NATIONAL BENEFITS OF IR&D

Aerospace
Industries
Association

NATIONAL BENEFITS OF INDEPEN

What is Independent Research and Development?

- Independent Research and Development (IR&D) is a company's investment in its future, a technology development effort intended to advance a company's competitive position.
- It differs from R&D performed under contract in that IR&D is company-initiated, company-funded and company controlled.

IR&D benefits industry because it

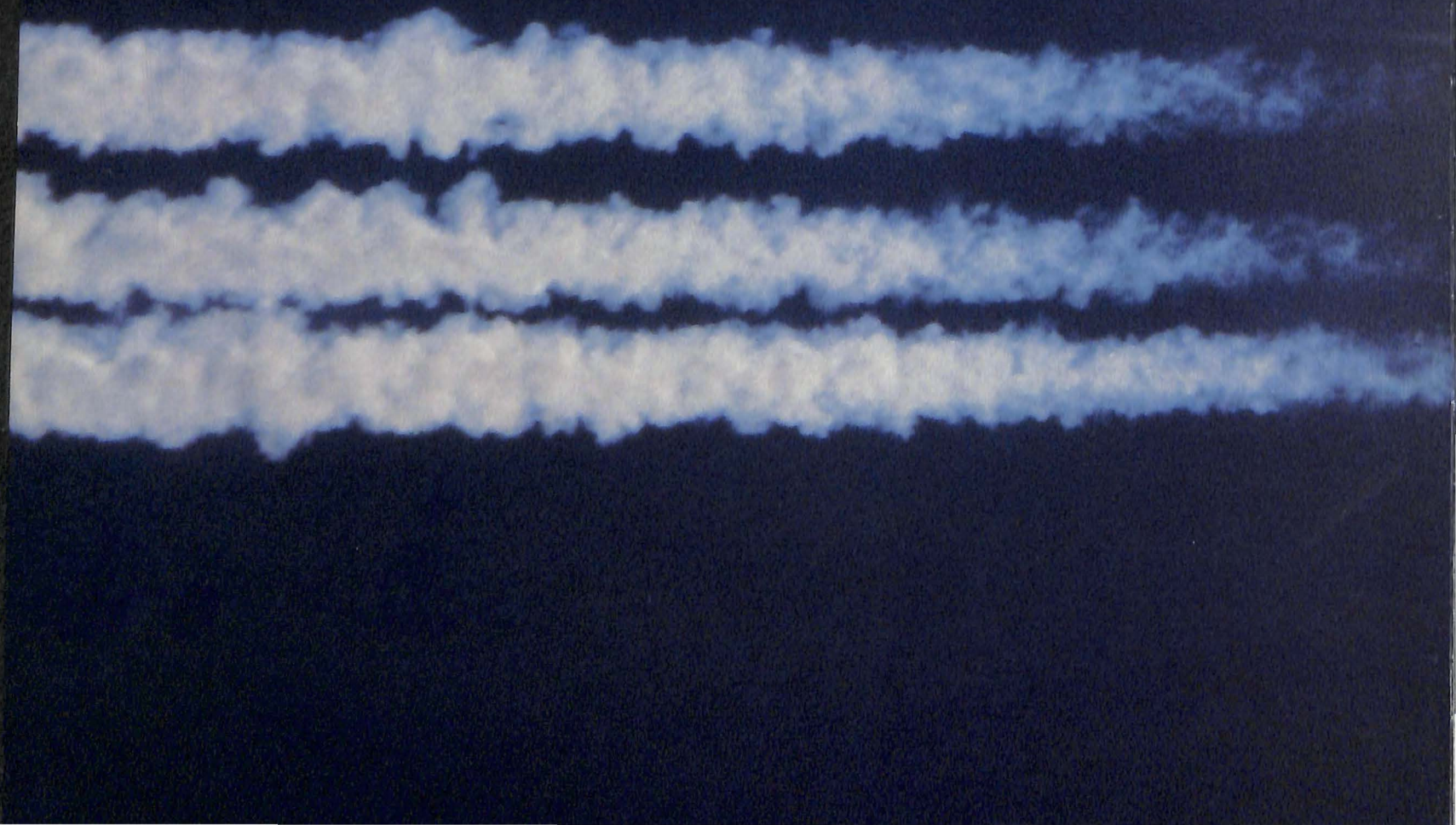
- Explores advanced concepts and creates new products and processes that make companies more competitive.
- Allows a company to pursue technology advancements selectively, in areas where customers' needs are greatest and the company's capabilities strongest.
- Is cost-effective and inherently flexible, permitting quick project expansion, redirection or termination without the cumbersome formalities associated with contractual R&D.
- Spurs company creativity.

IR&D benefits the government because it

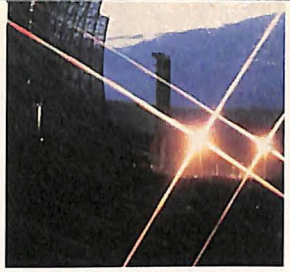
- Provides—at bargain levels—new technologies that contribute to improved U.S. defense and space postures.
- Offers a flow of new ideas that complement and multiply the capabilities of government managers, scientists and engineers.
- Stimulates competition among government contractors.
- Provides options for advanced developments at reduced risk, by demonstrating the feasibility of innovative technologies.

IR&D benefits the nation as a whole because it

- Expands the national technology base.
- Strengthens U.S. competitive capability in international trade.



DENT RESEARCH & DEVELOPMENT



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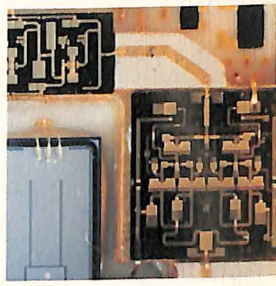
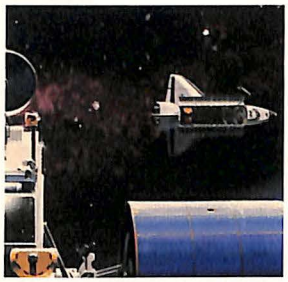
This brochure lists a representative selection of IR&D programs, and their attendant benefits, accomplished by member companies of Aerospace Industries Association. The examples range from small projects lasting a year or less to large, multiyear efforts involving millions of dollars. They are grouped in two general—and inevitably overlapping—categories: *Systems Development,* projects that provided improved systems or components of major systems, and *Advanced Technologies,* generic IR&D efforts that, for the most part, represent work on the basic technologies that are keys to future advancements.

January 1988





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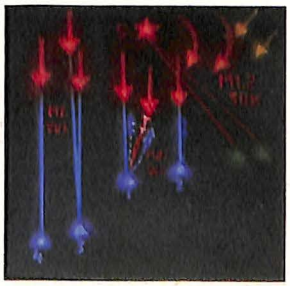
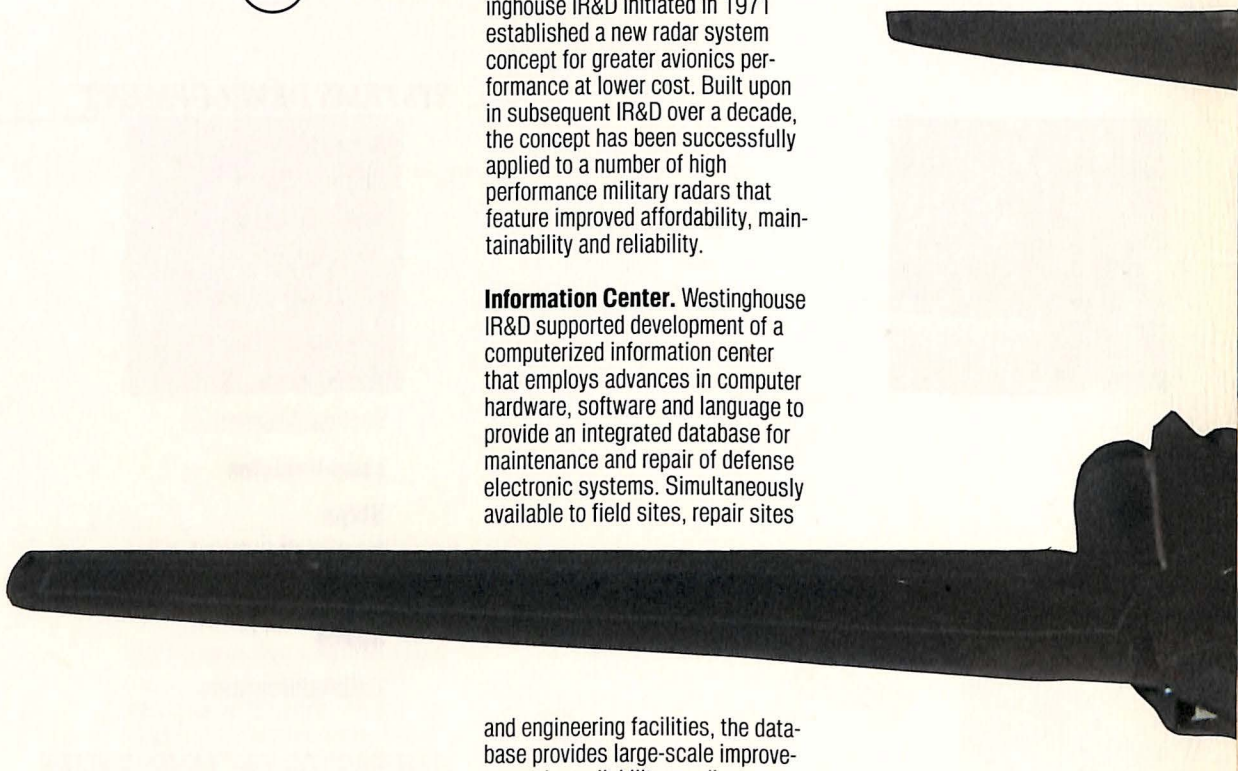


Strategic Aircraft

Westinghouse

High Performance Radar. Westinghouse IR&D initiated in 1971 established a new radar system concept for greater avionics performance at lower cost. Built upon in subsequent IR&D over a decade, the concept has been successfully applied to a number of high performance military radars that feature improved affordability, maintainability and reliability.

Information Center. Westinghouse IR&D supported development of a computerized information center that employs advances in computer hardware, software and language to provide an integrated database for maintenance and repair of defense electronic systems. Simultaneously available to field sites, repair sites and engineering facilities, the database provides large-scale improvements in availability, readiness, quality and cost of maintenance.



Honeywell

Radar Altimeter. Today's Honeywell radar altimeters are significantly better than their predecessors due to company IR&D advancements in microwave solid state circuitry. IR&D over a 20-year span reduced size and weight, lowered power requirements and increased fourfold the time between failures. The benefits extend to 75 percent of the U.S. military aircraft in service.

TEXTRON

Structural Component. Avco Textron IR&D over a 13-year period allowed development and subsequent improvement of composite materials, lighter yet stronger than the metals they replace, made of boron fibers bonded together by epoxy resin. Such a composite is used as a reinforcing material for the titanium dorsal longeron of the B-1B, reducing weight and improving aircraft performance.

Rockwell International

Diffusion Bonded Structure. Diffusion bonding is a process for joining metal components by the application of heat and pressure—without use of adhesives or other bonding agents—to form an integral part. A Rockwell IR&D effort developed a diffusion bonding process that allows fabrication of B-1B parts closer to finished dimensions than forged parts, thus affording substantial cost savings through reduction of the amount of raw material required.

