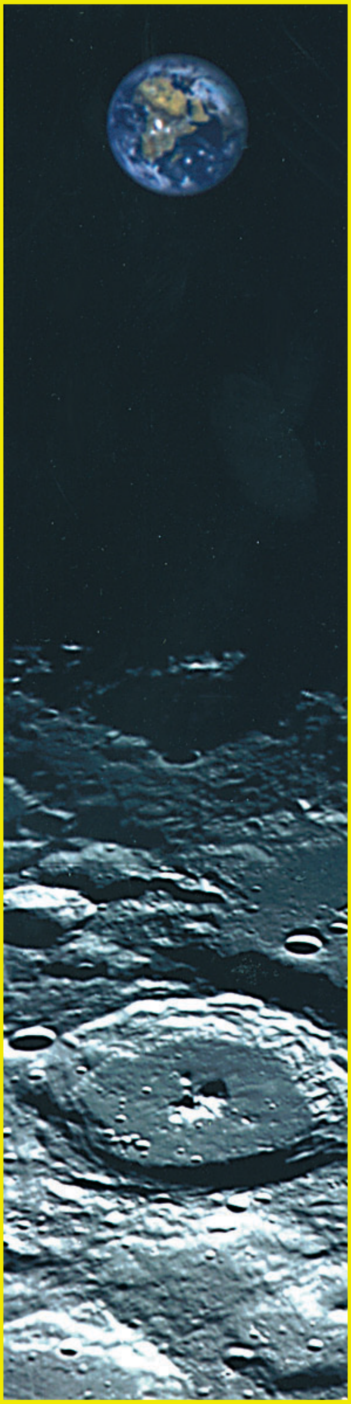
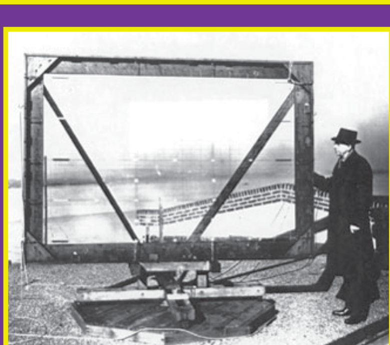
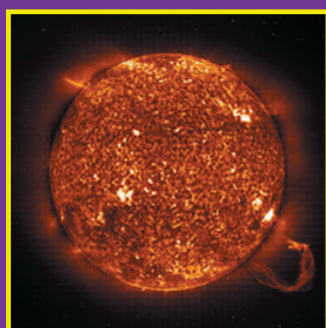
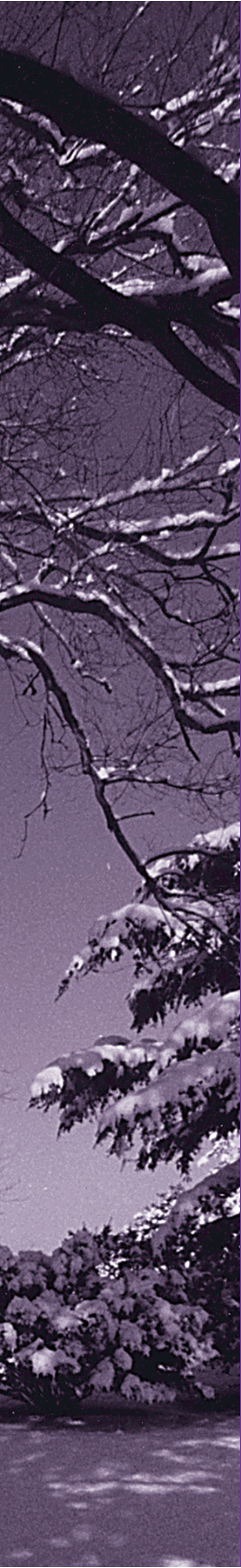


THE LITTLE BOOK of BIG ACHIEVEMENTS

NAVAL · RESEARCH · LABORATORY







As the numbers roll back to zeros, the urge is to pause and reflect. Where have we been, and where are we going? At the Naval Research Laboratory, fresh from celebrating our first 75 years, we're looking both fore and aft, reviewing what we've done and what we do so that we may better navigate our course into the next millenium.

NRL 2000

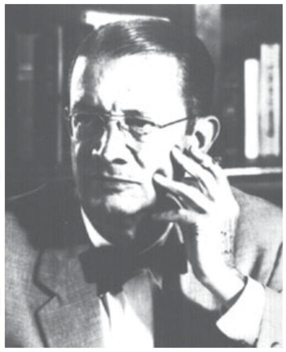
In 1999, we are a crew of 3000, about half of us scientists and engineers. We represent most of the major scientific disciplines and a host of supporting functions. We remain uniquely positioned to respond to the country's call for scientific and technological solutions.

As shown in these pages, we can boast a proud history of rising to the moment. Perhaps our long and impressive string of successes cannot be represented adequately by the 35 short histories offered here. Nevertheless, we hope that this little book will give you a taste of NRL's accomplishments and the time frames in which they occurred. While it is understood that large projects, from conceptualization to completion, generally go beyond easily traceable dates, we present here ranges of years in which the preponderance of work was accomplished for each achievement. We also present a primary reference for each achievement at the back of this book.

As we look back upon our successes, we pledge to apply our varied skills, our unique facilities, and our multidisciplinary approach to meeting problems head-on to the continued betterment of the U.S. Navy and the country.

Gamma-Ray Radiography

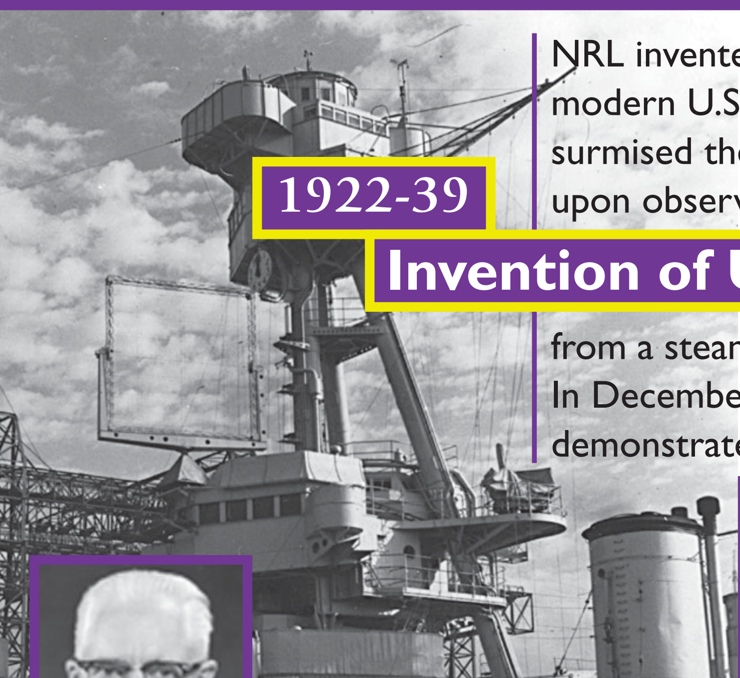
1920s-1930s



R. Mehl

The Naval Research Laboratory's Robert F. Mehl used gamma-ray radiography as a shadowgraphic technique to investigate the extent of suspected flaws in the sternpost castings and welds of new U.S. Navy heavy cruisers. NRL's efforts established gamma-ray radiography's usefulness in nondestructive testing of metal castings and welds. This innovation improved the production of high-quality steel for armor, ship frames, and fittings, thus contributing immeasurably to American seapower.

