EXPLORER 44

NEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

TELS. WO 2-4155
WO 3-6925

**FOR RELEASE:** Friday A.M.
July 2, 1971

RELEASE NO: 71-115

PRESS KIT

# PROJECT: NRL/NASA SOLRAD 10 (C)

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(NASA-News-Release-71-115) NASA TO LAUNCH SOLRAD SATELLITE (NASA) 20 p

N76-71754

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NEWS

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FOR RELEASE: Friday A.M.
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# NASA TO LAUNCH SOLRAD SATELLITE

The National Aeronautics and Space Administration will launch the Naval Research Laboratory's latest solar radiation (SOLRAD) measuring satellite no earlier than July 8 from Wallops Island, Va.

The 260-pound spacecraft, SOLRAD 10 (C) will be boosted into a near circular orbit, about 370 miles (600 kilometers) above the Earth by NASA's all-solid propellant Scout launch vehicle.

There are 14 experiments aboard the NRL satellite, designed to monitor continuously solar electromagnetic radiation (X-ray and ultraviolet and to measure, on command, stellar radiation (X-ray) from other celestial sources. Information gained by the satellite is expected to contribute to a better understanding of the physical processes involved in solar flares and other solar activity, and the potential effects of this activity on short-wave communications, as well as on future manned space travel.

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Satellites contribute to studies of solar phenomena in three major ways. They make possible the study of the ultraviolet, X-ray and gamma ray radiation which is absorbed in the atmosphere; they permit continuous monitoring of this radiation during solar cycles of activity; and they provide higher resolution than ground equipment through the elimination of atmospheric scattering.

The primary reason for the solar studies is to expand human knowledge of space phenomena. While this is an exciting and important reason for the work, there are also practical benefits to be gained.

Knowledge of solar radiation and its effects on the terrestrial environment, together with continuous monitoring of the entire spectrum of solar radiation, should result in significant advances in the understanding of, and effective accommodation of human activities to weather conditions.

Significant advance signs of solar activity can be used to predict periods of high probability of solar flares. This service will become a major contribution to communications, meteorology and manned space flights.

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One of the first missions in SOLRAD's anticipated three-year life span will be to aid the National Oceanic and Atmospheric Administration as a sentinel during the Apollo 15 mission later this month. Since the emissions resulting from unusual solar disturbances, especially large proton flares, may be harmful to men outside the protection of the Earth's atmosphere, SOLRAD's continual monitoring of the Sun will supplement the existing Apollo warning system enabling scientists on Earth to detect solar eruptions severe enough to be a source of potential danger.

This is the third in a series of solar radiation spacecraft launched in a joint NRL/NASA program. The previous two were SOLRAD 8, the Solar Explorer launched in 1965 during the IQSY (International Quiet Sun Year), and SOLRAD 9 in 1968 (Solar Explorer B). The 30-by-23-inch SOLRAD 10 (C), designed and built by NRL's Space Systems Division, will continue and expand the experiment capabilities of the earlier two. Unlike the previous satellites, its sensors will be continuously oriented toward the Sun. The sensitivity and accuracy of its sensors are also technologically improved over earlier versions.

The electronics aboard the 12-sided satellite are powered by four symmetrically placed 7-by-21-inch solar cell panels arranged like windmill blades. These panels also serve as the four elements of its "turnstile" antenna system.

The SOLRAD program is sponsored jointly by the Naval Air Systems Command and NASA's Office of Space Science and Applications (OSSA), with NRL providing project management for the mission. SOLRAD 10 is the most complex spacecraft in the SOLRAD series and extends the measurements of the Sun's emission spectrum into regions previously investigated only in short rocket flights.

As in previous experiments, the international scientific community has been invited, through the Committee on Space Research (COSPAR), to monitor the solar X-ray data telemetered from the spacecraft.

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(END OF GENERAL RELEASE: BACKGROUND INFORMATION FOLLOWS)

## BACKGROUND

The Earth is a body immersed in the atmosphere of a star, the Sun. Radiation from the Sun controls the environment of the Earth, of other solar system planets, and of interplanetary space. Because most emissions of radiation from the Sun are variable, the environment of the Earth is variable.

There is a cyclic pattern of solar activity, with maximum and minimum occurring about every 11 years, and a similar cyclic variation is evident in certain properties of the Earth's atmosphere, especially in the ionosphere.

The present period is one of descending solar activity. The next period of maximum activity is expected to be in 1979-1980.

