enigmatic and wonderful of *Gilder Technology Report* paradigms is the mandate of "wide and weak." You can define it by what it isn't. It isn't "long and strong" like television broadcasting at long wavelengths and high power. It isn't narrow and nuclear like atomic power or nano and nebular like **Nanosys**. It refers neither to an epidemic of obesity and unfitness nor to the Canutean case for human-caused sunrise, solar energy, resurrection, Tsunami, or global warming.

Hey, bear with me. It's January 23, and I'm just getting up steam for this month's letter. It's 10 below zero outside, snow is whirling by the window, the Patriots are winning in Pittsburgh, optics are moribund, and the market is dour. Wide and weak sums up the level of stock prices, running under 15 times the broad NIPA measure of corporate profits, showing an earnings yield close to 70 percent above the 4.1 percent interest rate on 10 year treasuries. Sub-par bond yields, sub-zero temperatures, and Michael Crichton's devastation of global warming theory (*State of Fear* with 1.5 million copies in print) should keep the bears in their caves.

Regulators, however, remain long and strong. With Michael Powell now out of the FCC, the formidable analyst-investors Bart Stuck and Michael Weingarten are urging a re-regulatory scheme for telecom in fifty states with new, improved, more sophisticated Telric price controls (if you don't know, don't ask), new litigious distinctions between local and long distance and between content and conduit, and a brand new "level playing field" no less. (Isn't the industry already leveled enough for them? Soon there will be no one left to pay the consultants.) Only a lawyer could imagine that there can be robust investment in a field with constantly changing rules, rising taxes, and capricious litigation in fifty states. And now discrete multitone DSL inventor John Cioffi, a venerable exponent of wide and weak, has called from Stanford with news of 200 megabit per second digital subscriber line, which for distances of a few hundred feet can enable gigabits per second over four twisted pairs. As he points out, that's faster than most fiber to the home deployments.

Cioffi has a new company, **Avvia**, to pursue this super DSL technology and it promises to push the BOCs ahead of cable for the first time in the bandwide race. He sold his last company, Amti, to Texas Instruments (TXN) and in ultimately gave TI leadership in the DSL chip market. His DMT (discrete multitone) technology now utterly dominates the field around the globe. His late lamented company ITeX even briefly took

CONTINUED ON PAGE 2

80 percent of the Korean market. (When it lost Korea it returned $100 million to its investors.) Meanwhile, the regulators claim to want something they call "competition," but they plunge into a Crichtonian state of fear whenever it threatens an existing competitor. That wide and weak system for the BOCs may prove too competitive for the regulators to handle.

Onward and upward. Deriving from Claude Shannon's information theory conceived at MIT more than 50 years ago, wide and weak depicts the optimal relationship between bandwidth and power. Bandwidth should be as wide and transmit-power as weak as practical. In computing, the corollary is "low and slow": lots of connected low-powered and slow transistors, processors, or neural synapses work better, cooler, cheaper, and faster than a few fast high-powered devices. It is the principle behind both Robert Metcalfe's law of networks (their value grows with the square of the number of terminals) and Gordon Moore's law of microchip density (cost-effectiveness doubling every 18 months), and to Carver Mead's demonstration that the power-delay product in semiconductors improves with the number of transistors on a chip: Many linked but low-powered nodes are far more efficient than a few high-powered ones.

NetLogic sizzles

Wide and weak explains the efficiency of **Google** (GOOG) with its 120,000 Pentiums and of the human brain, with its low-powered and slow neurons. It explains why among all the new network processors that parse packets in routers and other network nodes, the **EZchip** (LNOP) device performs better with 64 processors running at 250 MHz than the **Intel** (INTC) IXP2400 does with eight "microengines" running at 600 megahertz and the IXP2800 with 16 microengines running at 1.4 gigahertz. While it takes two high-powered Intel chips and arrays of advanced memory to process packets at 10 gigabits a second, EZ reaches this rate with one chip containing 40 megabytes of wide and weak embedded dynamic random access memory cells and four connected DRAMs. That may be why it has won designs at **Huawei-3Com, ZTE, Allied Telesyn, Nokia** (NOK), and scores of others that aim to encroach on **Cisco's** (CSCO) markets. With network processors increasingly confined in close quarters in boxes or on "blades" in racks, heat dissipation and hence low power has become an enabling metric for most applications.