(Ref. 1)

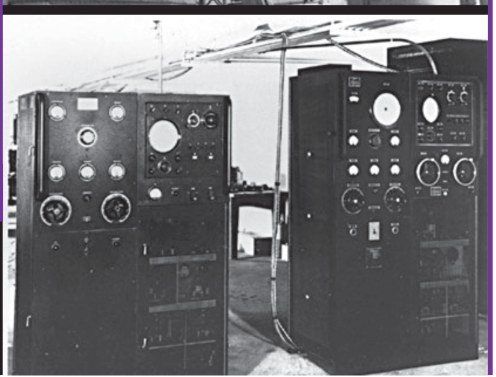


1922-39

Invention of U.S. Radar

NRL invented and developed the first modern U.S. radar. Researchers first surmised the principles behind it in 1922 upon observing "phase distortion" in radio waves reflected from a steamer on the Potomac River. In December 1934, NRL's Robert Page demonstrated the world's first pulsed radar. In 1939, NRL installed the first operational radar aboard the battleship USS *New York*, in time for radar to contribute to the victories of the Coral Sea, Midway, and Guadalcanal. Today, radar is a major player in transportation, weather forecasting, astronomy, and automation. (Ref. 2)

R. Page



1925 1926

Radio Propagation and the "Skip-Distance" Effect

NRL's discovery of the principles behind "skip-distance effect" laid the basis for modern HF wave propagation theory. "Skip distance effect" refers to radio signals reappearance at a considerable distance varying with frequency, time of day, and season. NRL's modification of Sir J. Larmor's theory on HF propagation explained the effect based on experimental data. This in turn led to NRL's later invention of over-the-horizon radar.

A.H. Taylor *E.O. Hulburt*

(Ref. 3)

1939 Proposal of a Nuclear Submarine

Soon after the discovery of atomic fission, Enrico Fermi addressed a meeting of Navy officials and civilian scientists. While other meeting participants dreamed of nuclear weapons, NRL's Ross Gunn envisioned using nuclear power for submarine propulsion. His efforts would make NRL the first to conceive, propose, and investigate this revolutionary concept. The atomic-powered submarine would become one of the most formidable weapons systems ever devised. (Ref. 4)

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

1 June 1939

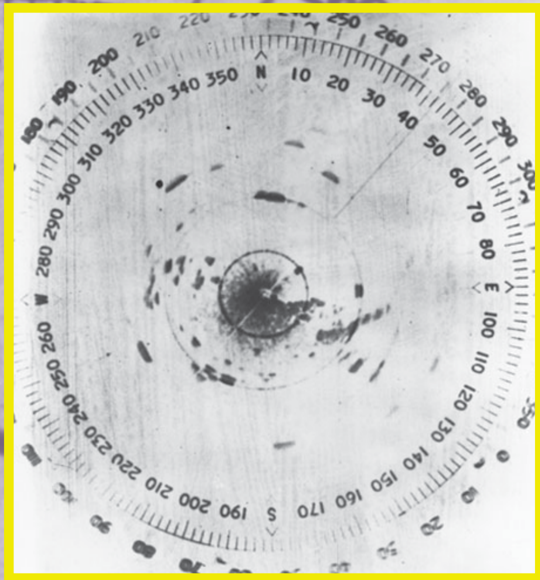
MEMORANDUM FOR THE DIRECTOR

Subject: Submarine Submerged Propulsion - Uranium Power Source - Status as of this date

1. Under certain special circumstances of bombardment by neutrons, the heavy element uranium dissociates into two other elements with the evolution of tremendous amounts of energy which may be converted directly into heat and used in a flash boiler steam plant. Such a source of energy does not depend on the oxidation of organic material and therefore does not require that oxygen be carried down in the submarine if uranium is used as a power source. This is a tremendous military advantage and would enormously increase the range and military effectiveness of a submarine.

1939-1940

Plan-Position Indicator



When NRL demonstrated the first U.S. radar, the XAF, during Fleet exercises in 1939, a clear need arose for a display that would show the range and bearing of all targets "visible" to the radar. NRL responded by developing the PPI, with its well-known round face and sweeping hand. It was also being developed independently in England at the same time although neither country knew of the other's work. The PPI is now used worldwide in detection, navigation, air traffic control, and object identification radar systems.

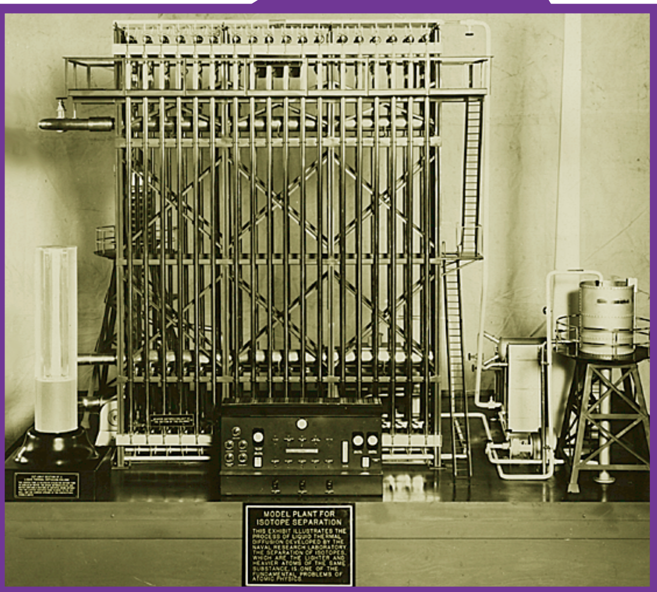
(Ref. 5)

1939-1944

Liquid Thermal Diffusion Process

Pioneering research by NRL yielded the first separation of uranium isotopes by the liquid thermal diffusion process, invented by NRL's Philip Abelson. This process was one of the three methods used by the Manhattan Project to obtain the enriched uranium necessary to make the first atomic bombs. The uranium separation plant in Oak Ridge, Tennessee, was built in 1944 to the blueprints of NRL's plant.

