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Powering the 21st Century

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Highly Ordered Power

We believe, more than ever before, in the technologies of freedom

We built what became the four bombs; they hijacked them. We supplied the engineers, turbines, and wings; they supplied suicidal fanatics and cardboard cutters. The Capitol was saved, apparently, because our civilians overwhelmed their conscripts in hand-to-hand combat on one of the planes.

Is it decent to publish a newsletter like this one at a time like this? Decide for yourself. When other markets were closed last week, we invested in the United Way's September 11 Fund and the Red Cross. We are going to continue investing, as well, in the companies that will develop and stock the arsenals of our civilization.

We believe—more than ever before—in the technologies of freedom. When Ithiel de Sola Pool wrote a book by that title in 1983, he focused, as our friend George Gilder does, on the Microcosm and the Telecosm, the expansive new universe of bits, information, networks, and interconnection. Our focus is on the Powercosm, the expansive new universe of highly ordered power. Power and logic, we have argued, depend on each other and advance hand in hand.

For the past two years we have explored how the growth in Powercosm technologies is being propelled by the convergence of new power technology on the supply side, and the rise of the civilian digital economy on the demand side. Now, military and civilian defense applications will further accelerate both the development of Powercosm technologies and growth in demand for the capabilities that they supply.

We take no joy in the fact that profits will accrue to companies that supply the high-tech weapons that secure America. But they will. And they should. The terrorists are inflamed by demented zealots. Our soldiers are empowered by high technology and the investors who fund its development and production. For our part, we will continue to do what we can to help advance understanding of the technologies of freedom.

Peace and War

When we introduced the term "digital power" in our inaugural issue in September 1999, we focused first on the millisecond electrical outages that crash computers and telecom systems. "High-9s power," we explained, was extremely reliable power—power with the chaos and disorder squeezed out, the microsecond spikes and dips smoothed out, the three-second sags removed, the two-hour outages eliminated. Digital machines, digital communications, and the entire information economy, we argued, are fueled by digital power.

As we discussed in subsequent issues, photons are a second principal domain of highly ordered power. Like most of what we encounter in the electrosphere, electromagnetic fields are usually quite chaotic. But they can become highly ordered—as they are, for example, in the red laser light that conveys bits down a strand of glass, or the RF carrier that delivers wireless Web to your Palm. (*Photon Power*, *June 2001*, and *Powering RF Photons*, *November 2000*)

And as we explored in subsequent months, highly ordered power is now displacing less ordered alternatives in the moving of atoms—under the hood of cars, buses, and trucks, and across the industrial landscape (*Broadband Power* and *The Silicon Car, December 2000; The Tunable Powercosm, January 2001; Networking the Digital Factory, September 2001*). Electrical systems are now rapidly superseding the click-click bang-bang control structures of the old mechanical world, because power electronics and control modules have advanced to the point where this transition is possible, and because electrical systems deliver more power, more precisely, in less space, and thus dramatically improve overall performance. Highly-ordered microwaves and optical radiation offer equally big improvements in speed, precision, and efficiency, in a wide range of atom-moving applications—heating, soldering, drilling, cutting, and materials processing.

Until now, our focus has consistently been on the burgeoning demand for highly ordered power in the civilian sector—in computers, cars, medical implants, cell towers, data centers, server farms, and factories. Yet time and again in our search for enterprises that were developing the technologies of the Powercosm, we were drawn to companies whose advanced power technologies had been developed, in the first instance, for the military.

