

HOW THE MILITARY RESPONDED TO THE LASER

A 'cash and crash' approach and interservice competition led to a premature shift of emphasis from research and exploration to development and scaling-up.

Robert W. Seidel

"I feel as do others here that the LASER may be the biggest breakthrough in the weapons area since the atomic bomb."¹ This statement, made in 1962 in a letter by Major General August Schomburg, head of the Army Ordnance Missile Command, reflected an attitude that was pervasive in the military in the first years after the birth of the laser. According to one contemporary assessment, there was "scarcely an Air Force, Army [or] Navy agency that does not now support, or talk of sponsoring in the near future, some type of basic or applied research or experimental development with optical masers."²

The invention of the laser stimulated emissions of interest from the military far more coherent than those from any other potential user: The military supplied most of the funding for laser research and development; military need suggested many of the laser's applications; and the military was the principal market for the laser. As I will shortly explain, however, military laser programs underwent a premature shift in emphasis, from research and exploration to development and scaling-up (see figure 1). A number of factors conspired to bring about these developments:

- ▷ Interservice competition to develop devices suited to the missions of each branch
- ▷ Institutionalization of research programs in military as well as in contractor laboratories
- ▷ Adoption of the Manhattan Project and the wartime program to develop radar as models for military laser development, as Schomburg's remarks suggest.

The services responded to the invention of the laser according to their widely varied missions in national defense. This centrifugal tendency was only partly overcome by the DOD agency that was responsible for frontier research, the Advanced Research Projects Agency.² Because the transition from basic research to development and thence to advanced development and deployment was a profitable one for many of the companies performing laser research, there was a dynamic built into the system that favored this scaling-up. Moreover, the services sought to develop their own clientele of researchers through programs sponsored by the Office of Naval Research, the Army Research Office and the Air Force Office of Scientific Research. The interservice rivalries that underlay this competitive organization of research could hardly be overcome by the Advanced Research Projects Agency, especially when such an exciting technology as the laser was to be developed.

Stimulation of research

The military interest in quantum electronics did not begin with the laser, as historian of science Paul Forman has shown. That interest intensified greatly, however, after the laser was reduced to practice. By forcing a change from small to big science, from academic to in-house and contract laboratories and from open research to classified development, military interest in the laser transformed the nature of laser research and development. This transformation was accompanied by, and in turn accelerated, a shift in laser technology from solid-state to gas and chemical lasers.³

Military interest in the laser developed even before the first laser was built. After Charles Townes and Arthur

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Airborne Laser Laboratory. Approximately 300 technical personnel at dozens of aerospace firms worked for 11 years to complete this demonstration platform for a high-energy laser weapon. In May 1988 the Airborne Laser Laboratory was moved from Kirtland Air Force Base in Albuquerque, New Mexico, to the Air Force museum at Wright-Patterson Air Force Base in Dayton, Ohio. **Figure 1**

Schawlow developed the theory of infrared and optical masers in 1958, Townes, who was then at Columbia University and a consultant to Bell Laboratories, thought enough of the military potential of the "optical maser" to offer it to John Wheeler of Princeton University, who was heading a project for the Institute for Defense Analysis and the Advanced Research Projects Agency. The project, as Wheeler explained at the time in a letter to Townes, sought "presently unappreciated ways in which science may be able to contribute vitally to national defense." Wheeler thought the laser "fell right in this ball park," and predicted that it would receive "the very serious attention of ARPA."⁴

That attention was forthcoming when Technical Research Group, a rising electronics firm with maser experience, bid for military support to develop the laser in 1959. TRG had hired Gordon Gould in 1958 from Columbia University, where, as a graduate student, he had written down the laser ideas for which he sought a patent in 1959.⁴ Perhaps because of the interest aroused at ARPA by Wheeler's assessment, TRG received \$1 million from ARPA, more than three times the amount TRG had sought. ARPA aimed not only to use the laser for radar and communications, as TRG proposed, but also to defend against the Russian missile threat, or "missile gap," with death rays.⁵