## SOLAR FLARES IMPORTANT

The solar flare appears to be the most important part of variable solar activity insofar as variable solar effects upon the environment of the Earth are concerned. In the red light emitted by the hydrogen atom, a flare is a sudden brightening of a part of the solar surface occurring in a few minutes and then slowly decaying over a period of tens of minutes to hours.

X-rays and intensified ultraviolet light emitted during the life of a flare increase the number of electrons in the Earth's lower ionosphere and thus disrupt short-wave radio communications by increased absorption.

The largest flares also emit great numbers of energetic protons which increase the radiation levels in interplanetary space and in the space over the Earth's poles. Greater knowledge of the radiations emitted by the Sun is required to understand these interactions between solar events and the Earth's upper atmosphere and ionosphere.

The Sun is an astrophysical object of prime interest to man. It is the only star whose surface characteristics we can resolve and study. Knowledge gained by studying the Sun will help us understand and interpret the data from other stars.

## VALUE OF SPACE RESEARCH

The techniques of space research permit scientists to expand solar studies in two ways: They can increase the resolving power of their telescopes through the elimination of atmospheric distortion, and they can observe over a very much larger part of the electromagnetic spectrum.

The Sun emits electromagnetic radiation covering the spectrum from radio waves through the visible and ultra-violet to X-rays and gamma rays. Only a fraction of the radiation is in the visible part of the spectrum that a human eye can see. Parts of the radio and the infrared portion of the spectrum can be observed on the ground. The rest of the solar radiation is absorbed in the Earth's atmosphere and can be observed only with instruments above the atmosphere.

Some of the absorbed portions of the spectrum are doubly important. They are the portions which vary with solar activity. To understand the mechanism of a solar flare, studies of the ultraviolet and X-rays emitted during a flare (both of which are absorbed in the atmosphere) must be made. Since the radiation is absorbed in the upper atmo-sphere, these portions of the solar radiation control the nature of the upper atmosphere.

## SEVERAL TECHNIQUES TRIED

In recent years, portions of the solar spectrum of radiations have been observed by ground-based monitors, balloon-borne instruments, high-flying aircraft, sounding rocket flights, deep space probes, and satellites. Scientists from industry, universities and several Government agencies have engaged in these efforts to unlock the Sun's secrets.

In 1949 the Naval Research Laboratory (NRL) began a program of observation of solar ultraviolet and X-ray emissions in which the V-2 and, later, Aerobee and other sounding rockets were used to lift sensitive instruments (spectrographs and photometers) above the absorbing layers of the atmosphere.

In 1956, NRL began trying balloon-launched rockets, ROCKOONS, in an attempt to test, by direct measurement, the theory that solar X-rays were responsible for sudden ionospheric disturbances (SIDs) during solar flares.

A rocket fired during a solar flare July 20, 1956 indicated a surprisingly high intensity of X-rays between altitudes of 75 and 100 kilometers (47 to 62 statute miles). This X-ray flux was the first ever measured at such short wavelengths and at such a low altitude in the ionosphere.

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## SOUNDING ROCKETS USEFUL

Subsequent ground-launched sounding rockets gathered considerable new data on X-ray emissions during 1957 through 1959. Rocket measurements were made during three solar flares each of which was accompanied by a large sudden ionosphere disturbance.

Sounding rocket experience by NRL, NASA and others provided the brief glimpses of the Sun's spectrum necessary to guide development of satellite instrumentation.

In the study of such spasmodic events as solar flares, however, the sounding rockets have three handicaps: They cannot be launched quickly enough to see the early phases of flare; they cannot stay above the Earth's atmosphere long enough to measure time variations of solar X-ray and ultraviolet emissions; and it is difficult to keep instruments pointed at the Sun due to roll and yaw of the rockets.

Therefore, scientists turned to satellites capable of providing a stable platform for continuous solar monitoring.

In June 1960, the SOLRAD 1, designed and built by NRL, became the first successful solar X-ray monitoring satellite. Because X-ray monitoring could be conducted only when SOLRAD I passed over a telemetry station, the experiment depended on the extensive network of NASA tracking and data acquisition stations.

## SOLRAD 1 RESULTS SIGNIFICANT

Despite its modest capabilities, 577 telemetry records were obtained from SOLRAD 1 between June 22 and Nov. 1, 1960. One hundred of these showed measurable X-ray fluxes.

The results were significant. SOLRAD 1 confirmed the hypothesis that solar X-rays cause sudden disturbances in the ionosphere during flares and determined the intensity necessary to trigger the changes.

It also established that active prominence regions, bright surges on the edge of the Sun, and certain solar edge (limb) flares have the same characteristics as major disk flares. The disk is the central portion of the Sun as viewed from the Earth.