The first issue we mailed to subscribers focused on the power-silicon aspirations of the Office of Naval Research's Power Electronics Building Block (PEBB) program (*The Law of the Powercosm: Burn Silicon*, *April 2000*). When we wrote about small turbines, we noted that they first powered modern war ships, the 1 MW Abrams M1 tank, and cruise missiles, because turbines are uniquely economical with space and weight (*Jet Engines for Dot-coms*, *July 2000*). When we wrote about RF amplifiers, we turned to a company that started out as a military contractor (*Powering RF Photons*, *November 2000*). When we wrote about ultracapacitors, we reported that the technology had been developed for military power systems that must provide the short, intense bursts of electric power required to initiate explosions, fire lasers, launch projectiles in electric guns, energize pulse radar, and dispatch pulses to disable hostile electronics (*Electron Cache*, *March 2001*). When we wrote about analog circuits, we discussed a leading manufacturer's origins as a military and aerospace contractor (*Analog Power, April 2001*). When we wrote about sensors, we traced a company's origins as a major defense supplier (*A Sense of Power, August 2001*). At our first Powercosm Conference in June 2000, we took the delegates on a tour of the USS Benfold, an Arleigh Burke class guided missile destroyer, to show them one of the advanced platforms on which some of the most advanced Powercosm technologies are being deployed.

So what is it about Powercosm technologies that unites people who build fighter jets, destroyers, and missile defense systems with people who build datacom hotels, passenger cars, and digital workstations? What is "highly ordered power" anyway?

Power Density

Highly ordered power begins with high power itself—more power, in less space. <u>Power</u> <u>density</u> is the first and the simplest measure of energetic order. All other things equal, a 10-Watt laser embodies more ordered power than 1-Watt laser. Dispersing the light or current across a wider area entails a loss of order too. In thermodynamic terms, higher power density means higher temperature, or its equivalent, which means less entropy per unit of energy, which means more order. Push things in the opposite direction, toward lower power density, and the order declines apace. Perfectly ordered crystals and quantum lattices form as temperatures drop down toward absolute zero. These structures are marvelously regular in their own right, but the one thing they are not is highly ordered <u>power</u>.

And highly ordered power is clearly better than the alternative. Intensity and focus are thus displacing dispersion and blur throughout the civilian side of our energy economy. Faster displaces slower. Higher density displaces lower. The simplest and clearest indicator of this trend is the progressive electrification of our energy economy.

As we discussed in our report *Powerchip Paradigm II: Broadband Power*, electricity is a tremendously dense and fast form of power. A high-voltage power line conveys about 1,000,000 kW of power through a cross section of a few square inches. The steel power train in a Buick uses about five times the cross-sectional area to transmit a mere 100 kW to the wheels. As the National Research Council (National Academy of Science) put it in a 1986 report *Electricity in Economic Growth*, "electrical energy is a highly-ordered form of energy; in the language of physics, its entropy is low."

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And electricity accounts for a steadily growing share of all the energy we use (*Heavy-Iron Lite, October 2000*). A century ago, electric power plants used a tiny share of all the primary fuels we consumed; today, they use about 40 percent, with the spinning steel shaft in the turbine serving as a mere stepping-stone to electricity, the much faster, denser form of power. Over 80 percent of all growth in U.S. energy demand since 1990 was supplied by kilowatt-hours.

Over the course of the next two decades, electricity will displace steel shafts, belts, pulleys, and hydraulic systems in automobiles, as well, thus pushing another 30 percent of the energy economy into the domain of the well-ordered electron. Another 20 percent will make the same transition as microwaves and lasers displace cruder forms of thermal energy in the industrial processing of materials.

And what happens once everything is electrified? As microwaves, lasers, and other digital power technologies illustrate, there are levels of order far beyond undifferentiated electricity. The high-voltage grid isn't the last word in the pursuit of highly ordered power—there is no last word. A steadily growing fraction of three-9s electricity gets converted to high-9s electricity. Electric ovens give way to microwaves. Incandescent electric bulbs, to light-emitting diodes and lasers.

Civilian markets have now grasped the advantages of higher power density—military planners grasped it a lot earlier. From the long bow to cannon to cruise missile and now into the domain of electromagnetic pulses and high-power lasers, the history of military technology can be reduced to a single chart that tracks rising power density on one axis, and rising speed on the other. The weapon that can project more power through a smaller window, faster and more accurately, prevails.