Meanwhile, Cisco is fighting back effectively, at the peril of hollowing out its proprietary boxes with standard chips that originate in fabless semiconductor companies. So far the hollow Cisco movement is mostly spurning wide and weak programmable solutions in favor of high-powered custom and application specific integrated circuits (ASICs). In high volume slots, ASICs can offer performance on the cheap. **Broadcom** (BRCM) has just raised the stakes with five whopping chips in its StrataXGS family that offer as many as 24 gigabit Ethernet ports and four 10-gig ports plus IPv6 tunneling and an array of security functions that can interface for private virtual networking with the fast increasing number of "trusted computers" on the edge of the network containing "trusted platform modules" and **Wave Systems** (WAVX) software. (Commercial insert: I am in the councils of Wave, which sits with **Microsoft** [MSFT], **HP** [HPQ], Intel, and **IBM** [IBM] on the board of the Trusted Computing Group). But Broadcom's chips are relatively inflexible and took two years longer to spin than EZ's wide and weak programmable device. The StrataXGS is an Ethernet switch technology, not a network processor.

Meanwhile **NetLogic Microsystems** (NETL) has 14 design wins at Cisco among a total of 31 for a custom layer 3 and 4 processor with 300 million transistors that specializes in security and quality-of-service lookups and complements the packet shufflers from Intel and Broadcom. NetLogic is an ascendant company in the Telecosm and in the marketplace, but its chips are only configurable, not programmable. NetLogic's challenge is to make this high-powered narrow functioned model prevail as the programmable seven-layer network processors from EZchip and others move down the Moore's law learning curve.

For now, NetLogic is taking market share from producers of content addressable memory (CAM) suppliers **Cypress** (CY) and **Integrated Device Technology** (IDTI). NetLogic hopes to complement, with higher layer services, the network processors in preparation from Broadcom's Maverick team picked up in 1999 and from **Marvell** (MRVL). Both are said to hover in the wings with sizzling high-speed packet shufflers that can also contribute to the ascendancy of movement among communications chip makers to hollow out Cisco. The competition heats up, as we all expected. But EZ's on-chip memory and links to cheap low and slow off-chip CMOS (complementary metal oxide semiconductors) DRAM make its NP1c (released nearly two years ago) and impending NP2 "wider and weaker" than the competition. The paradigm says that wide and weak will win.

Vyyo breaks through

This mandate of low and slow enabled the rise of low-powered CMOS to dominance in digital electronics over many faster materials such as gallium arsenide and silicon germanium or speedier device structures such as tunnel diodes and the Josephson junctions through which IBM once hoped to rule the world. It is the real secret behind the advance of Broadcom, a communications chip company that has defied gravity ever since its founding by putting virtually any design into cheap silicon CMOS that other companies hoped to make in more costly spreads. It guides the use of the electromagnetic spectrum in wireless or optical communications and it explains the comparative virtues of parallelism and power in computation or switching.

In the face of wide and weak solutions, broadcast television, like "long distance" telephony, is a technical scandal. When it goes away, along with its obnoxious advertising model, hundreds of megahertz of choice spectrum will be emancipated and broadband wireless in the local-loop will become bountiful. Watch the political wars over this spectrum as it is released over the next five years with the ascent of what will be called "digital" television (though it will actually take the form of Internet multimedia). If it becomes "WiMAX" spectrum, it will give Intel a new lease on life after the high-powered narrowband Pentium gives way to wide and weak alternatives.

Previously dominating both broadcast and cable TV were long and strong analog transmissions. Now a company called **Vyyo** (VYYO) in Israel is expanding cable bandwidth up to 3 gigahertz at relatively low power for perhaps a thousand two-way digital channels or one pipe running at terabits per second. My old favorite, **Narad Networks**, failed to break through with this general idea. With the inexorable ascent of Cioffi's digital subscriber line technology, perhaps the cable industry will come to its senses and adopt the wide and weak Vyyo solution.

Qualcomm and Essex communicate best

Wide and weak and low and slow usurped narrowband and centralized, mainframed and multi-fanned, powerful and timeshared, top-down and micromanaged. By halting the long climb toward ever faster, more powerful and centralized devices, it unleashed the entire era of digital electronics and fiber optics. Ingenious combinations of low and slow devices on wide and weak channels ended up producing the fastest systems in the world. And by undermining the concentration of political and technological power, it replaced vertical hierarchy with horizontal heterarchy and helped spread entrepreneurial capitalism and democracy around the globe.

In exploring the tradeoffs between power and bandwidth in digital communications, Shannon showed that large bandwidth at low wattage is more efficient than small bandwidth at high wattage. This was not obvious at the time. In the then analog world of communications where every point on the wave conveyed information, increasing the power of transmission reduced the number of needed transmitters and boosters and enhanced the all important signal-to-noise ratio. It was easier to hear a loud voice than a weak one, a strong signal than a soft one. Even makers of digital systems were entranced with the power of centralization. Herb Grosch of IBM codified the common wisdom that the computational power of digital machines rose by the square of their cost. A few large expensive mainframes would rule the world.