Data from SOLRAD 1 showed that solar X-ray fluxes provide a very sensitive measure of solar activity and can change significantly within one minute. It was found that long-duration X-ray events of moderate intensity can accompany rising prominences on the solar limb. Prominences are streams of cool gas that surge into the hot corona.

The second satellite in the SOLRAD series failed to achieve orbit and the third, SOLRAD 3, launched in June 1961, went into a tumbling mode that made data reduction difficult. Nevertheless, some of the data from SOLRAD 3 have been reduced and found useful.

## VARIATIONS DISCLOSED

The experiments of SOLRAD 1 and SOLRAD 3 made it evident that X-ray emission spectra vary greatly from one flare to another, and vary with time during a single flare event.

A highly successful satellite of the SOLRAD series was launched in January 1964 and was designated 1964-01D. During periods of good alignment relative to the Sun, the satellite provided 200 minutes-per-day of direct solar observations with measurements of solar X-ray emissions in the spectral bands of 1-8, 8-12 and 44-60 Angstroms. (The Angstrom (Å) is a measure of wavelength: 1 Å equals $10^{-10}$ meter, or about four one-billionths of an inch.)

The 44-60 Å wavelength band proved especially sensitive to even the smallest solar event and its observed flux has been correlated with plage phenomena. Plages are bright, hot areas that appear on the Sun's photosphere. The photosphere is the visible disk of the Sun.

SOLRAD 8 was a highly successful satellite of the series launched in November 1965 and was also designated Explorer XXX. It marked the first time that an attempt was made to use a data storage system in the series. Although the system malfunctioned after one month, the satellite continued to provide useful information in real time until November 1967.

SOLRAD 8 provided evidence that an increase in background solar X-ray emission can be interpreted as a precursor of flare activity and the subsequent disruption of radio communications. It also gave the best definition of the sizes of X-ray active regions thus far obtained. They were derived from observations made by Italian scientists with their instruments as the satellite passed through the May 1966 eclipse shadow across Greece.

In a recent advancement to the state-of-art for radiation satellites NRL's SOLRAD 9 (also designated Solar Explorer 37) was launched by NASA, March 5, 1968. The satellite, which weighs 195 pounds and is in the shape of a twelve-sided drum, is some 30 inches high and 30 inches across. Since its launching, SOLRAD 9 has continuously transmitted measurements of solar X-ray emissions as they are made and has stored selected measurements in a memory for special transmissions to NRL's ground station at Blossom Point, MD.

Short-term solar flare activity forecasts derived from information furnished by SOLRAD 9 during America's historic Moon landings in Apollo flights assisted in safeguarding the astronauts and their communication systems as it and SOLRAD 10 (C) are expected to do in the future.

Scientists are "elated" over the long life of SOLRAD 9 which will continue to be used as a backup solar radiation monitor for SOLRAD 10 (C).

Since NASA was established in October 1958, there has been a close working relationship between NRL and NASA personnel in numerous scientific projects of mutual interest. Vanguard II, the first satellite launched by NASA (February 1959), was developed by an NRL team that was transferred to NASA.

Much of the NASA-NRL cooperation and interagency support has been in work related to solar physics.

## SOLAR RADIATION MEASUREMENTS

All radiant energy, including that from the Sun, is emitted in many diverse forms and over a tremendous range of frequencies, or wavelengths. All these forms of radiant energy are electromagnetic in nature, obey the same basic laws and travel through space at the speed of light (about 186,300 miles-per-second). They differ in wavelength, origin and the ways in which they manifest themselves and cover the entire electromagnetic spectrum.

Wavelengths corresponding to radio frequencies are usually expressed in meters; infrared in centimeters or microns; visible light, ultraviolet X-rays and gamma rays in Angstroms. X-ray and gamma photons are often described by specifying their energy in electron-volts.

Instrumentation on the SOLRAD 10 (C) will make measurements in the X-ray and ultraviolet regions of the electromagnetic spectrum. Radiation measurements will be obtained by photometers, photomultipliers and Geiger tubes.

