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Report to the Space Science Board

on the

SPACE SCIENCE

AND

APPLICATIONS PROGRAMS

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SPACE SCIENCES & APPLICATIONS PROGRAMS

Presented to the Space Sciences Board

by

H. E. Newell

Associate Administrator for
Space Sciences & Applications

NASA Headquarters

Dec~~ember~~ 1963

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SPACE SCIENCES & APPLICATIONS PROGRAMS

PAST ACCOMPLISHMENTS

The following is a list of the successful major satellite and space probe firings that have been carried out in connection with the NASA program since the creation of NASA in 1958:

1958

PIONEER I	Magnetic field, radiation belts
PIONEER II	Magnetic field, radiation belts, cosmic rays
PIONEER III	Radiation belts, cosmic rays

1959

VANGUARD II	Cloud cover
PIONEER IV	Radiation belts, cosmic rays
EXPLORER VI	Magnetic field, radiation belts
VANGUARD III	Magnetic field
EXPLORER VII	Radiation belts, cosmic rays, thermal radiation, micrometeors

1960

PIONEER V	Magnetic field, cosmic rays
TIROS I	Cloud cover
ECHO I	Air density, passive communications
EXPLORER VIII	Ionosphere, micrometeors
TIROS II	Cloud cover, thermal radiation

1961

EXPLORER IX	Air density
EXPLORER X	Magnetic field, plasma
EXPLORER XI	Gamma radiation

(1961 - Continued)

TIROS III	Cloud cover, thermal radiation
EXPLORER XII	Magnetic field, radiation belts, cosmic rays
EXPLORER XIII	Micrometeoroids
	1962
TIROS IV	Cloud cover, thermal radiation
OSO I	Electromagnetic radiation from sun
ARIEL I	Ionosphere, radiation
TIROS V	Cloud cover
TELSTAR I	Active communications
ECHO II	Passive communications
MARINER II	Energetic particles and magnetic fields, cosmic dust, Venus IR and microwave radiation
TIROS VI	Cloud cover
ALOUETTE	Ionosphere topside sounding, radio noise, cosmic rays
EXPLORER XIV	Energetic particles, magnetic field, cosmic rays
EXPLORER XV	Radiation Belts
ANNA 1-B	Geodesy
RELAY I	Active communications, radiation
EXPLORER XVI	Micrometeoroids, radiation
	1963
EXPLORER XVII	Atmosphere structure
TELSTAR II	Active communications

(1963 - Continued)