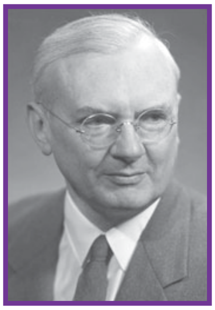
(Ref. 6)



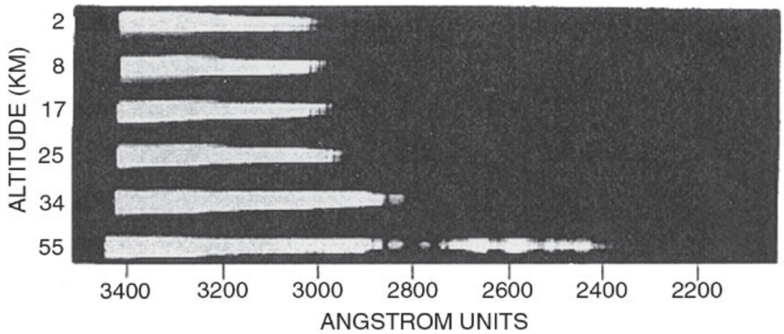
1 · 9 · 4 · 6

First Far-Ultraviolet Spectrum of the Sun

By using captured German V-2 rockets, NRL obtained the first far-ultraviolet spectrum of the Sun from beyond the atmospheric boundary. This feat was featured on the front page of the *Washington Post* and later in the *New York Times*, *Times Herald*, and *Washington Star*. More importantly, this achievement heralded the birth of both space-based astronomy and the U.S. Navy's space program.



R. Tousey



(Ref. 7)

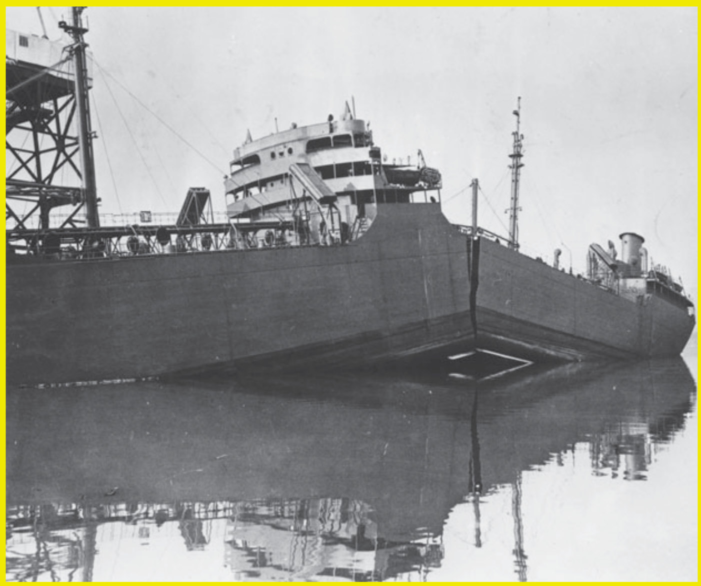
1947

Synthetic Lubricants

When the U.S. military needed lubricants that could maximize the performance of their new gas turbine-powered aircraft, especially in combat, NRL answered the call. NRL chemists conducted fundamental studies relating molecular structure to lubrication and temperature/viscosity and then used the results to develop the first hydrocarbon ester lubricants. By the early 1950s, NRL-developed lubricants were used in Navy turbine engine aircraft and soon after in virtually all military and civilian gas turbine-powered aircraft. (Ref. 8)

W. Zisman

1947 The Principles of Fracture Mechanics



NRL's G.R. Irwin pioneered modern fracture mechanics. He studied the relationships between applied stresses and cracks or other defects in metallic materials and enabled the first calculations of the strength of structures containing defects. NRL used those principles to solve commercial jet aircraft and Polaris missile fracture problems. Fracture mechanics is used worldwide to design such critical structures as nuclear reactor pressure vessels, aircraft, submarines, and toxic material storage tanks.
(Ref. 9)

1949 First Detection of X Rays from the Sun

H. Friedman

Again using a V-2 rocket, NRL first detected X rays from the Sun, confirming that the Sun is the principal cause of ionization in the E region of the Earth's ionosphere. This greatly improved understanding of the Sun's effect on radio communication, especially at HF frequencies. NRL's H. Friedman, who directed this effort, received the National Medal of Science and the Wolf Foundation Prize in recognition of his contributions to X-ray astronomy.
(Ref. 10)

1952-1963

Why did *Liberty* ships in WWII break up dockside in calm waters?

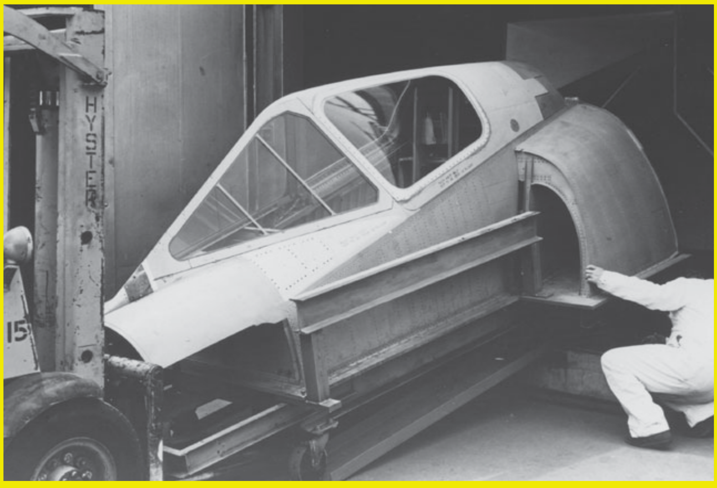
Fracture Test Technology

Needing to build reliable ships and to safeguard their crews, the Navy turned to NRL for the answers. NRL responded by developing new engineering approaches to designing ships and selecting materials based on metallurgical principles. Research in brittle fractures is still relevant for today's high-performance Navy craft and armaments. NRL-developed test methods, including the Dynamic Tear Test and the Explosion Bulge Test, have been applied to submarine design and to proving the superior fracture resistance of HY-80 steel.
(Ref. 11)

1953-1961

Improved Aircraft Canopy and Window Materials

NRL's pioneering research in fracture mechanics soon met its first practical application – the failure of combat aircraft canopies, which was a serious source of fatal accidents. NRL researchers gauged the toughness of canopy materials by shattering hundreds of aircraft canopies with projectiles and then carefully reassembling them to trace the crack paths. This research led to collaborative efforts with the Air Force and commercial manufacturers to introduce stretched acrylic plastic for military canopies, which provides increased toughness, reduced weight, and prolonged service life, and is now in use in both military and commercial aircraft.
(Ref. 12)



1955-59

Vanguard Program
The Rocket

NRL conducted the first American satellite program, Project Vanguard, as the U.S. participation in an international effort to study the Earth's physical properties. NRL's task was to design, build, launch, place into earth-orbit, and track an artificial satellite carrying a scientific experiment. The contractor for the rocket project was the Glenn L. Martin Company. The program culminated with the successful launch of the three-stage *Vanguard I* on March 17, 1958, only 2½ years after program startup, less than half the time previously needed to successfully launch a new rocket. (Ref. 13)