And that principle holds true at every stage in the projection of force. It holds for delivery platforms—Air Force fighters, Marine helicopters, Navy ships, and Army tanks—just as it does for the systems that project destructive energy to its ultimate target—guns, lasers, cruise missiles, electromagnetic-pulse generators, armor-piercing projectiles, and explosives. The Navy recognized some years ago that the all-electric ship can pack much more power into much less space, and move it much faster and more precisely—move the ship itself, launch aircraft from a flight deck, and project power from the floating platform by means of a new generation of extremely compact, fast, high-intensity weapons. The PEBB program therefore aims to develop standardized, plug-and-play power modules that can be stacked and assembled throughout the vessel.

The military, in short, certainly needs highly ordered power, too. For the military, however, the difference between better power and worse isn't just profit and loss. In the armed forces, there is a direct trade-off between the speed and quality of your power and the lives of your soldiers and the civilians they protect.

The fastest, most power-dense instrument the terrorists could grab on September 11th was a fully-fueled jumbo jet, so that was what they grabbed. The technologies of the Powercosm make it possible to pack more destructive power than that into a much smaller space and to project it much farther, much faster and much more accurately. America will be developing and deploying such technologies more rapidly than ever now in both our military and our civilian sectors.

Sense and Control

Power density is the first key dimension of highly ordered power. The second essential, required to maintain the first, is fast, intelligent control.

High power density is inherently unstable. It's easy to keep a warm bath within the bounds of "comfortably warm," because the bounds are fuzzy from the get go, and because tub temperatures change slowly. The target voltage, current, and frequency in an electric power line are defined far more precisely, and they are also much more vulnerable to small disturbances—a single squirrel can black out a thousand homes. The higher the energetic order at the outset, the harder it is to maintain.

Civilian markets have now grasped the advantages of higher power density–military planners grasped it a lot earlier

It takes power logic to create and maintain highly ordered power. And with power, as in computers, logic begins with switches—arrays of gates that can open and close as directed, to add or subtract power precisely and thus to build the exact power profile required. This is the reality that launched this newsletter with *The Powerchip Paradigm* two years ago. As we argued, improvements in materials, device architecture, and manufacturing infrastructure have brought the powerchip to the golden knee of the technology curve, the sharp bend in the hockey stick of growth—about where microprocessors stood around 1980. The powerchip defines a completely new paradigm of power switching. It doesn't improve on the electromechanical switch incrementally; it improves upon it by three to six orders of magnitude, along the single dimension that matters the most: raw speed. It makes possible, and propels, a fundamental, radical restructuring. (*The Law of the Powercosm: Burn Silicon, April 2000*)

Powerchip switches merely switch, however, they don't think. The full electrification of power trains in cars, trucks, and factory machines, and of jet fighters, Humvees, tanks, and destroyers—the complete displacement of mechanical and fluidic control systems—became possible only when smartchips developed to the point where they could handle the massive number-crunching capabilities required to control high-power-density electrical technologies. Supersonic jet fighters with forward-swept wings are far more maneuverable than conventional designs precisely because they are dynamically unstable—so unstable that they remained wholly impractical until digital logic linked to digital power systems took over the flight controls.

Power-logic gates get their instructions from smartchips—computers—that are fast enough to perform the massive number crunching needed for high-precision electrical control. Together, smartchip and powerchip transform junk power from the grid, or a microturbine, or a flywheel, into high-9s power suitable for the servers in a megawatt-level datacom hotel. Together, they control an F-16 or the drive train of a silicon car, or modulate a high-frequency radio transmission with the extreme precision required to punch megabits of data through the airwaves, or megawatts of RF target-acquisition photons through the dust and fog of a battlefield. Together, they control a stepper motor that moves a wafer through a chip fab, or a servomotor that adjusts an aircraft's flap or steers the wheels of a car.