TIROS VII	Cloud cover
SYNCOM II	Active communications, synchronous orbit

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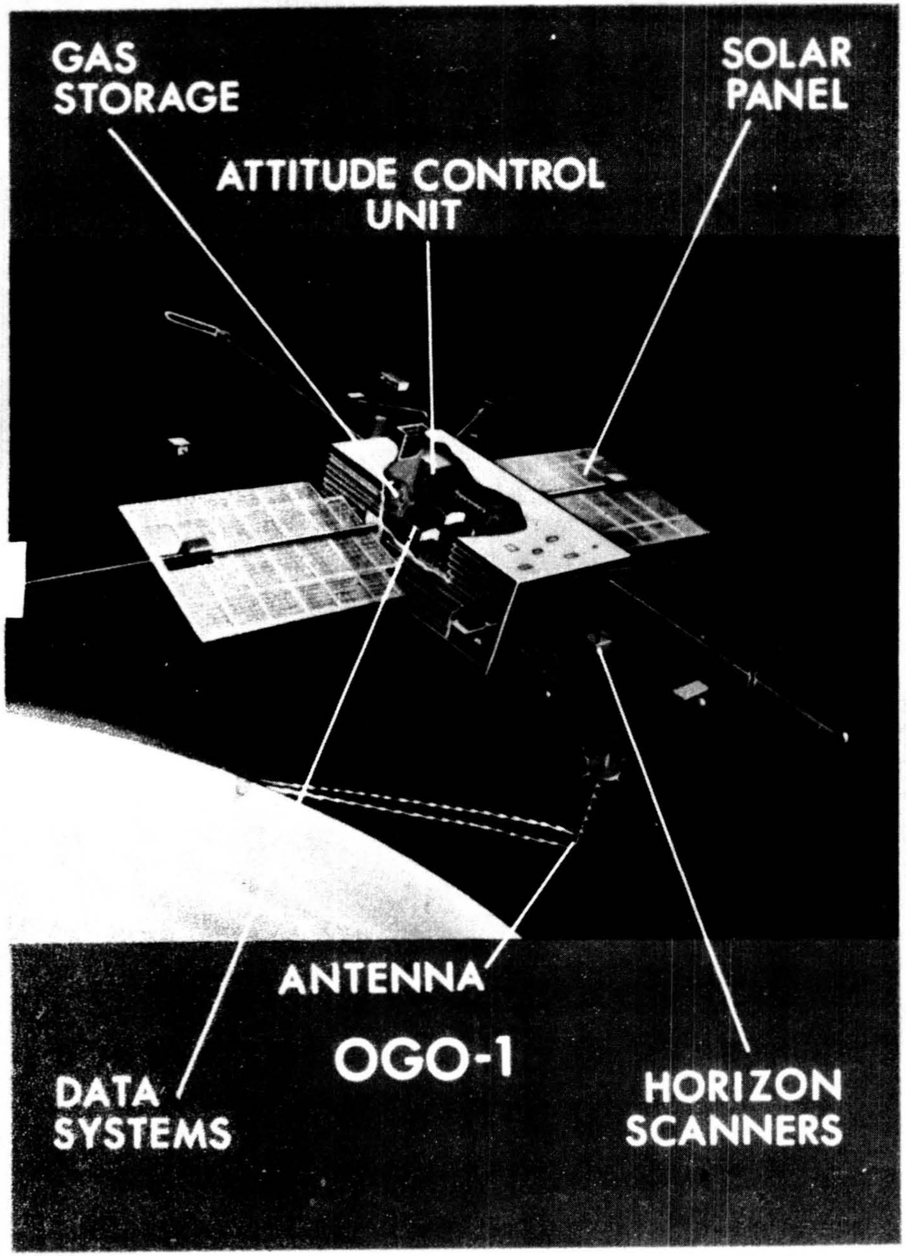
OSS&A PLANNED FLIGHT SCHEDULE

PROGRAM/PROJECT	LAUNCH VEHICLE	CY 1963 1	CY 1963 2	CY 1963 3	CY 1963 4	CY 1964 1	CY 1964 2	CY 1964 3	CY 1964 4	CY 1965 1	CY 1965
GEOPHYSICS & ASTRONOMY											
OSO	D					X			X		X
OAO	AAG										X
OGO	AAG, TAT							X		X	XX
EXPLORERS &	Sc		(1)					(10)			(6)
INTERNATIONALS	D, TAD		(1)					(2)			(2)
	TAG										(1)
LUNAR & PLANETARY											
RANGER	AAG					XX	X	X			XXX
SURVEYOR LANDER	C									X	XXXX
MARINER C	AAG								XX		
PIONEER	TAD										XX
BIOSCIENCES											
BIOSATELLITE	D, TAD										X
COMMUNICATIONS											
ECHO	TAG					X					
RELAY	D					X					
SYNCOM	D						X		X		
METEOROLOGY											
TIROS	D, TAD				X			X	X	X	X
NIMBUS	TAG, TAT					X		X			X

ORBITING GEOPHYSICAL OBSERVATORY



GROSS WEIGHT	- 1,000 LBS
INSTRUMENT WEIGHT	- 150 LBS
INVESTIGATIONS	- 20
POWER	- 500 WATTS
STABILIZATION	- ACTIVE 3 AXIS
DESIGN LIFE	- ONE YEAR
LAUNCH VEHICLES	- ATLAS - AGENA THOR - AGENA
ORBITS	- HIGHLY ELLIPTICAL INCLINED ORBIT - NEAR CIRCULAR POLAR ORBIT
STATUS	- FIRST FLIGHT 1964

NASA SD63-1449

INSTRUMENTS AND INVESTIGATORS FOR FORTHCOMING MISSIONS

ORBITING GEOPHYSICAL OBSERVATORIES

The Orbiting Geophysical Observatories (OGO) are a series of standardized spacecraft capable of accommodating thirty or more scientific investigations in various orbits reaching far from the earth. Two types are planned:

(1) The eccentric orbiting geophysical observatory will be placed in a highly eccentric orbit reaching from a perigee of 170 miles to an apogee of 69,000 miles. It will be useful for investigations beyond the geomagnetic field, within the field, and within the Van Allen radiation belts.

