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Attack of Carver's Clones

Even as we savor Foveon, the chief investment opportunity in the Telecosm, we look ahead to more systemic disruption that will be unleashed by Carver Mead's analog apex, Impinj

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Vegas!!! Personally, I don't believe in gambling or divorce, but tell that to the telcos. Here for the Money Show and NetWorld + Interop, I find that the money is divorcing the network. Fresh from a star turn on stage at a panel of the Network Processor Summit, even Eli Fruchter of **EZchip** (LNOP) is worried, and he has 500 gigabits per second of memory bandwidth all integrated onto his own 200 megahertz network processor that operates at all 7 networking layers on just 15 watts of sleepy-time electrons. Yes, the sages nod wearily, but can it run a Wall Street vibrator? Can it convert fried dough into gold, like **Krispy Kreme** (KKD)? At Bally's Resort in the center of Vegas, the Money Show pullulates with contradictory speakers (buy platinum, buy hedges, buy newsletters, buy coins) and cagey investment strategies and software investment tools, but at Interop they grouse, Show me the Money!

Interop is at the Hilton out on the edge, teetering toplessly on the verge of the desert. I prefer the towers and turrets of the strip, the phosphorescent panorama of a confectionary Europe in the sands, nearly free of crime and grime. Offering a thousand forms and figments of music and display, cuisine and choreography, with the gymnasts and funambulists of the Cirque de Soleil, with impressionist paintings on the walls straight from the Hermitage and the Louvre and with **Intel** (INTC) Inside Interop, Vegas seems a vast luxurious convoy of spectacular ships propelled by galley slaves. Underpinning all the upscale entertainments were myriad ranks of servitors rowing for their lives and fortunes on the casino floors, pulling addictively on the joy-stick oars of the slot machines. If they stopped rowing, all the eight layers of confectionary superstructure above would drift into the sands.

It made me think of the Telecosm. Similarly would languish all the radiant loops of infrared optics if the people should escape their bondage to the telephone. And although no one has stopped making calls except the telco purchasing departments, the world might as well have gone on a telephone strike. By all reports from Interop, the phone companies have zeroed out their capital budgets and invested their spare cash in lawyers, senators, and bankruptcy impresarios, which to the companies up the supply chain making lasers, multiplexers, network processors, Raman amplifiers, and fiber lines is pretty much like Vegas without slots or slaves. Even Simon Cao seems to be giving up.

At least our Charlie Burger offers Telecosm investors glimmers of hope with his latest analysis on Internet traffic. **RHK** reports that U.S. backbone traffic is now around 100 petabytes (10^{15} bytes) per month according to data supplied under nondisclosure by the top carriers. Combining RHK's results with figures from both Larry Roberts of **Caspian Networks** and Andrew Odlyzko of the University of Minnesota yields a trend-line of 2.1x annual growth since 1997.

Although an annual doubling represents a slowdown in traffic growth, RHK estimates that the ratio of network *lit capacity* to *average traffic* was 10:1 in 2001 and they anticipate the same ratio in 2002. This means that carriers are pushing the envelope on bandwidth use. Think of those hapless souls who famously drowned in the river that averaged only two feet deep. The volatility of traffic over data networks leads to a ratio of peak-to-average traffic between six and ten to one. Using the more conservative 6:1 estimate, we conclude that, on average, backbone links

are using 60 percent of available bandwidth to carry peak traffic loads. Confirming this is a **Telechoice** finding that 17 of 22 major long-haul routes in the U.S. exceed 60 percent active capacity utilization.

When peak traffic exceeds 80 percent of capacity, network quality degrades precipitously. Increase average network utilization by only 3.3 percent, from 10 to 13.3 percent, and we scrape the 80 percent threshold. True, if the capacity to average traffic ratio holds at 10:1 through 2002 while total network traffic continues to double, it means that even at today's anemic rate of capex, carriers are able to double network capacity and still operate at just under saturation. This may signal an early triumph of WDM, in which dark lambdas on lit fibers can be activated relatively easily and inexpensively when compared to lighting a new fiber.

JDSU is uniquely positioned to become the master builder of the Telecosm

Nonetheless, relatively small perturbations in these growth rates could paralyze complacent carriers. For instance, if annual traffic growth were to creep up to 2.7x, the backbone network would saturate in 12 months if carriers continued to double capacity. Faced with another jolt similar to the Browser Boom of 1995–96 when traffic increased one hundredfold, the U.S. Internet backbone would drown in data in just two months.

JDSU: the right stuff

No company is more dependent on Internet traffic growth than **JDS Uniphase** (JDSU), supplier of just about any and every optical component and module. With $1.5 billion cash and a clean balance sheet, the biggest threat to Josef Straus's optical components kingdom is not the spiraling telecom downturn nor the hundred guru-startups each vying for superiority in one or two technologies. No, Straus's biggest threat is failure to recognize his company's defining technology.

At trade shows we hear much about JDSU's new products. Indeed, JDSU *should* have more new products than any other components vendor simply because it has more components lines. But new products are not unique to JDSU. Why buy the latest tunable lasers from JDSU instead of **Bandwidth9**, **Blue Sky**, **Fiberspace**, **Agere** (AGR.a), **Altitun** (ADC), or **iolon** all relentlessly improving their inventions?