The laser offered a coherent, directed, concentrated beam of light that promised to realize an ancient dream, epitomized in Archimedes's idea to attack the Roman fleet at Syracuse by using mirrors and lenses to focus burning solar rays on ships at sea. Science fiction's preoccupation with burning "death rays" added modern sanction to the ancient dream.⁶ The Soviet Union's large boosters, which lofted Sputnik and the first cosmonauts into space and might equally well launch warheads, provided suitable targets for the rays. The promise of beam weapons enhanced the services' interest in lasers and launched a number of industry and service research programs that transcended the interest in laser ranging, communication and detection.

Industrial defense organizations were quick to pursue beam-weapon applications. Within months of Theodore Maiman's invention of the ruby laser in 1960, his employer, Hughes Aircraft, had an in-house program to develop beam weapons, beginning with a "kill-a-rat" laser. Martin Marietta's advanced program division sought a cryogenic hydrogen "laser capable of beaming a million-degree ray to vaporize hostile space weapons." This "disintegrator ray is being designed for use at altitudes of 100 000 feet or farther out in space," reported *Electronics*. "It would be the size of a large army searchlight."⁷

The military services soon picked up on the work,

which was marketed aggressively by the firms involved. "Seldom has a development in technology fired the imagination of the scientific and technical community as has the development of the laser," the Air Force Office of Scientific Research reported in 1964, after finding more than 500 research groups studying the laser.⁸ In the wake of Sputnik and a generation after the development of the atomic bomb, such a stimulus was eagerly awaited in the military, particularly in those laboratories that were its captives. Laser research and development was amplified by the dozens of in-house laboratories and hundreds of contractor laboratories to which the laser meant not only an exciting technical challenge, but the promise of profits. "Defense at the speed of light!" became a rallying cry for the military-industrial complex.

Pumping

The Defense Department's interest was important because of its position as the chief funder of scientific research and development in the United States since World War II.⁹ Whether or not paying the piper means calling the tune in basic research, it is certainly true that in the competition for Federal dollars, military interests and priorities affect applied research. In defense contractor organizations such as Hughes Aircraft, where the laser was first built, basic research is certainly heavily influenced by the corporate interest in pleasing the customer. And Hughes, like many other defense firms, had only one real customer.

The rapid proliferation of laser types in the 1960s and 1970s made available a large number of candidates for advanced development and marketing to the services. Some, such as the neodymium glass and neodymium YAG lasers, the gas-dynamic and electron-beam sustained CO₂ lasers and the hydrogen fluoride chemical laser, became the foci of major military programs that scaled them to higher powers and higher energies.

The funding for the research that provided those lasers proved to be a significant fraction of the total national support for laser research and development. With most practical applications in the nondefense commercial sector too risky to fund, the large military commitment to lasers allowed industrial and university researchers to turn to the Department of Defense for research and development support.

Even after they won research and development contracts, industrial firms often funded their own research programs aimed at generating hardware and knowledge to market and to develop for other military purposes. The contractors supported this research until they could find a friendly program manager in one of the service research and development commands to fund it. Fundamental inventions tended to occur in these so-called "independent" research and development programs, so that firms retained proprietary rights in them.

As the services provided contracts for development as well as research, they were more attractive patrons of research than most. The DOD's official patron of ad-

