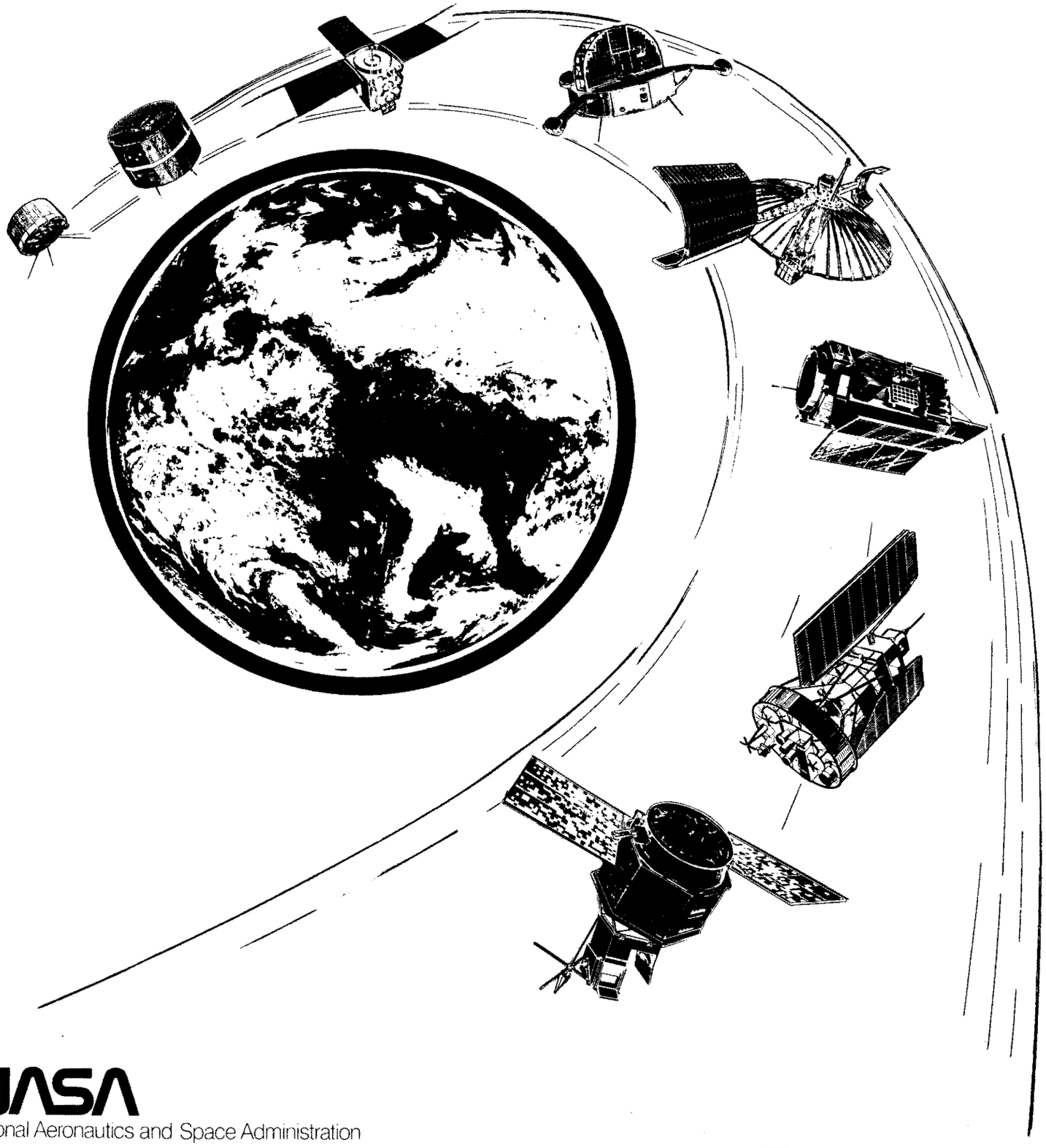


NASA

National Aeronautics and Space Administration

20th ANNIVERSARY

Oct. 1, 1958-78

Robert H. Goddard . . .