Airframe Design. Rockwell International and other aircraft companies conducted extensive IR&D to reduce the observability of the B-1B to enemy airborne and surface radars. The program produced several new technologies that collectively reduced the B-1B's radar cross section by one to two orders of magnitude, thus significantly improving the aircraft's ability to penetrate enemy defenses.

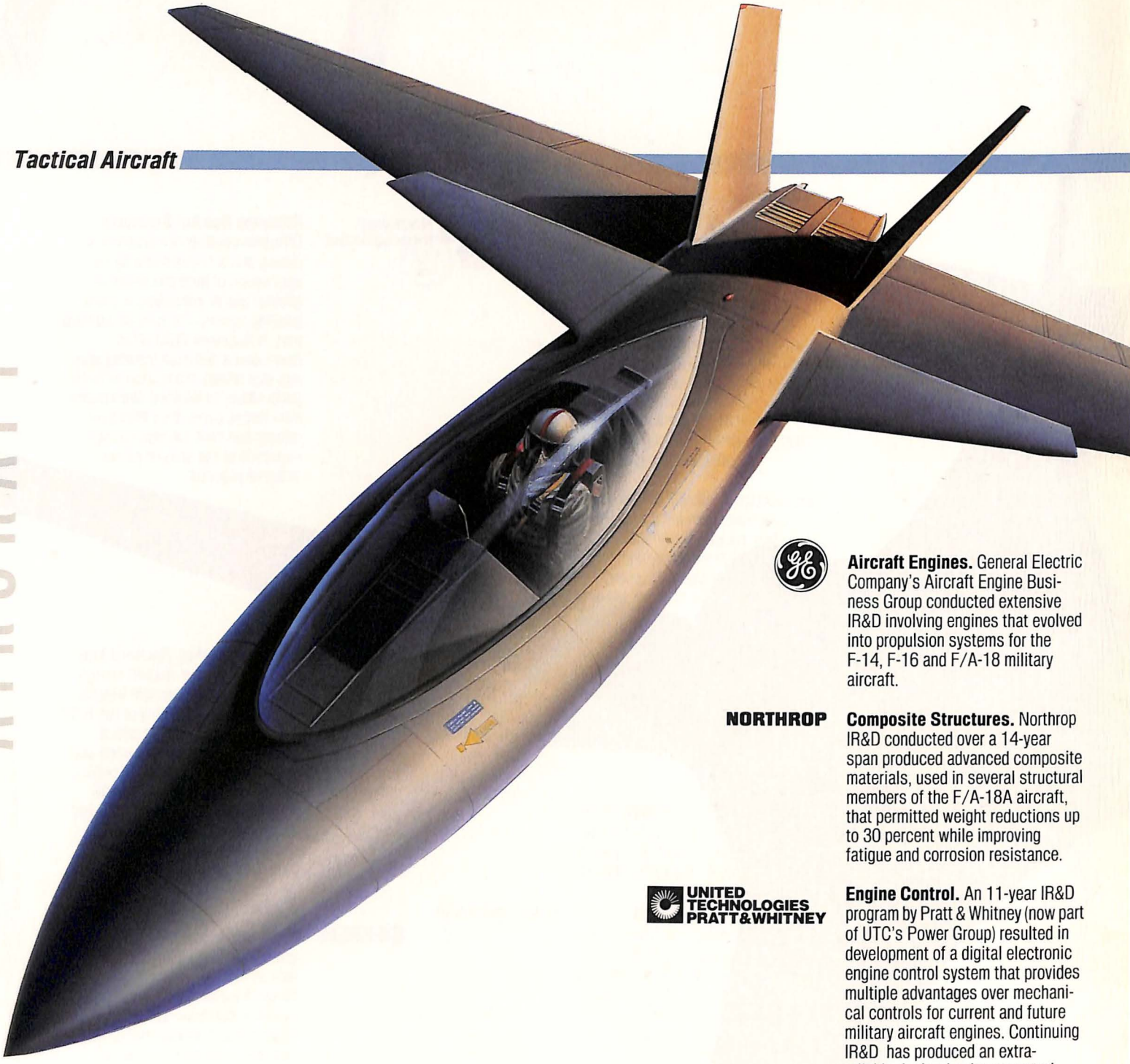
SINGER

Navigation System. Using a production inertial navigation system as a departure point, a four-year Singer Kearfott IR&D program resulted in computer software and other product improvements that enabled development of an advanced inertial navigator with a fourfold increase in accuracy.

BOEING

Avionics. IR&D by Boeing Military Airplane Company developed an expertise in integrating complex avionics systems and led to contracts for avionics integration involving the B-52 and B-1B aircraft. Related IR&D was instrumental in Boeing's receipt of a contract for the highly sophisticated B-1B Aircrew Weapon System Trainer.

Tactical Aircraft



Aircraft Engines. General Electric Company's Aircraft Engine Business Group conducted extensive IR&D involving engines that evolved into propulsion systems for the F-14, F-16 and F/A-18 military aircraft.

NORTHROP

Composite Structures. Northrop IR&D conducted over a 14-year span produced advanced composite materials, used in several structural members of the F/A-18A aircraft, that permitted weight reductions up to 30 percent while improving fatigue and corrosion resistance.

UNITED TECHNOLOGIES PRATT&WHITNEY

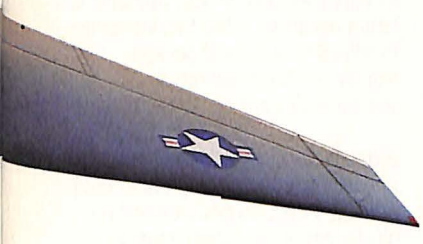
Engine Control. An 11-year IR&D program by Pratt & Whitney (now part of UTC's Power Group) resulted in development of a digital electronic engine control system that provides multiple advantages over mechanical controls for current and future military aircraft engines. Continuing IR&D has produced an extra-reliable dual redundancy control system that will eliminate the need for a mechanical backup and reduce weight and cost.

GENERAL DYNAMICS

Control System. IR&D by General Dynamics' Forth Worth Division resulted in development of an advanced, quadruple-redundant digital fly-by-wire control system now incorporated in the company's F-16 Air Force fighter.

Allied Signal

Aircraft Brakes. A long-term Allied Bendix Aerospace IR&D effort on aircraft brake friction materials significantly advanced carbon composite brake technology and developed materials that increase brake life five times, reduce brake weight by about 40 percent and provide quieter, smoother operation than the metal/ceramic materials they replace.



Aircraft Flight Control System. IR&D by Allied Bendix Aerospace resulted in development of a new digital computer and application of advanced microelectronics technology to reduce the cost and increase the reliability of a flight control system for tactical aircraft. Compared with the analog system it replaced, the digital system offers aircraft performance advantages plus an 85 percent cost reduction, a 75 percent weight reduction and a sevenfold increase in reliability.

Rockwell International

Radio Circuitry. Rockwell IR&D allowed development of a new Large Scale Integrated (LSI) circuit for the frequency synthesizer module of a military aircraft. The single-chip circuit replaces 25 other integrated circuits and parts, permitting the entire frequency synthesizer to be packaged in one-third the space with one-fourth the power drain; the development also provided substantial cost savings in the radio systems used on nearly all Navy tactical aircraft.

LTV

Fighter/Attack Technology. Initiated in 1976 and still in progress, an LTV Aerospace IR&D effort seeking advancements in fighter/attack aircraft technology generated such benefits as improved engines, a new forward-firing cannon, an advanced navigation and weapon delivery system, new air-to-ground ordnance capability, a night attack system, improved reliability and reduced maintenance requirements.

GRUMMAN

Infrared Suppression. Grumman Corporation IR&D on infrared signature analysis resulted in development of an infrared supression kit for the Army's OV-1 observation craft that reduces engine exhaust system hot parts and exhaust emissions, hence makes the aircraft less detectable.

Technology Demonstrator. Grumman IR&D over a 15-year span on advanced technologies for tactical aircraft resulted in a government contract for the X-29 Technology Demonstrator, which features a forward-swept wing made of composite materials, variable camber, a digital flight control system and a variety of advancements intended to increase flight efficiency and aircraft agility.

Honeywell

Ring Laser Gyroscope. Honeywell research, mostly performed under IR&D, developed technology for an advanced ring laser gyroscope that affords revolutionary capability for guidance, navigation, positioning and control. Developed for the F-15 fighter and for strategic and tactical missiles, the gyro offers 10 times better mean time between failures, five times faster start-up, and high immunity to G forces and shock.

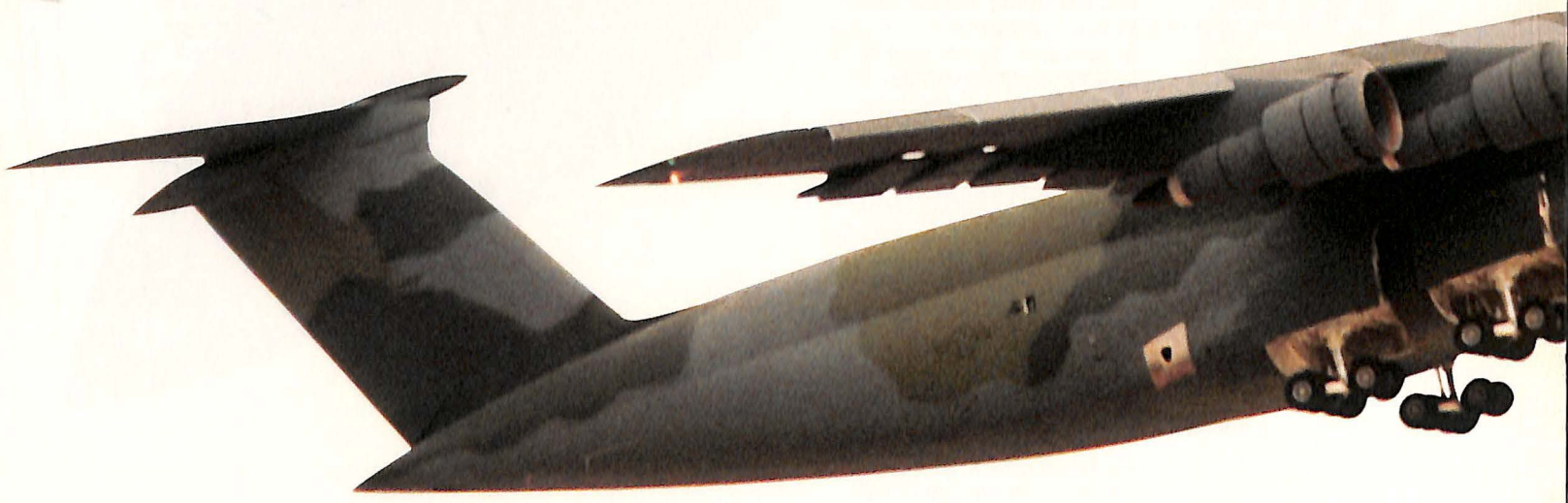
Transport Aircraft

HERCULES

Fuel Measurement System. Hercules Aerospace IR&D resulted in development of an advanced fuel quantity measurement system for military transport aircraft that offers better accuracy, a fourfold increase in reliability, improved cockpit display and the capability to detect and communicate system failures.

MCDONNELL DOUGLAS

Externally Blown Flaps. Douglas Aircraft invested in six years of fluid dynamics IR&D to advance technology for externally blown flaps, in which engine exhaust is blown across the wing flaps to provide extra lift. The program identified ways to minimize take off and landing distances while maintaining efficient cruise performance, technology that is incorporated in the C-17 advanced military transport.