By contrast, Shannon showed that communications channel capacity rises linearly with the bandwidth and only logarithmically with the signal-to-noise power. Put power on the horizontal x-axis and bits-per-second on the vertical y-axis, and the logarithmic slope quickly flattens to a nearly imperceptible capacity incline as it moves out to the right. Reduce the power by roughly a factor of 10 and increase the bandwidth from 25 kilohertz to 1.2 megahertz, though, as **Qualcomm** (QCOM) did with CDMA (code division multiple access), and you directly enhance the communications capacity over 40-fold. Add in Terry Turpin's super wide and weak Opera technology of analog optics from **Essex** (KEYW) and you can null out all the cell's other transmitters and give personal wireless mobile gigabits to each customer. By contrast, going long and strong, you can increase the signal power the same 40-fold and you get only about 5.5 times more capacity.

EZ's chips are wider and weaker than the competition. The paradigm says that wide and weak will win.

Above the physical layer, Qualcomm's CDMA systems benefit from huge systemic gains. These advantages mean that in practical systems, communications efficiency may rise by the square of the bandwidth and inversely with the wattage of individual devices. I know, Shannon would not put it that crudely. (Several years ago, Qualcomm's Irwin Jacobs publicly reproached me for my crude version of Shannon.) When sending a 40 megabit per second signal (perhaps six HDTV bitstreams), however, Shannon showed some 45 years ago that a fourfold increase in bandwidth can lower the needed signal-to-noise ratio from a level of one million to one to a ratio of 30.6 to one, or 33 thousand times. You could optimize communications by expanding the bandwidth of the system, multiplying transmitters, and lowering the power of each.

From T.J. Rodgers of **Cypress** (CY) early upholding the cost effectiveness of low and slow CMOS, to Jacobs of Qualcomm espousing the magic of low-powered spread spectrum cellular systems, to David Huber of **Broadwing** (BWNG) and Turpin of Essex exalting the efficiency of thousands of wavelengths in fiber optics, none of the champions of wide and weak is currently creating more bandwidth than DMT-DSL inventor Cioffi.

TELECOSM TECHNOLOGIES

Advanced Micro Devices	(AMD)
Agilent	(A)
Altera	(ALTR)
Analog Devices	(ADI)
Broadcom	(BRCM)
Broadwing	(BWNG)
Cepheid	(CPHD)
Chartered Semiconductor	(CHRT)
Equinix	(EQIX)
Essex	(KEYW)
EZchip	(LNOP)
Flextronics	(FLEX)
Intel	(INTC)
JDS Uniphase	(JDSU)
Microvision	(MVIS)
National Semiconductor	(NSM)
NetLogic	(NETL)
Power-One	(PWER)
Qualcomm	(QCOM)
Semiconductor Manufacturing International	(SMI)
Sprint	(FON)
Synaptics	(SYNA)
Taiwan Semiconductor	(TSM)
Terayon	(TERN)
Texas Instruments	(TXN)
Wind River Systems	(WIND)
Xilinx	(XLNX)
Zoran	(ZRAN)

Note: The Telecosm Technologies list featured in the Gilder Technology Report is not a model portfolio. It is a list of technologies that lead in their respective application. Companies appear on this list based on technical leadership, without consideration of current share price or investment timing. The presence of a company on the list is not a recommendation to buy shares at the current price. George Gilder and Gilder Technology Report staff may hold positions in some or all of the stocks listed.

Advanced Micro Devices (AMD)

PARADIGM PLAY: INTERNET COMPATIBLE PROCESSORS

JANUARY 25: 15.75; 52-WEEK RANGE: 10.76 – 24.95; MARKET CAP: 5.78B

Looking more and more like a recipe for sweet n' sour sauce, AMD finished 2004 on both the ascendancy and the retreat. Taking off was the microprocessor business, making a profit with revenue up 9% sequentially and now representing 58% of total sales. Coming in for a hard landing was the memory group, swinging to a loss in the quarter with revenue down 8% to garner 40% of total sales.

AMD has the best strategic position in microprocessor products with Athlon, with its Geode line of embedded processors that should see gains as x86 moves into consumer electronics, and with its x86 extensions for 64-bit processors. Reflecting these strengths, AMD grew microprocessor revenue by 29% last year compared to 12% for Intel, capitalizing on cost and performance advantages in both the desktop and server markets. (AMD chips may have been used in 42% of desktop systems sold in the US in 2004, up from 22% a year earlier.) Putting yet more pressure on Intel, AMD this year will likely beat its rival to market with dual-core processors by several months.