1955-59

Vanguard Program
Minitrack and Space Surveillance

After the U.S.S.R. launched *Sputnik I* in 1957, tracking foreign satellites became a major national security issue. Designed by NRL as Project Vanguard's tracking component, "Minitrack" demonstrated its capabilities by predicting and tracking the orbits of *Sputnik I* and *Explorer I* before being applied to *Vanguard I* in March 1958. As the world's first satellite tracking system, "Minitrack" was the prototype for tracking networks created for Project Mercury missions and ushered in the era of space surveillance. (Ref. 14)

1955-1961

Over-the-Horizon Radar

When NRL demonstrated the MADRE (Magnetic Drum Radar Equipment) in 1961, it pioneered HF over-the-horizon radar, which can detect targets at distances and altitudes beyond the line of sight. Overcoming the horizon limit gave radar an order of magnitude or more increase in range, and formed the basis for the Air Force's continental air defense radar and the Navy's Relocatable Over-the-Horizon Radar (ROTHR).
(Ref. 15)

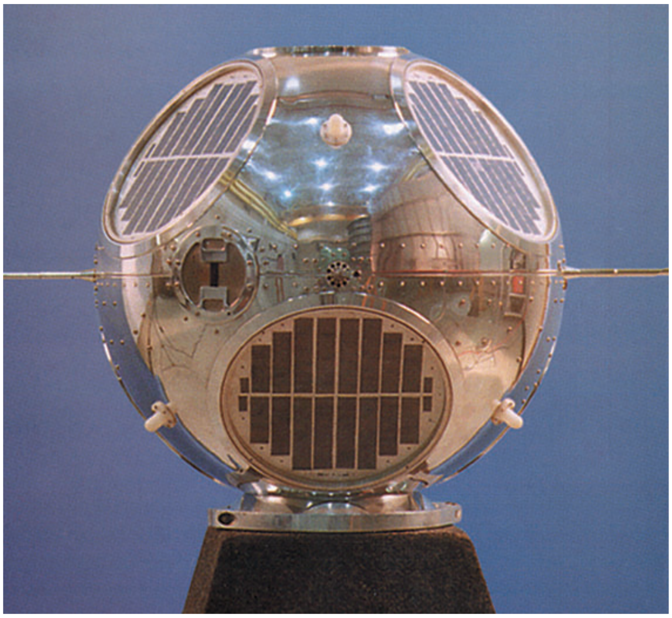
1955-59

Vanguard Program
The Satellites and the Science

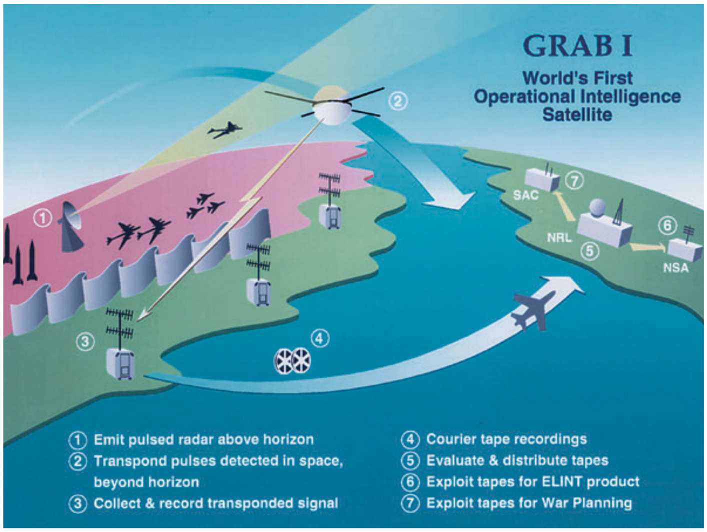
NRL's Project Vanguard was a progenitor of American space exploration. *Vanguard I* achieved the highest altitude of any man-made vehicle to that time, confirmed the Earth's pear shape, initiated the use of miniature circuits, and was the first satellite to use solar cells as a power source. *Vanguard II*, launched in February of 1959, was the first satellite to observe and record the Earth's cloud cover, thus becoming the forerunner of future meteorological satellites.
(Ref. 16)

America's First Operational Intelligence Satellite

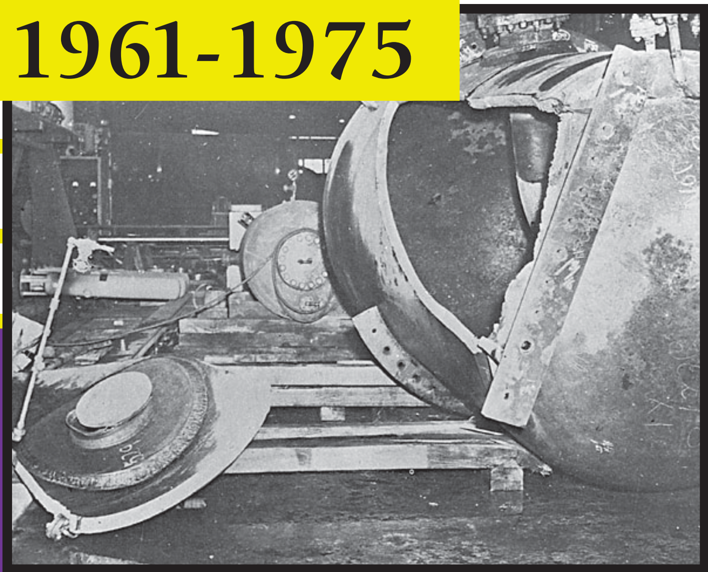
·1960·



NRL's *Galactic Radiation and Background I* (*GRAB I*) satellite was the first U.S. operational intelligence satellite. It was launched in June 1960, only 52 days after a U-2 was lost on a mission over Soviet territory. When *GRAB I* began sending space-intercepted electronic intelligence signals back to Earth, it proved that a spacecraft could collect as much information as all sea, air, and land-based reconnaissance platforms within the satellite's field-of-view. But it could do so at a fraction of the cost and with no personnel risk. The intelligence information it gathered helped to keep the Cold War "cold." (Ref. 17)