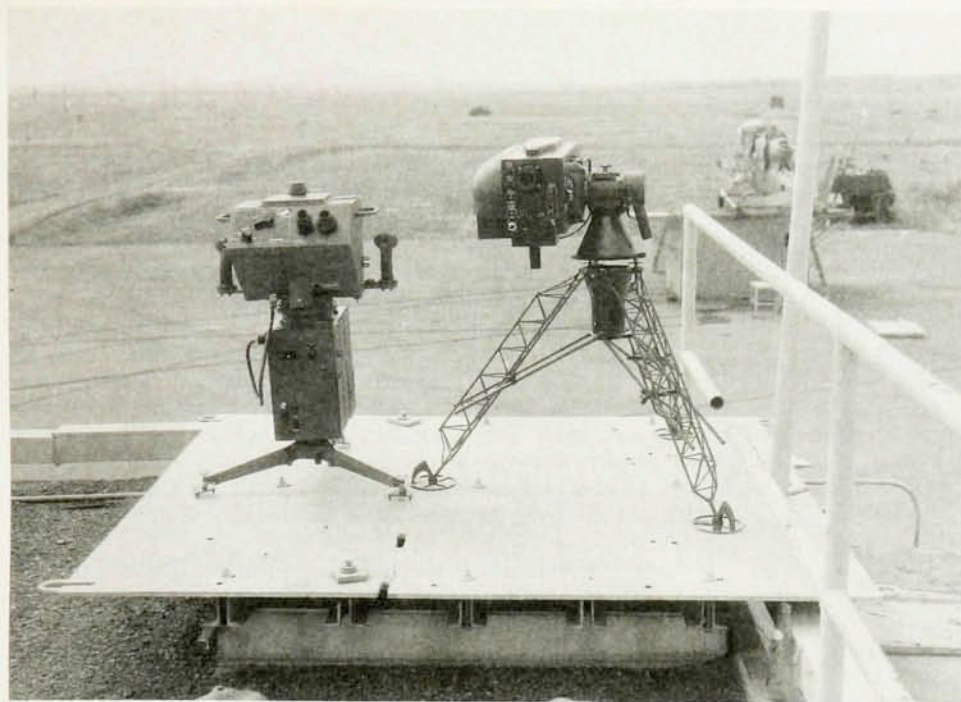
vanced research, ARPA director Jack Ruina, strongly opposed Air Force and Army laser programs, fearing the "dilution of effort which parallel programs cause, in addition to the natural tendency of the industry to prefer service programs to ARPA programs. Service programs can lead to big development contracts."¹⁰ ARPA's efforts to control this tendency were, however, overcome by the dynamic already established in the development of the laser.

The Army and the laser

The Army felt that it should participate in laser research "in order to protect its specific interests and requirements."¹¹ As early as 1960 the Army's Office of Ordnance Research asked that the TRG laser work sponsored by ARPA be declassified. It was interested in the laser beam "for the illumination of small targets for guided missiles equipped with optical homing devices, [such as] antitank weapons," which "would be relatively secure, since a coherent infrared source is essentially undetectable at any position outside the very narrow beam." The Army also coveted high-energy beam weapons for its antiballistic-missile and antipersonnel missions.

Research implied trained manpower. To "stimulate defense oriented research in modern optics," the Office of Ordnance Research donated \$2 720 500 to 23 universities. The University of Rochester got the largest amount, \$315 000, with other universities receiving from \$35 000 to \$200 000. The Army "recognized the adverse effects the continued shortage of trained optical research scientists could have on advanced and sophisticated defense programs." Supplying these universities with expanded optical facilities was "expected to provide inroads into advanced measurement in the reentry and midcourse ICBM flight regime." It also enhanced the supply of academic research.¹²

In its effort to develop a high-energy laser radiation weapon, the Army Missile Command Laboratories selected neodymium glass as the lasing medium because it could be produced in large and varied sizes, with high concentrations of ion doping and high optical quality, and was easily worked and shaped. Moreover, its 1.06-micron radiation was both invisible to the naked eye of the enemy and detectable with Army sensors. After scaling up these lasers to the point where the power and energy growth curves leveled off and further increases required "larger arrays and brute force increases in the size of devices," the Army researchers attempted to use them in laser blinding weapons such as a jeep-mounted system tested in 1968, but the devices offered repetition rates too low to be useful on the battlefield. The Army's efforts to scale up glass laser weapons for ABM uses led to devices such as the Big-X laser, which focused the output of several glass rods pumped by one of the world's largest induction power supplies. The transfer of the missile defense effort away from the Army Missile Command to the Army Ballistic Missile Agency in 1968 terminated efforts in this area. Between