In flash memory, Intel came on like Flash Gordon, slashing prices with reckless abandon and inflicting a serious wound on AMD. As a result, inventory grew $68m sequentially to $875m or 106 days, mostly because of an increase in 0.11 micron flash memory parts. Year earlier inventory was 81 days, and the increase should alert investors to a potential inventory write-down. Management, however, insisted that there are adequate reserves against potential obsolescence and that it will take on Intel to reverse flash fortunes by year-end.

Overall, revenues were up 2% sequentially to $1,264m and AMD earned $0.38 per share for the year (not counting a one-time charge of $50m to retire debt) after three years of losses. Gross margin improved steadily through the year from 37.8% to 41.2%, but operating income plunged from 5.5% of revenue to 1.8% sequentially due to startup costs for Fab 36 and a marketing push. Anticipated capex of $1.5b for 2005 is more than the $1.0b in cash generated from operations last year. But cash flow has been steadily increasing, up from $300m in 2003, and working capital was flat at about $1.4b in 2004. With only minimal payments required on long-term debt of $1.6b over the next two years, AMD should have no trouble paying for growth. The stock currently trades at 41x last year's earnings and 35x projected 2005 earnings, pricey when compared to shares of rival Intel.

Altera (ALTR)

PARADIGM PLAY: SOFTENING HARDWARE, HARDENING SOFTWARE

JANUARY 25: 18.33; 52-WEEK RANGE: 17.50 – 25.50; MARKET CAP: 6.82B

In line with company guidance, revenue in the December quarter was down 9% sequentially to $240m with an EPS of $0.15. By business segment: sales of communications chips slid 24% and computer/storage fell 14%, but industrial/automotive rose 10% and consumer products gained 7%. Despite the decline in revenues, gross margin edged up to 69.8% from 69.4% in September, aided by the sale of written-off products. Not surprisingly, inventory days jumped to 84 from 66 in September and 57 a year ago, for combined days and Altera and distributors rose sequentially to 126 from 105. Management said that finished goods (primarily new products) are less than 20% of stock, and that most of the inventory growth came in generic die. Though March quarter revenue is forecast to grow below the seasonal average, gross margin is not expected to slip below 69%.

Like competitor Xilinx, Altera is also shipping 90 nm products and boasts the highest density FPGA shipping today in its Stratix II family, claiming 82% more logic elements than Xilinx. Yet despite healthier gross margins and inventory, Altera trades at a discount to rival Xilinx (see below), with a forward PE (through March) of 28.3 and an enterprise value to free cash flow multiple 20.2.

Essex (KEYW)

PARADIGM PLAY: "TURPIN'S LAW" – ANALOG OPTICS GALORE

JANUARY 25: 17.17; 52-WEEK RANGE: 7.30 – 21.36; MARKET CAP: 261.83M

In night-and-day contrast to its furtive military contracts and advanced analog optics, Essex Corporation's financials are a paradigm of clarity and simplicity. With a gross margin on contract sales a steady 25% and virtually all other expenses summed up in two items—R&D costs of about $1m per year and SG&A, running consistently at 20% of sales—we easily estimate net income in 2005 of $4m for an EPS of $0.18 based on the company's forecasted $100m in revenues. Trading at forward PE of just under 100, investors are clearly pricing in substantial growth for Essex and also rewarding the company's adept management: Essex turned cash-flow positive beginning in September and raised $92m at its November public offering to boost working capital to about $112m, no doubt with some acquisitions in mind. With no long-term debt, enterprise value of $277m is a very reasonable 2.8x forward sales.

Subsequent to management's 2005 revenue outlook, the company announced its intent to acquire Windmere Group, a private defense contractor with annual sales of $64m, and also announced a $178m expansion to a military contract that runs through 2007. With a potential doubling of projected 2005 revenues to $200m, forward EPS drops to 43. The company's greatest weakness has been commercializing its technology breakthroughs beyond the hothouse markets of the military and intelligence. They will come, but are likely years away. In the meantime, with no real competitors and a superb portfolio of analog optics inventions, look for continued upside surprises in defense work, responsible for a fourfold jump in revenues from $16m in 2003 to $67m last year, and now a possible triple to $200m in 2005 or a little beyond. If you invest in Essex today, expect to hold for years to reap rewards.