Westinghouse

Electric Power Systems. Westinghouse conducted IR&D over a four-year period toward development of a family of variable speed constant frequency electric power systems, solid state electronic alternatives to mechanical constant speed drives, that offer reduced cost and weight, simplified circuitry and increased reliability.

Rockwell International

Flight Control Systems. A major problem affecting pilots is the necessity for rapidly making multiple decisions with respect to aircraft control. Rockwell IR&D built a technology base for servo control devices, computer elements and associated display systems that relieve the pilot of much of that responsibility. Now in operational service, the equipment permits more accurate control, improved navigation and general mission safety.

UNITED TECHNOLOGIES HAMILTON STANDARD

Propfan Propulsion. United Technologies Hamilton Standard (now the Controls Group) IR&D activity in propfan propulsion sparked NASA sponsorship of a full-scale single-rotation propfan, now being flight tested, and resulted in a program for multi-company development of a full-scale flight demonstration propfan propulsion system that offers sharply reduced fuel consumption for military and commercial aircraft.

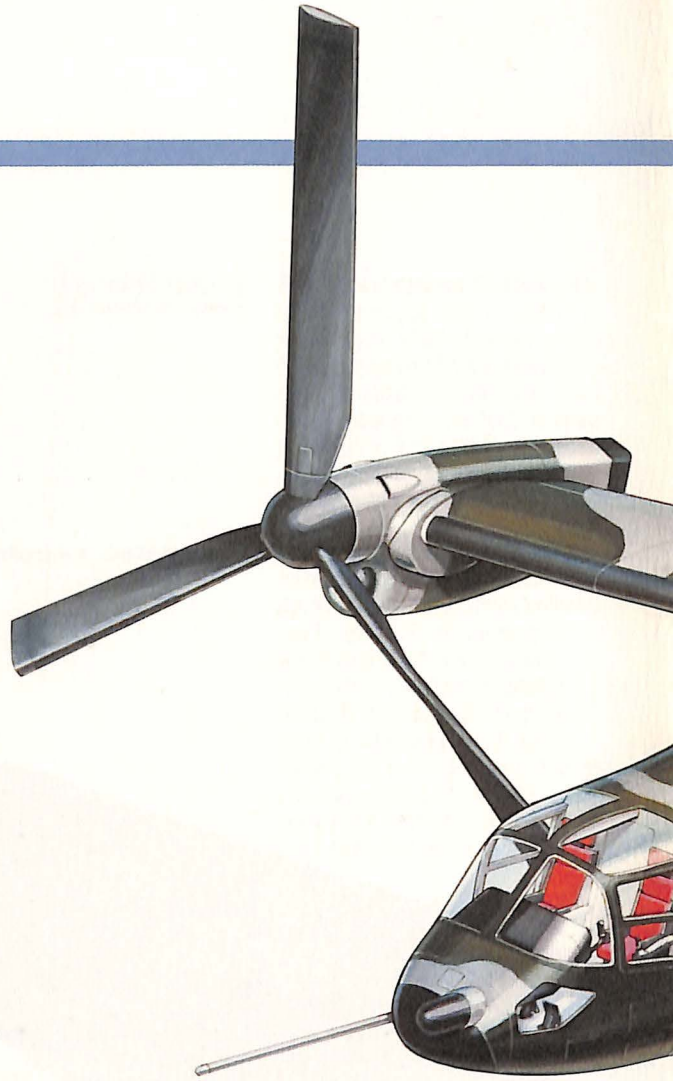
Aircraft Engine. IR&D programs conducted by General Electric Company's Aircraft Engine Business Group contributed to development of the CFM56 engine, a version of which was selected for the re-engine program for the Air Force KC-135 tanker.

BOEING

Windshear Detection. Boeing Commercial Airplane Company IR&D in detection and avoidance of windshear, and optimal guidance in the presence of windshear, provided the basis for development and certification of windshear detection, alert and guidance equipment for Boeing production model airplanes.

Riblets. Boeing Commerical Airplane Company has used IR&D funds to develop—in conjunction with 3M Company—the application of riblets, drag-reducing grooves molded into thin plastic film and applied to external surfaces of an airplane. Applicable to in-service as well as new aircraft, the technology is expected to reduce fuel expenditure by three percent.

Rotary Wing Aircraft



TEXTRON

Helicopter Prototypes. Bell Helicopter Textron's product development strategy relies heavily on company-developed helicopter prototypes and components produced by an aggressive IR&D program over the past two decades. Six of nine prototypes spawned new production helicopters, government procurement of which totaled more than 7,600 units—a most favorable return on the government's investment of approximately one-third the cost of the prototypes.

BOEING

Vertical Lift Aircraft. Independently-conducted IR&D in the late 1960s by Boeing Vertol and Bell Helicopter Textron played a key role in eliminating the safety risk of aeroelastic instability that was impeding progress in tilt rotor aircraft research, clearing the way for development of the XV-15 tilt rotor demonstrator and eventually the military V-22 Osprey.

Ride Quality. Boeing Vertol IR&D produced solutions—incorporated into current helicopters—for reducing vibration, thereby improving ride quality and crew productivity, and contributing to reduced vibration-caused damage.

Honeywell

Helmet Display. A quarter century of ongoing Honeywell IR&D produced an optical/electronic subsystem in which mission information—such as night navigation data, night vision imagery, weapon aiming and delivery functions—is displayed in the pilot's helmet. It is in use on several helicopters and planned for advanced tactical aircraft.

Allied Signal

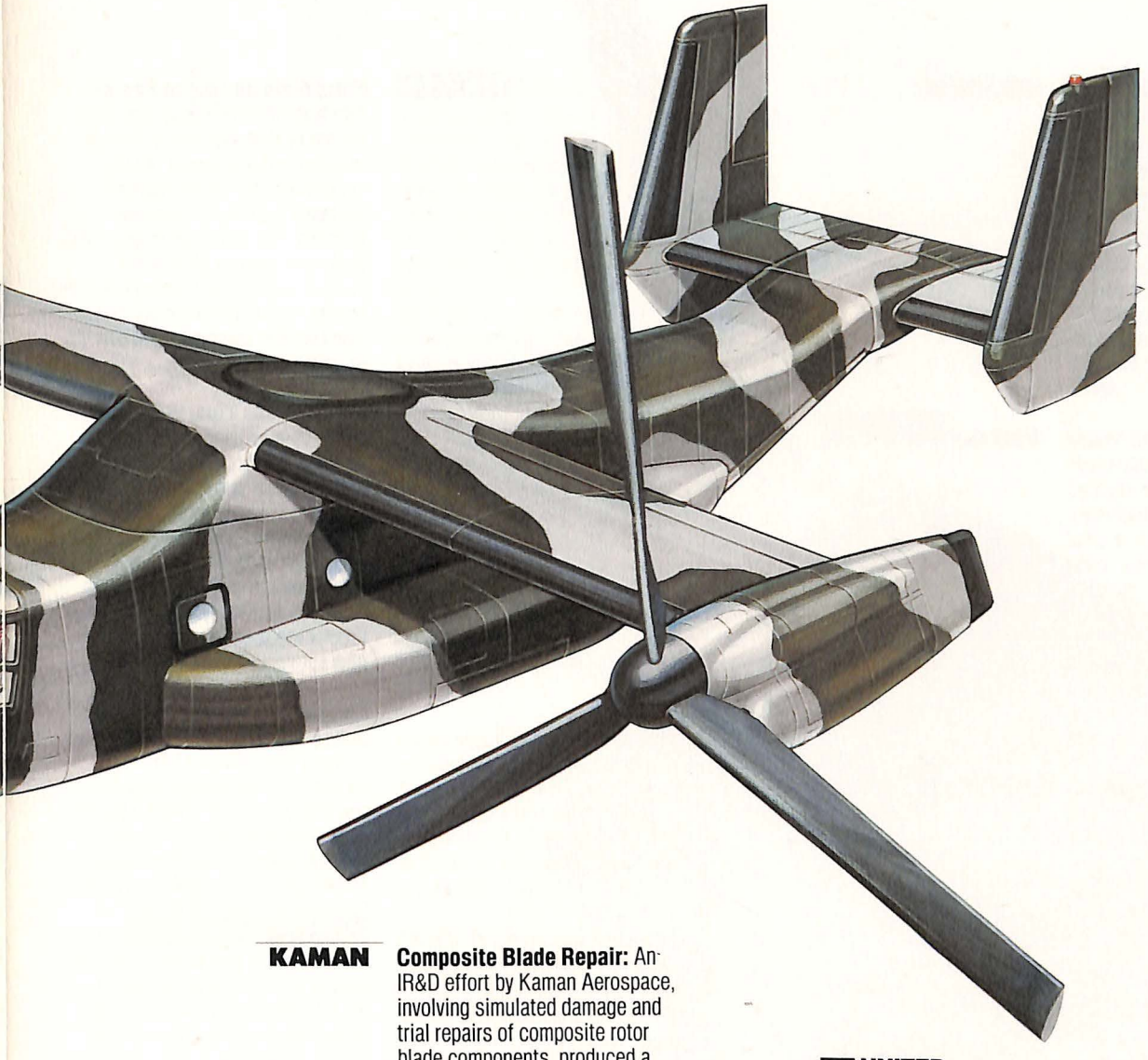
Control Actuator. Allied Bendix Aerospace IR&D generated development of a high pressure flight control actuation system for rotary and fixed wing aircraft that can reduce the weight of the craft's hydraulic system by 40 percent and thus increase payload and/or performance.

SINGER

Velocity Sensor. IR&D on advanced radar technology conducted by Singer-Kearfott resulted in development of a Doppler Velocity Sensor that provided a threefold improvement in helicopter navigation accuracy along with increased radar system reliability and sharply reduced weight and cost.

GM Allison

Digital Control. A decade of GM's Allison Gas Turbine Division IR&D on a digital electronic control for small turboshaft engines produced a successful development that offers decreased pilot workload, improved operational reliability and reduced unscheduled maintenance due to wear or contamination of mechanical parts.



KAMAN **Composite Blade Repair:** An IR&D effort by Kaman Aerospace, involving simulated damage and trial repairs of composite rotor blade components, produced a process and a tool—now standard in the military services—that permit field personnel to repair and/or maintain composite helicopter main rotor blades without sending them to a depot or even removing them from the aircraft, affording significant life cycle savings.

Helicopter Engine. The General Electric T700 engine, now the power plant for several military helicopters, benefited from IR&D programs conducted by GE's Aircraft Engine Business Group.

UNITED TECHNOLOGIES **Tail Rotor:** A six-year UTC Defense & Space Systems Group IR&D investigation of helicopter tail rotor design and fabrication produced a major innovation: a composite "flexbeam" that enabled elimination of the bearings used on conventional tail rotors. The resulting all composite, bearingless tail rotor—successfully incorporated into three production-type military helicopters—has a fatigue strength of three times that of aluminum blades and a parts count only one-third of the prior design.

TEXTRON

Navigation/Guidance System. Two separate IR&D programs conducted by Bell Aerospace Textron resulted in development of major components for the navigation/guidance systems of strategic missiles. The advances reduced the cost, size and weight of ICBM navigation/guidance equipment, improved missile guidance and provided greater component resistance to radiation.

Missile Nose Tips. IR&D by Avco Systems (a division of Textron) involving research in high temperature materials and development of new techniques for manufacture and quality control of carbon-carbon composite materials, provided improvements to the Peacekeeper ICBM—specifically, advanced nose tips for the re-entry vehicles and a new antenna window.