Which they can readily do, if—and only if—they're informed by concomitantly fast and accurate sensors. Every tightly-controlled application of force, torque, pressure, or photonic radiation depends on precise sensing of how much power is being conveyed in the shaft, fluid, or beam, and what effect it's having on the target or the payload. (*A Sense of Power, August 2001*)

If sense and control are essential in civilian-sector uses of highly ordered power, they are even more critical in military applications. A bomb, artillery shell, or missile is one part matter—the size of the bang—and several parts mind—where the bang occurs. In smart weapons, pounds of guidance substitute for tons of explosive. Radar and laser-based systems and computers track the trajectories of incoming shells, so that the return fire can be instantly lethal. Cruise missiles and the latest-generation bombers carry more computers and fewer bombs—and do much more damage. The contest between Patriot missiles and Scuds is likewise one of information against mindless mass. Patriots were originally designed to shoot down planes, not missiles. When they were modified for anti-missile defense, most of the redesign was centered in the "vision" system and computer software, not the propellants or explosives.

In civilian and military applications alike, microprocessors, networks, bits, and bandwidth, thus play essential roles in creating and maintaining the order in highly ordered power. The bit-handling layers of battle remain one of the principal priorities of the Defense Advanced Research Projects Agency (DARPA), whose mission it is "to act as the technical enabler for radical innovation for national security." In Congressional testimony last June, for example, the Agency's Director Tony Tether described DARPA's vision of "network-centric" combat systems, composed of manned and unmanned nodes.

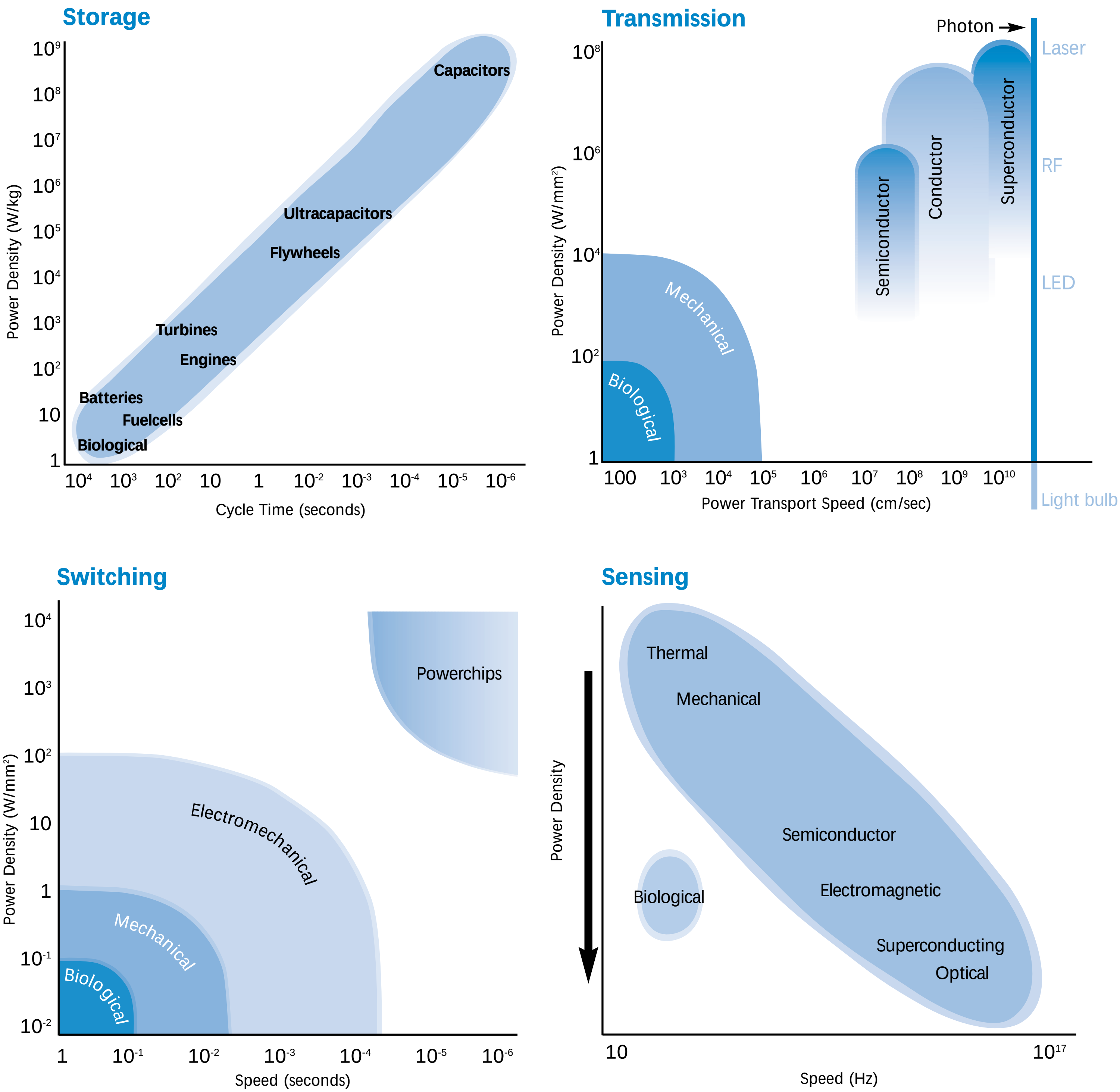
But the obvious bears repeating—bits themselves don't move control surfaces on a wing or intercept a missile, or pulverize terrorists in their caves. The control and projection of <u>that</u> kind of power begins and ends not in the Microcosm or the Telecosm, but in the Powercosm—in the technologies that can project enough power to destroy. The ultimate objective, as Mr. Tether himself made clear, isn't a smart battlefield, it's the destruction of the enemy. It is, in DARPA's military-speak, "affordable, precision moving target kill for both offensive and defensive missions."