Intel (INTC)

PARADIGM PLAY: MICROPROCESSOR KING MOVES ONTO NETWORK

JANUARY 25: 22.26; 52-WEEK RANGE: 19.64 – 32.49; MARKET CAP: 140.75B

Fresh off a sequential revenue increase of 13% in the final quarter of 2004, Intel turned bullish on 2005. Gross margin was a challenge last year as startup costs for advanced processes and capacity expansion coincided with a decrease in demand. Expected to hold in the current mid-50% range into next quarter, Intel projects an average gross margin of 58% for the year, implying a surge to over 60% during the second half of 2005 (but still lower than the 63.6% in Dec 03). Though startup costs are forecast to taper off during the normally busier second half, Intel's projection aggressively assumes another year of double-digit growth in PC sales, including acceleration in the notebook and server markets. Last quarter, microprocessor revenue grew 15% sequentially and chipsets and motherboards grew 19%. Flash memory, part of the communications group, grew 1% as Intel took market share from AMD by slashing prices. (The communications group reported a $196m operating loss in the quarter.)

Intel reinforced its commitment to shrink transistors by upping its capital budget for the coming year to $4.9b - $5.3b from $3.8b in 2004. Most of the money will be spent on 300 mm and 65 nm equipment, and Intel is still driving for 45 nm and below in the future. Shrinking transistors was once relatively straightforward since their characteristics scaled uniformly. That's coming to an end. Statistical variation among transistors increases as the doped area shrinks. Some will be fast, others slow. Some will leak a lot, others won't. Overall circuit behavior may deteriorate at the same time production costs escalate rapidly. These are some of the problems that will face Paul Otellini, who this spring will become Intel's first CEO with no engineering background. Rather than simply sell individual microprocessors, Otellini is pushing to sell technology platforms of multiple chips similar to Centrino, which combines microprocessors, communications chips, software, and other tools for laptops. Intel's just announced overhaul of its business divisions into five groups—mobility, enterprise, home entertainment, and the new digital health care and global markets groups—was designed to facilitate the move to platforms while addressing evolving customer priorities.

Up a little from its 52-week low of $19.64 last September and down significantly from its year-ago high of $33.38, Intel shares currently trade at a reasonable 20x 2004 earnings and about 18x projected 2005 earnings.

NetLogic (NETL)

PARADIGM PLAY: CUSTOM LAYER 3 AND 4 PROCESSOR

JANUARY 25: 11.29; 52-WEEK RANGE: 5.92 – 12.50; MARKET CAP: 198.46M

Added to the list this month, NetLogic reports Q4 2004 earnings the evening of January 26.

Qualcomm (QCOM)

PARADIGM PLAY: AIR KING – WORLD'S BEST TECHNOLOGY COMPANY

JANUARY 25: 36.66; 52-WEEK RANGE: 27.81 – 44.99; MARKET CAP: 60.09B

If you're buying Qualcomm on dips, now may be an opportunity. Shares sank 8% on the December quarter earnings report in which the company's estimated EPS for the March quarter came in three cents below analyst expectations. Yet nothing fundamental has changed and all signs continue to point to Qualcomm's increasing dominance of most of the key components of mobile devices. In fact, with 3G demand expected to accelerate through the year, Qualcomm actually raised its projected 2005 earnings a penny to about $1.18. WCDMA, a 3G standard that competes with Qualcomm's CDMA2000 and once thought to be a threat, is now driving results after Qualcomm mastered the technology ahead of the competition: WCDMA contributed 32% to royalty revenues from September quarter shipments, up from 12% a year ago. Overall, the CDMA and WCDMA handset market has grown from 117m in 2003 to an estimated 165m last year, and phone chips shipped increased from 103m to 145m over the same period. WCDMA subscribers increased 60% between the third and fourth quarters of last year, from 10m to 16m. With WCDMA handset sales of about 17m last year expected to grow to about 45m in 2005 and accelerate quickly thereafter, the migration to 3G has just begun. With a forward 2005 PE of 32 (down from 35 before the earnings report), Qualcomm appears well valued to the conventional eye. But its unique mix of low risk and high growth and consistent execution should make it a core technology holding.

Terayon (TERN)

PARADIGM PLAY: MOVING CDMA INTO CABLE

JANUARY 25: 3.06; 52-WEEK RANGE: 1.44 – 5.85; MARKET CAP: 233.08M

Heading into 2005 with falling revenues, this paradigm player in cable broadband is looking to digital video as a new long-term opportunity. In October, Terayon exited the cable modem head-end business, citing slower deployments by cable operators. Sales of subscriber cable modems also began eroding around mid-year due to increased competition; for instance, VoIP equipment may include cable modems that operators can piggyback off of. This leaves the digital video product line as the company's sole growth area, totaling about $34.4m last year out of some $150m in overall revenues. High-definition video programming and symmetric services such as peer-to-peer, video conferencing, online gaming, and digital-into-digital insertion of targeted, localized ads and graphics all demand high-bandwidth techniques. Terayon's DOCSIS 2.0 advanced modem system for cable increases upstream bandwidth for these applications better than DSL, with up to 30.7 Mbps per channel. Based on Terayon's once proprietary S-CDMA modulation scheme, DOCSIS 2.0 should be the preferred solution to increase bandwidth in the last mile. Beginning the year on a bright note, on January 18 Terayon announced that it has been selected as a primary supplier of voice cable modems for a major rollout of residential VoIP in Hong Kong.