1961-1975

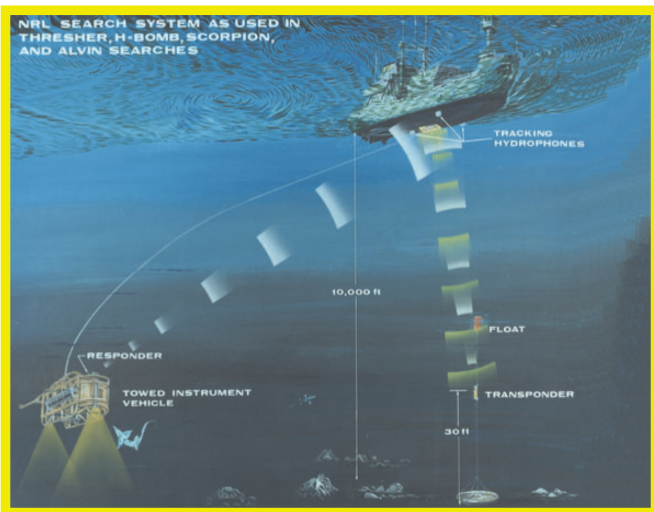


Nuclear Reactor Safety

Starting in the early 1960s, NRL's fracture-test technology was applied to the Nuclear Regulatory Commission's testing of nuclear reactor pressure vessels. NRL evaluated the safety of 12-inch-thick steel as a function of thickness and temperature. This multiyear effort's results are reflected in the ASME Code rules for the operation of nuclear pressure vessels, and a 1975 book by NRL's L. E. Steele became a landmark guide for specialists worldwide. All military and civilian power reactors that feature a steel pressure shell are designed or operated, or both, on the fracture principles developed by NRL. (Ref. 18)

Deep Ocean Search 1963-1970

We can indirectly thank NRL for those ghostly images of the HMS *Titanic*'s final resting place. NRL pioneered this field of crucial importance to the Navy when it responded in 1963 to an undersea tragedy. On April 10 of that year, the nuclear submarine USS *Thresher* and its crew of 129 were lost 260 miles east of Boston. NRL-developed deep-towing technology was called into action. After an eight-month delay due to bad weather, the search resumed, and NRL's "fish" (a deep-towed heavily instrumented unmanned vehicle) detected the *Thresher*'s hull after only eight hours of searching the seafloor. Its photos were later assembled to show the major parts of the sunken submarine. NRL later helped locate and recover a lost H-bomb, and locate and photograph the lost USS *Scorpion* submarine, the deep submersible *Alvin*, and the French submarine *Eurydice*.
(Ref. 19)



1964-1966

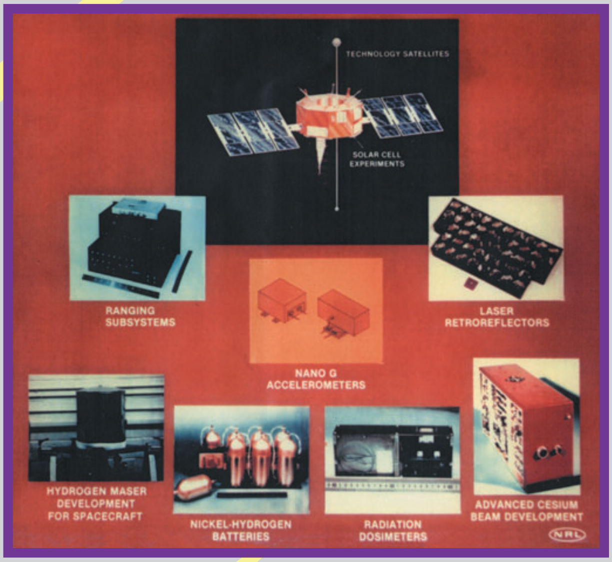
Aqueous Film-Forming Foam

All branches of the U.S. military and NATO, and almost all fire departments throughout the U.S. and many around the world use AFFF, which was developed by NRL in the early 1960s to fight hydrocarbon-based fires aboard ships. AFFF's unique, self-healing capability enables rapid firefighting and also prevents reignition and evaporation of the extinguished fuel.
(Ref. 20)

TIMATION and NAVSTAR GPS

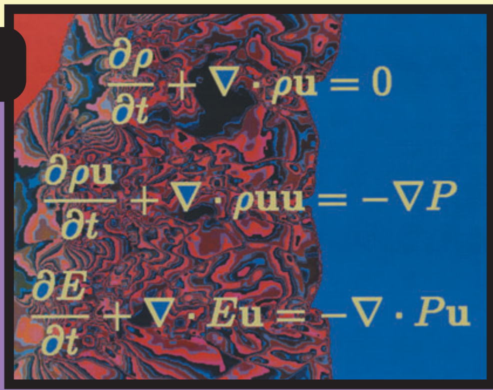
1964-1977

NRL's TIMATION (TIMe/navigATION) program was the progenitor of the NAVSTAR Global Positioning System (GPS). The TIMATION concept led to NRL's invention and development of the first satellite prototypes of the GPS. The 1967 *TIMATION I* and 1969 *TIMATION II* satellite missions were proof-of-concept for a revolutionary navigation system that would use passive ranging techniques and highly accurate clocks to provide three-dimensional (longitude, latitude, and altitude) coverage throughout the world. In 1993, the National Aeronautics Association honored the GPS team for "the most significant development for safe and efficient navigation and surveillance of air and spacecraft since the introduction of radio navigation 50 years ago."
(Ref. 21)



1970-1976

Flux-Corrected Transport

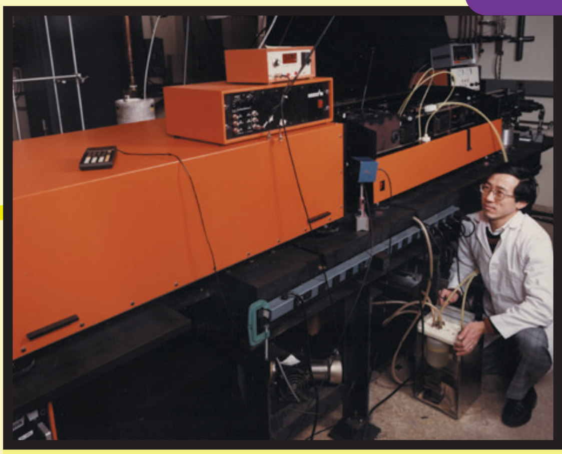


As a result of research performed for the Defense Nuclear Agency in the late 1960s, NRL developed a new technique for solving fluid dynamic continuity equations using computers. Named flux-corrected transport (FCT), the technique enabled far more accurate calculation of shock and steep gradient phenomena by eliminating oscillations, ripples, and numerical diffusion. FCT has been adopted by over 500 laboratories, universities, and companies, and applied to defense and civilian uses ranging from missile silo design to solar weather prediction.

(Ref. 22)

1975-1979

Excimer Laser Technology



The technology behind the late-1990s technique for surgically correcting vision through corneal sculpting sprang from NRL's discovery by S. Searles and G. Hart of the first excimer laser. These lasers operate in the ultraviolet, propagate through gas, and have short-duration pulses that enable the study of fast processes. They can be more tightly focused than can visible spectrum lasers and are more efficient than other UV lasers. This new class of lasers has become a new tool for fundamental research in biology and medicine, and for photolithographic production of semiconductor integrated circuit chips.