(2) The polar orbiting geophysical observatory will be launched into near-earth polar orbits (160 to 570 mile polar orbits). It will emphasize the investigation of the phenomena of the polar regions, such as the radiation belt "horns", auroral activity, low energy cosmic rays, the geomagnetic field, the ionosphere, and anomalous temperature and density changes.

The OGO spacecraft will weigh approximately 1,000 pounds, of which 150 pounds is allotted to investigations. The first eccentric orbiting observatory is scheduled to be launched with an Atlas-Agena during 1964 from AMR. The first polar orbiting observatory is scheduled for launch with a Thor-Agena during 1965 from PMR.

Spacecraft design, development, fabrication, assembly, integration of investigations, and test and evaluation are being carried out under contract by the Space Technology Laboratories, Los Angeles, California.

The design for the OGO spacecraft calls for a body about 2-3/4 ft x 2-3/4 ft x 5 ft containing portions of the stabilization control, power supply, communications, and data handling and thermal control systems, as well as space for investigations. The power supply system consists of solar cell panels, nickel cadmium batteries, and a charge control system. A maximum power of 500 watts and an average power of 250 watts will be available. Maximum power allocated to scientific investigations is 80 watts and the average power is 50 watts. Angular orientation of the spacecraft is accomplished through torques developed by motor-driven inertial flywheels and by gas jets. Deviations of the spacecraft from the sun axis are sensed by solar cells; deviations from the earth's local vertical are determined by horizon scanners. Thermal control is accomplished by use of radiation shields and louvers. The data processing and communications system accepts ground commands to program investigations, to vary transmission rates, and to apportion information bits to the data generated by the investigations and by vehicle performance parameters. Storage of 84 million bits of data is possible by use of two magnetic tape recorders. Two redundant wideband telemetry transmitters in the spacecraft are capable of sending scientific and spacecraft engineering data back to earth, either in real time, on command, or from storage.

The following are the final lists of scientific investigations and investigators for OGO's A, B, C and D. An invitation has been issued for proposals for experiments on OGO's E and F.

OGO's A and C

Investigations and Investigators

1. Solar cosmic rays, 10-90 Mev, using a scintillation detector to measure fluxes.

   K. A. Anderson
   University of California (Berkeley)

2. Positron and gamma ray detection, using double gamma ray spectrometer to measure positrons (0 to 3 Mev) and to monitor solar photon bursts.

   T. L. Cline and E. W. Hones, Jr.
   Goddard Space Flight Center

3. Trapped radiation studies, with ion-electron scintillation detector, of trapped electrons with directional energy flux, 10 Kev E 100 Kev, and protons with directional intensity, 120 Kev E 4.5 Mev.

   L. R. Davis
   Goddard Space Flight Center

4. Galactic cosmic rays and isotope abundance with cosmic ray telescope.

   F. B. McDonald and D. A. Bryant
   Goddard Space Flight Center

5. Low energy galactic cosmic ray flux, using charged particle telescope to study protons above 0.2 Mev and other nuclei at higher energies.

   J. A. Simpson, C. Y. Fan and P. Meyer
   University of Chicago

6. Trapped radiation, using Geiger tubes to measure omnidirectional intensities of outer belt electrons exceeding 40 Kev, 120 Kev, and 1.5 Mev.