Terayon has never made a profit. By its own admission, revenue should be down in 2005. Gross margin is only 34% while R&D consumes 23% of sales and SG&A consumes about 24%. Though up significantly from its August low of $1.44, shares are still trading at only 1x sales, based on enterprise value. But Terayon is not a value play, since net cash is only

48 cents per share, down from $1.39 per share two years ago. Working capital declined from $172.8m to $112.6m over the same period. The only long-term debt is in converts, and the company still has some time to turn itself around; but since revenues should decline and losses increase this year, it could get very tight by 2006.

XILINX (XLNX)

PARADIGM PLAY: PIONEER OF PROGRAMMABLE LOGIC

JANUARY 25: 27.16; 52-WEEK RANGE: 25.21 – 43.73; MARKET CAP: 9.46B

As preannounced several weeks ago, revenue in the December quarter was down 12% sequentially to $355m with an EPS of $0.17 excluding one-time items. By business segment: sales of communications chips slid 12%, led by wireless (-35%), wireline (-25%), and enterprise networking (-15%). The consumer/industrial market was off 5%, but storage/servers rose 14%. In response to the decline in sales combined with an unfavorable product mix, gross margin slipped to 62% from 64% in September. More critically, inventory days jumped to 144 from 117 in September and 60 a year ago, and combined days for Xilinx and distributors rose sequentially to 174 from 156.

Management promises to reduce combined inventory days to 150 this quarter and insists that stock is primarily in newer products, making a write-off unlikely. But that means the newer chips have not been selling (though Xilinx claims to lead the industry in 90 nm shipments), and with March quarter revenue forecast to grow below the seasonal average, could 2005 be the first year Xilinx fails to increase PLD market share since 1997? Despite more challenging gross margins and inventory, Xilinx trades at a premium to rival Altera (see above), with a forward PE (through March) of 31.2 and an enterprise value to free cash flow multiple 25.7.

– Charlie Burger

Crucial transformations

When John Cioffi calls, the *GTR* pays attention. Cioffi has contributed more bandwidth to actual customers around the world than anyone since The Beatles. Sure, the creators of wavelength division multiplexing (WDM) produced more raw communications power, out on the backbones of the network, but Cioffi took it to the home and the business where it could be enjoyed.

When in the early 1990s I first met Cioffi, he was then the founder of Amati Corporation in Palo Alto. At the time, a last-mile broadband technology called CAP (carrier-less amplitude/phase modulation) was dominant in the local-loop and put the local exchange players far behind the cable industry in broadband potential. Cioffi said that CAP far underexploited the possibilities of twisted pair phone lines. He invented a system called discrete multitone, a multicarrier approach based on orthogonal frequency division multiplexing (OFDM). Rather than three high-powered signals used by CAP for voice, video, and data, Cioffi proposed the use of between 256 to 8,000 separate low-powered slow carriers created by Fourier transforms, the ultimate weapons system for the exponents of wide and weak.

Conceived by Jean Baptiste Joseph Fourier in Napoleonic France, Fourier transforms are a compute-intensive mathematical technique that resembles the effect of a prism in separating white light into an array of separate colors, or back again inversely into white light. Turpin built Essex by doing these transforms and their many derivatives with actual prisms and other lenses. Linking the lenses to Bragg cells that convert the light through an acoustic intermediary into electronic form, Turpin then digitized the output and manipulated it for pattern matching and other purposes, such as interpreting data from synthetic aperture radar or exploring Bin Laden's cave from a Predator drone.

In the jargon, Fourier math converts a complex repetitive wave from the time domain, where we see it as it changes through time and space, into the frequency domain, where it disaggregates into a fundamental sinusoid frequency, such as a pure sound or color, and its multiple harmonic frequencies. Thus Fourier creates a spectrum of pure frequencies that sum to the original waveform. In the transform, the frequencies are mapped as a series of amplitudes and phases that can be modulated or altered for communications. Ideally performed optically through non-linear crystals, this conversion entails no expenditure of power beyond the emission of the white light (or other electromagnetic waves, radio and microwave).