## NRL/NASA SOLRAD 10 (C) EXPERIMENTS

| NO. | PARAMETER | SENSOR | PURPOSE |
|---|---|---|---|
| 1A | 0.5 - 3 Å | Ionization Chamber | Solar X-ray Monitor |
| 1B | 0.5 - 3 Å | Parallel Plate Ionization Chamber | Solar X-ray Monitor |
| 2 | 1 - 5 Å | Ionization Chamber | Solar Electron Temperature |
| 3A | 1 - 8 Å | Ionization Chamber | Solar X-ray Monitor |
| 3B | 1 - 8 Å (Back-up) | Ionization Chamber | Solar X-ray Monitor |
| 4A | 8 - 16 Å | Ionization Chamber | Solar X-ray Monitor |
| 4B | 8 - 16 Å (Back-up) | Ionization Chamber | Solar X-ray Monitor |
| 5 | 1 - 20 Å, 44 - 60 Å | Ionization Chamber | Solar X-ray Monitor |
| 6 | 1 - 20 Å | Ionization Chamber | Solar X-ray Monitor |
| 7A | 1080 - 1350 Å | Scanning Ionization Chamber | Solar Lyman Alpha Bursts |
| 7B | 1080 - 1350 Å | 2 - Ionization Chambers | Solar Lyman Alpha Monitor |
| 8 | 1225 - 1350 Å | 2 - Ionization Chambers | Solar Ultra-Violet Monitor |
| 9 | 1500 - 1700 Å | Ionization Chamber | Solar UV Continuum Flash |
| 10A | 0.5 - 3 Å | Ionization Chamber (5° ∠ to sunline) | Background X-ray level |
| 10B | 1 - 8 Å | Ionization Chamber (5° ∠ to sunline) | Background X-ray level |
| 11 | 0.1 - 0.5 Å (20 - 150 Kev) | Cs I (Na) Scintillating Crystal and Photomultiplier | Solar Hard X-ray Monitor |
| 12 | 170 - 600 Å | LiF Photometer | Solar Excitation of F-layer |
| 13 | 0.1 - 1.6Å | Ionization Chamber | Solar Hard X-ray Continuum |
| 14 | Degrees Temperature | Thermistor | Skin Anti-solar Temperature |
| 15 | 0.5 - 15 Å | Large-Area Proportional Counter | Stellar X-ray Variations (STELRAD) |

Aspect Sensors
Housekeeping Sensors

## SPACECRAFT DESCRIPTION

The spacecraft is a 12-sided structure which measures 30 inches in diameter across the corners and approximately 23 inches in height. The spacecraft weighs 260 pounds. There are four symmetrically placed 7-by-21-inch solar cell panels, hinged at the center station of the structure, which are folded along the length of the structure and deployed after third stage burnout. These panels also serve as the four elements of a turnstile antenna system.

The electronic subsystems of the satellite include two nonredundant telemetry transmitters operating on separate frequencies of 137.710 MHz and 136.380 MHz, three spin replenishment and four spin-axis attitude control subsystems, and a command subsystem. The telemetry systems are under the exclusive operational control of NRL.

The spacecraft uses two separate telemetry subsystems for the transmission of data to the ground stations. Telemetry subsystem 1 is a realtime subsystem which uses the linearly mixed output of five voltage-controlled IRIG subcarrier oscillators (SCOs) to phase modulate the transmitter. The SCOs are frequency modulated by their individual inputs of Pulse Amplitude Modulation (PAM), analog and Pulse Code Modulation (PCM) data. Telemetry subsystem 1 will normally transmit on a continuous basis. Telemetry subsystem 2 is a Pulse Code Modulation/Phase Modulation (PCM/PM) system which radiates on a frequency of 136.380 MHz and power output of 3 watts. The system transmits the contents of a 54 kilobit memory store of experiment data upon ground command. It is anticipated that the subsystem will be read out several times a day by command from the NRL tracking station at Blossom Point, Md. The memory dump operation will require about five minutes of transmission time for the readout and the transmitter will remain off at all other times.

No special beacon or tracking equipment is provided on board the SOLRAD 10 spacecraft for tracking by the ground stations. Since the 137.710-MHz telemetry transmitter will be continuously transmitting, it will serve as the signal source for tracking assignment under control of the NRL. No tracking support will be required from the NASA Goddard Space Flight Center (GSFC) STADAN stations.

The spacecraft contains three spin replenishment and four spin-axis attitude control subsystems designed to maintain the spin rate at 60 rpm and the spin-axis within ± 2° of the Sun line.

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Solar sensors determine the angle to the Sun and automatically apply control signals to the attitude spin subsystem. The spin rate is observed on the telemetry signal and is corrected by commanding a low-thrust ammonia or hydrazine gas system.

Attitude control subsystems 1 and 2 are redundant and share a common toroidal tank containing 9.5 pounds of liquid anhydrous ammonia. Each attitude control subsystem contains a solenoid valve, a latching valve and a nozzle. The latching valves and power for the solenoid valves are controlled by ground command and operation of the solenoid valves is controlled by solar sensor pulses. Upon receipt of the solar sensor pulses, ammonia vapor passes through the two sets of valves and nozzles and precesses the spin axis to within ± 2° of the Sun line.