J. A. Van Allen and L. A. Frank
State University of Iowa

7. Trapped radiation, using spectrometer to measure electron energy up to 4 Mev.

J. A. Winckler and R. L. Arnoldy
University of Minnesota

8. Fluctuations in vector magnetic field in frequency range 0.01 to 1000 cps using triaxial search coil magnetometer.

E. J. Smith
Jet Propulsion Laboratory

R. E. Holzer
U. C. L. A.

9. Rubidium vapor magnetometer to measure magnitude and direction of magnetic fields over the range 1 to 100 gammas.

J. P. Heppner
Goddard Space Flight Center

10. Electrostatic analyzer used as plasma probe to measure proton concentrations (10^{-2} to 10^{-4} particles per cm^3) as a function of proton energy, 0.2 to 20 Kev.

J. H. Wolfe
Ames Research Center

11. Proton and electron Faraday cup plasma probes to measure proton flux and energy spectrum, and their variations, in the energy range, 10 ev to 10 Kev.

H. Bridge, A. Bonetti, B. Rossi, A. J. Lazarus, F. Scherb
Massachusetts Institute of Technology

12. Spherical ion and electron ion trap to measure concentration and energy distribution of charged particles in energy range 0 to 1.0 Kev.

R. C. Sagalyn and M. Smiddy
Air Force Cambridge Research Institute

13. Planar ion and electron trap to obtain densities and energy distributions of charged particles of both polarities in the low energy or thermal range.

E. C. Whipple, Jr.
Goddard Space Flight Center

14. VLF noise and propagation at frequencies of 200 to 100,000 cps.

R. A. Helliwell and L. H. Rordan
Stanford University

15. Radio astronomy in frequency band 2 to 4 Mc, primarily to measure the dynamic radio spectra of solar bursts.

F. T. Haddock
University of Michigan

16. Radio beacon to radiate linearly polarized signals (40 and 360 Mc) toward the earth to measure number of electrons beneath the satellite.

R. S. Lawrence and H. J. A. Chivers
National Bureau of Standards (CRPL)

17. Ion mass spectrometry to obtain direct measurements of positive ion composition in the range 1-50 AMU.

H. Taylor and N. W. Spencer
Goddard Space Flight Center

18. Micrometeoroids; vector velocity distribution, cumulative mass distribution, effect of geocentric distance.

W. M. Alexander and C. W. McCracken
Goddard Space Flight Center

19. Lyman-alpha scattering in the geocorona and the interplanetary medium.

P. M. Mange
Naval Research Laboratory

20. Back-up investigation. Geogenschein photometry in ultraviolet, green and infrared regions.

C. L. Wolff
Goddard Space Flight Center

OGO's B and D

Investigations and Investigators

1. Radioastronomy measurements of galactic emission at 2.5 and 3.0 Mc/s.

   F. T. Haddock
   University of Michigan

2. VLF measurements of terrestrial and other emissions in the frequency range, 0.2 to 100 Kc.

   R. A. Helliwell
   Stanford University

3. VLF terrestrial and other emissions at 0.5 to 10 Kc.

   M. G. Morgan and T. L. Laaspere
   Dartmouth College

4. Magnetic field fluctuations in the low audiofrequency range using search coil magnetometers.

   R. E. Holzer
   University of California (L. A.)

   E. J. Smith
   Jet Propulsion Laboratory

5. World magnetic survey with rubidium-vapor and helium magnetometers

   J. P. Heppner, H. R. Boroson, and J. C. Cain
   Goddard Space Flight Center

6. Comparison of ionization over polar regions with that measured by space probes (such as Mariner, Ranger, etc.)

   H. V. Neher
   California Institute of Technology

   H. Anderson
   Jet Propulsion Laboratory

7. Determination of nucleons, 0.3 to 30 Mev, by means of a scintillation telescope.

   J. A. Simpson
   University of Chicago

8. Energy spectrum and charge particle composition of galactic and solar cosmic rays as observed with a modified Cerenkov detector.

W. R. Webber
University of Minnesota

9. Net downflux of corpuscular radiation in the auroral zones and over the polar caps, using Geiger tubes as detectors.

J. A. Van Allen
State University of Iowa

10. Low energy trapped radiation and auroral particles (electrons, 10-100 Kev; protons, 100 Kev to 4.5 Mev) as observed with scintillation detector.