Composite Nozzles. Avco Specialty Materials (a division of Textron) has—since 1975—conducted IR&D to develop processes and reduce costs of manufacturing carbon-carbon composites, with attendant benefit to the Peacekeeper, Trident and Small ICBM programs. Similarly, a decade of United Technologies R&D investigations of carbon-carbon application to nozzle throats and exit cones increased the reliability and lowered the cost of the Improved Tomahawk cruise missle, the Trident 2 fleet ballistic and NASA's Inertial Upper Stage space booster.

HERCULES

Extendible Missile Components. A new concept for an extendible nozzle cone for the rocket motor of the Peacekeeper missile's third stage was developed by Hercules Aerospace in an IR&D program of the latter 1970s. The development increased stage thrust by six percent and range (or payload) by eight percent, improvements that allowed meeting mission requirements with smaller solid propellant motors and significantly lowered system costs.

Solid Propellants. Under IR&D funding, Hercules Aerospace conceived and developed a family of high energy slurry propellants that improved rocket motor performance and allowed meeting range/payload requirements within volume, weight and cost restraints for the Trident, Peacekeeper and SICBM strategic missiles.

Lockheed

Aerospike. Lockheed IR&D effort resulted in development of an "Aerospike" for the Trident missile, an extendible attachment to the front end of the missile intended to increase aerodynamic performance and increase range.

MARTIN MARIETTA

SICBM Systems. Martin Marietta Denver Aerospace IR&D resolved a number of technical uncertainties related to development of the Small ICBM (SICBM), for example, qualification of new materials for managing propellants in the SICBM velocity control system; new environmental materials to protect SICBM from dust/debris contamination; and techniques that cut SICBM assembly time from five days to approximately three hours. These and other IR&D advances improved the company's competitive position and helped it bid successfully for the SICBM post-boost vehicle contract.

NORTHROP

Inertial Measurement Unit. Northrop Electronics IR&D on ICBM guidance system technology resulted in development of an advanced gimballess Inertial Measurement Unit (IMU) for the Peacekeeper missile that improved IMU accuracy, reliability, producibility and radiation hardening. The work enhanced Northrop's competitive status and led to contracts for the Peacekeeper IMU and a similar unit for the Small ICBM.

UNITED TECHNOLOGIES

Upper Stage Propellants. United Technologies' Defense & Space Systems Group conducted IR&D investigations of high energy propellants suitable for use in improved upper stage rockets. In the course of these studies, the division discovered a method of producing propellants with expanded temperature limits, an advancement that benefited the Trident 2 fleet ballistic missile and the Small ICBM programs.

MORTON THIOKOL, INC.
Aerospace Group

Composite Cases. A decade of Morton Thiokol IR&D on composite materials led to development of significantly lighter solid rocket motor cases, a benefit to the Peacekeeper and Small ICBM missile programs.

Rockwell International

Missile Computer. Computer technologies developed under Rockwell International IR&D were incorporated into the electronic and control assembly of the Peacekeeper ICBM, providing greater missile accuracy and software simplification.

TRW

Thrust Vector Control. TRW IR&D intended to improve rocket engine performance and reduce procurement costs led to development of a thrust vector control system for the Tomahawk cruise missile. As a result, the submarine-launched version of the Tomahawk will have a 10-20 percent increase in range/payload.

SINGER

Motion Sensor. Missile inertial navigation systems employ computerized gyroscopes and accelerometers to sense and control the direction, velocity and acceleration of the vehicle. Singer-Kearfott IR&D resulted in development of a new type of sensor—the ring laser gyro—that employs counter-rotating light beams as the basis for measuring vehicle motion. These ring laser gyros were integrated into an improved inertial navigation system that offers a threefold gain in reliability and a fivefold better reaction time, with power requirements reduced by half.

Rockwell International

Laser Seekers. Ten years of Rockwell International IR&D provided the technical base for development of the now-operational Hellfire and Laser Maverick missiles; continuing IR&D on extensive use of the plastic parts and digital autopilot technology has effected significant cost and performance improvements.

GENERAL DYNAMICS

Submunitions Dispenser. General Dynamics Convair conducted IR&D on technologies associated with dispensing large numbers of small submunitions from a cruise missile, a program that resulted in development of a new member of the Tomahawk family whose warhead has a submunitions dispenser. The development provided a multiple-target-per-missile capability and allowed targeting of many more objectives, including enemy defenses.

LTV

Advanced Concepts. A mobile rocket battery, the Army's Multiple Launch Rocket Systems (MLRS) is an important battlefield support system in service with the Army since 1983 and in multiyear production. The selection of LTV Aerospace as system developer, later as production source, and the award of three subsequent Army contracts for MLRS advancements, all stemmed from company IR&D.

Hypervelocity Missile. LTV Aerospace IR&D generated key technologies to support the Hypervelocity Missile (HVM) concept, a low-cost weapon system offering substantially increased fire power for both ground and air forces. The IR&D led to a series of development contracts for HVMs to be used by the USAF, Navy, Marine Corps and Army.

UNITED TECHNOLOGIES

Missile Guidance. New tactical missiles require high maneuverability at all flight speeds, attainable by altering the direction of rocket thrust to effect changes in the weapon's flight path. United Technologies' Chemical Systems Division (now part of the Defense & Space Systems Group) conducted IR&D involving technology development for course-changing movable rocket motor nozzles and a system to actuate them. Used in a long range fleet defense missile, the technology allows more compact packaging and reduced power requirements.

NORTHROP

Inertial Guidance. A Northrop IR&D effort to advance inertial guidance and gyroscopic instrument technology resulted in significant improvements in the midcourse inertial guidance system and the radar target seeker of the USAF's Advanced Medium Range Air-to-Air Missile. The weight of the Inertial Measurement Unit was reduced by 25 percent; an advanced target seeker gyro resulting from the IR&D costs 60 percent less and occupies 40 percent less space than the gyros formerly used for the same task.

BOEING

Air Defense System. A Boeing IR&D project demonstrated that low-cost concepts integrating mature, existing production components can meet Army requirements for countering future short-range air defense threats. When cancellation of another weapon program made it imperative that the Army accelerate development of its Pedestal Mounted Stinger, a low-cost, air defense missile system, such acceleration was possible only because the Boeing IR&D had provided the requisite technology base.

TEXTRON

Turbine Component Coating. An Avco Lycoming Textron IR&D program produced an aluminide coating that provides improved oxidation/corrosion protection for turbine blades and nozzles in land vehicle propulsion systems.

Superalloy. Increased reliability, longer service life and reduced life cycle cost for Lycoming land vehicle engines are benefits that accrued from IR&D by Avco Lycoming Textron. The IR&D permitted development of a superior cast nickel alloy, now used in all Lycoming engines, that offers double the high temperature strength of an earlier alloy and four times better resistance to hot corrosion.

Tank Engine Control. Avco Lycoming Textron IR&D toward design and development of an analog fuel control for the AGT 1500 tank engine produced the first large-scale production electronic fuel control. It provided a lower cost, more reliable, more accurate control than the conventional hydro-mechanical unit on the M1 tank, a one-third reduction in volume and a 20 percent improvement in the tank engine's fuel consumption.

Test Equipment. Long-term IR&D by General Electric Company's Aerospace Business Group on potential advancements in Simplified Test Equipment (STE) resulted in fielding more than 7,500 STE units for repair and readiness work on jeeps, trucks, tanks and combat vehicles. Additionally, GE has received Army contracts for advanced STE equipment for future maintenance of land vehicles.

Engine Technology. IR&D by General Electric Company's Aircraft Engine Business Group contributed technology in compressors, all electric controls and accessory systems, and regenerative engine controls that combine to enhance the LV100 engine, which will power the next generation of tracked military vehicles.

MARTIN MARIETTA

Vehicle Armor. Increased armor protection for military land vehicles at lighter weight is the principal benefit of Martin Marietta IR&D in composite materials, including development and field testing of composite armor designed to counter threats up to .50 caliber.

HERCULES

Ignition System. Hercules Aerospace IR&D contributed advancements in ignition system design for land vehicle engines, including the ability to withstand a nuclear environment.

SHIPS

Air Defense Radar General Electric's Aerospace Business Group IR&D on phased array radar, radar signal processing and microelectronics generated a number of advancements for the AEGIS shipboard air defense system, in particular reductions in the radar system's size and cost, a doubling of signal processing capability, greater reliability and improved performance in the presence of intensive electronic countermeasures.

NORTHROP **Cruise Missile Simulator.** With the advent of sea-skimming antiship cruise missiles (ASCM) and consequent Navy concern about defending against this threat, Northrop Ventura conducted IR&D over a five-year span to create an ASCM simulator, a much-improved, extensively modified version of an existing target drone that has since become the Navy's primary training target.

UNITED TECHNOLOGIES HAMILTON STANDARD **Water Wash System.** Turbine-powered naval vessels may encounter contamination problems—accumulation of dust and moisture—on turbine inlet air filters, causing reduced engine performance and possible engine damage. United Technologies Hamilton Standard (now the Controls Group) IR&D provided an answer: a maintenance-simplifying shipboard "water wash" system that allows the filters to be washed with either fresh or salt water while the engines are operating.

Raytheon **Ship Sonar.** Under IR&D, Raytheon designed and developed an entire ship sonar system intended to satisfy Navy requirements for small surface ship sonars at reduced cost. After Navy testing, the system was moved from IR&D directly into production, thus enabling the Navy to buy "off the shelf," and was subsequently deployed with the fleet.

Westinghouse **Minehunting Sonar.** A Westinghouse IR&D effort spawned development of technology for multibeam side-looking sonars that offer substantial increases in the effectiveness of helicopter-towed underwater minehunting systems.

Allied Signal **Towed Array.** Allied Bendix Aerospace IR&D focused on advancements in towed arrays for detecting enemy ships. Among improvements effected are a 10-decibel reduction in acoustic sensor self-noise, which resulted in a greater enemy vessel detection capability for the array; computer modeling advances that provided significant array cost reductions for the Navy; and materials/design advances that collectively reduced the system's parts count by 60 percent.

UNITED TECHNOLOGIES NORDEN SYSTEMS **Surveillance Radar.** IR&D by United Technologies Norden Systems (now a part of the Defense and Space Systems Group) on radar system architectures and subsystems components provided a technological basis for the Navy's next generation shipboard air surveillance radars. The same technology base helped Norden win a Federal Aviation Administration contract for an upgraded air route surveillance radar for the U.S. civil air traffic control system.

BOEING

Antisubmarine Missile. Currently in the design phase, the Navy's Sea Lance program involves development of a submarine-launched antisubmarine warfare missile system to be used in forward areas. A major technical question was how to launch a missile from a submerged submarine without warning the target. Boeing IR&D in advanced composite materials led to development of a composite capsule for initial launch.

Avionics System. To counter the growing Soviet submarine threat, the Navy's P-3 Update IV program is developing an improved avionics system for the P-3 airborne antisubmarine warfare (ASW) platform. Before the project could be initiated, the Navy had to find an affordable solution for retrofitting an existing airframe with an entirely new avionics system. Boeing IR&D provided the essential technical breakthrough by developing affordable avoinics technologies for the integration of airborne ASW sensors with improved maintainability and increased reliability.

UNITED TECHNOLOGIES

Acoustic Receivers. United Technologies' Defense and Space Systems Group conducted IR&D in acoustic signal processing to improve discrimination between enemy sonar transmissions and background noise (from sea life, own ship and friendly ships). This work provided technology for a significant upgrading, by retrofit, of the Norden Acoustic Intercept Receiver with which all U.S. nuclear submarines are equipped—and therefore a major increase in the Navy's capability for finding enemy submarines.