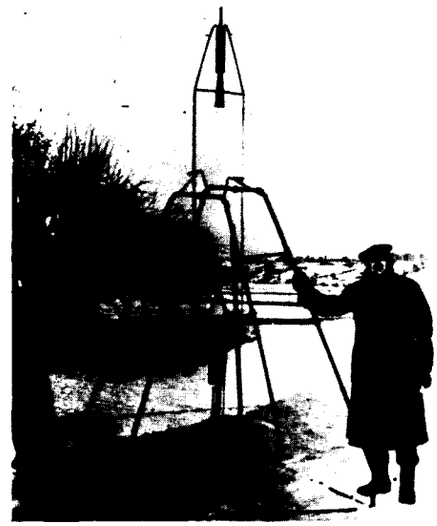
For hundreds of years, rocketry lived with the limitations of the solid, gunpowder-type propellant developed by the Chinese in the 13th century.

Then on March 16, 1926, Dr. Robert H. Goddard, a New England professor, successfully launched the first liquid fueled rocket. It's two-and-a-half second flight at a speed of 60 mph, reached a height of 41 feet above the Earth.

In his diary, Dr. Goddard wrote this description of the rocket's flight: "It looked almost magical as it rose, without any appreciably greater noise or flame, as if it said, 'I've been here long enough; I think I'll be going somewhere else, if you don't mind.' . . . Some of the surprising things were the absence of smoke, the lack of very loud roar, and the smallness of the flame."

The successful flight culminated 17 years of study and experiment by Goddard, who as early as 1909 recognized that solid fuels would never provide the velocities and altitudes achievable with liquid fuels.

When Goddard died in 1946, the importance of his work was still largely unnoticed. But as the United States began to prepare for space travel in the 1950's, American rocket scientists discovered it was virtually impossible to construct or launch a satellite without recognizing the debt they owed to the pioneer of American rocketry.



Right: Dr. Robert H. Goddard stands beside his 1926 liquid fuel rocket.

. . . and his legacy

The Goddard Space Flight Center

Named in honor of Dr. Robert H. Goddard, the Goddard Space Flight Center continues the tradition of this imaginative professor who was also a practical engineer.

Since it opened in May 1959, the center has successfully worked both to advance man's knowledge of the universe, and to use that knowledge to better life on Earth.

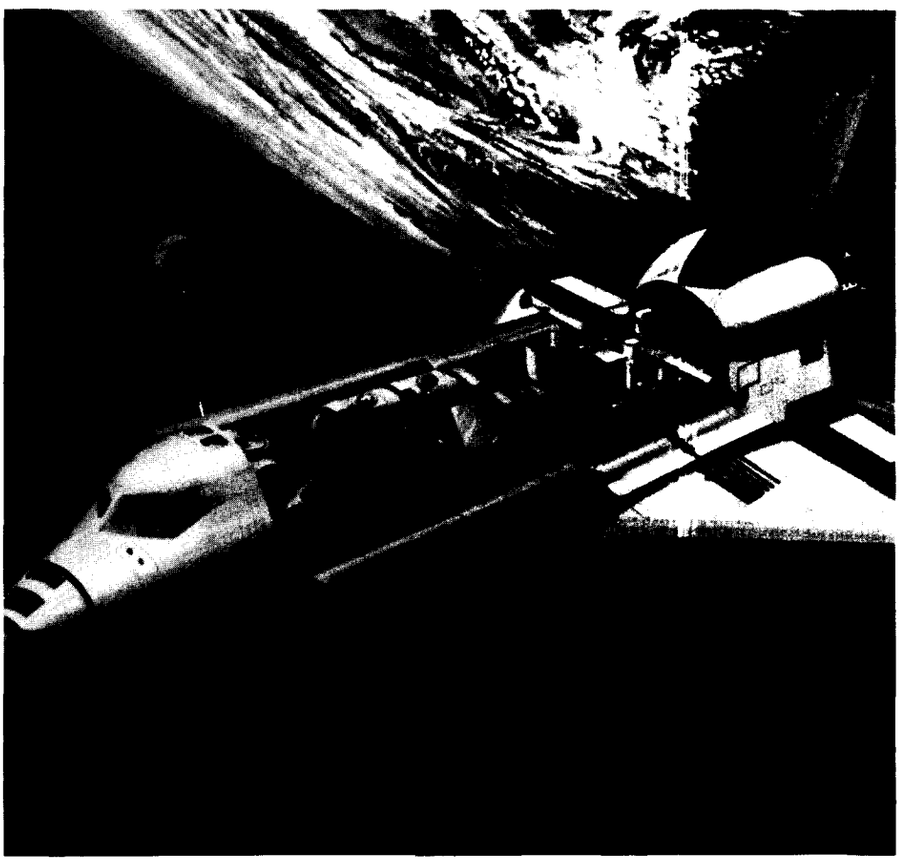
Goddard's work with communications satellites laid the groundwork for low-cost trans-Atlantic telephone calls and radio and television broadcasts. Its research with meterological satellites is revolutionizing studying and predicting the weather. And its Earth resources satellites are developing the means for planners to take constant inventory of the Earth's limited supply of natural resources.