(Ref. 23)

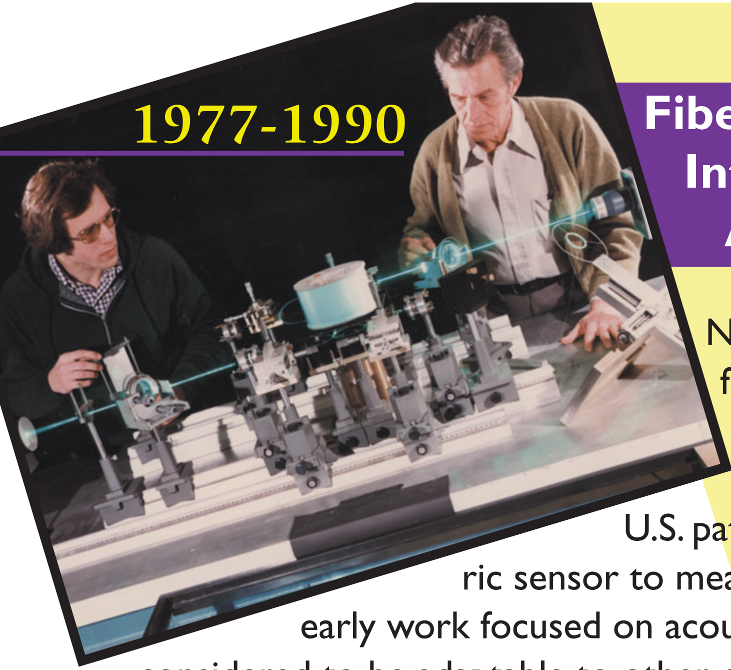
1977-1988

Specific Emitter Identification

In a crucial advance in electronic intelligence gathering, NRL scientists discovered how to uniquely identify specific radar transmitters by their particular signal "fingerprint," catalog the radar's host platforms, and "handoff" these emitters for tracking by other systems. The National Security Agency recognized NRL's concept and equipment in 1993 as the SEI national standard after a competition among industry and other service laboratories. SEI systems are currently deployed on ships, aircraft, submarines, and ground sites throughout the armed services.

(Ref. 24)

1977-1990



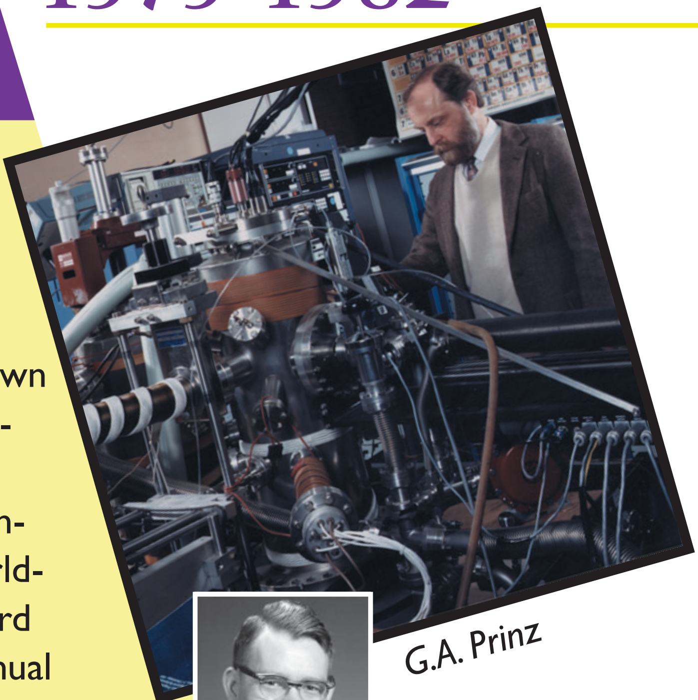
Fiber-Optic Interferometric Acoustic Sensors

NRL demonstrated the world's first fiber-optic interferometric acoustic sensor in 1977. In 1979, NRL received the first U.S. patent for an optical interferometric sensor to measure external fields. Although early work focused on acoustics, NRL's device was considered to be adaptable to other external perturbations, such as electric and magnetic fields and temperatures, depending on the fiber coating and mounting structure used. NRL's follow-on fiber-optic sensor system (FOSS) program was the first Navy/DoD project to center on the development of fiber interferometric sensors. Future applications of this technology should result in more accurate acoustic, magnetic, electric, thermal, vibration, and flow sensors and, in turn, impact military operations, medical care, and nondestructive evaluation. (Ref. 25)

Magnetic Materials and Semiconductor Technology

1979-1982

Pioneering work by NRL led directly to the discovery by three other laboratories in France and Germany, of the giant magnetoresistance effect of Fe/Cr multilayers grown epitaxially on GaAs. The use of magnetic films on semiconductors for sensors is now widespread. This technology is now commonly found worldwide in read heads for computer hard disks and will impact the $100 B annual magnetic computer memory market. It also promises better performance of satellites, missile guidance, and aircraft navigation. (Ref. 26)



G.A. Prinz

J.J. Krebs

Semi-Insulating Gallium Arsenide Crystals 1979-1989

NRL in the 1970s developed a method of growing high-purity single crystals of gallium arsenide (GaAs), thus sparking tremendous growth in the production and use of GaAs semiconductors. The high purity allowed ion-implantation of the crystals to produce micrometer and millimeter wave devices and integrated circuits. NRL was also instrumental in transferring the technology to industry. Starting from an investment of only $528,000, NRL research yielded a technique estimated by the Navy in a 1986 study to save the Department of Defense approximately $560 M between 1979 and 1989. The technique also was less expensive to perform, and thus brought the U.S. more than 65% of the GaAs wafer production business in 1997 compared with virtually zero percent in 1980. This technology is the basis of many military radar, weapons, and communications systems, and commercial radar, satellite, and cellular communications systems. (Ref. 27)

1980-1985

Permanent Magnet Materials

NRL's N.C. Koon was the first scientist to explore the rare-earth-iron-boron alloys' magnetic properties for use as permanent magnet materials. NRL did the first work in this area and holds the fundamental U.S. patents. These materials are attracting both military and industry interest for their potential application to microwave tubes, sensors, electric motors and generators, computer peripherals, and faster, more compact actuators. (Ref. 28)

B. Bas

N.C. Koon

1982-1998

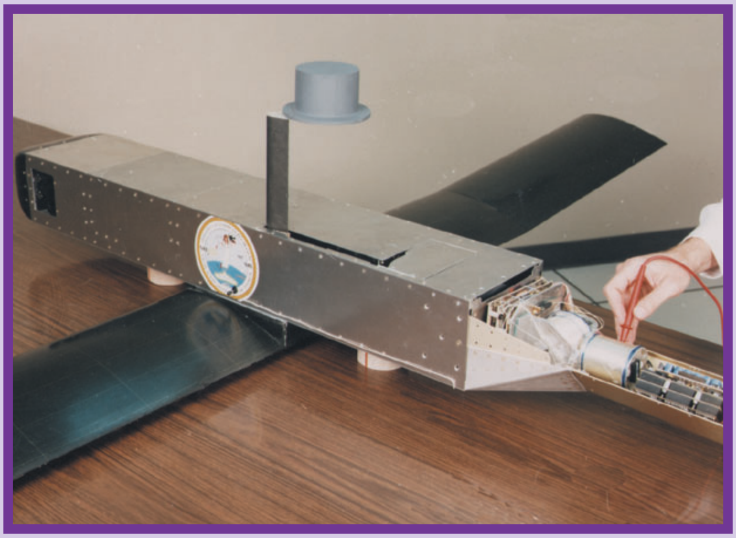
Generalized Nearfield Acoustical Holography (GENAH)