Because, says Straus, we will supply our customers "with leading optical solutions for all the markets that we serve." But that's unrealistic. There are too many small-shop geniuses that know more about a niche technology than all the researchers in JDSU combined. Straus can buy some of these technologies, but he can't buy them all. Nor should he, since their integration into JDSU would become a burden and a distraction.

Straus covets these higher-margin modules. So does **Avanex** (AVNX), which has leading-edge offerings such as the PowerExpress amplifier and dispersion compensator subsystem. And **Corning's** (GLW) prized liquid-crystal modules recently achieved design wins with **Corvis** (CORV) and **Ciena** (CIEN). Modules will not set JDSU apart.

There is a technology that will, however. Think about JDSU's revenues, $262 million in the March quarter. Compare that to Avanex/**Oplink's** (OPLK) combined $20 million and Corning's $34 million in photonics components. JDSU leads its closest followers by an order of magnitude in sales and probably even more in volume. When Straus calls himself a one-stop components shop, he comes closest to defining his key technology.

The key is in the process—making all the stuff. JDSU is uniquely positioned to achieve manufacturing efficiencies. If the company leverages its production platforms for flexibility, timeliness, and volume—it will be able to lead the Telecosm out of the craft guild stage. It will define production standards. It may even become a "fab" for "fabless" gurus designing the latest Bragg gratings or whatever. In some cases, a best-of-class product may not fit into JDSU's portfolio if it requires a disruptive production process for low-volume sales. Let the custom shops handle it.

Straus's choice on the one hand is to try to wrestle interleaver technology leadership away from Avanex or laser-locking technology leadership from Fiberspace. Or he can provide an efficient, cost-effective supermarket of variety and quality while the competing specialty shops live-or-die on high margins—until the next guru disrupts them. JDSU should become the master builder of the Telecosm.

Brain drain

Under the technology leadership of Simon Cao, Avanex was one premium-components maker destined to flourish alongside JDSU. Perhaps more than anyone else in the industry, Simon understands the lambda paradigm and its network implications. After developing the WDM product lines at E-TEK and Oplink, he co-founded Avanex in 1997 with the goal of making lambdas ubiquitous. Like Carver Mead, Simon listened to the technology. Instead of trying to force photons to behave like electrons by processing them in solid-state devices such as silicon waveguides, Simon allowed the lightwaves themselves to lead his innovative path into the free-space environment where photons flourish, developing Avanex's photonic processors based on ingenious improvements to the etalons and gratings of classical optics. As a result, Avanex's PowerMux wavelength multiplier, the technology platform for most of the company's other components and modules, combines and separates more lambdas onto a single fiber-optic strand, at a lower cost, than any other commercial multiplexer.

Thus, we view Simon's "resignation from Avanex" as a potentially life-threatening blow to the company. Next-generation products already in customer labs will undoubtedly be successfully commercialized over the next several quarters under the able leadership of Avanex's new CTO,

Giovanni Barbarossa. But down the road, after the Oplink merger, will Avanex continue in its role as the leading vendor of cutting-edge components which multiply and manipulate more and more lambdas across the Telecosm? Or will it lose Simon's vision and instead try to become the "other JDSU," a components supermarket continually lagging the leader? The goal of being number two in the industry did not succeed for Oplink and will not succeed for Avanex if it gives up its unique powers of invention on the frontiers of WDM, where lambdas improve their behavior as they multiply.

We are told that Simon will continue to play an important advisory role to be determined over the next several weeks as the merger proceeds toward its due date in June. Though skeptical that such an arrangement could continue to foster the company's cutting-edge WDM leadership, we await Simon's decision and any sign that a merged Avanex/Oplink will maintain his vision. We will also be watching the ledgers for insider sales.

Even more devastating for the telecosm than carrier crumblings or Simon's resignation is the latest news on broadband. Just as the Baby Bells announce that broadband DSL subscriptions are improving, the Supreme Court endorses and enshrines TELRIC, the Telco Extortion Law Ravaging Internet Commerce. Also known as total element long-run incremental cost, or the Federal Communications Commission regime of forced sharing of telecom assets at far below-market rates, it has blocked the real facilities-based roll-out of the broadband local loop. Now it promises to drive the only obvious remaining money out of the market for last-mile equipment. In dissent, Justice Stephen Breyer, joined by Scalia and Thomas, questioned how the FCC could reconcile the abstruse new TELRIC pricing model, which blocks new investment by essentially forbidding profits, with the explicit statutory goal of "reduced regulation."

Despite this regulatory schlerosis, the FCC's Michael Powell is doing his best to dismantle the Gore-Hundt-Kennard regime from within. In April the FCC ruled that cable modems are "information services," not "telecommunications services," and are thus exempt from the forced sharing requirements burdening copper telephone lines. Powell has even begun a similar proceeding for copper DSL, a move that could obsolesce much of the TELRIC-open-access nonsense. But it won't happen tomorrow. The telcos remain trapped in their technocratic copper cages.