Shannon showed that information entropy measures surprise: the unexpected bits in a communication. Taking more liberties with Shannon, I have summed it up by saying it takes a low-entropy carrier (no surprises) to bear a high-entropy message (unexpected data). Fourier transforms can generate infinite numbers of pure low-entropy frequencies that can in theory be modulated for communication (the ultimate in wide and weak). At the time of Fourier himself, Fourier series were conceptually elegant but too complex to be manually computable. Fourier math became feasible at wirespeed (or wireless speed) through the creation of high-speed digital signal processors (DSPs) now a specialty of TI, **Analog Devices** (ADI), and other companies. Also crucial was the invention of the simplified Fast Fourier transform (FFT) and inverse FFT in 1965 at IBM by John Tukey and James Cooley based on an idea of Gauss more than a century and a half earlier.

The winning strategy

OFDM's low and slow technique is used in cable modems and in WiMAX wireless experiments. Intel wants to put WiMAX on every computer motherboard and communications card and liberate the world from Qualcomm. **Flarion**, with Qualcomm founder Andrew Viterbi on the board, also wants to exploit OFDM to establish a new standard, though Flarion suffered a setback when **Sprint** (FON), a Qualcomm house, bought Nextel, which was considering the Flarion system.

Prompted by reports from Flarion, **Motorola** (MOT), and **Siemens** (SI) of mobile tests conducted showing OFDM performance at hundreds of megabits per second over 20 megahertz bands (compared to CDMA 1.2 MHz and 5 MHz bands), speculation has arisen on the *GTR* subscribers' Telecosm Lounge (*www.gildertech.com*) that OFDM would usurp Qualcomm's CDMA. OFDM is a marvellous technology, which Qualcomm understands better than most of its current come-lately exponents. It invokes Fourier transforms to supply infinite numbers of hypothetical channels, each capable of modulation to send data. It is the essence of Terry Turpin's hyperfine optical wavelength division mux system. It performs wonders in a dispersive channel such as DSL or the cable system or point-to-point wireless. It is not a substitute for CDMA but could serve as a carrier for it, though its benefits increase with bandwidth beyond the available allocations for cellular in most areas. Qualcomm is currently using it, together with smart multiple antennas, for its MediaFlo broadcasts. If you hype up any system with smart antennas and other costly upgrades it can outperform CDMA services that have to provide cheap robust phone calls for millions of people in noisy environments across many cells. But Qualcomm can use CDMA in conjunction with OFDM much as it currently uses CDMA in conjunction with TDM (time division multiplexing) in EvDO, in order to manage channels and provide soft handoffs and simple frequency management.

OFDM's Fourier muxing and demuxing gets better as channels are moved closer together in frequency space. If the frequency channels are spaced by what is the bit rate or symbol rate in the time domain, they become orthogonal: they do not interfere with each other even if they overlap. Indeed, when they overlap in exactly the right way, each frequency channel becomes a null (imperceptible) to the other frequencies, and one high-speed signal from the transmitter blooms into thousands of more robust low and slow signals, each of which can bear voice, video, or computer data. Low and slow is the winning strategy.

At Essex, Turpin uses the same principle in his Hyperfine fiber-optic mux-demux device that can put 16,000 WDM carriers on a single fiber thread. In the frequency domain, low and slow wavelengths closer together function better than a few wavelengths spaced far apart. Real hyperfine WDM is cooler, faster, cheaper, better than coarse WDM. Ultimately this principle (and the advance of optics at the chip level through John Treeza's **Xan3D**, Kleiner-Perkins's **Infinera**, Simon Cao's **Aracor** and others) will enable WDM to dominate the realms of connectivity as it currently dominates the domains of backbone bandwidth. But first Cioffi will have his day…again.

Marvelous Marvell

From the infinite Fourier palate, Cioffi's DMT makes do with a few thousand frequencies. Then, in a technique that distinguishes his technology from typical OFDM, his system adapts each of the tones ingeniously to the ambient conditions of noise and interference in real time, channeling the most power and data into the frequencies that are least corrupted and thus have the largest capacity. By this means, he came close to the Shannon limit (perhaps 200 megabits per second) for transmitting information through a single twisted pair of copper wires, such as the line to your phone. But these lines commonly are bound in leaky bundles and talk to each other while you download your file or film. Thus in practice DSL delivers less than 1 percent of its potential capacity. Called dynamic spectrum management (DSM), Cioffi's new revolution in Avvia solves this problem by adding to the optimization of each tone and each twisted pair a new level of management and optimization for the entire bundle. Providing these services cost effectively for the Bells, he can close the performance gap between them and the cable industry and render fiber to the neighborhood as effective as fiber and coax to the home.

People interested in making money in technology should follow Cioffi closely. Like Carver Mead's classes at Caltech that have spawned scores of companies in Silicon Valley, Cioffi's PhD classes at Stanford have sent multiple graduates to high-level positions in most of the chip companies on the *GTR* list, and around it, from Qualcomm and TI to Broadcom and Intel, from Motorola, **ArrayComm**, and Flarion to **Atheros** (ATHR) and Marvell.