US ARMY MISSILE COMMAND

Ground laser locator designators, which range and mark targets. These prototypes were made by International Laser Systems (left) and Hughes Aircraft Company (right). The devices were the result of seven years of research and three years of advanced development at the Army Missile Command Laboratories, Redstone Arsenal, Huntsville, Alabama. In 1980, after another six years of engineering development, both designators went into production. **Figure 2**

1962 and 1968, the Army spent \$8.8 million on high-energy lasers, which they divided about equally between in-house and externally funded research.¹³

The Army Missile Command was more successful with laser target designators and guidance systems. In 1962, David Salonimer, an engineer at the Missile Command Laboratories at Redstone Arsenal in Huntsville, Alabama, developed the concept of using a pulsed Q -switched laser to guide artillery projectiles or missiles. Q -switching, which kept the energy storage factor Q of the laser cavity low while inverting the population and then switched it to a high value to produce a very high rate of stimulated emission, provided pulses powerful enough to serve this purpose. Here neodymium glass lasers proved superior, too, because of their invisible beams, greater efficiencies and compatibility with highly sensitive sensors. A variety of systems were designed and some, such as the laser-guided bomb used in Vietnam and the Hellfire and Copperhead laser-guided tactical missiles, were successfully entered into the arsenal.¹⁴ Figure 2 shows prototype laser designators, which range and mark targets.

The Army's greatest success was with laser rangefinding. After the invention of the laser, Army Ordnance set up a \$100 000 emergency fund to study the laser, and formulated a \$700 000 rangefinder program. The Army Electronics Command developed a rotating Q switch for rangefinder applications in 1962, while the Hughes Aircraft Company developed a Kerr-cell optical Q switch under Army contract. By the mid-1970s, the Army fielded the AN-GVS-5 hand-held rangefinder (figure 3) as well as tank laser rangefinders, and Hughes was doing a \$50-\$100 million a year business producing rangefinders.¹⁵

In the Army programs, work on tactical battlefield applications of the laser supplemented the more common focus on the ABM uses of the new device. The "down to earth" applications were more practical, but required technological innovations to provide greater eye safety for the troops using the lasers and to pulse and code the beam to insure reliable information and frustrate countermeasures. The "smart" weapons resulting from this work appeared in the Vietnam War less than a decade after the

invention of the laser and became the staple product of the industry for the military. The laser has continued to find its greatest military usefulness in such weapons.

The Air Force and the laser

Space applications dominated Air Force thinking about lasers, just as Earth-bound uses shaped Army plans. Frustrated by the civilian thrust of the space program after 1957, Air Force General Bernard Schriever convened a high-level scientific advisory committee to review the space program of the Air Force Research and Development Command. The committee, which was formed just before the 1960 election under Trevor Gardner, president of Hycon Manufacturing Company, underlined the threat posed by Sputnik, "which could have contained military intelligence and communication equipment or possibly a nuclear warhead," and had done "great damage to our image of world leadership." The committee urged Schriever's newly formed Air Force Systems Command to carry out a program of fundamental scientific investigation for space exploration and for the development of orbiting arms-control satellites. Spaceworthy systems of this sort were fundamental to the reception of the laser by Air Force laboratories.

Representative of Air Force responses to the need for space-based systems were the solar-powered laser, high-transmission-rate laser communications systems, and systems to identify and track objects in space.¹⁶ As in the case of the Army's interest in laser-based defenses against ballistic missiles, the Air Force's focus on applications of the laser in space was at best premature and at worst unproductive of any practical devices.