Rockwell International

Advanced Gyro. A primary requisite for submarines carrying underwater-launched long range ballistic missiles is a capability for very high precision navigation for long durations without updates from external sources. This is accomplished by Ship Inertial Navigation Systems (SINS) which employ gyros and accelerometers to track ship motions and provide continually updated position information. Rockwell International IR&D toward solution of a gyro problem that was causing navigation errors resulted in development of an advanced electrostatically suported gyro which was retrofitted in existing submarines and integrated into new construction, extending the time that submarines can remain submerged with high navigational accuracy.

NORTHROP

Laser Communications. Northrop Electronics IR&D in blue excimer laser communications technology led to the division's selection as developer of the transmitter module for a DARPA/Navy program involving development of a satellite-relayed submarine laser communications system. The company's IR&D reduced the technical risk associated with the advanced technology program.

Honeywell

Antisubmarine Torpedo. The sophisticated MK-50 torpedo is a Navy answer to the threat posed by new Soviet submarines. IR&D by Honeywell provided a number of contributions to the torpedo's efficacy, among them significant component size reductions major improvements in sonar performance, better engine control and enhanced target detection/classification capability.

Honeywell

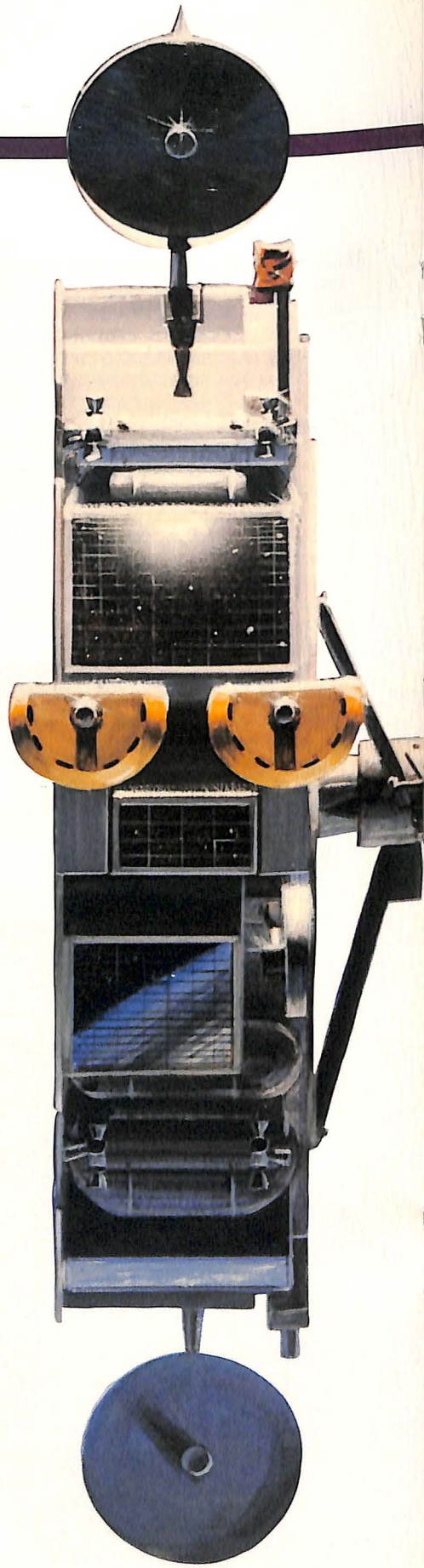
Computer Memory. Honeywell research, conducted for the most part with IR&D funds, resulted in development of an advanced computer memory, based on a new concept in which Large Scale Integrated Circuit metallization was employed in lieu of plated wire memories. Applicable to such programs as the Strategic Defense Initiative, the new memory offers a fourfold speed increase, together with significant reliability and radiation resistance improvements and major reductions in volume and cost.

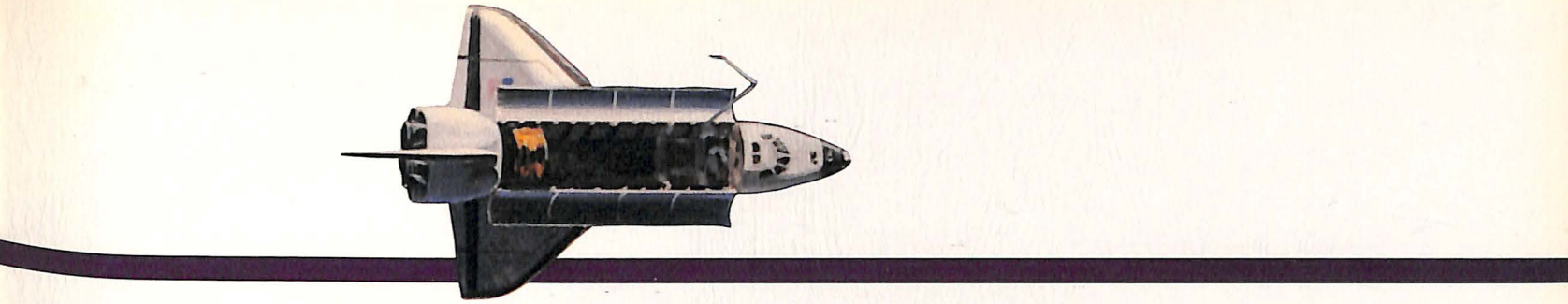
Westinghouse

Electromagnetic Launchers. Among promising systems for defense against ballistic missiles contemplated under the Strategic Defense Initiative is the space-based electromagnetic launcher (EML) or "rail gun," which employs electromagnetic forces rather than chemical propellants to accelerate projectiles. This concept allows hypervelocity flight, thus offering greater probability of hitting and destroying a target. Westinghouse IR&D in power generation systems and other EML components, including development of laboratory demonstrator systems, has significantly advanced electromagnetic launch technology.

MARTIN MARIETTA

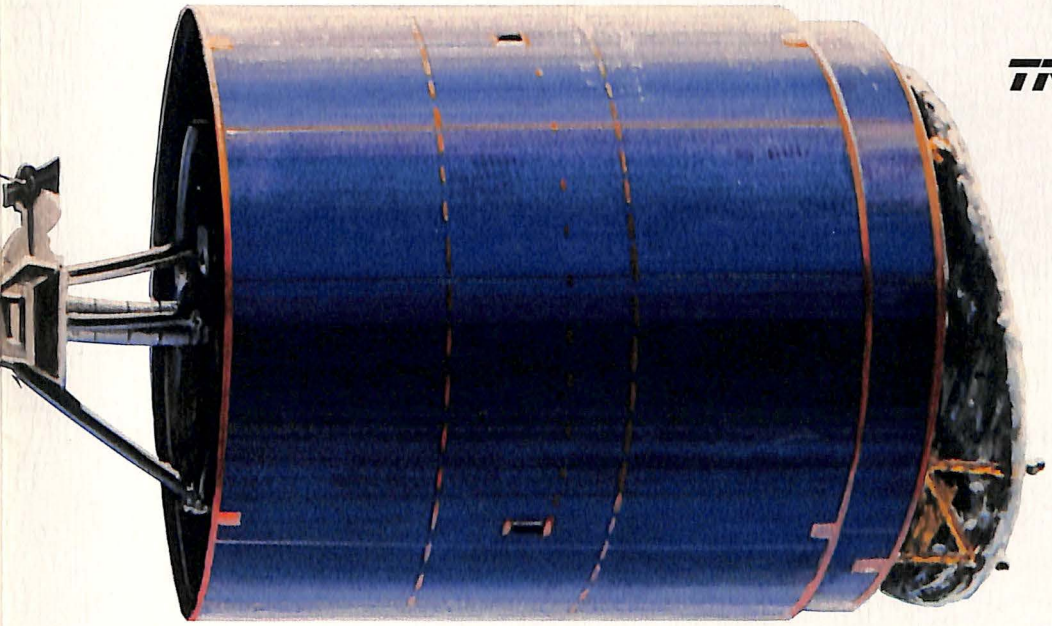
Welding Technique. A Martin Marietta Michoud Aerospace IR&D effort explored Variable Polarity Plasma Arc (VPPA) welding techniques that were potentially capable of eliminating quality and productivity problems associated with tungsten/inert gas (TIG) welding. The successful program allowed the company to replace TIG welding with VPPA on components of the Space Shuttle's External Tank, a switch that reduced required weld repairs by 90 percent and reduced weld preparation time with consequent savings of substantial order.





MORTON THIOKOL, INC.
Aerospace Group

Space Motors. IR&D by Morton Thiokol has advanced a number of technologies—propellants, igniters, composite materials, exit cones, etc.—associated with small upper stage rocket motors used to inject satellites into orbit. This work resulted in current availability of a series of reliable, high performance upper stage boost systems; more than 90 percent of the free world's satellites are sent into orbit by Morton Thiokol space motors.



TRW

Variable Thrust Rocket. NASA's Orbital Maneuvering Vehicle (OMV), a Shuttle-complementing space tug in development, requires a reusable, high-performance, long-life rocket engine with exceptional versatility, because it will be required to perform high thrust orbital changes as well as low thrust operations in tug-maneuvering other spacecraft. IR&D by TRW achieved advances in rocket specific impulse, operating life and thrust control, and played a part in NASA's selection of TRW as development contractor for the OMV and its variable thrust engine.

Spacecraft Electrical Power. TRW IR&D in such areas as spacecraft solar cell arrays, energy storage and automated electrical power systems generated technology advances that offer reductions in the weight and deployed areas of spacecraft electric power sources, thereby permitting larger payloads, and improved survivability in nuclear and laser weapon environments.

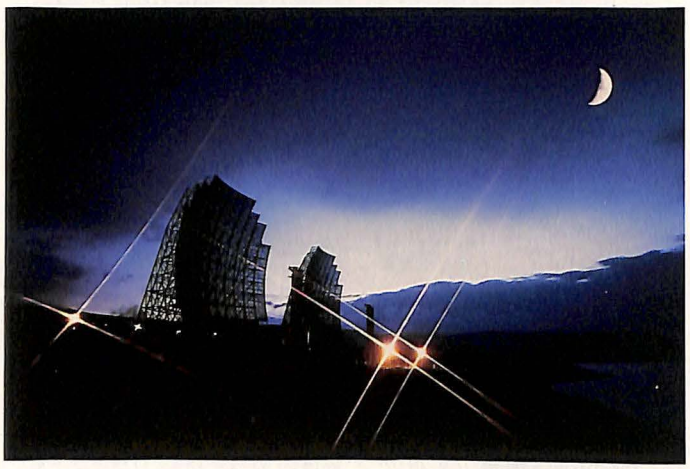
GE

Spacecraft Computer. "Hardening" space systems, improving their ability to survive in a high-radiation nuclear environment, is a priority objective of the Department of Defense. General Electric's RCA Aerospace developed, under IR&D, a radiation-hardened spaceborne computer that was certified for use in the Defense Meteorological Satellite Program.

Rockwell International

Engine Material. Significant reductions in fabrication costs and weight of the Space Shuttle Main Engines were made possible by Rockwell International IR&D development of a new high-strength, high-conductivity metallic material that enabled design of advanced heat exchangers for the engines.