This new measurement technique, developed and implemented by NRL, has revolutionized experimental acoustics in the area of noise characterization and control throughout the world. From a single array measurement, GENAH can provide a complete global analysis of the vibration, radiation, and scattering of structures in air and underwater. This has significantly improved efforts to produce quieter U.S. submarines. Major acoustical measurement companies have applied this technology to noise control in automotive and aerospace industries. (Ref. 29)

1983-1986

Optical Fiber Gyroscope

NRL's demonstration of long-term, inertial-quality performance in a fiber-optic gyroscope was a pivotal milestone in the device's development into a practical, precision navigation instrument. With a longer lifetime, higher reliability, and lower weight, size, and cost than spinning mass gyroscopes currently in use, the fiber-optic devices represented a revolution in rotation-sensing technology. These devices are impacting both military and commercial navigation and are being produced in the U.S., Europe, and Japan.
(Ref. 30)



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Molecular Structure Analysis and the Nobel Prize

NRL's J. Karle and H. Hauptman were awarded the Nobel Prize for Chemistry in 1985 for devising direct methods of determining complex crystal structures by using X-ray diffraction analysis.

I. Karle, building on this work, developed methods that led to the analysis and publication of the molecular structures of many thousands of complicated molecules annually.

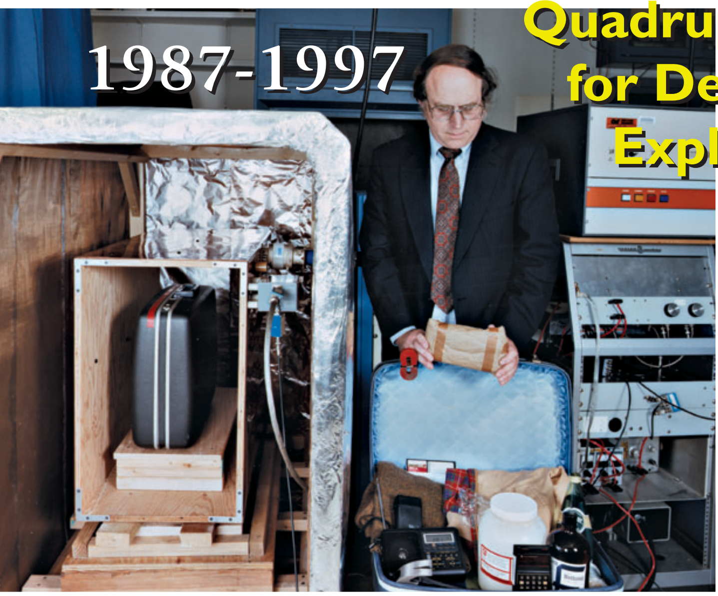
This methodology has enabled the characterization of potent toxins, antitoxins, heart drugs, antibiotics, anti-addictive substances, anticarcinogens, anti-malarials, and explosives and propellants. (Ref. 31)

J. Karle and I. Karle

H. Hauptman

1987-1997

Application of Nuclear Quadrupole Resonance for Detection of Explosives and Narcotics

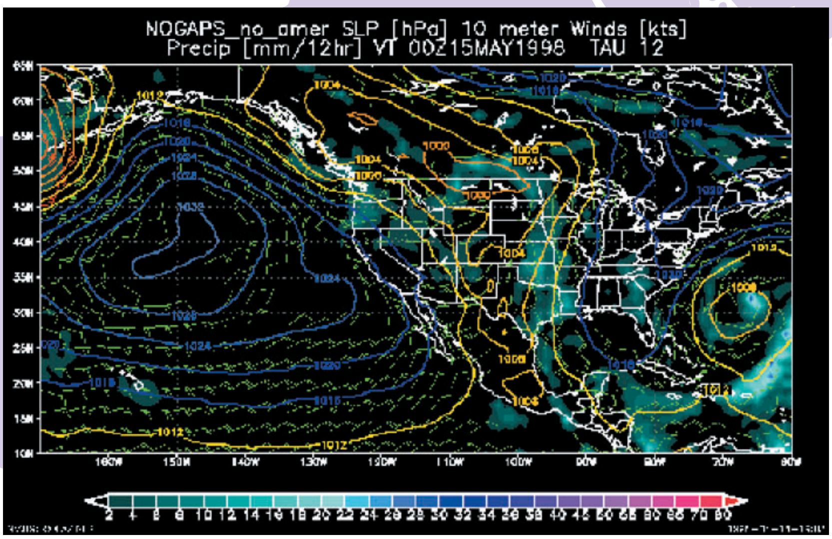


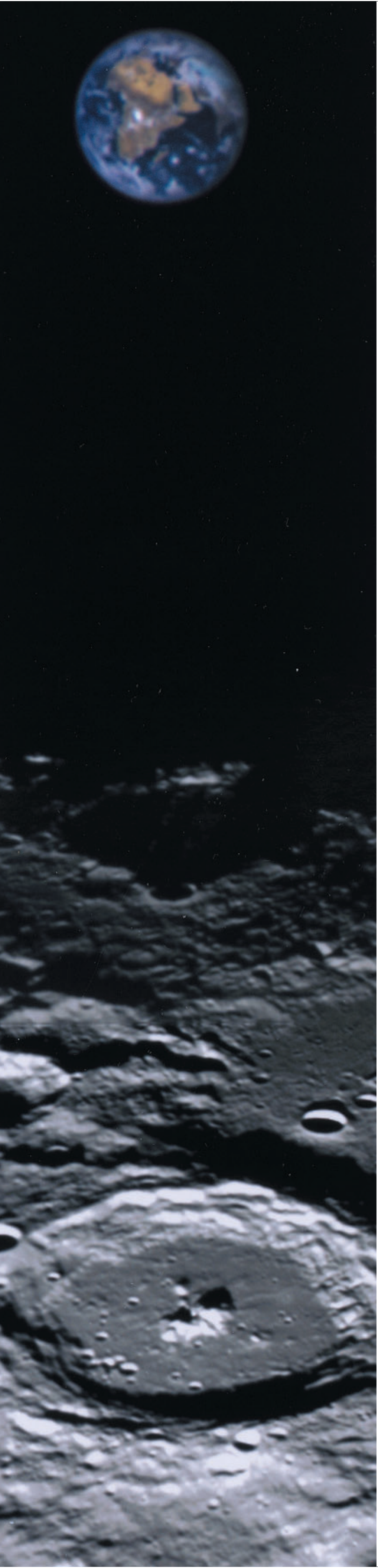
NRL applied nuclear quadrupole resonance (NQR) to the detection of explosives and narcotics, thus giving a major boost to the U.S. war against drug smuggling and terrorism. NRL overcame several major technological impediments in fielding the equipment and transferred the technology to industry for production. This NRL-developed technology has been recommended for use in airports for package and baggage scanning, and is under investigation for mine detection, which is a worldwide military and humanitarian priority. (Ref. 32)