We've said it from the beginning: cable companies have two huge advantages over the telephone companies—less regulation and bigger bandwidth. During the first quarter of this year, led by **Time Warner's** (AOL) 278 thousand new subscribers, cable modems picked up close to 900 thousand customers and stretched their lead over DSL, which lagged with half that many adds. More significant still, with just 14 percent of the subscribers, cable modems comprised some 73 percent of all Internet access bandwidth. With **Narad Networks** promising to accentuate the bandwidth divide between coax and copper, cable is more attractive than ever.

Depressed by their general association with tech and telecom, and by some fuzzy math at **Adelphia** (ADLAE), U.S. cable companies are trading near historically low price-to-EBITDA multiples, which remain meaningful because of cable's deliberately profitless (and taxfree) model. Diamonds in the rough include the four Cs: **Comcast** (CMCSK), **Cox** (COX), **Charter** (CHTR) and **Cablevision** (CVC). Cable modem chip specialists **Broadcom** (BRCM) and **Terayon** (TERN) are also attractive, with Broadcom near its September low and Terayon near its all-time low. Terayon's continued quarterly losses are a concern, but it has a definite time-to-market advantage over Broadcom and **Texas Instruments** (TXN) in S-CDMA-based DOCSIS 2.0 modems, which triple upstream bandwidth (crucial for cable's 675 thousand small business customers) and enable voice-over-IP and other two way Internet applications. Seven of the eight largest U.S. cable service providers are testing the new Terayon product.

The goal of being number two in the industry did not succeed for Oplink and will not succeed for Avanex if it gives up its unique powers of invention

The chief investment opportunity in the Telecosm, however, is still **Foveon**, a private company 64 percent owned by two public companies—**National Semiconductor** (NSM) 49 percent and **Synaptics** (SYNA) 15 percent—that is launching a consumer product revolution in a $20 billion dollar market. Having fallen back after a meteoric IPO in January, Synaptics joins our list this month. Foveon is just one of several companies launched by Carver Mead to prosecute a new paradigm, 20 years in development, of heavily parallel analog electronics. Now this once academic pursuit of Caltech students is bringing into reach two of the industry's paramount technical and commercial targets—first the single-chip-camera, motion and still, and soon the single-chip cell-phone. In technology investment, it does not get any hotter than that. But even as we savor Foveon (see GTR Aug 97, May 99, Feb 02), we look ahead to the more systemic disruption that will be unleashed by Carver's analog apex, **Impinj**.

Carver's clones

When Chris Diorio walked into Carver Mead's Caltech office for the first time in 1992, he encountered a provocative sign on the door: "All the world's an analog stage. Digital plays only bit parts."

By now you are familiar with Professor Mead's own "bit parts" in the digital computer revolution. Among dozens of key innovations, he was the key researcher behind Moore's law, conceiver of the VLSI (very large scale integration) design

TELECOSM TECHNOLOGIES

JDS Uniphase (JDSU)

ACTIVE AND PASSIVE OPTICAL COMPONENTS

APR '02 MONTH END: 4.34 | 52-WEEK RANGE: 4.06 - 24.50 | MARKET CAP: 6.5B

NO LOITERING—When you have nothing to do and you're JDSU, you buy a startup. With revenues down to $262M (from $286M last quarter and $920M a year ago) and projections of $210M–$230M next quarter, we still "may not be seeing bottom" according to subdued CFO Anthony Muller, avoiding any appearance of optimism that might entice jackleg esquires. Not one to twiddle thumbs, however, JDSU used some of its $1.5B cash pool to grab startup Scion Photonics for $43M. Industry watchers, worried that JDSU is losing the technology race in planar waveguides with its PIRI platform acquired in 2000, believe that Scion's more advanced waveguide process gives JSDU hope. But the real question is, with each of JDSU's superbasket of components and modules under attack by 20 different startups all focused on that one thing, what's JDSU to do? Answer: what it's doing—buoy R&D at 20% of sales…acquire attractive technologies…drive nontelecom sales to 25%…and amass a supermarket of standardized offerings that leverage the company's overwhelming advantages in volume production. By contrast, lower-volume competitors stand or fall on one or a handful of premium products which must reap high margins. A few will succeed; most will fail. The components kingdom is JDSU's to lose.

Cloudbreak: CEO Jozef Straus breached hope, claiming that North American carriers are saturating capacity on major intercity routes. Straus sees new equipment purchases for these links within six months.

Avanex (AVNX)

ADAPTIVE PHOTONIC PROCESSORS

APR '02 MONTH END: 3.15 | 52-WEEK RANGE: 2.70 - 19.20 | MARKET CAP: 218.4M

BRAIN DRAIN—Avanex is one premium-components maker that should thrive against JDSU—provided the intellectual legacy of founder Simon Cao lives on. Master of paradigmatic free-space optics, Cao unexpectedly resigned as CTO ostensibly to spend more time with his family. His future role with Avanex, not yet determined, may include extensive consulting over a period of months or years. A potential blow to Avanex, we will keep close tabs on developments. Under Simon, Avanex continued to invest over 60% of revenues on R&D. Though unsustainable in the long run, the spending foretells of coming upside surprises from the likes of the PowerShaper dispersion compensator (a replacement for bulky, lossy, noisy dispersion compensating fiber), the next-generation PowerMux wavelength combiner, and new optical add-drop and power balancer modules based on liquid crystals. All of these products should begin commercial revenues within several quarters. We've already seen one upside surprise—a large long-haul order in the March quarter—which helped push revenues up by 23% over December.