R. A. Hoffman, L. R. Davis, A. Konradi, and J. M. Williamson
Goddard Space Flight Center

11. Photometer airglow measurements at 6300A, 5577A, 3914A, and in the near ultraviolet region.

J. Blamont
University of Paris

E. I. Reed
Goddard Space Flight Center

12. Airglow studies in the Lyman-alpha, far ultraviolet, and 1230A - 1350A regions with UV ion chamber.

P. M. Mange, T. A. Chubb and H. Friedman
Naval Research Laboratory

13. Ultraviolet spectrometer for airglow measurements between 1100A and 3400A.

C. A. Barth
Jet Propulsion Laboratory

L. Wallace
Yerkes Observatory

14. Paul massenfilter mass spectrometer for neutral particle and ion composition in the mass ranges 0-6 AMU and 0-40 AMU.

L. M. Jones and E. J. Schaefer
University of Michigan

15. Bennett RF ion mass spectrometer for mass ranges 1-6 AMU and 7-45 AMU.

H. A. Taylor, Jr. and H. C. Brinton
Goddard Space Flight Center

16. Density of neutral particles with Bayard-Alpert ionization gage.

G. P. Newton
Goddard Space Flight Center

17. Micrometeorites; spatial density, mass distribution, velocity, and charge.

W. M. Alexander, C. W. McCracken, O. E. Berg, L. Secretan
Goddard Space Flight Center

18. Ionosphere charged particles and solar UV radiation observed with a combined retarding-potential analyzer.

R. E. Bourdeau
Goddard Space Flight Center

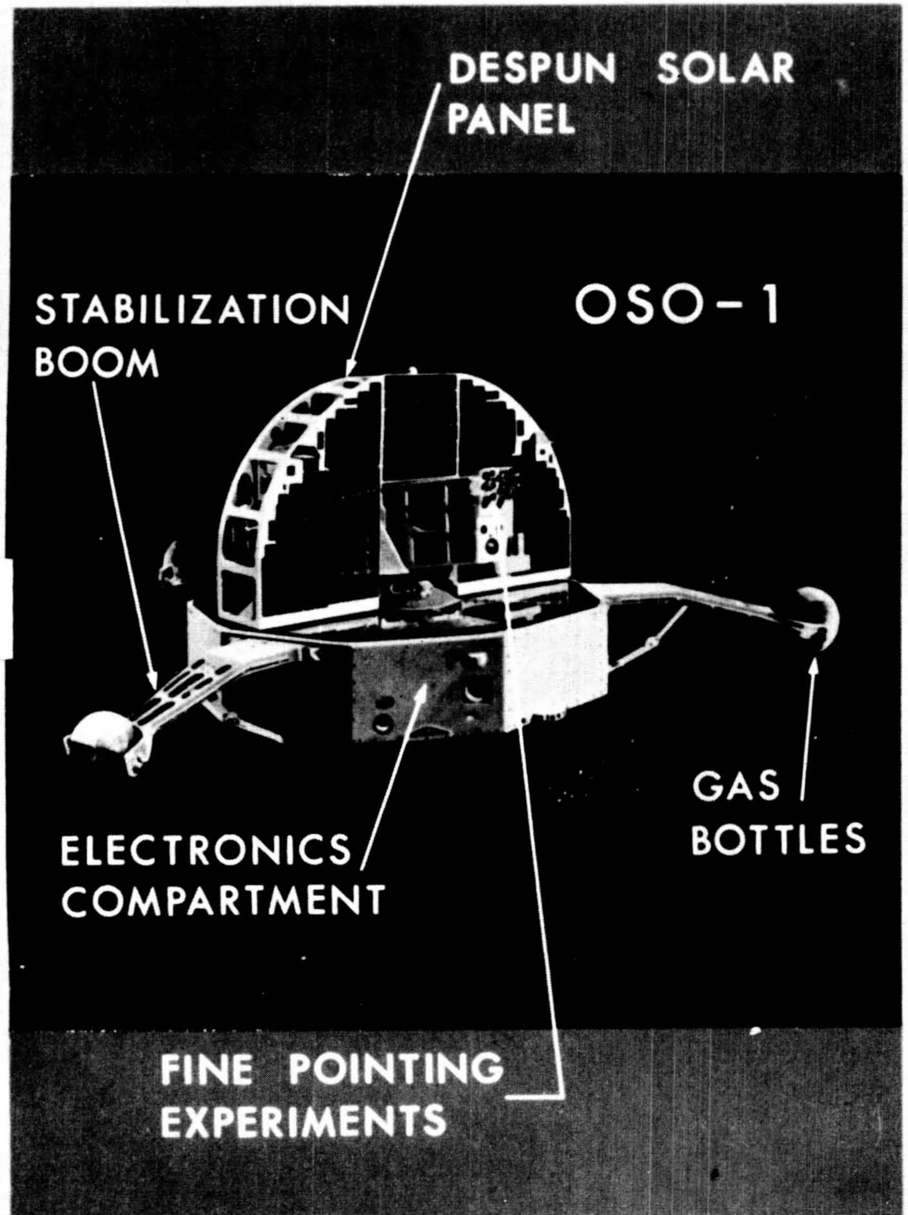
19. Time variations in solar X-ray emissions in the 0.5-3A, 2-8A, 8-16A, and 44-60A bands.