The Air Force also had an air defense mission, and for the associated tactical needs worked to use lasers in rangefinding, precision delivery of weapons, navigation and location, reconnaissance and imaging, anti-tactical missiles and other countermeasures. The war in Vietnam presented technological opportunities for the laser, and the Air Force responded by setting up a quick-reaction program in 1965. Project 1559, as it was called, provided funds for translating research and development projects into weapons in six months to a year. After the Army

suggested the concept of laser guidance for the precision delivery of weapons, the Air Force contracted with Texas Instruments to build the Paveway guided bomb. Although its advantages over conventional bombs were disputed, the laser-guided bomb won the hearts and minds of the service.¹⁷

The laser-guided bomb project also developed a laser target-illuminator system, Pave Arrow, for use by airborne forward air controllers in guiding F-100D strike aircraft to well-camouflaged and hidden targets in the Vietnamese jungle. Laser designator systems such as Pave Spike, Pave Tack and Pave Penny used television and infrared detectors to pick up visible and invisible laser radiation reflected from targets designated by ground or airborne reconnaissance forces and to allow weapons to home in on these targets.

The Air Force also investigated other, more direct applications of laser energy, such as damaging sensors used by the enemy. Like the Army's antipersonnel laser applications, these were not successful. However, as a sensor, the laser extended the range of human senses far beyond other optical devices such as telescopes and binoculars. Representative systems such as the KA98 imaging system used gallium arsenide lasers to scan target areas.¹⁸

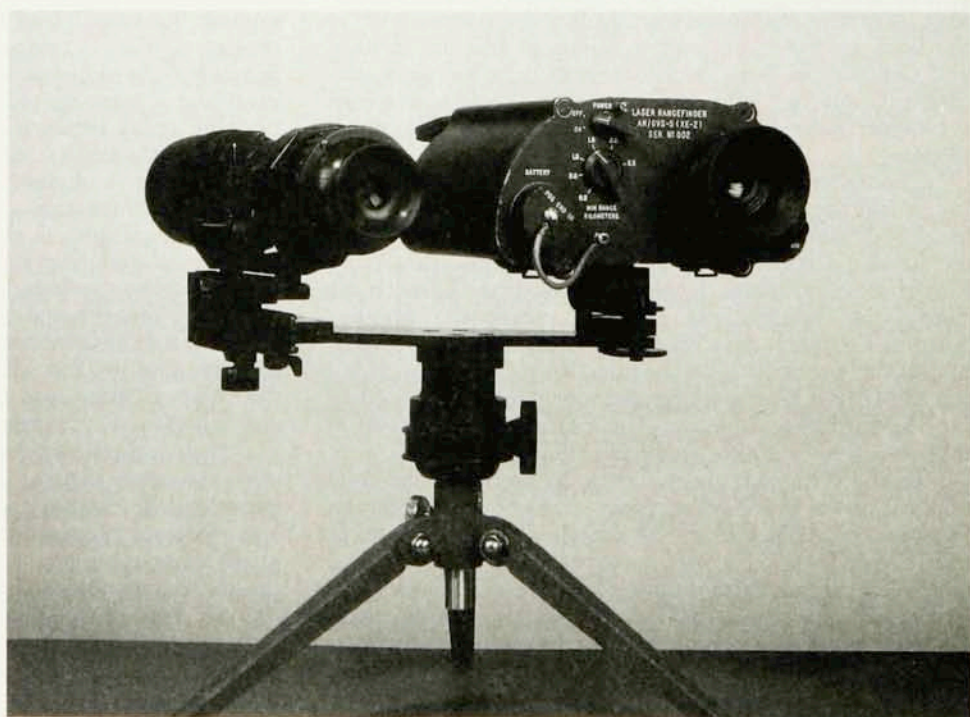
The Air Force response to the laser was a wide-ranging exploration of its aerospace applications. It even created a career track that allowed Air Force officers to advance through the ranks in research and development. In-house research by Air Force officers distinguished the Air Force program from the other services. Beginning early in 1962 at the Air Force Weapons Laboratory at Kirtland Air Force Base in Albuquerque, New Mexico, these "blue suiters" conducted research on laser effects and laser damage, and ultimately they became active in developing laser devices. The Air Force Cambridge

Research Laboratory built the first Air Force laser and became a center of fundamental ruby and glass laser research.¹⁹ Laser research and development, especially in high-power and high-energy systems and their components, became a *raison d'être* for these groups, especially when fundamental laser phenomena were classified.