ONI Systems (ONIS)

METRO WDM PLATFORMS

APR '02 MONTH END: 5.23 | 52-WEEK RANGE: 3.50 - 39.99 | MARKET CAP: 740.3M

THRICE THREE—ONI had a thing for the threes during the quarter ending the third month (March): three new customers …three 10% customers…$3M in bad debt expenses. Indeed, ONI announced three new customers in each of the previous three quarters as well. In a story perhaps more appealing to numerologists than technologists, ONI has set its wedding date with Ciena for quarter three, expanded its customer base to 33, is in trial in 30 labs, and shipped to 21 customers for revenues of $21M (each divisible by 3). Now, if only they'll find a cash flow multiplier.

Fire Extinguisher: ONI must be having lots of fire drills. The OEM burned a mere $12M during the March quarter, report out-of-breath workers. Looking more and more like old flames, Ciena and ONI could wind up with a JDSU-like $1.5B in cash reserves after they get hitched.

Essex (ESEX.OB)

OPTICAL PROCESSORS

APR '02 MONTH END: 5.07 | 52-WEEK RANGE: 3.30 - 8.25 | MARKET CAP: 26.8M

PREACHING TO THE CHOIR?—When Mike Piacenza, Essex VP of business development, was asked by David Chaffee (fibertoday.com) whether Terry Turpin has developed a relationship with nearby Ciena, just 15 miles down the road, Piacenza was quoted as saying, "We are singing from the same hymnbook." Hmm. Last month we reported Ciena's announcement of an all-optical add/drop mux based on Corning liquid-crystal technology. With more emphasis by Ciena on both all-optical modules and cornucopian wavelengths, its proposed merger with ONI looks more interesting every day—especially for ONI, since Turpin's Hyperfine wavelength multiplier is finding increasing interest in the access and metro regions among Gigabit Ethernet vendors. Will Terry salvage a Ciena/ONI union for the paradigm?

Glee Club: Terry Turpin will sing with Brad Mells of Fiberspace next month at Supercomm, Terry doing Hyperfine trills at 6.25 GHz while Brad Gridlocks the beat. For the program, see last month's GTR.

Corvis (CORV)

WDM SYSTEMS, RAMAN AMPLIFICATION, EDGE SWITCHES

APR '02 MONTH END: 1.20 | 52-WEEK RANGE: 1.02 - 8.94 | MARKET CAP: 438.1M

TESTING 1, 2, 3—What's the premier ultra-long-haul system vendor, master of the all-optical express network, doing with an electronic switch that shuffles bits? Getting testy. WDM guru Dr. David Huber, who has already shipped his OCS (optical convergence switch) for trials with Florida's EPIK Networks and two unnamed North American carriers, has just gotten a call from his model all-optical customer, Broadwing (BRW). But we've skirted the question—what's up? The pleated, twofold answer: OCS puts intelligence at the network edge, where it belongs, giving Corvis customers a flexible and seamless end-to-end network of wavelength connections. Perhaps even more critical, with an opaque switch Corvis can hold hands with the remaining carriers, each fearful of the optical paradigm, and guide them bit by bit over the rainbow.

Festoonfest!: Courtesy of France Telecom, now connecting underwater coastline links of up to 350 km, minus inline amplifiers, using Corvis's Raman-soliton combo.

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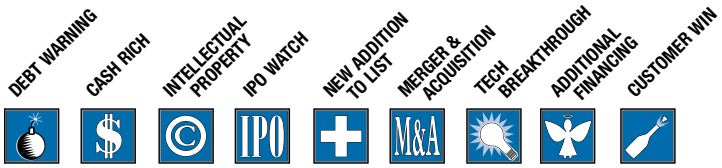

MEAD'S ANALOG REVOLUTION (see Carver's Companies/page 8)

National Semiconductor (NSM)
Synaptics (SYNA)
Sonic Innovations (SNCI)
Foveon
Impinj
Applied Neurosciences
DigitalPersona

COMPANIES TO WATCH

Analog Devices (ADI)
BlueArc
Cablevision (CVC)
Charter (CHTR)
Comcast (CMCSK)
Cox (COX)
Terayon (TERN)
Xilinx (XLNX)

StorageNetworks (STOR)

DATA STORAGE MANAGEMENT, SOFTWARE

APR '02 MONTH END: 2.91 | 52-WEEK RANGE: 2.39 - 23.54 | MARKET CAP: 285.5M

WE STAND ALONE—Managing the largest globally distributed networked storage environment in the world, STOR has scaled capacity by 400% in the last 10 months, to 1.5 petabytes of stored data, with a zero increase in labor costs. But with fewer fees coming in this quarter from contract negotiations and STORfusion partner training, watch out for falling EBITDA. The STORfusion offering is a set of pre-engineered storage software and services, plus training, that enables service and telecom providers—like BellSouth, EDS and Fujitsu—to rapidly enter the storage management services market by partnering with STOR. On May 14 STOR announced STOROs, a software product designed for large, centrally managed, globally distributed, networked storage topologies, like that of beta customer Ford Motors, with 300-plus terabytes of data spread across 1,000-plus data center hosts.