Other Goddard projects look beyond the Earth to set the foundations for future, perhaps yet undreamt of, applications. Balloons, recoverable rockets and satellites study the influence of the Sun on the Earth, and observe the stars and planets to learn more about cosmic processes. Other satellites, along with experiments aboard deep space probes, provide new insights into the physics and chemistry of the atmospheres of our own and neighboring worlds.

Over the years, Goddard has become known as the nation's foremost satellite center. Yet its full capabilities span the entire range of spacecraft activities.

The Center manages the highly successful Delta rocket, which to date has successfully carried out 132 of 144 satellite launches. And Goddard serves as the central control for NASA's world-wide Spaceflight Traking and Data Network.

Goddard is also the home of the National Space Science Data Center, the central repository of scientific data collected from space flight experiments.



The Space Shuttle will routinely carry a wide variety of experiments into space.

Landsat satellites take inventory of Earth's diminishing resources

The now-famous deep space photographs of the Earth from NASA's Apollo lunar spacecraft dramatize the uniqueness of this planet, and especially the fragility of its environment. These photographs have also brought out the global nature of many problems such as pollution, drought, and climatic changes.

A new means of surveying the Earth was thus born with the establishment of the Earth Resources Survey Program in 1965. Satellites and other space vehicles were soon to take on this new role.

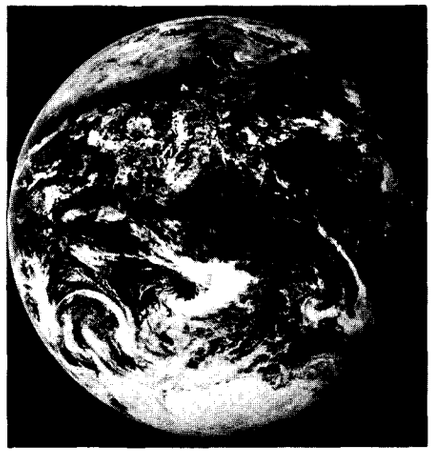
This program has since evolved into an effort to apply space and aircraft technology to global problems now becoming acute: food production, increasing scarcity of metals and fossil fuel supplies, and environmental degradation, to mention just a few.

The program continued to grow, acquiring new and continuing information on such diverse regional activities as forest cutting, changing land use, water storage, and coastal sedimentation effects.

Goddard's role in the Agency's Earth Resources Survey Program includes management of the Landsat satellites along with another series called the Applications Explorer Mission.

To date, the Center has overseen the development and launch of three Landsats. Scientists in over 100 foreign countries have conducted experiments to evaluate Landsat images and other information products. Four nations operate their own ground stations capable of receiving data directly from the satellites and seven others are planning or constructing similiar facilities.

From vantage points high above the Earth, the satellites take an overview of the planet. With special sensors they are able to distinguish different types of crops and to measure varying temperatures on the ground. By repeatly orbiting and scanning the globe, they can trace the patterns of flood, erosion, storms and drought.



The value of studying the Earth from space was first realized from pictures such as this "portrait" of the planet taken by Apollo 17 astronauts (above).

Since then Earth watching has moved from hand held cameras to Landsat satellites. A Landsat view of Cape Canaveral is at left.

Landsat satellites carry radiation detectors that "picture" the Earth in a variety of wavelengths of light. As they radio back their information to Goddard, it is reconstructed and compiled by computer into photographic images of the Earth and other information products that detail areas as small as 40 meters square.

In one major test of Landsat's remote sensing capabilities, Goddard scientists are evaluating use of its imagery for predicting water supplies from snow runoff in mountains. One such program involves the western U.S. mountains and another is underway in the Alps.

Another long term Landsat project, called the Large Area Crop Inventory Experiment (LACIE), was undertaken to evaluate satellite remote sensing for inventorying and forecasting crops yields.

And the two existing Landsats are expected to play a vital role in the 1980 census. They will be used principally for urban land classification mapping to delineate urban area boundaries in support of the census.

Today Landsat data have cut the cost of surveying in some cases to 1/20th of what it was before. And the future rewards of satellite's observing the Earth have been estimated in the billions of dollars annually.