1988-1992

Navy Operational Global Atmospheric Prediction System

NOGAPS is a unified global weather analysis/forecast system that predicts the weather in areas of DoD operations worldwide. This NRL-developed system provides global atmospheric and oceanographic support, including cloud cover prediction, estimation of weather effects on weapon systems, tropical cyclone formation and movement, and high seas warnings. Other government users of NOGAPS weather products include the Coast Guard, NOAA, and DoE. (Ref. 33)





Deep Space Program Science Experiment (*Clementine*)

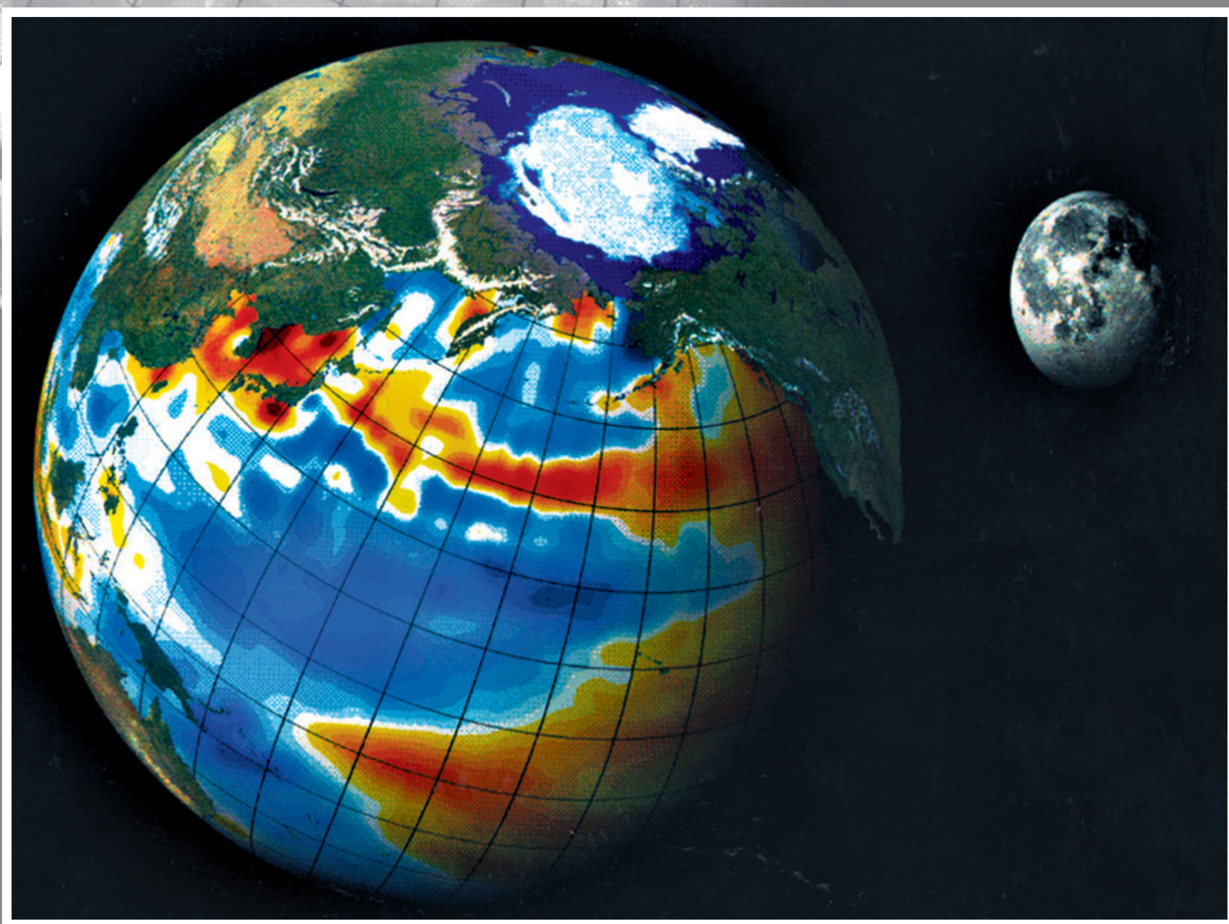
1991-1994

A joint NASA/DoD study concluded in 1991 that a deep space mission could test Ballistic Missile Defense Organization technological developments and simultaneously yield significant scientific return by imaging both the Moon and the asteroid Geographos. NRL was tasked with mission design, spacecraft engineering, spacecraft manufacture and test, launch vehicle integration, terrestrial support, and flight operations. When NRL successfully placed the *Clementine* satellite in lunar orbit in 1994, the U.S. returned to the Moon for the first time since the Apollo missions. *Clementine* completed a high-quality multispectral mapping mission of the entire lunar surface. These images will help answer questions in lunar geology and evolution. The mission also proved that the "faster, better, cheaper" goal was attainable: NRL built the satellite in only 22 months (half the usual time) and for 1/5 the usual cost of similar space probes.
(Ref. 34)

1994

Decadal Impact of El Niño

Scientists thought that the long-range effects of El Niño events were restricted to changes transmitted through the atmosphere. But NRL research showed for the first time that the oceanic effects of El Niño events can be extremely long-lived, and indeed may have influenced weather patterns across North America for a decade. *Discover* Magazine named NRL's discovery of the decadal impact of El Niño one of the top 75 science stories of 1994. (Ref. 35)



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Cover photos/images captions:

1. This colorized image showing the full Earth over the lunar north pole was adapted from data taken by *Clementine* in March 1994.
2. The Galactic Radiation and Background (GRAB) satellite was the first U.S. reconnaissance satellite system.
3. Launch of NRL's Vanguard rocket from Cape Canaveral.
4. This plot shows the deviation of Pacific Ocean sea surface temperatures in 1992-1993 from the mean values of the previous seven years. This deviation is evidence of decadal impact of the 1982-1983 El Niño climatic event.
5. The Robert J. Collier Trophy was awarded in 1992 to the Global Positioning System team composed of researchers from NRL, the U.S. Air Force, and three private corporations.
6. Dr. Jerome Karle receives the 1985 Nobel Prize in Chemistry from King Carl Gustav XVI of Sweden.
7. Dr. Robert Page stands next to an antenna developed to test the performance of the 200 MHz radar installed on the USS *Leary*.
8. Image of the Sun in Helium II at 304Å from the Extreme Ultraviolet Imaging Telescope on the SOHO satellite.

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