Scale Eight

MASSIVELY PARALLEL GLOBAL STORAGE

PRIVATE

INDUSTRY TRANSFORMING—With the company named to the Red Herring 100 list and CTO, Josh Coates, named one of *MIT Technology Review's* "world's 100 brilliant young innovators" for his "paradigm shattering idea" disrupting the $20 billion data storage market, Scale Eight has been getting a lot of ink this month. Watch next month for a big customer win out of Japan.

Mirror Image Internet

GLOBAL CACHING AND STOREWIDTH PLATFORM

PRIVATE

MEETING DEMANDS—Noticing an up-tick in demand for streaming media services, Mirror Image Internet is actively building in streaming service enhancements. Watch for a strong push in the streaming arena in the next few months. A recently announced partnership with Miami-based Conectron also gives MII a welcome South American market window of opportunity.

Equinix (EQIX)

SECURE INTERNET BUSINESS EXCHANGES

APR '02 MONTH END: 0.57 | 52-WEEK RANGE: 0.33 - 3.53 | MARKET CAP: 48.3M

STEP IN THE RIGHT DIRECTION—Equinix posted its seventh consecutive quarter of revenue growth on April 24, remaining on track for profitability in 4Q02, despite the tough IT spending environment. First quarter revenue was up 15% sequentially and 60% year over year. EQIX signed 31 new customers this quarter, including Broadwing, AT&T, and RCN, and lost 17, ending the quarter with 232 customers and additional orders from 46 existing customers. EQIX's network provider customers, such as MFN, could present some challenges in terms of lost revenues. Wall Street wavers on whether $256 million in debt is too much. Termination of its European facilities lease was a first step in the right direction.

Sprint PCS (PCS)

NATIONWIDE CDMA WIRELESS NETWORK

APR '02 MONTH END: 11.21 | 52-WEEK RANGE: 7.22 - 29.05 | MARKET CAP: 11.1B

SPRINTING AHEAD—Last month we noted Sprint PCS had blown away the Street's estimates for net additions, churn, and EBITDA. Net additions of 725,000 were 21% of total Big Six additions. Continuing the momentum, Sprint PCS announced (1) a new corporate e-mail offering that dramatically improves on the old version and (2) the August launch of its nationwide 1x mobile Internet services. Legacy base station upgrades have been completed, and 20% of the handsets sold in 1Q02 were 1x enabled, bringing total 1x enabled handsets in the PCS customer base to 3 million.

Qualcomm (QCOM)

CDMA MICROCHIPS, IP, SOFTWARE

APR '02 MONTH END: 30.16 | 52-WEEK RANGE: 28.56 - 71.04 | MARKET CAP: 23.2B

OPPORTUNITY KNOCKS—More W-CDMA delays coupled with a crackdown on Korean handset subsidies sent QCOM's stock price to a 52-week low. But not for long. In Korea, April 1x handset sales of 870,000 were down 45% from March, but look for a rebound as 1x EV-DO handsets hit the market just in time for the World Cup. Japan's KDDI signed up 330,000 subscribers in its first month of 1x service, more than tripling the 105,000 subscribers NTT DoCoMo has landed in its seven months of operation. And India's Supreme Court is expected to remove regulatory hurdles and allow Reliance Telecom to deploy a CDMA wireless local loop network.

Altera (ALTR)

PROGRAMMABLE LOGIC DEVICES

APR '02 MONTH END: 20.56 | 52-WEEK RANGE: 14.66 - 33.60 | MARKET CAP: 7.9B

THE COMPETITION—Xilinx's strong 20% sequential revenue growth was its 2nd fastest ever. Sales of Virtex E products grew 40% QoQ, the first sequential increase in more than four quarters. Altera, meanwhile, saw just 6% sequential revenue growth. Xilinx attributes its success to increasing use of 300mm (12-inch) wafers and the incorporation of more comm-IC functionality into its PLDs. Robertson Stephens now believes that Xilinx controls 54% of the programmable logic market up from 52%; Altera, meanwhile, dipped to 34% from 37%. Xilinx's Virtex II, manufactured on 0.13 microns by IBM, is shipping now while Altera's Stratix family begins rolling out at the end of this quarter.

See-Saw: The Street continually favors Xilinx over Altera due to valuation and superior growth, but Merrill Lynch is encouraged that Altera introduced both processor core (Excalibur) and transceiver core (Mercury) products before Xilinx and believes Altera could eventually overtake Xilinx as the PLD leader.