Special Communications (C^3I)



Lockheed

Signal Processing. Today's airborne communications jammers are neither agile enough nor fast enough to counter the threat posed by communications networks that use "spread spectrum" techniques. Under IR&D, Lockheed developed a unique, airborne radio frequency signal acquisition system cable of intercepting, detecting and identifying both traditional and spread spectrum communications signals in the dense signal environment, including the presence of intentional jammers.

TRW

Signal Detection System. IR&D work by TRW on advanced software provided technology for substantially improved Department of Defense signal intelligence collection and surveillance systems. In addition, the work resulted in development of a specially configured workstation for applying new electronic surveillance techniques: the workstation offers a capability for analyzing signals that heretofore escaped detection

ITT DEFENSE

Voice Control. The many systems and controls in advanced fighter aircraft that demand a pilot's attention keep him extremely busy and threaten his effectiveness in a combat environment. Among a number of projects intended to reduce pilot workload is IR&D by ITT Defense communications Division involving development of speech and speaker recognition techniques, including demonstration of working systems that allow a pilot to control a number of normally hand-operated functions by using voice commands.

Fiber Optics. Exposed to nuclear radiation, in particular gamma radiation, typical commercial optical fiber systems "darken" due to reactions caused by dopants used in the manufacturing process, causing communications failure. An IR&D effort by ITT Electro-Optical Products resulted in development of glass dopants that are not permanently affected by gamma radiation and allow resumption of communications within seconds after exposure.

Raytheon

Advanced Radars. Raytheon IR&D performed over a span of more than two decades provided advances in phased array radar concepts, development of critical components and design/construction of several types of demonstration arrays. This work provided a technology base for later full-scale development of advanced phased array radars for Army/Air Force air defense, surveillance and aircraft landing systems.

TEXTRON

Antennas. Bell Aerospace Textron conducted extensive IR&D that led to development of antennas and microwave systems capable of dual frequency operation and other performance advances. This equipment is applicable to airborne, shipboard and ground communications terminals associated with the Department of Defense's space-based Milstar Secure Communications System.

High Power Systems

TRW

Directed Energy Weapons. Conducting IR&D in such areas as chemical and free electron lasers, neutral particle beams, high power microwaves and beam combining techniques, TRW has accomplished a number of breakthroughs that offer a solid base for development of directed energy weapons.

BOEING

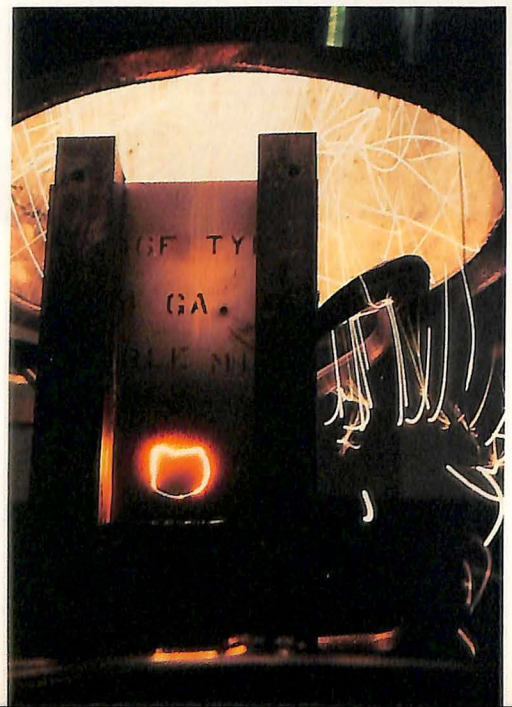
Free Electron Laser. The Ground-Based Free Electron Laster (BGFEL) is a Strategic Defense Initiative program directed toward development of a laser system for destroying enemy ballistic missiles in the boost phase. Boeing IR&D in this area led to sponsored contracts that demonstrated the performance feasibility of a free electron laser and such demonstrations sparked initiation of the GBFEL program.

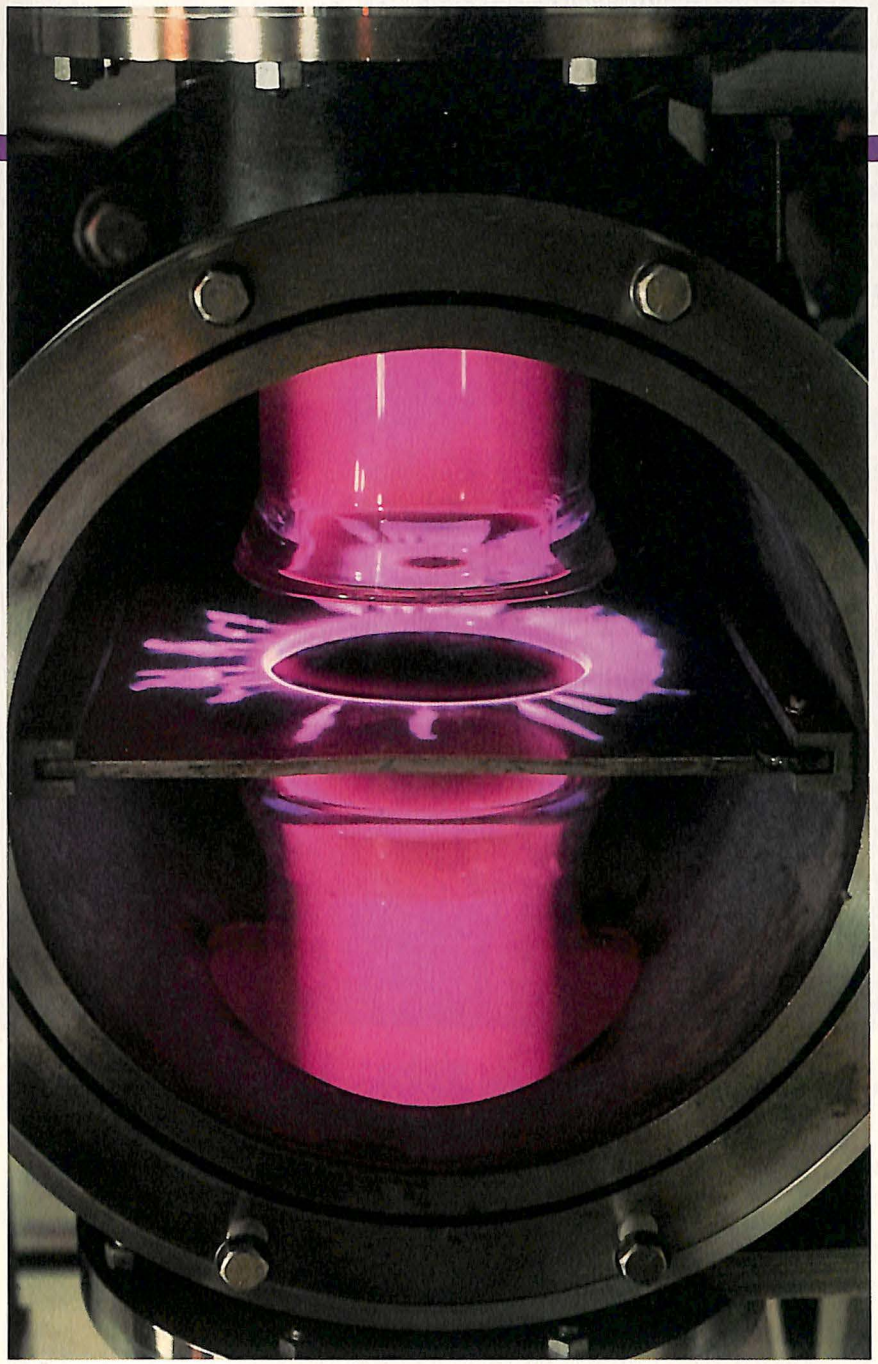
GENERAL DYNAMICS

Superconducting Magnets. For more than a decade, General Dynamics has been performing IR&D toward production of superconducting magnets as large as 25 feet in diameter. In a related project, the company has developed a new transformer concept that allows 90 percent energy transfer and eliminates the need for a high power breaker switch.

Rockwell International

Power Systems. Rockwell International IR&D on solar dynamic power systems developed the fundamental technologies for large-scale—up to 400 kilowatts—generation of power for future spacecraft and space platforms. The effort demonstrated the feasibility of generating continuous power during eclipse periods in low Earth orbit.





TEXTRON

Power Generation. Avco Research Laboratory (Textron) conducted IR&D in power plant systems analysis and development of a combustor and magnetohydrodynamic (MHD) channel for power generation, establishing a technology base for the Department of Defense in MHD electric power generation at multi-million watt levels. The technology is applicable to directed energy and kinetic energy weapon systems being explored in the Strategic Defense Initiative.

Laser Mirrors. A number of Department of Defense programs, in particular the Strategic Defense Initiative, involve use of laser mirrors. IR&D by Bell Aerospace Textron during 1973-85 built a technology base for materials and design approaches to minimizing distortions in high energy laser mirrors of complex configuration and large size.

Laser Devices. IR&D by Avco Research Laboratory (Textron) on excimer lasers advanced by several years the state of the art for high power pulsed electric-driven laser devices. Such devices have applicability in the USAF's antisatellite weapons development effort and in ballistic missile defense systems.

TEXTRON

Metal Composites. Avco Specialty Products (Textron) IR&D aims to cut costs and improve fiber strength and other key characteristics of various types of metal matrix composites (MMC), used to reduce the weight of such equipment as gun barrels, torpedos, tank pins and aircraft parts. Similarly, LTV Aerospace and Defense IR&D on MMCs for aerospace applications to advanced aerospace structures led to the first successful firing of a solid rocket with an MMC casing weighing significantly less than the regular aluminum motor case but of equal structural integrity.

MORTON THIOKOL, INC.
Aerospace Group

Thermoplastic Binders. Morton Thiokol IR&D on thermoplastic binder systems for advanced rocket propellants and munitions has indicated potential for very significant cost reduction without performance sacrifice.

TRW

Space Structure Control. Controlling the large, complex, lightweight structures of space stations or orbiting platforms very precisely demands structural control and pointing requirements from one to three orders of magnitude greater than for any existing system. Under IR&D, TRW developed new structural control approaches, actuators and sensors to meet the extremely high performance levels required by such systems as directed energy weapons platforms.

BOEING

Advanced Composites. Boeing Commercial Airplane Company conducted IR&D on advanced composites, involving development and evaluation of composite wing panel, spar and major joint designs. Applicable to the wing of the V-22 Osprey military tilt rotor and other aircraft, the technology offers extended service life and a major wing box weight reduction.

MCDONNELL DOUGLAS

Fabrication Technique. Superplastically Formed/Diffusion Bonded is a technical term for an advanced method of fabricating aerospace vehicle components. McDonnell Aircraft IR&D led to use of this technology in the F-15E advanced USAF fighter; it eliminates many substructure elements and fasteners, and it offers a 40 percent cost reduction relative to the existing production design.