Tracking Friend and Foe

The challenge was to take a picture from a plane. A world war was in progress, and the targets shot back, so the planes had to fly high, and at night. MIT's Harold Edgerton developed high-intensity stroboscopes to illuminate the targets of nighttime aerial reconnaissance. The only way to make extremely intense light in those days was to make a flash that was very short. A longer pulse would have incinerated the aircraft, if Edgerton had somehow managed to pack enough batteries in the plane to create it. Every source of photons in those days emitted far more heat than light.

Half a century later, technology has advanced to the point where much smaller cameras photograph the heat itself. Stealth bombers fly at night, relying on thermal night-vision technologies to locate their targets. Military systems see both friend and foe by projecting power across the acoustic and electromagnetic spectra—sonar, ultra-long-wavelength radio signals to communicate with submerged submarines, microwaves in radar, and lasers in both visible and invisible bands.

The power of sight begins with power itself. So far as the basic physics go, the only way to see something is to detect the flow of power from there to here. Passive systems rely on the ambient sources of power (like daylight) for illumination, or else on the noise or heat generated by the target itself. So far as the basic engineering goes, there are only two ways to see things better. Build a better detector—a better eyeball, so to



Digital power is highly ordered power. Power density is the first key attribute of energetic order; speed is the second. The Powercosm gravitates toward storage technologies that pack more energy in less material, and that can move it in and out faster than alternatives. In transmission systems, the evolution is toward more power per unit area of shaft, wire, or photonic beam, with transmission speeds rising from speed of sound to speed of light. For switching, digital power depends on powerchips, because they outperform conventional switches by three to five orders of magnitude, in both power density and speed. In sensing, the best technologies are once again the fastest, but the best sensors are the ones that drain the least amount of power from the systems that they monitor - here too, all-electric and optical technologies displace older electro-mechanical and thermal alternatives.

speak, or supply better illumination—a better light bulb. Both center on power—power sensors and power projectors. From CAT scans, to barcode readers, to DVD video players, and on across a far broader span of advanced military devices, the new seeing technologies depend on highly ordered power to shine brighter, see further, and penetrate deeper.