Major General Donald L. Lamberson (figure 4), who worked on some of the early laser effects studies at the Air Force Weapons Laboratory as a lieutenant, developed the Airborne Laser Laboratory (figure 1) there in the 1970s as a colonel. This laser systems laboratory and demonstration prototype showed that one could install lasers in planes and use them against threats such as Sidewinder antiaircraft missiles and jet drones simulating cruise missiles.

For Lamberson and other military and civilian Air Force scientists, the laser became the focal point for the development of a new kind of scientific career. The Air Force Institute of Technology, at Wright-Patterson Air Force Base in Dayton, Ohio, developed a curriculum to train them for it; the Air Force extended tours of duty for researchers and hired them after they left the Air Force to staff its laboratories and continue their work; and the Air Force Weapons Laboratory created organizations such as the Laser Division, a "big science" facility to house the work.

Trained in Air Force schools and exposed to some of the largest laser devices in the world at the Air Force Weapons Laboratory or at captive contractor laboratories, these men had unparalleled opportunities to work on the frontiers of high-energy laser technology. Many of them became point men for the development of other laser systems as well as for the Strategic Defense Initiative. In 1982 Lamberson became deputy assistant secretary for directed-energy weapons to the under secretary of defense, "the focal point for the President's initiatives on defense



Hand-held laser rangefinder. The AN-GVS-5, built by Hughes for the Army, had become standard military issue by the mid-1970s. Figure 3

US ARMY

against ballistic missiles."²⁰ Martin Stickley of the Air Force Cambridge Research Laboratory and Gregory Canavan of the Air Force Weapons Laboratory became directors, successively, of the inertial confinement fusion program at the Department of Energy. Peter Avizonis and Arthur Guenther headed large laser damage and weapons programs at the Air Force Weapons Laboratory. Although these men, unlike Lamberson, shed their Air Force blues, they remained with the Air Force as civilian researchers for many years, training new generations of technical officers.

Controlling laser research

Even as the first service programs proliferated in the wake of the invention of the laser, ARPA created a joint venture with the third service, the Navy, to contain the burgeoning research in lasers. Project Seaside was conceived by William Culver, whom Townes had brought to the Institute for Defense Analysis in 1961 from the Rand Corporation, where Culver had been a resident expert in optics. ARPA had asked IDA early in 1961 to review the service and contractor programs in radiation weapons.²¹

ARPA was concerned about the proliferation of these programs, and wished to pursue them "within the constraints of scientific sobriety and by organization and personnel of appropriate caliber." To that end, it asked IDA to determine whether or not projects were clearly devoted to achieving a feasible radiation weapon, appropriate in size. "If the project cannot be justified on a weapon or weapon technology basis," then ARPA wanted to know if it could be justified "as a means of supporting basic research, i.e. high caliber research . . . which contributes importantly to the total fund of knowledge in a specialized area." Albert Weinstein, the Pentagon's manager in the field, stated the goals of radiation weapons studies: "maintaining a sufficient knowledge and high sensitivity to new knowledge to assure that we would recognize a potential breakthrough in its very early stages" and "constraining the program within the boundaries of scientific sensibility and resisting the natural tendency to make this area a 'glamour wagon' upon which questionable programs would be loaded."²²