New Earth watch satellites study surface temperatures and geology

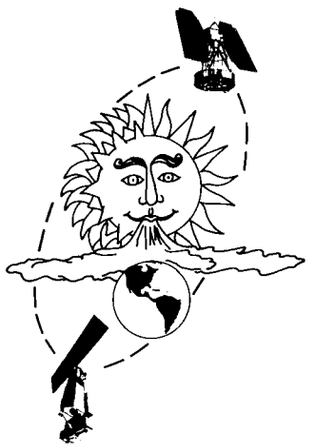
In May, NASA launched a first satellite to map day-night temperature differences of the Earth's surface. Named the Heat Capacity Mapping Mission it is just the first in a new series of Apllication Explorer Mission satellites managed by Goddard.

Researchers will be able to use the temperature information from the Landsat-3 and HCMM satellites to identify rock types, monitor soil moisuture changes and plant stress, and to study the effects of urban heat islands on local weather.

Next year, NASA will launch its first geological applications satellite, termed Magsat. The satellite, which Goddard is now developing, will measure near-Earth magnetic fields on a global basis.

The data Magsat sends back will aid in mineral and oil exploration and in updating world and regional magnetic charts which are necessary for some navigation and surveying.

Atmospheric research satellites prove systems for weather service



The historic trail of meteorology by satellite leads directly to Goddard.

Projects managed here provide the testbed for today's operational weather prediction service and basic research in meteorology.

Early in 1960, the Goddard managed TIROS (Television Infra-Red Observation Satellite) series began laying the groundwork for the National Oceanic and Atmospheric Administration's use of satellites for predicting the weather.

Today a third generation of TIROS Operational System spacecraft provide cloud cover imagery, data relay to small ground stations, and other meteorological service. TIROS-N, first of eight in this new series, is scheduled for launch in Fall, 1978.

Meteorology was introduced to the stationary orbit by the Goddard-managed series of Applications Technology Satellites initiated in late 1966. Positioned over the equator at the stationary orbit altitude of 22,300 miles, a single satellite can view nearly one-third of the globe continuously.

Based on Goddard's Synchronous Meteorological Satellite, NOAA operates the Geostationary Orbiting Environmental Satellite series.

All operational weather satellites are launched by NASA, checked out by Goddard management teams, and then turned over to NOAA's National Environmental Satellite Service.

On the research side, NASA initiated the Nimbus satellite program in the early 1960's. Designed to meet the research needs of the nation's atmospheric and Earth scientists, the Nimbus series is also managed by Goddard. Nimbus-7, the final spacecraft in this series, is due for launch in the Fall of 1978 into a near-polar orbit at about 600 miles altitude as were all of its predecessors. This final Nimbus satellite is designed to monitor man made and natural pollutants in the atmosphere.

Much of the atmospheric, oceanographic, and Earth energy budget information collected with both operational and research satellites is used in the development and validation of numerical models of the atmosphere for the international Global Atmospheric Research Program (GARP).

The GARP is aimed at improving the quality and duration of weather forecasts. Accurate forecasts extending one and perhaps two weeks are believed achievable. The first major experiment to test this thesis is scheduled for late 1978 and early 1979.

Sounding Rockets

Sounding rockets are low altitude, recoverable rockets used for conducting very specific experiments.

Such rockets provided man's first exploration of Space and charted the path for many following satellite experiments.

Goddard supplies launch vehicles and supporting instruments for some 35 to 45 sounding rocket experiments per year. The Center also manages these flights, which are launched primarily from the White Sands Missle Range in New Mexico.

Goddard: birthplace of communications by satellites

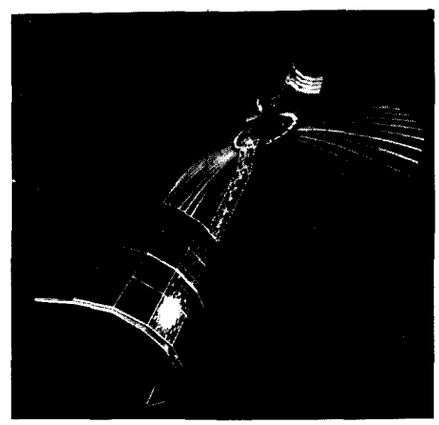
In the 1950's, communications by satellite was an idea, a potential for the future.

Today, most international communications are relayed by commercial satellites. Some 115 countries, territories and possessions have full-time satellite service. Nine others lease satellite time for domestic use. Satellites also provide high quality links for ships at sea.

The genesis for this quiet revolution stems from the dedication of Goddard people. They proved their genius through research first on passive signal reflectors like the 100-foot diameter Echo balloons to the active repeater satellites like Relay, Syncom, and the Applications Technology Satellite series.