Edison's light bulb was a power projector. So were Edgerton's flash lamps. Higher power density and higher speed—better-ordered power—let you see more than the alternatives do. Power that is very precisely tuned and directed makes it possible to illuminate—and thus see—through fog, flesh, deep water, and—with ground penetrating radar and precision seismography—deep into the earth itself. Just as electricity and Edison's bulb marked a great advance over gas lamps, highly ordered power makes possible the surreal vision of a CAT scanner, a magnetic resonance imaging (MRI) unit, or a nuclear magnetic resonance (NMR) system. Likewise for the radar in the collision-avoidance avionics of a jumbo jet, underwater sonar systems, and the ultrasound units that let a doctor peer inside the womb. Highly ordered power is equally essential, of course, to the lighting that we call telecommunications. Replace the semaphore with laser light in fiber optic glass, and you can see the blinking light a thousand miles away. Our cell phones and television screens see a wireless signal transmitted from a distant tower. In every one of these applications, the seeing depends on the very precise projection of highly ordered power.

Founded in 1922, the company renamed itself Raytheon–literally "light of the gods"

The power projectors are matched, on the receiving end, by solid-state eyeballs—the charge-coupled devices in digital cameras and videocams, the gigahertz photodetectors in optical circuits, the piezocrystal sensors for material analysis, or haptic computing. (Push this same technology up the power curve, and you get to solar power –silicon photovoltaics.) The SQUID (superconducting quantum interference device) is a thin sandwich of conductors and superconductors assembled into an ultrasensitive detector of electric and magnetic fields—sensitive enough to detect the currents flowing through nerve cells in the brain, or ancient geophysical changes in rocks deep in the earth, or the magnetic fields created by submarines miles away. Other quantum detectors exploit the direct interactions between electric fields and photons to detect current flows and voltage, or between acceleration and its relativistic impact on light.

Light of the gods

Many impressive companies supply high technology to our armed forces. Among them, however, Raytheon (RTN) (Cambridge, MA) is the leading pure play in the development of digital power for military applications. Of its $17 billion in annual revenues, over 80 percent comes directly from electronic hardware and systems that harness highly ordered power to detect, track, guide, and destroy. Defense Department programs alone generate two-thirds of Raytheon's revenues. Much of the remainder comes from sales of closely related civilian technologies used in airports, weather radar, and most recently, sensors and imaging systems used in cars.

Founded in 1922, the company renamed itself Raytheon—literally "light of the gods"—after the product that propelled much of its early growth: a highly successful vacuum-tube rectifier for radios. In World War II Raytheon took the lead in developing and manufacturing a practical magnetron—the core component of ground-based radar. It followed with the first sea-based radar (1942), the first missile guidance system (1948), the transmitter tubes and guidance computers for Apollo XI, the Patriot Missile, the first gallium-arsenide monolithic microwave integrated circuit (MMIC) (1983), and the national Pave Paws early warning, over-the-horizon radar. (Designed to detect sea-launched ballistic missiles, the latter can detect basketball-sized objects from 2,000 miles.)

Today, Raytheon's products fall into two main, complementary categories: <u>see</u> on the one hand, and <u>control</u> on the other. Complete systems, of course, require both, together with the deep expertise in software and microprocessor design needed to translate digital information into high-precision, digitally-controlled action suitable to battlefield conditions.

On the <u>see</u> side, Raytheon's microwave-vision systems play key roles across the entire range of defense, aerospace, and many civilian applications. Raytheon is a leading provider of air traffic control systems, Doppler Weather Radar, marine radar, depth sounders, and global-positioning-system (GPS) receivers. Raytheon radar is used on virtually every major platform, from the familiar F14, F15, and F18 to the awesome Phalanx gun for ship anti-missile defense. Raytheon technology is being used to upgrade the anti-aircraft and anti-missile (AEGIS) system on the Arleigh Burke class guided missile destroyers. Raytheon detectors and guidance systems control the radar-busting HARM missiles, and the Navy's new Sea Sparrow Missile, which protects ships against low-altitude threats. For its next-generation radar systems, Raytheon is developing solid-state radar elements that can be assembled by the hundreds or thousands into plug-and-play arrays to create active electronically scanned systems suitable for a wide range of different platforms and missions. The costs of the individual elements are plummeting as semiconductor costs generally do—down ten-fold in the last decade, with another three-fold drop projected in the next few years. Advanced radar will soon be as cheap and ubiquitous as binoculars and telescopes once were.