By December Culver was ready to report that the wagon was even more glamorous than Weinstein dreamed: "Current Optical Maser developments," he wrote, "have led a number of people in government and industry to believe that it may be possible to generate and direct enough coherent optical power to make a useful radiation weapon." Since Maiman's invention, he explained, ten different types of lasers had been developed. Ruby lasers had emitted 10-megawatt peak powers and 50-joule pulses, burning holes through steel 0.1 inch thick. With 12 joules per pulse for every cubic centimeter of ruby, the only limit appeared to be the size of the crystal one could produce. Moreover, the invention of the neodymium glass laser, which could be made very large and which had per unit volume 50 times as many lasing ions as ruby, promised proportionately greater powers. Already service programs exceeded several million dollars per year, and they would become much larger if any of the ideas they were pursuing for generating high power proved practical. Although Culver believed that the chances for this were much less than 50-50, he recommended bringing together a group of prominent experts in masers to look at the problem. These people included



Major General Donald L. Lamberson. Lamberson led the Air Force high-energy laser program in the 1970s as a colonel and developed the Airborne Laser Laboratory (figure 1) before becoming deputy assistant for directed-energy weapons in the office of the under secretary of defense for research and engineering. Figure 4

Townes; Nicolaas Bloembergen of Harvard, the inventor of the three-level maser; Robert Kingston from Lincoln Laboratory, a solid-state maser expert; and Norman Kroll of Columbia University, a theoretical physicist.

The meeting convened at the end of 1961 and recommended that ARPA fund a high-priority research and development project in high-power laser techniques. The project, code-named Seaside, was set up under representatives of the office of the deputy secretary of defense for research and engineering, ARPA, IDA and ONR to build within a year and a half a scale model high-power device that would produce 10^3 – 10^4 joules of laser energy.²³ Project Seaside investigated laser kill mechanisms, scaled up the neodymium glass laser, funded projects to improve ruby and glass laser materials and built four high-power solid-state laser weapon prototypes. It focused Department of Defense laser research on the exploration of solid-state rather than liquid lasers. When the development of the carbon dioxide laser and the application of aerodynamic technology to it produced a superior device—the gas dynamic laser—the era of the solid-state antiballistic missile laser weapon gave way to the second phase of military laser development, which concentrated on flowing gas lasers.

In addition to running Seaside, ONR also organized the Department of Defense Conferences on Laser Technology, as well as a variety of smaller meetings on specialized laser topics, permitting researchers from the various services to share classified and unclassified research results. It became the focal agency for military interest in

high-energy lasers, but did not, as Ruina intended, eclipse service programs.

In its coordination of high-energy laser programs, Seaside prefigured later projects such as ARPA's Eighth Card, a restricted-access program that sought to develop gas-dynamic carbon dioxide lasers in the late 1960s while unsuccessfully restraining service efforts in this area, and its successor, the Tri-Service Laser Program, which developed test beds of tactical laser weapons to acquaint all three services with the new technology. The laser team at ONR presaged later coordinating groups such as the High-Energy Laser Review Group, a Defense Department unit that sought to coordinate and control service laser research as it grew by leaps and bounds in the early 1970s. By concentrating in-house and contractor efforts on goals such as the development of antiballistic missiles, anti-airship missiles and anti-aircraft missiles, these groups paralleled the role played by the Special Group on Optical Masers, a unit of the Pentagon's Advisory Group on Electron Devices that coordinated low-energy laser research and tried to constrain laser development to agreed-upon goals and budgets.

Mixed results

Because of the enthusiastic response of the services to the laser, however, these controls were not sufficient to arrest the development of experimental weapons systems. The Airborne Laser Laboratory, which carried a gas-dynamic CO₂ laser, and the Mobile Test Unit, a tank that carried a CO₂ laser sustained by an electron beam, both went ahead and eventually disappointed expectations and broke budgets. The Navy's counterpart system, the Coastal Crusader, a ship that was to have housed a chemical laser, was halted by the office of the deputy secretary of defense for research and engineering and the High-Energy Laser Review Group, but the Navy ARPA chemical laser and the MIRACL system (figure 5) eventually were built by TRW and became the most powerful laser technology available.