EZchip (LNOP)

10 GIGABIT NETWORK PROCESSORS

APR '02 MONTH END: 12.84 | 52-WEEK RANGE: 2.70 - 16.45 | MARKET CAP: 93.5M

COMPETING CLAIMS—Bay, Terago, Cognigine, Internet Machines and a host of network processor start-ups and incumbents continue to make big claims. But EZchip is still by far the world's most highly integrated network processor. Bay, for instance, boasts an on-board traffic manager, where EZchip adds a separate traffic management chip to its on-board device for large core routers. EZchip, however, integrates all the classifying engines, reducing total chip count, board space, and power con-

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sumption some 80%. Getting the classifiers on-chip offers the biggest performance bang for the buck. But only EZchip can do it, courtesy of embedded DRAM from IBM and 64 of its own parallel Task Optimized Processors.

Take Away: The customer situation at EZchip is murky, but the stock has pulled back from recent highs.

Broadcom (BRCM)

BROADBAND INTEGRATED CIRCUITS

APR '02 MONTH END: 34.50 | 52-WEEK RANGE: 18.40 - 53.35 | MARKET CAP: 9.2B

CABLE KING—A May 7 announcement that Motorola would second-source its cable modem chips to Texas Instruments led to massive over-selling and left shares near their September lows. But Broadcom has posted 3 quarters of sequential growth on both the top and bottom lines, and will benefit from continued inventory flushing and an enterprise business pick-up at Cisco, its biggest customer.

Texas Instruments (TXN)

DIGITAL, ANALOG, MIXED-SIGNAL PROCESSORS

APR '02 MONTH END: 30.93 | 52-WEEK RANGE: 20.10 - 42.91 | MARKET CAP: 53.6B

THE COMPETITION—First quarter revenues at TI competitor Analog Devices improved 5% sequentially to $413 million. Both TI and ADI will face major challenges from Impinj in the near future. Analog, mixed-signal, DSP, single-chip-systems—nothing is safe.

National Semiconductor (NSM)

SINGLE-CHIP SYSTEMS, FOVEON IMAGERS

APR '02 MONTH END: 31.52 | 52-WEEK RANGE: 19.70 - 37.30 | MARKET CAP: 5.6B

CROSS-TALK, SCHMOSS-TALK—Foveon (49% owned by National) further put to rest charges that its digital camera imagers suffer from "cross-talk." Collecting every color at every pixel is a feature, not a bug. In fact, it's the key to the single-chip-camera. "Our spectral response curves come close to meeting the 'Luther condition' that tells when perfect color is possible. Film and most other sensors do not come close," says one inside expert.

Visibility: On May 20, NSM bumped its sequential revenue growth expectations to 12 % to 13% from the 6% to 9% range.

Narad Networks

GIGABIT ETHERNET COAXIAL CABLE NETWORKS

PRIVATE

TOTALLY RAD—Narad announced a partnership with RAD Data to offer TDM over IP services via coaxial cable networks….Still no takers for Narad EVP Andy Chapman's bet that a Bell will go bankrupt by 2007 (http://www.longbets.org/bet/13).

TAS: Check out "Copper Killers" in the May/June issue of The American Spectator.

Soma Networks

BROADBAND WIRELESS ACCESS, NETWORK SOFTWARE

PRIVATE

UNWIRED—With the U.S. Supreme court enshrining the abominable TELRIC regulations and locking the Bells in their copper cages, look for a big shift in the local loop—from wired to wireless. Now if the FCC can just get the spectrum issues right.

Turbocharged: Soma announced an agreement to license France Telecom's Turbo Codes that double the capacity of its CDMA-based broadband wireless system.

The Telecosm Technologies list is not a model portfolio. It is a list of technologies in the Gilder Paradigm and of companies that lead in their application. Companies appear on this list only for their technology leadership, without consideration of their current share price or the appropriate timing of an investment decision. The presence of a company on the list is not a recommendation to buy shares at the current price. Mr. Gilder and other GTR staff may hold positions in some or all of the stocks listed.

techniques that still dominate the industry, and chief prophet of industry disaggregation into "fabless" semiconductor design houses and independent, high-volume, generic fabs.

By the time Diorio showed up to start his electrical engineering doctorate, however, Mead was more than half a decade into the process of disrupting his own digital regime. Today, no fewer than six Mead-inspired companies are leading their fields in *analog* electronics—**Sonic Innovations** (SNCI) in hearing aids and Synaptics in lap-top touch-pads, for example, as well as Foveon in the $20 billion photography market. While these companies are delivering superior products, and in the case of Foveon, a true revolution, it is Impinj, co-founded by Mead and Diorio, whose technical innovations could have the broadest and deepest impact on the semiconductor landscape.

The Holy Grail of communications semiconductors is systems-on-a-chip (SoC). If you can put digital signal processing (DSP), microprocessing (μP), network, memory—and maybe even some analog—functionality on one chip, you can dramatically lower power, cost, and real estate. And increase performance. Telecosm companies like Broadcom, Texas Instruments, **Analog Devices** (ADI), and National Semiconductor are leaders at integrating components for the cable, DSL, LAN, and mobile phone markets. **Altera** (ALTR) has just introduced field programmable gate arrays (FPGAs) with up to 114,000 logic elements, 28 DSP blocks, and 10 megabits of RAM, all on a single chip.