The major applications of communications satellites to date have been to provide trunk line services between large, fixed terminals miles apart.

The key to future growth in satellite communications is the broadcast satellite, which can beam signals directly to small rooftop size terminals. One satellite in a stationary orbit could serve thousands of such terminals with interference-free communications.



The Applications Technology Satellite-6 in orbit.

The way already has been paved for such future systems with a myriad of experimental projects using Goddard's Applications Technology Satellite-6 in stationary orbit.

Not only will satellite communications further shrink our globe on the future, they will also make travelling around it a great deal safer.

NASA plans to include an experimental search and rescue monitor on the sixth Tiros-N environmental satellite to be launched in 1982. The monitor will be able to locate within 10 to 20 km. the standard emergency transmitters which all U.S. airplanes and inspected marine vessels now carry by law.

A joint effort by the U.S., Canada and France, this experimental program could be the forerunner to a future system of four satellites providing global search and rescue coverage.

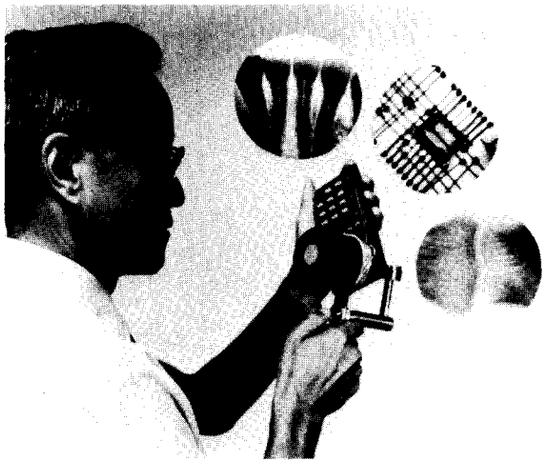
Inventions for space find uses on Earth

When President John F. Kennedy set the goal to land a man on the Moon, the United States began the most predigious technological advance in human history.

Twenty years later, the benefits from space research have reached and enriched many facets of our lives.

Space travel has stimulated new inventions in fields ranging from microcomputers to insulation.

Much of the know-how that resulted could almost instantly be put to use on Earth. Other knowledge has been carefully modified into everyday benefits by programs at NASA centers, dozens of Universities and many private research organizations.



With the pull of a trigger, the Lixiscope sends a low dosage of X-rays from a radioactive source through the object to be examined, and reproduces them instantly on a screen as visible light. The high sensitivity of the Lixiscope makes it possible to reduce the dose of radiation to the patient significantly from levels used by conventional machines.

"Spin-off" technology

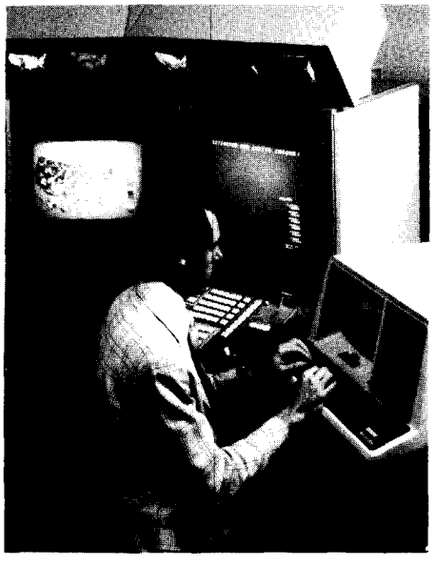
Goddard scientists have "spun-off" new technology for medicine, construction and handling census statistics, to name just a few efforts.

In the medical area Goddard's Technology Utilization Program has used space age components to develop a long lasting rechargable cardiac pacemaker. The device has ended the necessity for heart disease patients to face surgery every two years in order to replace batteries in conventional pacemakers.

One day, medics may be carrying another Goddard designed device to the scene of accidents. Called a Lixiscope, it is a hand held X-ray machine powered by a pocket size battery. The concept for the instrument was originally conceived for use in X-ray astronomy.

In another unique space spin-off, Goddard's NASTRAN computer program for designing space structures found wide application in private industry. It is being used to analyze a computerized design of a building, for example, and predict how it will react to many different conditions of stress and strain. This not only makes possible safer structures, but also offers substantial savings in reduced development time and materials requirements.

A Goddard computer turns census statistics into maps showing national trends.



Mapping census data

To help make reams of census statistics more readily accessible to government planners, Goddard is cooperating with the Census Bureau. Together the agencies demonstrated to Congress and the White House how a space age computer can pull together millions of numbers into easy to read maps—in seconds.