Raytheon is likewise a world-leading provider of infrared-vision technologies for a wide range of military applications, including the Hellfire missile, the Night Sight thermal imaging on Stinger missiles, and the hand-carried weapons of foot soldiers. The company is now rapidly adapting this same technology for cars, law enforcement, search and rescue, and industrial applications. (Raytheon has donated state-of-the-art infrared systems to aid in the World Trade Center search.) Raytheon's next-generation fog-penetrating infrared vision system will have a range four times better than the current-generation systems—the new system is sensitive enough to distinguish red strips from white on an American flag, at four miles, in the dead of night, because of tiny differences in the amount of thermal radiation emitted by different colors on the cloth.

Raytheon works with optical beams, too. The company has produced over 30,000 solid-state lasers for rangefinders and target designators. And it is now taking lasers from <u>see</u> to <u>move</u> in developing for the Army a 100-kW solid-state laser to destroy targets at the speed of light. Skeptics still scoff at the notion of photon-power weapons. Raytheon is quietly building them.

The technologies of the Powercosm play crucial roles in all of these systems—and their capabilities keep improving rapidly, even as their costs drop apace. A first consequence is that the platforms and weapons in which they are deployed are constantly being upgraded. A second is that the range of systems in which they are used continues to expand. What begins as very costly technology for a fighter-jet cockpit soon migrates into the foot soldier's helmet and backpack. Sensing and aiming systems that start off in tanks soon land in Humvees and Jeeps.

Raytheon is currently retrofitting GPS systems into anti-aircraft and anti-missile systems, as well as into the HARM anti-radar missiles, which can now fly unerringly to target even when the radar operator shuts down in an attempt to hide from sight. At the same time Raytheon remains heavily engaged in the development of entirely new weapons systems. In a billion-dollar joint venture with Lockheed Martin, Raytheon is helping to build the Javelin, a next-generation anti-tank missile. The company is developing the Excalibur, a guided projectile that will triple the accuracy of standard artillery shells. Last July, Raytheon completed the third (successful) test of a ballistic missile defense system that integrates the company's early-warning radar and its most advanced missile-guidance technology. Raytheon's <u>see</u> and <u>control</u> technologies are likewise integral to the new YF22 joint strike fighter.

What begins as very costly technology for a fighter-jet cockpit soon migrates into the foot soldier's helmet and backpack

Raytheon squares off against formidable competitors: it ranks behind Boeing and Lockheed Martin as the third largest U.S. defense contractor. TRW (TRW), ITT Industries (ITT), Teledyne (TDY), Northrop Grumman (NOC), and quite a number of smaller companies (e.g. Omnitech Robotics, BAE Systems (BA.L), and Integrated Defense Electronics) also compete in various segments of markets that Raytheon serves. But Raytheon has a uniquely clear focus on digital power. Its only significant division outside the fold is Raytheon Aircraft, a $3 billion business that includes Beech and Hawker.

When almost everyone else was trying to get out of military technologies, Raytheon was shedding everything but—educational publishing, home appliances, heating and air conditioning, commercial laundry, semiconductors, and most recently, Raytheon Engineers & Constructors, which Raytheon sold in July 2000. (Note: The buyers in that last transaction went bankrupt and Raytheon is now the target of a $1.5 billion lawsuit.) At the same time, Raytheon was acquiring the defense-related businesses that most everyone else was selling: AMBER Engineering (for its infrared seeker technology); E-Systems (reconnaissance and surveillance systems, command and control, guidance, navigation, communications); European-based marine navigation and communications businesses; Chrysler Technologies' defense electronics businesses; Texas Instruments' Defense Systems and Electronics business (precision-guided weapons, night vision systems among other capabilities); all culminating in 1997 in Raytheon's $9.5 billion merger with the defense operations of Hughes Electronics (advanced defense electronics systems and services).