599 too many

But clearly we have a long way to go. A new 3G phone from **Ericsson** (ERICY), for instance, has more than 600 discrete components, all devouring power, taking up space, and requiring interconnection on a printed circuit board.

The two biggest SoC integration obstacles are dynamic random access memory (DRAM) and analog transistors. Until now, neither analog circuits nor DRAM cells have scaled with logic CMOS. Last month, however, **IBM** (IBM) broke through the DRAM barrier, building 5 megabytes onto EZchip's world-beating 10-gigabit network processor.

Soon Impinj will tackle the $40 billion analog and mixed-signal SoC markets. Using a previously unknown, but ever present, transistor phenomenon discovered and patented by Diorio, Impinj can make mixed-signal systems-on-a-chip that are 30 times smaller, use 10 times less power, cost much less to build, and by some metrics perform 2 orders of magnitude better than today's leading-edge products. With its first product already released and a multitude in the pipeline, the 40-person Seattle start-up will be challenging some of the world's largest semiconductor companies within the year.

Analog devices detect, transmit, and create real-world waves or continuous fluxes of voltages, current and phase (timing) that travel through the air or down wires. Two of the most important analog components are the aptly-named

digital-to-analog converter (DAC) and analog-to-digital converter (ADC). The A to D process of converting messy high-frequency waves coming in through the air or over a wire into digital signals is by far the more difficult task. After a wave is detected by an antenna, it is passed through several layers of RF (radio frequency) and IF (intermediate frequency) down-conversion and then to the ADC, all before a TI, ADI, or **Qualcomm** (QCOM) DSP goes to work. To accurately represent an analog signal as a digital string of ones and zeros, an ADC must sample the signal at a rate at least twice its bandwidth. A 5 MHz signal, for example, must be sampled more than 10 million times each second.

In other words, required increases in accuracy impose exponentially increasing burdens of digital processing. Today, an ideal 14-bit converter handles 16,384 voltage levels per sample, although most 14-bit or even 16-bit products deliver 12-bit effective performance. Working in the analog domain, Impinj has just taped out a "true" 16-bit, 75 Msps (millions of samples per second) ADC that stores 65,536 voltage levels. With a 90+ dB dynamic range and 75 MHz of bandwidth, it can usurp much of the IF circuitry in a cell phone or base station.

Oil and water

Impinj stands for *Imp*act-Ionized Hot-Electron *Inj*ection. Of course. But before you get too excited, let's review why analog and digital components mix like oil and water.

Digital electronics scales with Moore's law. As logic transistors shrink, they get faster, cooler, and cheaper. Their job is to register ones and zeros, and as long as they can do that, they are good enough. Digital chip designers can operate in their virtual, abstract worlds of Boolean logic—and let Moore take care of the device physics. Because of their less rigorous task (registering ones or zeros), two similarly designed logic transistors that contain real-world defects are still functionally equivalent.

In analog, however, even slight variations in theoretically identical transistors can prove deadly. "The Achilles Heel of analog is that every transistor is different," says Diorio. As analog transistors shrink, moreover, small imperfections are magnified by the square of the reduction, creating an overwhelming incentive for analog designers to use *larger* transistors, entirely incompatible with the scaling magic of Moore's law.

While a bachelor's EE can design digital chips after a few months of training, analog chip design is an exacting "black art" that often takes 20 years to learn. *IEEE Spectrum* reports there are only 1,800 experienced analog designers working in the U.S. today. There are hundreds of thousands on the digital side. Handcrafted analog thus suffers from a technological bottleneck *and* a personnel bottleneck.

Analog automation

Impinj breaks these bottlenecks by "tuning" its transistors. When Diorio received his first Impinj digital-to-analog converter (DAC) chip back from **Taiwan Semiconductor Manufacturing Company** (TSMC), it essentially didn't work. None of his chips do—initially. Impinj builds its circuits in advanced sub-micron CMOS geometries (e.g., 0.18 microns) ill-suited to analog. Mismatched, noisy, and otherwise defective transistors mean competitive leading edge products might outperform Diorio's chips by a factor of two. But Impinj's transistors change, they morph, they *learn*. Through external and self-adaptive calibration—post-fabrication—transistor performance improves enough to overtake DAC competitors by a factor of three or four—while saving 30x in space and 10x in power and enabling integration with DSP and µP logic, memory, and other components. Plus, young engineers can now design "sloppy" analog circuits and clean them up afterwards. Redesigning a product for a new geometry—say, going from 0.25 to 0.18 microns—would have taken an eight-person team a year. Now it takes three people one weekend.

Impinj can also improve upon, and replace, digital components like DSPs and just as easily integrate them onto a single-chip-system. Like the best exemplars of Moore's law, Impinj's "self-adaptive" silicon co-opts much of the functionality of almost every nearby component. High-precision analog in digital CMOS: this is the road toward the cell-phone-on-a-chip.