UNITED TECHNOLOGIES

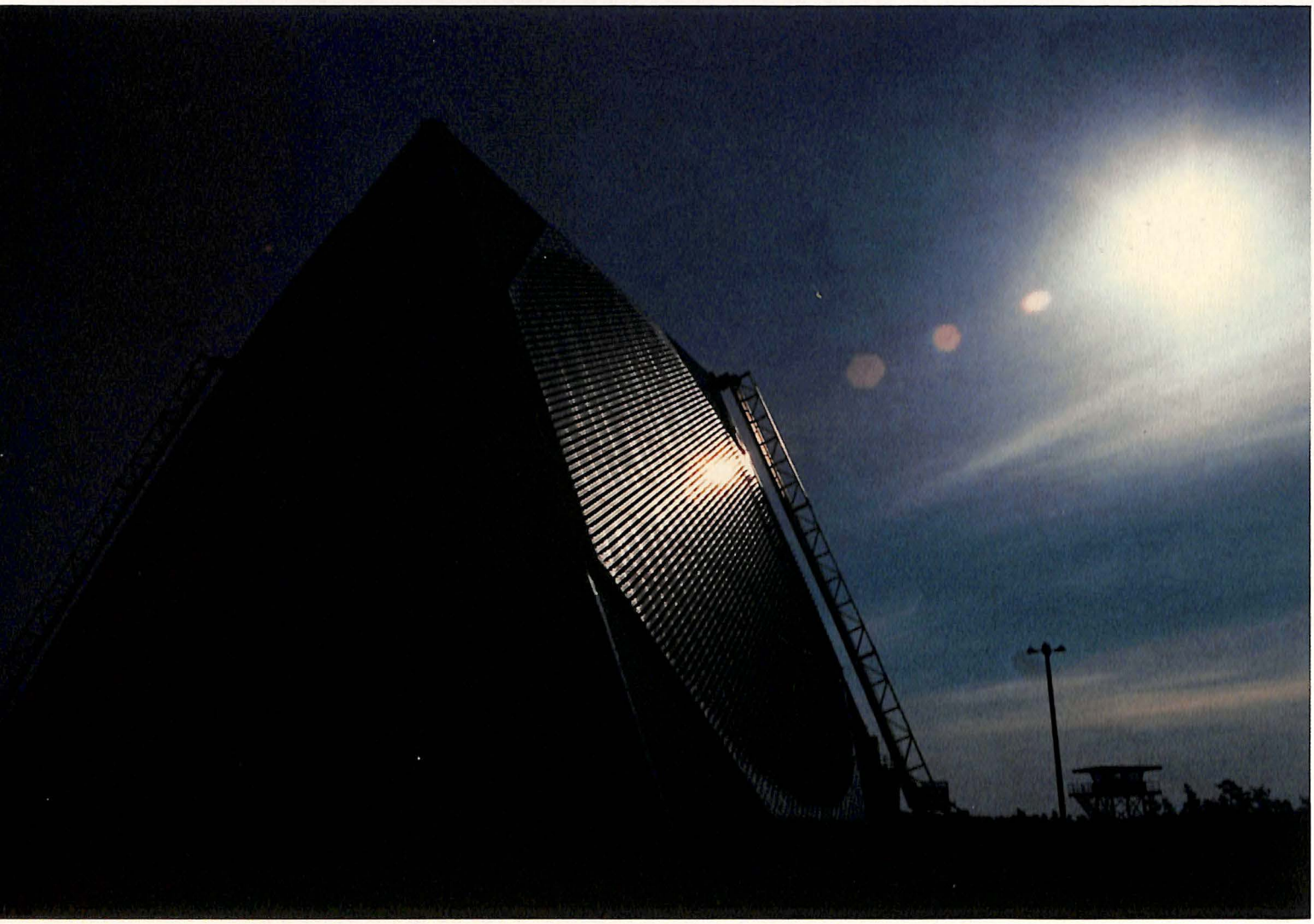
Composite Molding. Seeking an improved method of molding composite materials, United Technologies Defense and Space Systems Group performed IR&D that resulted in development of an "isostatic" process that enables molding rocket motor parts in a single operation. One-step processing eliminates bonding and assembly problems, reduces manufacturing costs and cuts product loss.

NORTHROP

Thermoplastic Composites. Northrop Advanced Systems IR&D in an area of structures/materials technology known as thermoplastic matrix composites, or TMCs, resulted in development and demonstration of TMC fabrication processes, plus fabrication of full-scale prototype structural composites suitable for advanced aircraft applications.

GRUMMAN

Composite Structures. Under IR&D, Grumman Corporation has developed advanced composite structures optimized for structural efficiency, aeroelastic performance and life cycle cost. The effort has generated many government contracts, including the X-29 Technology Demonstrator.



High Intensity Cooling. Sundstrand IR&D in heat transfer resulted in development of a high intensity cooling concept for such applications as cooling power transistors. Applied to the power transistor package of a torpedo electric propulsion motor, the development allows a 50 percent weight reduction and a 60 percent volume reduction over standard packaging techniques for power transistors.

Thermal Management System. Sundstrand IR&D in zero G heat transfer enabled development of a two-phase thermal management system that offers savings in power and weight. It is applicable to the NASA Space Station and to contemplated Strategic Defense Initiative space systems.

HERCULES

Electric Motor/Controller. Hercules Aerospace IR&D resulted in development of a high performance brushless electric motor and controller whose improved performance, reduced maintenance and increased motor reliability enables application of electromechanical actuators to primary flight controls.

BOEING

Power Systems. Continuing IR&D by Boeing Electronics Company on power processing and control has produced successful advances in a number of areas and promises increased performance, reliability and maintainability, coupled with reduced weight, volume and cost, for aircraft, missile, space and ground-use power systems.

NORTHROP

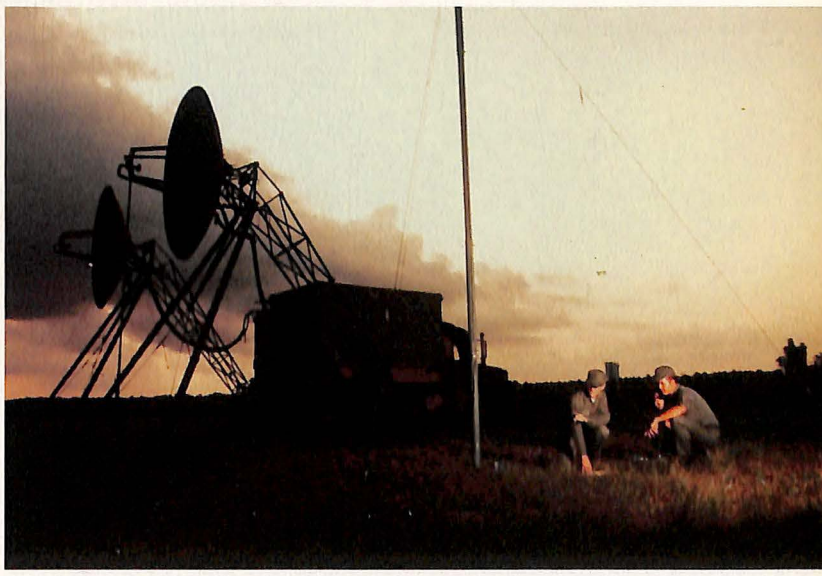
Power Supply. A key result of Northrop Defense Systems IR&D over a 1975-85 span is development of high voltage power supplies for traveling wave tubes with considerably reduced volume/weight and substantially greater operational efficiency. The technology is applicable to the internal electronic countermeasures set of the F-15 fighter.

IBM

Power Processing. IR&D in power processing technology at IBM Owego focuses on ways to make electronic data processing equipment smaller and more reliable. Among research areas are identification of loss mechanisms, development of circuits for power conversion at very high frequencies, circuits to control power factor and electromagnetic interference. In addition to many military uses, the work has immediate applications in commercial and industrial hardware.

Lockheed

Satellite Power. Evolution of satellite systems has resulted in requirements for increased power levels, more efficient performance of power systems, longer life and, in military systems, radiation hardening. A Lockheed IR&D effort developed more compact, more efficient and more reliable power supply circuits that afford fivefold savings in size and weight.

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UNITED TECHNOLOGIES SIKORSKY AIRCRAFT

Flying Test Bed. Tomorrow's utility and attack helicopters will be required to fly nap-of-the Earth patterns, in some cases with only a single pilot, a prospect that demands assessment of the effect on crew workload and the potential benefits of advanced systems. For such assessment, Sikorsky (now part of the UTC Defense and Space Systems Group) had developed—under IR&D funding—the *Shadow* experimental flight demonstrator helicopter which, equipped with a number of advanced cockpit systems, significantly advances the Group's design capability by allowing the company to choose the optimum configuration for a given mission at reduced cost.

NORTHROP

Ring Laser Gyro. Northrop Research & Technology Center IR&D on ring laser gyro optics for inertial navigation systems focused on development of low-loss mirrors for strategic missiles and magnetic mirrors for tactical applications, key areas of the ring laser gyro development because the gyro's performance depends on the quality of the mirrors. Northrop Research has developed ring laser gyro materials, techniques and processes applicable to current and future missile guidance systems.

Signal Processor. IR&D by Northrop Electro-Mechnical Division is investigating signal processing software hardware designed to improve automatic target detection, classification and tracking. The work resulted in development of a multisensor Generic Signal Processor applicable to a variety of airborne and surface platforms and capable of combining a number of image/signal processing functions, such as tracking, cueing, multiple data fusion and targeting handoff in real time.

BOEING

Flat Panel Displays. Continuing IR&D by Boeing Electronics Company, started in 1984, concentrates on monochromatic flat panel displays for aircraft cockpits. The technology is intended to replace cathode ray tubes, thereby allowing reductions in volume (60 percent), weight (70 percent); power (80 percent); and life cycle cost (50 percent).

Lockheed

Avionics System. Lockheed Corporation is engaged in an IR&D technology demonstration involving development, fabrication and flight testing of an innovative avionics system for tactical air transport vehicles. The system is intended to provide comprehensive automatic aircraft control for reduced pilot workload and expanded mission capabilities.

Head-Up Display. Pilots of future tactical airlift aircraft will have to fly "head-up"— observing the outside world—while simultaneously monitoring aircraft operating information. Lockheed IR&D toward flight station concepts for airlift missions of the 1990s and beyond has produced many emerging technologies—such as a holographic head-up display—that are being flight tested in the company's C-130 High Technology Test Bed.

Crew Escape System. Lockheed IR&D led to development of a crew escape system for advanced aircraft that allows safe ejection at speeds, altitudes and aircraft orientations that would prove fatal with existing escape technology.

UNITED TECHNOLOGIES

Advanced Radar. United Technologies Defense and Space Systems Group IR&D on synthetic aperture radar and radar missile guidance IR&D has advanced the technology and produced a system for simultaneous radar precision guidance of multiple standoff weapons against multiple surface targets. The technology is being applied in advanced tactical aircraft and in the USAF/Army Joint Stars program to field a common radar and attack control system for land/air battle management.

Honeywell

Infrared Imagers. Many weapon systems employ long wavelength infrared imaging devices that require cooling to low temperatures, and therefore have high logistics costs. Under IR&D, Honeywell has been pursuing novel concepts in infrared detection under IR&D and developing *uncooled* detectors that will drastically lower both initial and life cycle costs, significantly reduce size and improve the ruggedness of infrared imaging systems.

NORTHROP

Day/Night Passive Sensors. Northrop Electro-Mechanical Division IR&D on focal plane arrays (FPA), made possible development of infrared FPA technology that will provide nighttime imaging capability for present day-only TV camera systems used by tactical aircraft for target detection, identification and tracking.