With a program developed by the Census Bureau, a Goddard computer that normally applies satellite imagery to studying the atmosphere, the oceans and other Earth resources, instantly translated stores of housing and education statistics into full-color maps depicting national trends.

The demonstration was requested by the Executive office of the President to stimulate thought about the usefulness of such a system to government analysts and decision makers.

Community applications

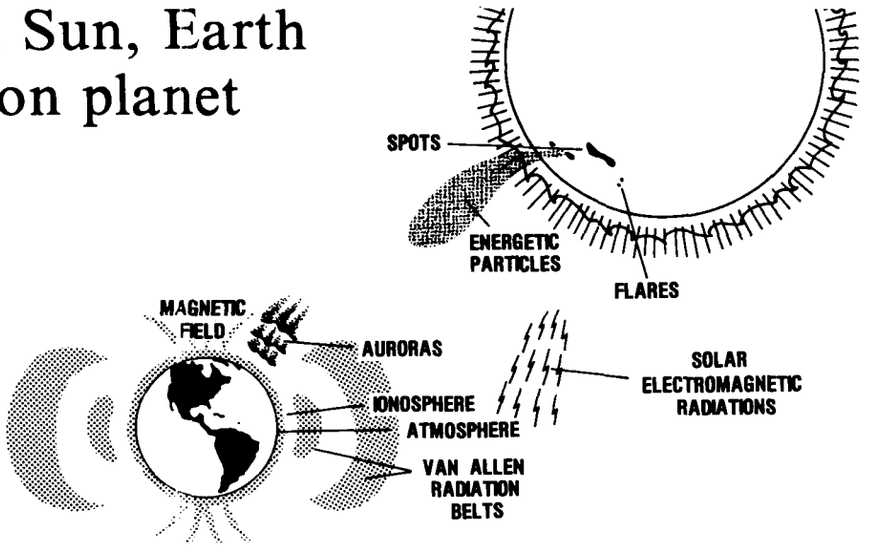
In a special kind of NASA effort to pave the way for community sponsored application of technology benefits from space, Goddard helped design a solar energy project for the town of Greenbelt, Md.

The town's residents, who share utility and maintenance costs, became interested in solar heating in 1973 as a possible means of alleviating rising fuel oil costs. The community asked nearby Goddard to conduct a demonstration of solar heating using four of its homes.

Greenbelt solar energy research homes.

Results to date indicate the solar panel have substituted for almost half of the fuel oil previously needed in the homes for hot water and heating.

Spacecraft between Sun, Earth study star's effects on planet



Space measurements have brought about vast changes in our understanding of the Sun's influence on the Earth.

We no longer simply think of sunlight and warmth coming to the Earth through an almost ideal vacuum. We now know that the Sun also continually emits an energetic stream of charged particles (called the solar wind) that flows about the Earth and outwards to the very limits of the solar system.

Solar particles that pass through the protective boundary of the Earth's magnetic field come into direct contact with the Earth's ionosphere and atmosphere, particularly at high latitudes.

The magnetic field carried within the solar wind interacts with the Earth's magnetosphere-ionosphere to produce electrical variations above the Earth, often resulting in the "visible fireworks" of the auroras.

And evidence is accumulating that solar disturbances and resulting magnetic storms over the Earth may somehow indirectly affect some aspects of our climate and perhaps even the weather.

". . . Goddard satellite research programs play a key role in investigating the consequences of solar terrestrial relationships . . ."

The International Sun-Earth Explorers are investigating the solar wind, with particular interest in wind fluctuations associated with solar flares and coronal holes, which are linked with many types of disturbances occuring about 100 km above the Earth.

The Interplanetary Monitoring Platforms are studying the boundaries of the Earth's magnetosphere, how charged particles are injected into it, and the mechanisms of magnetic storms.

And Atmosphere Explorer satellites are examining changes in the chemistry and dynamic motions of upper atmosphere and ionosphere particles, stimulated by variations in both the solar radiation and the solar wind.

Goddard also cooperatively manages with Germany two HELIOS satellites which are orbiting the Sun. The spacecraft's instruments send back data about radio noise, magnetic fields and energetic particles streaming from the star.

In 1979, at the height of the next 11 year cycle of maximum solar activity, NASA will launch Goddard's Solar Maximum Mission to study the entire electromagnetic spectrum of solar flares to aid in unravelling the mystery of their physical origin.