Tall tails

Carver Mead had predicted this route in *Analog VLSI* (1989): "The best way to ensure that a circuit will tolerate…variations is to have it self-compensate….Self-compensation has another advantage: as circuits age and change and shift with time, the system tunes itself up." Trouble was, Mead didn't know exactly *how* to do it. So he pointed some of his best students down one possible path.

Early on in Diorio's doctoral program, Mead asked him and two colleagues to find out what they could do with a floating gate transistor. A floating gate is a layer of polysilicon that "floats" between layers of oxide insulator. Sealed in oxide, floating gates are free from any direct electrical contact and are therefore good stores of charge for non-volatile memory and other uses. Mead himself had researched these devices, which were invented in the late 1960s and are the foundation of EEPROMs (electronically erasable, programmable read only memories) and flash memory. He always thought their potential went unrealized, but what Diorio found surprised him.

"Look at these little tails," Diorio told Mead, showing him some supposed noise in his data. "The tails shouldn't be there….What are they?" Mead didn't know. "It's the only time I ever caught Carver," says Diorio.

Electrons were in fact being injected into the floating gate of the transistor. It occurred in both *p*-FETs and *n*-FETs, the two basic types of CMOS field effect transistors. Diorio soon found that by using Fowler-Nordheim tunneling at the opposite end of the floating gate, he could also

expel electrons from the transistor. He could even "read and write" at the same time. If he could add and subtract electrons from a transistor at will, a transistor that is a non-volatile memory like an EEPROM, and do so at sub-threshold voltages, Diorio realized he could create a synapse-like structure that could both *store* and *process* high-resolution analog information. Unlike many previous attempts in floating-gate research, Diorio's transistor could morph through the use of local feedback, not an external or awkward on-chip mechanism. He had invented a non-volatile analog memory with locally-computed updates on a single transistor. *Impact-ionized hot-electron injection* was a major boost to Mead's vision of creating neural systems in silicon.

Although Diorio's work, patented in 1996, earned a prestigious IEEE award, and served as his 1997 CalTech doctoral thesis, it was not until 2000 that he recognized the immediate commercial potential. Racing street cars at the Laguna Seca Racetrack in Monterey, it hit him. He called Mead, and that very night they had dinner at Fresh Cream, "Monterey's best restaurant seven years running." Diorio, by that time a University of Washington professor, told Mead his silicon synapses could change the communications IC market. A week later, Mead had Diorio in the offices of Silicon Valley's Venture Law Group signing incorporation papers.

Meanwhile, a friend and former colleague of Diorio's at **TRW** (TRW), Bill Colleran, had just sold his company, Innovent, to Broadcom. Innovent developed the chips that now form Broadcom's Bluetooth and 802.11 Wi-Fi product lines. Colleran, an articulate EE Ph.D. and Harvard J.D., quickly joined his friend Diorio in Seattle as CEO of Impinj.

The Mead method

Diorio and Colleran oscillate between hinting at Impinj's enormous potential and offering practical short-term product road-maps, but they know what they've got in those 14 patents. One big idea, not yet a product, is a massively parallel analog front-end, previously unthinkable because massive parallelism implies massive transistor mismatch. It would divide an incoming signal into perhaps hundreds of low-and-slow pathways to greatly reduce uncorrelated errors, jitter, and thermal and substrate noise. Diorio has shown how simple digital inverters aren't really digital at all: the entire transition phase—the continuous voltage swing between the "one" and the "zero"—can be used for analog signal processing. Diorio's doctoral thesis was also a major breakthrough in the field of neural networks: it envisions his transistors as the key building blocks of field programmable *learning* arrays.

With Foveon, Synaptics, and Impinj achieving major breakthroughs this year, Mead's method is igniting the Telecosm's second phase. Of the key analog players—TI, ADI, **Linear** (LLTC), **Maxim** (MXIM), **Fairchild** (FCS) and the rest—only National, with its key role in Foveon, is sure to play more than a bit part on the world's analog stage.

George Gilder, Charlie Burger, and Bret Swanson
May 23, 2002

CARVER'S COMPANIES

Synaptics (SYNA)

TOUCH-SENSORS, FOVEON IMAGERS

APR '02 MONTH END: 16.83 52-WEEK RANGE: 12.29 - 20.75 MARKET CAP: 389M

Synaptics made further inroads with Japanese OEMs with the introduction of its new cPad LCD touch-pad product. Unveiled its state-of-the-art capacitive TouchScreen system for ATMs, Web phones, gaming machines, ticket dispensers, medical displays, industrial displays, and gas pump displays. Announced a significant design win with IBM, which will be incorporating a Synaptics TouchPad, along with the IBM Trackpoint, in the ThinkPad T30 notebook. Synaptics reported net revenue of $24.4 million for the March quarter, a 24% YoY increase. Net revenue for the nine-month period ending March 31, 2002 was $74.4 million compared to net revenue of $52.1 million for the comparable period in the prior fiscal year. Even without these revenues from its market-leading touch-pad technology, Synaptics may be undervalued by virtue of its 15 percent stake in Foveon. If Foveon achieves a mere $2.6 billion capitalization after it goes public in a revived economy, the revolutionary camera chip company would account for all of Synaptics' current $400 million market-cap.

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