ITT DEFENSE

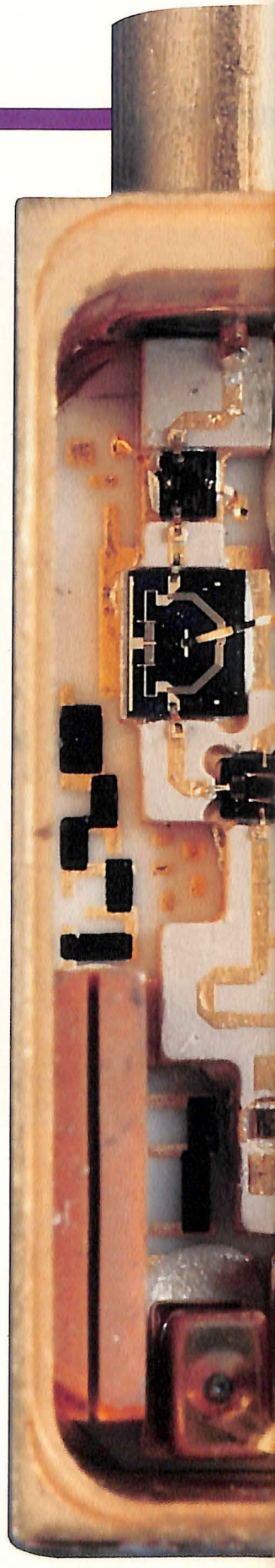
Passive Radar. Conventional radars are readily located by enemy systems that detect transmitted energy, thus are operationally vulnerable to directive jamming, antiradiation missiles and electronic intelligence targeting. An IR&D effort by ITT Gilfillan has generated technology for a passive surveillance system, one that does not transmit energy; it utilizes the energy transmitted from a remote radar emitter, which can be either cooperative or uncooperative, friendly or enemy radar.

LTV

Laser Radar. LTV Aerospace and Defense IR&D toward development of carbon dioxide laser radar sensors led to a USAF contract for design of an Automatic Laser Target Classifer using data collected from real targets in representative backgrounds. It is expected that this technology wil provide a new generation of sensors and signal processors of unprecedented capability, making feasible new weapon systems concepts.

Westinghouse

Tactical Radar Antenna. Westinghouse IR&D on antenna systems, in particular investigation of ultra-low sidelobe arrays for ground-based tactical radar, provided technology for greatly enhanced radar system performance through reduced clutter, reduced sensitivity to obstacles, and reduced vulnerability to jamming.



TRW

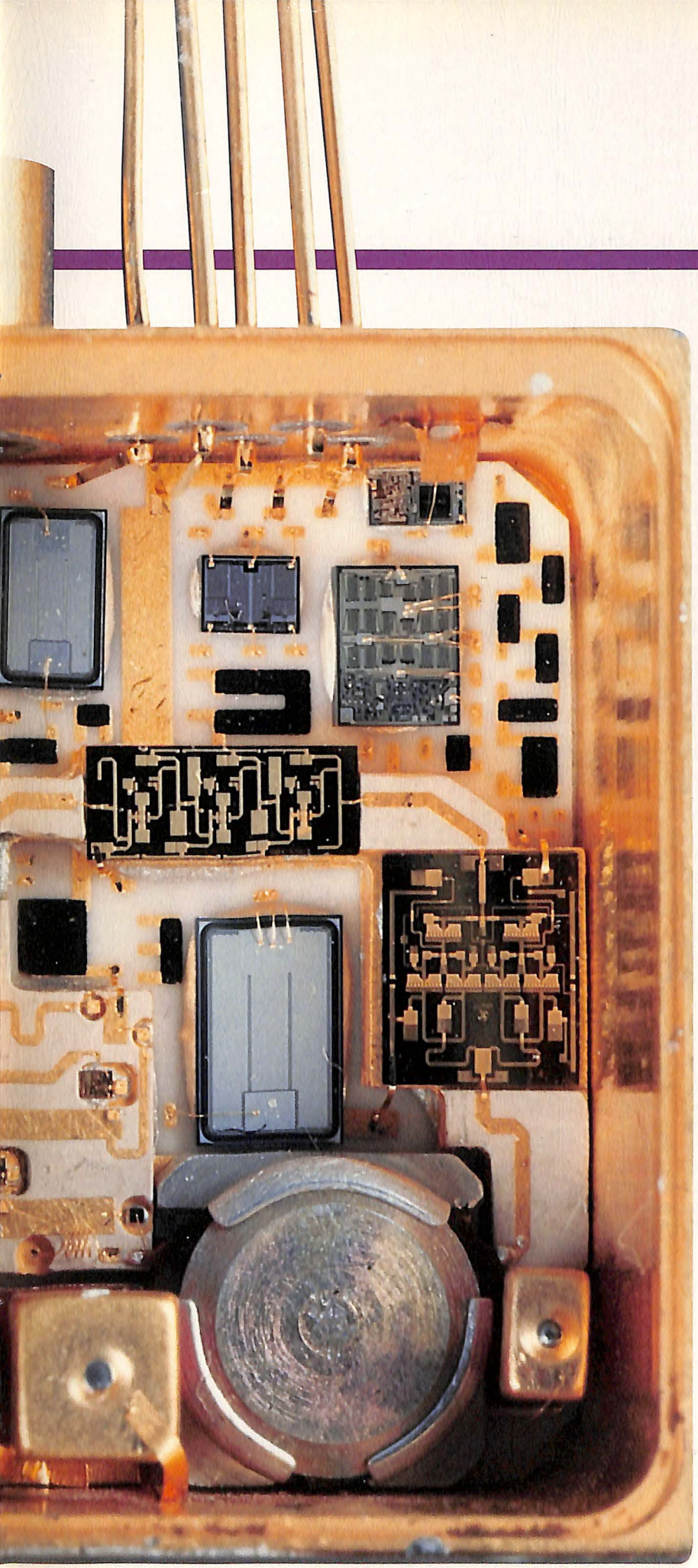
Programmable Processor. TRW IR&D in Very Large Scale integration and Very High Speed Integrated Circuits resulted in development of a programmable processor and the linking of many such processors to attain speeds of seven million characters a second in high speed data search systems. Applicable to Department of Defense text search and improved signal intelligence collection/analysis, the development allows data searches up to 16 times faster than is possible with current systems with fourfold savings in hardware costs.

Honeywell

Advanced Circuits. Large scale IR&D investments by Honeywell in Very High Speed Integrated Circuit (VHSIC) technology helped expedite a new generation of silicon integrated circuits. Among Honeywell VHSIC applications in development are systems for underseas surveillance, space signal processing, automatic target detection and computer-generated imagery for trainers.

UNITED TECHNOLOGIES NORDEN SYSTEMS

Commercial Computer Adaptation. UTC has been designing, developing and building—under license from Digital Equipment Corporation (DEC)—military counterparts of DEC commercial computers with identical software. Used in a large number of defense programs, Norden's military versions provide substantial cost, schedule and performance benefits to the government through use of proven commercial software and low cost computers rather than full "mil spec" computers.



ITT DEFENSE

Very High Speed Circuits. IR&D by ITT/GTC involved development of fabrication techniques for integrated circuits that use gallium arsenide as the semiconductor material and design of circuits applicable to advanced military needs. The development makes possible very high speed signal processing with low power, small size components; it also allows extension of high frequency technology to systems such as radar and communications—where small size and low power consumption can offer significant advantages.

Signal Processing IR&D by ITT Gilfillan resulted in development of two application specific integrated circuits for high speed signal processing that offer increased reliability and significant reductions in power, size and weight.

Advanced Circuits. Multiyear IR&D by General Electric's Aerospace Business Group in monolithic microwave integrated circuits (MMIC) for solid state arrays generated contract awards from the Department of Defense for MMIC applications in radar, electronic warfare and communications systems.

UNITED TECHNOLOGIES PRATT&WHITNEY

Turbine Engine Advances. Propulsion system IR&D by Pratt & Whitney (now a part of the UTC Power Group) resulted in development of an advanced segmented combustor cooling liner concept capable of increasing combustor life three to four times in comparison with conventional sheet metal designs. Concurrent IR&D on advanced materials and cooling technology permitted development of single crystal alloys for turbine blades and advances in film cooling for blades; these develoments combine to allow a significantly increased inspection interval for engine hot sections.

Allison

Hybrid Rotors. More than a decade of IR&D effort by Allison Gas Turbine Division of GM on diffusion-bonded hybrid turbine rotors resulted in a capability to bond separately-manufactured turbine blades and a powder metallurgy disc hub into a single-piece rotor. This allows a major increase in turbine operating temperature and construction of engines with higher power to weight ratios.

Ceramic Components. Allison Gas Turbine Division IR&D on engine components made of ceramic materials has established the feasibility of operating turbines with ceramic components at higher temperatures with better specific fuel consumption and lower cost. A major benefit is reduced dependence on strategic materials normally used in turbine engine manufacture.

UNITED TECHNOLOGIES

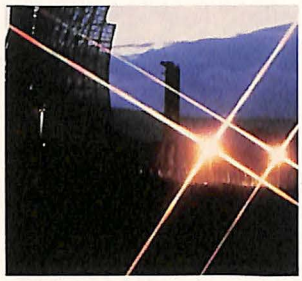
Engine Control Circuits. IR&D by the Controls Group of UTC brought development of CMAMs—Custom Monolithic Analog Modules—which represent a state-of-the-art technology for incorporating components of an engine control system circuit into an integrated silicon chip. CMAMs tested have an average 50 fewer components and 200 fewer interconnections than the conventional circuits they replace, and are approximately 1/13th the size and four times more reliable.

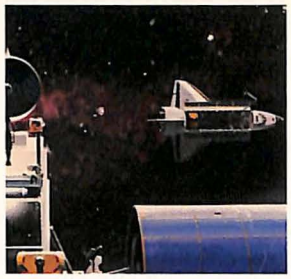
Engine Control Sensors. UTC's Control Group IR&D explored many aspects of pressure transducer technology and resulted in development of small, rugged and less costly precision pressure sensors for application in future electronic engine controls.

TEXTRON

Small Rockets. Bell Aerospace Textron IR&D on miniaturized engines, tanks and components for rocket propulsion systems produced a family of small, lightweight (one to 25 pounds) rocket engines for satellite attitude control and for kinetic energy weapon systems contemplated in the Strategic Defense Initiative.

MEMBERSHIP LIST





Aerojet General

Aeronca, Inc., A Fleet Aerospace Company

Allied-Signal Aerospace Company
- Defense Systems Company
- Aircraft Equipment Company

Aluminum Company of America

Argo-Tech Corporation

B.H. Aircraft Company, Inc.

The Boeing Company

Celion Carbon Fibers
- A Division of BASF Structural Materials, Inc.

Colt Industries, Inc.
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  - Abex Aerospace Division
  - Cleveland Pneumatic Company
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The Interlake Corporation

ISC Defense & Space Group, Inc.
- ISC Marquardt
- ISC Defense Systems
- ISC Cardion Electronics
- ISC Electro-Magnetic Processes
- ISC Datacom/Microwave

ITT Defense Space Group
- ITT Aerospace/Optical Division
- ITT Avionics Division
- ITT Defense Communications Division
- ITT Gilfillan

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Textron Inc.
- Bell Aerospace Textron
- Bell Helicopter Textron
- HR Textron Inc.

TRW Inc.

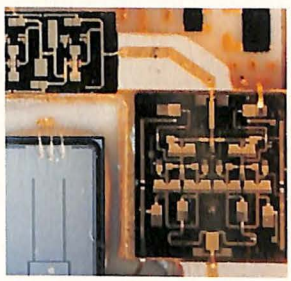
United Technologies Corporation

Western Gear Corporation

Westinghouse Electric Corporation
- Energy & Advanced Technology Group

Wyman-Gordon Company

Zimmerman Holdings Inc.



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Aerospace Industries Association of America, Inc.
1250 Eye Street, NW
Washington, DC 20005