Intelligent Power

Digital power is highly ordered power, power that precisely tracks a target trajectory. AC and DC electricity define two familiar forms of what should be—but rarely is—a precisely controlled power waveform. High precision lasers deliver photonic equivalents. A very precise, complex power trajectory is required in the fly-by-wire electric control systems of a fighter jet, or the drive-by-wire electric control systems of the next-generation SUV, or Humvee. All datacom and telecom applications likewise depend—in their physical transport layers—on the projection of digital power—electrons pulsing through metal wires, or photons through glass or the airwaves. It is the very precise and complex projection of power across space that conveys a phone call, e-mail message, Web page, or a television picture—or the image and location of an enemy's trucks, weapons, huts, tents, or sleeping bags. It is the precise projection of power that destroys what must be destroyed, and allows the rest to stand.

The technologies of the Powercosm add the essential order to the older, pig-iron sources of electrons, and their quantum cousins, photons. Energetic order is the most valuable good produced in our energy economy, and the most essential component of every weapon. It is also the least understood. None of the conventional metrics of energy and power, the obsolescent pig-iron accounts of octane-rated gallons, therms of natural gas, BTUs, kilowatt-hours, or kiloton metrics of explosive power, capture the new reality. Wall Street doesn't even know what to call these new Powercosm technologies. It ranks them variously as "semiconductors" or "industrial machines" or "software" or "transportation," or simple "military" if packaged in an F15 fighter or an M1 tank. They are none of the above. They are, instead, the ascendant technologies of power, both civilian and military. Our economy pursues ordered power because the order in the energy is worth far more than the energy itself.

The better ordered the power, the better we can aim it, and the less extraneous junk we end up having to move along with the real payload. Microwaves can heat just the water in the soup, not all the air and stovetop around it—or they can be aimed and focused to penetrate a target to disrupt and disable its guidance system. Lasers can perform the almost impossibly delicate task of separating one isotope from another—or, with inconceivable speed and precision, the brute force destruction of a missile's shell.

Highly ordered power lets us see better, too—immeasurably better than the relatively chaotic lights it displaces. Order lets us aim a spot of light just where it's needed on the alarm clock, dashboard, or taillight, or down into the gall bladder during keyhole surgery—or on to an enemy's bridge, artillery piece, or radar installation. It lets us illuminate targets in bands that will punch through fog or water or the earth itself. And it lets us pick up the reflections and echoes with equal precision.

Energetic order is the most valuable good produced in our energy economy and the most essential component of every weapon

Highly ordered power is, finally, the essential fuel of the digital Microcosm and Telecosm. Higher information density requires higher power density; the two are ultimately inseparable. Highly ordered power is intelligent power, from which the residual chaos has been squeezed out. Only the very purest electricity can execute a billion error-free logic instructions per second; if the power were less pure, the Pentium would lose bits willy nilly, and be reduced to a puddle of sand by the first voltage spike. Only the very purest light can convey a trillion error-free bits per second; if it were any less pure, the fiber-optic line would be just a long and skinny light bulb. It is the utter absence of extraneous "information" in the power to begin with that makes possible the systematic processing and carriage of information thereafter. The highest intelligence comes first, in the cleansing of power.

Raytheon lost four valued employees on September 11th: Peter Gay, a vice president of operations, Stanley Hall, a director of program management, David Kovalcin, a senior mechanical engineer for Electronic Systems, and Kenneth Waldie, a senior quality control engineer for Electronic Systems. It was a terrible blow, for four families, four communities, and one venerable company. But 85,000 other Raytheon employees survive. The cardboard-cutter murderers made a big mistake in rousing these fellow citizens of ours to wrath.

Peter Huber and Mark Mills
September 16, 2001

In light of the tragic events of last week and the subsequent closing of the US stock markets, the issue will not include the Power Panel as information can not be updated at this time. The Power Panel will be updated next month.