Beginning in the early 1980s at the precursor to IBM's Almaden Research center for storage technologies (now partly **Hitachi's** [HIT]), Cioffi focused on how to maximize the data flows onto disk drives. As a professor at Stanford, he and several students addressed the problem of read controllers in disk drives that have to detect bits in the gigahertz range. The project migrated to Marvell with the Cioffi students, but because of a non-compete agreement with TI made when he sold Amati, Cioffi did not join the Marvell board until 1999. By that time it already dominated the market for hard drive partial response read channel detectors and controllers. Cioffi saw that gigabit Ethernet receivers operated in the same gigahertz range and required the same order of sensitivity and observed most of the same formats and standards. He recommended that Marvell enter the business of making gigabit Ethernet chips. As a result, Marvell became the first company to develop GigE transceivers and controllers and now dominates the business up to 10 GigE with Broadcom, another company full of Cioffi

Marvell now is entering the market for Wi-Fi controllers and gaining share against many rivals including Broadcom and Intel

graduates. Last year Marvell purchased Galileo in Israel, which supplies GigE switches. Marvell now is entering the market for Wi-Fi controllers and gaining share against many rivals including Broadcom and Intel. We like Marvell and only wish that Cioffi had told us about it sooner.

A valuable tale

Cioffi exalts his copper revolution. In his new book on dynamic spectrum management, he concludes: *"A 500 meter cable of 50 twisted pairs has a capacity of 10 Gbps in each direction to be shared among the customers of the telephone plant, greater than Hybrid Fiber Coax, and yes, even greater than a single fiber shared in the most popular projected fiber to the home architecture known as a passive optical network (PON). Today's DSL operates at less than one percent of this capacity. Dynamic spectrum management offers the promise of eventually realizing the goal of broadband connection at 100BT-like speeds [100 base T on copper at 100 megabits per second] to every customer of every phone line in the world, thus enabling the broadband age."*

Why then is John now touting a new Ethernet passive optical network (PON) company called **Teknovus**? Well, for one thing, it was started by a former student who worked at Amati named Jacky Chow. Chow initially called the company Jubilant, but for the optics arena he has toned it down to Teknovus. **NEC** (NIPNY) was the original investor and it was focused on DSL components. Joined by **Mitsubishi** and **Samsung**, the company is now geared for the huge Japanese market in EPONs (Ethernet PONs) launched when **NTT** (DCM) announced a plan to invest $48 billion in the technology in Japan. Korea and China are following. Teknovus makes the transceivers on both ends of the fiber: a network terminal component on the customer side and a line terminal control unit on the service provider side. Their only competitor is **Pessave** of Israel. Teknovus chairman is Mike Callahan, formerly of **Advanced Micro Devices** (AMD) and its CEO is Rex Naden, formerly CEO of Atheros, the Wi-Fi chip stalwart, and of **Quicksilver**, the configurable processor pioneer.

In the U.S., the Bells are committing to APON (ATM-based PON) and GPON (gigabit PON) systems based on ATM (asynchronous transfer mode) that is more familiar to the telcos. **Alcatel** (ALA) is the major supplier in the U.S. and Europe both for DSL and PON. But the Asians are moving much faster and offer simpler systems more compatible with the Internet.

Fiber and DSL are complements. Both are wide and weak. All Cioffi's dreams depend on the penetration of fiber deep into every neighborhood. But he offers a valuable cautionary tale to those who expect fiber to the home to become ubiquitous. Further, by greatly enlarging the portfolio of possible broadband solutions in the local-loop, he will also spur the deployment of fiber optics throughout the network, up to the last copper links.

– George Gilder, January 26, 2005

GILDER TECHNOLOGY REPORT PUBLISHED BY GILDER PUBLISHING, LLC AND FORBES INC. • Copyright ©2005, by Gilder Publishing, LLC

291A MAIN STREET, GREAT BARRINGTON, MA 01230, TEL: (413) 644-2100, FAX: (413) 644-2123 • EMAIL: INFO@GILDER.COM

EDITOR IN CHIEF	EDITORS	EXECUTIVE EDITOR	TECHNOLOGY ANALYST	MANAGING EDITOR	ART DIRECTOR	SUBSCRIPTION DIRECTOR	CUSTOMER SERVICE
George Gilder	Nick Tredennick Brion Shimamoto	Bret Swanson	Charlie Burger	Mary Collins	Peter Johnstone	Rosaline Fernandes	Sandy Fleischmann

For subscription information telephone toll free: (800) 292-4380 • WWW.GILDERTECH.COM