Future programs including Dynamics Explorer, OPEN (Origin of Plasma in the Earth's Neighborhood), and the Upper Atmophere Research Satellite will provide detailed investigations of the coupling mechanisms by which solar energy in its many forms is transferred within our near-Earth environment.

NASA's 'workhorse' Delta rocket

One of Goddard's most successful programs has been the management of the Delta Launch Vehicle.

Delta rocket number 144 blasts off from Cape Canaveral.

Termed NASA's "workhorse rocket," the Delta has performed with a 90 percent success rate since the first launch in 1960.

To date the Deltas have launched a total of 144 satellites, with only 12 failures.

As NASA prepares to switch the burden of placing satellites and experiments into orbit to the Space Shuttle, Goddard looks back proudly on Delta's contributions.

A Delta rocket launched NASA's first communications satellite, Echo-1, into orbit in August 1960. The program followed with scientific and applications satellites at the rate of eight per year.

Because of its reliability and economy, the Delta rocket has attracted a wide array of non-NASA users in recent years. These have included other U.S. government agencies, industries and a number of foreign countries.

Last year, with almost one Delta launch per month, over half the launches were for foreign or commercial users, who reimbursed NASA for all hardware and launch service costs.

Space age astronomy opens man's eyes to invisible universe

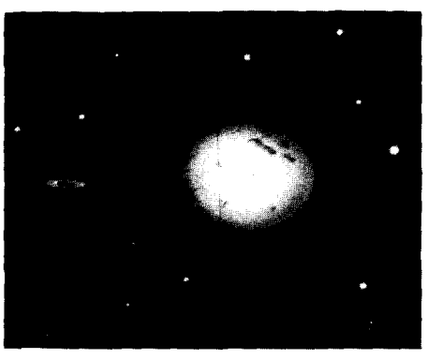
Spacecraft have widened man's window on the universe from a tiny crack to a broad vista.

Until the space age, man could only know of the stars through their visible light and radio waves. The Earth's atmosphere blocked all the rest of the stars' emissions, which cover the entire electromagnetic spectrum, from view.

Each wavelength in the spectrum provides different information about the star. By looking at the different wavelengths in a star's spectrum, one can tell, for example, the relative abundence of its different elements. Such data can then be used to determine, among other things, the age of the star and the chemistry of its atmosphere.

Ultraviolet and X-ray emissions

The first Orbiting Astronomical Observatory (OAO), launched in 1968, allowed astronomers to look for the first time at energy that is emitted by stars as ultraviolet and X-rays.



Artist's concept shows black hole siphoning the atmosphere from a companion star.

Astronomers developed a star atlas in the ultraviolet spectrum from the first OAO and a second observatory named Copernicus.

With the first of three Small Astronomy Satellites (SAS-1 or Uhuru), they were able to complete a thorough map of the skies for X-ray emitting objects.

One of these objects was Cygnus X-1, the first black hole to be spotted. This collapsed star is so dense that not even light can escape it.

With eight Orbiting Solar Observatories scientists have studied the Sun in both its ultraviolet and X-ray emissions.

Space objects ranging from planets in our solar system to the most distant objects of the universe are now being examined by the International Ultraviolet Explorer (IUE), a cooperative effort between NASA, the United Kingdom and the European Space Agency.

The Space Telescope will be regularly serviced by the Space Shuttle.

Astronomers from many nations come to Goddard to use the IUE satellite as guest investigators. The satellite has been pointed at some of the greatest mysteries in the universe, such as quasars (the most powerful and puzzling transmittors of energy known) and black holes.

"Hows" and "Whys" of Cosmos

Other Goddard satellites are studying the "hows" and "whys" of cosmic processes by looking at gamma and cosmic ray emissions from stars and other space objects.

Gamma and cosmic rays, the highest energy portions of the spectrum, indicate processes going on in space that involve energies much higher than most ordinary processes at the surface layers of stars.

Three International Sun-Earth Explorers are monitoring high energy events resulting from solar flares. And Goddard is participating in a series of High Energy Astronomy Observatories (HEAO) designed to examine X-ray, gamma ray and cosmic ray sources in the sky.

A Gamma-Ray Observatory scheduled for the mid-80's will attempt to find new solutions to physical phenomena that have not been explained in other bands of the spectrum. The satellite will look anew at black holes, for example, as it maps gamma ray sources and bursts throughout the universe.

The Gamma Ray Observatory will advance earlier work in this portion of the spectrum by Goddard's SAS-2.

The atmospheres of the planets, our own as well as others in the solar system, is a major field of interest for astonomers.