Spin replenishment subsystems 1 and 2 are also redundant and share the same tank as attitude control subsystems 1 and 2. Each spin replenishment subsystem consists of a solenoid valve, a latching valve and a nozzle. Both the latching valves and the solenoid valves are controlled by ground command when spin replenishment is desired.

Attitude control subsystem 3 and spin replenishment subsystem 3 share a pair of spherical tanks containing five pounds of hydrazine and pressurized to 130 psi. Each subsystem contains a latching valve, a solenoid valve, a catalyst bed and a nozzle. The latching valve and power for the solenoid valve of attitude control subsystem 3 are controlled by ground command; operation of the solenoid valve is controlled by solar sensor pulses. Both the latching valve and the solenoid valve of spin replenishment subsystem 3 are controlled by ground command. The hydrazine system is being tested for future application in high-altitude follow-on SOLRAD satellites.

# SCOUT LAUNCH VEHICLE

Scout is NASA's only solid propellant launch vehicle with orbital capacity. The first-development Scout was launched July 1, 1960. Since the Scout was recertified in 1963, the launch vehicle has attained a 94-per cent success record.

Scout B is a four-stage solid propellant rocket system. Scout No. S-173 and the spacecraft will be set on an initial launch azimuth of 90 degrees to obtain a 214x800-kilometer orbit with 2.9 degrees inclination and 94.8 minutes to complete one revolution.

The four Scout motors -- Algol II, Castor II, Antares II, and Altair III -- are interlocked with transition sections that contain guidance, control, ignition, and instrumentation systems, separation systems and the spin motors needed to stabilize the fourth stage. Control is achieved by aerodynamic surfaces, jet vanes and hydrogen peroxide jets.

The launch vehicle is approximately 73 feet (22.25 meters) long and weighs about 40,000 pounds (17,144 kilograms) at liftoff.

The Scout program is managed by NASA's Langley Research Center, Hampton, VA. The launch vehicle is built by LTV Aerospace Corp., Dallas.

## Launch and Orbit Sequence of Events

The sequence of events from liftoff until the spacecraft is fully operational is as follows:

| | |
|---|---|
| Liftoff | 0.00 seconds |
| First stage burnout | 77.1 |
| Second stage ignition | 77.3 |
| Second stage burnout | 116.9 |
| Heat shield separation | 121.3 |
| Third stage ignition | 123.0 |
| Third stage burnout | 159.7 |
| Spin-up | 568.9 |
| Fourth stage ignition | 575.2 |
| Fourth stage burnout | 610.8 |
| Payload separation | 840.4 |

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## WALLOPS STATION LAUNCHING SITE

NASA Wallops Station is responsible for project coordination relating to scheduling, reporting, launch vehicle and tracking and data acquisition, as well as the usual launch operations and pre-launch support provided for the Scout SOLRAD C launch.

The SOLRAD 10 (C) satellite will be launched from Launch Area 3A, and will be the fifteenth satellite placed in orbit from Wallops Island. Nearly 8,000 rockets have have been launched from Wallops Island since 1945. Wallops' efforts have assisted in obtaining scientific data about the Earth's atmosphere and its near-space environment, as well as providing support for programs such as space sciences and applications, aeronautics and Earth Resources. The Scout four-stage solid-propellant launch vehicle is the largest rocket launched from Wallops Island and is the only one with orbital capability from the island.

## NRL/NASA SOLRAD 10 PROJECT TEAM

### National Aeronautics and Space Administration

| | |
|---|---|
| Raymond Miller (Headquarters, Office of Space Science and Applications) | Program Manager |
| J. M. Weldon (Headquarters, Office of Space Science and Applications) | Program Scientist |
| Wendell Lee (Wallops Station) | Project Coordinator |
| R. D. English | Head, Scout Project Ofc. |
| Larry Tant | Payload Coordinator |
| Clyde Winters (Langley Research Center) | Operations Engineer |
| R. L. Mitchell (Goddard Space Flight Center) | Tracking and Data Systems Manager |

### Naval Research Laboratory

| | |
|---|---|
| E. W. Peterkin | Technical Project Manager |
| R. W. Kreplin | Scientific Program Manager |
| P. G. Wilhelm | Assistant Project Manager (Spacecraft) |
| C. H. Chrisman | Assistant Project Manager (Data Processing) |

### Industry

| | |
|---|---|
| R. D. Stone LTV Aerospace Corp., Missiles and Space Division | Contractor/Scout Launch Vehicle Systems Coordinator |

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