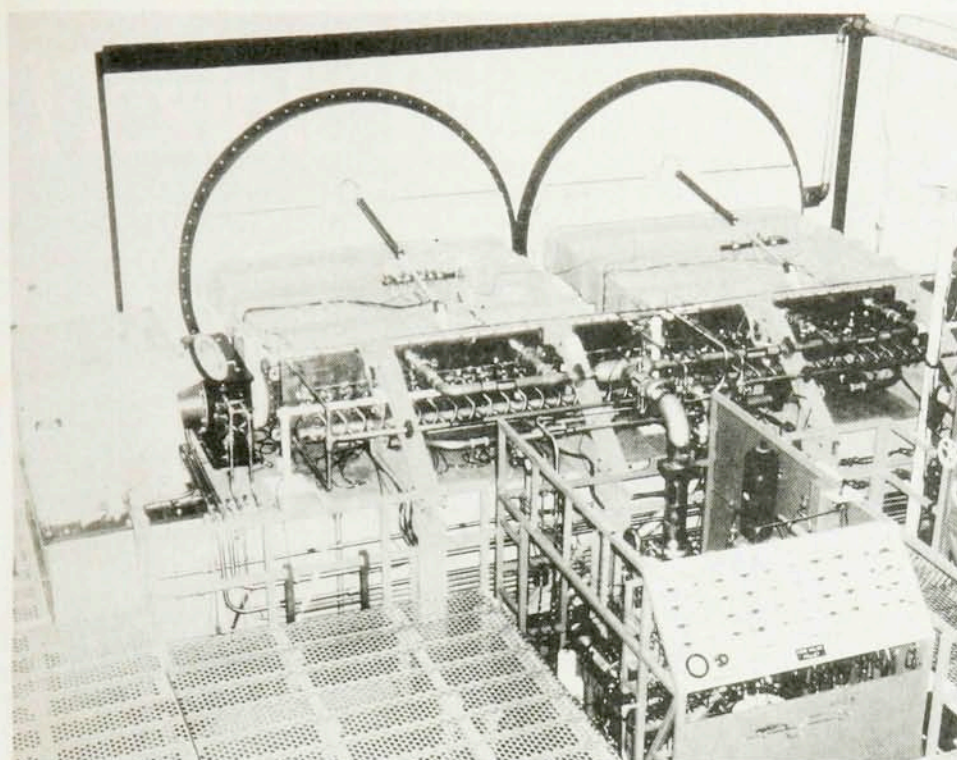
All of these programs demanded increasing funds as they scaled devices to engineering proportions. In the late 1970s the high-energy laser research and development programs ran at about \$150–200 million per year, and by 1980 they had consumed \$1.5 billion, according to evidence presented to Congress. Low-energy laser research and development, which produced fieldable devices, absorbed a similar sum, and in 1980 the government's fraction of the laser market was about 60%, or \$453 million. Clearly, the military dominated the laser industry.²⁴

Despite the development of a number of scaled-up high-power and high-energy laser devices, the military programs were most successful in those areas where traditional research and development produced components and systems of more modest ambition. The glamour wagon attracted personnel, funding and interest from the services, stimulating growth in the industry and the laboratory, but has yet to travel very far. As in the case of the atomic bomb, a program eventually emerged to accelerate the development of this technology and consolidate the rival service programs under a single agency, the Strategic Defense Initiative Office. However, the earlier projects suggest that it was not a failure to scale up candidate laser devices nor an overemphasis on research that frustrated the search for laser weapons. Rather, the attempts to have the laser provide different devices for different applications corresponding to different missions concentrated efforts on development and early deployment, while the high power and high energy levels required for lethal effects in antimissile applications forced development of high-energy laser weapons that proved, for one reason or another, impractical. Unlike the

atomic bomb, the laser did not scale into the "megaton" range very readily. In pursuing both the bomb-like and the radar-like aspects of the new technology, the Department of Defense may have chosen incompatible models of technological development.

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