Goddard is studying the physics and chemistry of planetary atmospheres through satellites, balloons, low altitude, recoverable rockets, ground telescopes, and experiments aboard interplanetary space probes.

For instance, the Atmospheric Explorer satellite is studying the chemistry of the Earth's atmosphere and ionosphere, including the endangered ozone layer, while Goddard instruments aboard Pioneer Venus will conduct similar studies of our neighbor planet.

The Dynamics Explorer will expand the planetary atmosphere research in the early 1980's by investigating the relationship between the Earth's magnetosphere and its atmosphere, and in the mid 1980's, the Upper Atmosphere Research Satellite will provide the first comprehensive scientific study of the middle regions of the Earth's atmosphere.

Sky in radio and infrared

Goddard satellites are also exploring the skies in the radio and infrared portions of the spectrum.

The first complete map of low frequency radio sources in our galaxy was provided by the Radio Astronomy Explorer, which also discovered intensive emissions of such radio waves from the Earth and Jupiter.

An experiment planned for 1983 will use infrared waves to address the question of the very origin of the universe. The Cosmic Background Explorer satellite will attempt to confirm the presence of background radiation in space believed to be the residual radiation from the violent explosion which created the universe.

While beginning to explore the skies in all parts of the spectrum, astronomers have not ceased to watch stars by their visible light. Goddard and the Marshall Space Flight Center in Huntsville, Ala., will greatly advance this effort, as well as studies in ultraviolet light, with the launch of the Space Telescope in the early 1980's.

The Space Telescope will be launched by the Space Shuttle and be operated from a control center at Goddard.

Flying economy from Earth

Cutting costs with Space Shuttles and multi-use modules

Early in the 1980's the Space Shuttle should begin making routine round-trips into space. Eventually, it will blast off the Earth perhaps as frequently as 40 missions per year.

A combination rocket and airplane with a large cargo bay, the Space Shuttle can carry a wide variety of satellites into orbit. This capability will reduce the need to launch individual spacecraft for specific missions, lessening the cost of space travel and opening the door to vast new opportunities of space exploration.

Taking the Shuttle's lesson of economy one step further, Goddard is developing a standardized satellite "container" that can house a diversity of experiments and instruments.

The "Multimission Module Spacecraft," which can be launched either by a rocket or aboard the Shuttle, is designed to provide power supply, altitude control, communications and a stable temperature for payloads at any orbit.

To enable the Space Shuttle to deliver its cargo to a variety of orbits, without travelling to each, Goddard is designing a standard booster engine which can be attached to satellites. This booster capability is called a Spinning Solid Upper Stage.

A Space Shuttle Payload Program at Goddard is responsible for developing new concepts for use of the Shuttle, and for analyzing their economic and scientific feasability.

One of the first tasks of the program will be to work closely with the European Space Agency (ESA), on developing, choosing and managing experiments for Space. Spacelab is a self-contained, reusable space laboratory designed by ESA to operate within the Shuttle's cargo bay.

Goddard also has responsibility for administering the Shuttle's "Getaway Special Program." Through this program, individuals, industries, research groups and other nations can place small experiments aboard the Shuttle for as little as $3,000, space available.

The Space Shuttle rockets from the Earth, jettisoning its supplementary fuel tanks for recovery.

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The Bermuda station of the Goddard managed Spacecraft Tracking and Data Network.

Giant satellites to track 1980's spacecraft

From the days of the earliest communications satellites to the Apollo manned missions, Goddard has been the control center for two way communications with all NASA spacecraft orbiting the Earth and flying to the Moon.

Today Goddard scientists are applying this experience to revolutionizing spacecraft communications. In 1980 the center will replace most of NASA's worldwide Spaceflight Tracking and Data Network ground stations with two giant communications satellites which will remain in fixed positions over the Atlantic and Pacific.

The two Tracking and Data Relay Systems Satellites will greatly increase total available spacecraft communications capability. By closing 60 percent of the ground stations, they will save NASA some $100 million a year.

The satellites will provide coverage for spacecraft orbiting below 5,000 km. For higher altitude orbits, the reduced number of ground tracking stations will provide primary support service.

Presently, data and voice communications from spacecraft flow to Goddard from NASA's 16 ground tracking stations through some three million circuit miles of electronic circuitry via cables and satellites.

Goddard relays the data on to other NASA facilities that may be directing a specific mission, and passes commands back to spacecraft. Frequently, the quantity of information flowing through the center every mission minute approaches the equivalent of an encyclopedia Britannica.