R. W. Kreplin, T. A. Chubb, H. Friedman
Naval Research Laboratory

20. Scanning spectrometer to monitor solar emission in the 200-1600A region.

H. E. Hinteregger
Air Force Cambridge Research Laboratories

ORBITING SOLAR OBSERVATORY



GROSS WEIGHT	- 454 LBS
INSTRUMENT WEIGHT	- 173 LBS
INVESTIGATIONS	- 13
POWER	- 16 WATTS
STABILIZATION	- SPIN
DESIGN LIFE	- 6 MONTHS
LAUNCH VEHICLE	- DELTA
ORBIT	- APOGEE 322 NM PERIGEE 299 NM INCLINATION 33°
STATUS	- LAUNCHED 7 MARCH 1962

NASA SD63 - 1440

ORBITING SOLAR OBSERVATORIES

The Orbiting Solar Observatories (OSO) are a series of stabilized space platforms designed primarily for solar oriented investigations. The spacecraft consists of a rotating wheel-like structure, containing nine wedge-shaped compartments for instrumentation, connected to a fan-shaped stabilized section by a shaft. The oriented portion of the spacecraft points continuously at the center of the sun with an accuracy somewhat less than 2 minutes. The wheel investigations are in general sky mapping investigations comparing radiation from the sun to that in other portions of the sky. The observatories are launched from AMR by Thor-Delta vehicles and are intended to orbit the earth in a circular orbit at an altitude of 300 miles.

The first Orbiting Solar Observatory, OSO I, was launched successfully on March 7, 1962, and returned useful, unique data concerning the sun during eleven weeks of continuous operation and several additional weeks of intermittent operation.

The second OSO will be launched in the first quarter of 1964, and the third, in the fourth quarter of 1964. The second and third OSO's will carry equipment for the following scientific investigations:

Second OSO Spacecraft, OSO-B

Investigations and Investigators

1. Ultraviolet spectrometry in the ranges, 75-600A and 500-1500A.

   W. Lillier, L. Goldberg
   Harvard University

2. Solar X-ray bursts in the 8-20A and 44-66A regions.

   T. A. Chubb, R. Kreplin
   Naval Research Laboratory

3. White light coronagraph

   R. Tousey, J. Purcell
   Naval Research Laboratory

4. Solar scan in the Lyman-alpha region.

   R. Tousey, J. Purcell
   Naval Research Laboratory

5. Intensity and direction of polarized light from interplanetary space.

E. P. Ney
University of Minnesota

6. Arrival direction and energies of primary cosmic rays, 50-1000 Mev.

C. P. Leavitt
University of New Mexico

7. Gamma ray energy spectrum, 0.1 to 5 Mev.

K. J. Frost
Goddard Space Flight Center

8. Ultraviolet stellar and nebular spectrophotometry in the region, 900-3800A.

K. L. Hallam, W. A. White
Goddard Space Flight Center

9. Emissivity stability of surfaces in a vacuum environment.

G. G. Robinson, C. B. Neel
Ames Research Center

OSO-C

Investigations and Investigators

1. Monochromator measurements of solar extreme ultraviolet (pointing section).

H. E. Hinteregger
Air Force Cambridge Research Laboratories

2. Studies of the solar spectrum from 1 A to 400 A (pointing section)

J. C. Lindsay, W. M. Neupert, W. E. Behring, W. A. White
Goddard Space Flight Center

3. Emissivity stability of low temperature coatings.

C. B. Neel, G. G. Robinson
Ames Research Center

4. Earth albedo from 1000 A to 4 microns.

C. B. Neel, G. G. Robinson
Ames Research Center

5. X-ray and gamma ray astronomy

L. E. Peterson
University of California, La Jolla

6. Gamma ray astronomy

W. L. Kraushaar, G. W. Clark, G. Garmire, R. Baker
Massachusetts Institute of Technology

7. Solar X-rays

R. G. Teske
University of Michigan

8. Solar gamma rays

E. M. Hafner, M. F. Kaplon
University of Rochester

Alternate Investigations and Investigators

1. Proton-Electron Measurements

S. D. Bloom, E. Schrader, J. A. Waggoner, R. Kaifer
UCLRL

2. Solar Flare X-ray Spectroscopy.

H. Friedman, T. A. Chubb
Naval Research Laboratory

OSO-D

The investigations below have been selected for OSO-D:

1. Solar Flare X-ray Spectroscopy (pointing section).

H. Friedman, T. A. Chubb
Naval Research Laboratory

2. Normal incidence scanning spectrometer for 300-1300 A (pointing section).

   L. Goldberg, E. M. Reeves, W. H. Parkinson
   Harvard College Observatory

3. Solar X-radiation (pointing section)

   R. Giacconi
   American Science and Engineering, Inc.

4. Cosmic or Non-solar X-rays.

   R. Giacconi
   American Science and Engineering, Inc.

5. Total solar X-ray Emission over wide bands (1.2-3.6A, 3-9A, 6-18A, 44-55A, 44-70A).

   E. A. Stewardson, R. L. F. Boyd
   Leicester University and University College London

6. Proton/electron detector.

   J. A. Waggoner, S. D. Bloom, C. D. Schroder, R. Kaifer
   UCLRL

7. Solar He II resonance emission (303.8 A).

   R. L. F. Boyd
   University College London

8. Monitoring of solar radiation (8-16A, 2-8A, 0.5-3A, 0.1-1.6A).

   T. A. Chubb, R. W. Kreplin, H. Friedman
   Naval Research Laboratory

9. Lyman-Alpha night sky glow.

   T. W. Mange, T. A. Chubb, H. Friedman
   Naval Research Laboratory

Back-up Investigations

1. X-ray spectroheliograph.

   E. A. Stewardson, R. L. F. Boyd
   University of Leicester and University College London

OSO-E

The following investigations have been approved for OSO-E:

1. X-ray spectroheliograph (pointing section).

   E. A. Stewardson, R. L. F. Boyd
   University of Leicester and University College London

2. White light coronagraph and extreme ultraviolet spectroheliograph (pointing section).

   J. D. Purcell, R. Tousey, H. Friedman
   Naval Research Laboratory

3. The solar spectrum from 1-400 A (pointing section).

   J. C. Lindsay, W. M. Neupert, W. E. Behring, W. A. White
   Goddard Space Flight Center

4. Self-reversal of the solar Lyman-alpha line.

   J. Blamont
   University of Paris

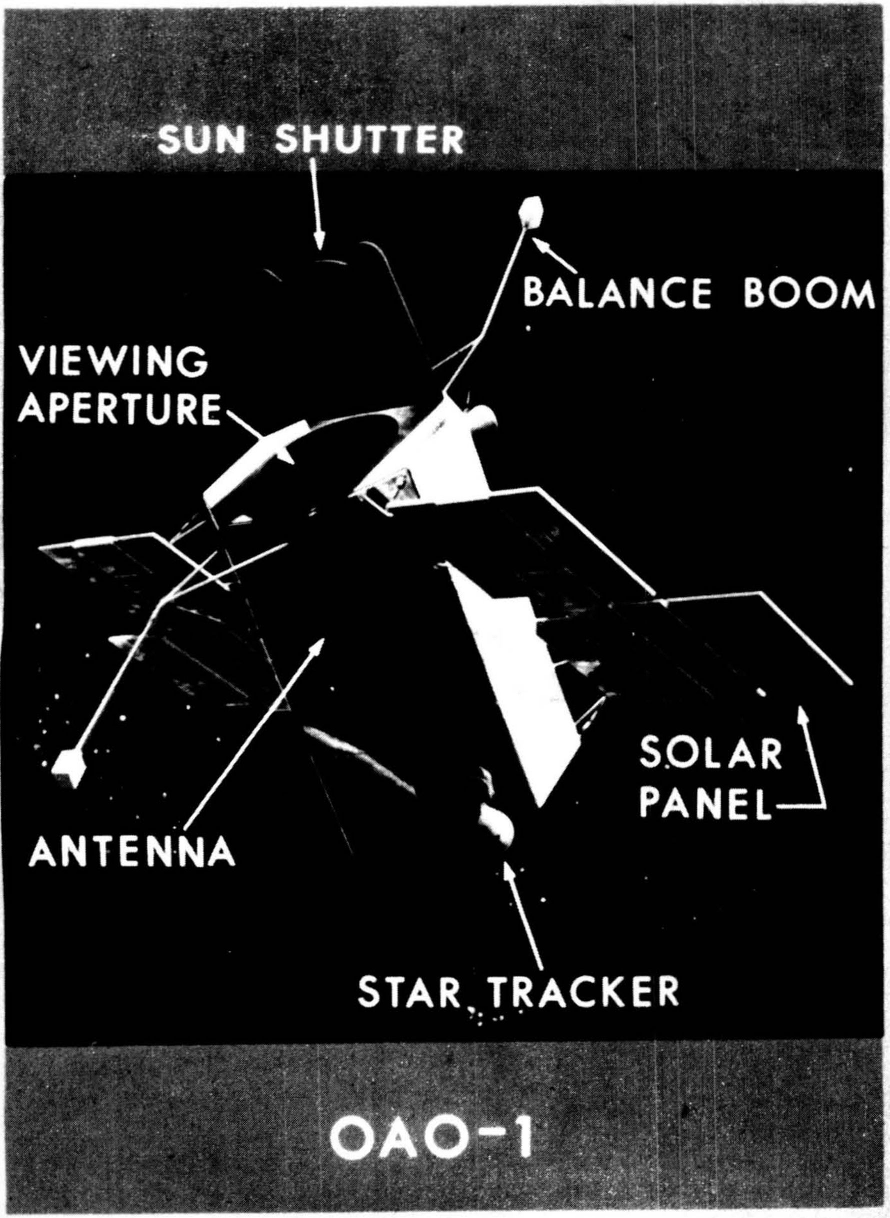
5. Solar radiation monitoring

   T. A. Chubb, R. W. Kreplin, H. Friedman
   Naval Research Laboratory

6. Low energy gamma ray observations of sun.

   K. Frost, H. Horstman, E. Rothe
   Goddard Space Flight Center

ORBITING ASTRONOMICAL OBSERVATORY



GROSS WEIGHT	- 3,600 LBS.
INSTRUMENT WEIGHT	- 1,000 LBS.
INVESTIGATIONS	- 11
STABILIZATION	- ACTIVE 3 AXIS
DESIGN LIFE	- 1 YEAR
LAUNCH VEHICLE	- ATLAS - AGENA
ORBIT	- CIRCULAR - 434 NM INCLINATION 32°
STATUS	- FIRST FLIGHT 1965

NASA SD63 - 1450
REVISED 7 - 63

ORBITING ASTRONOMICAL OBSERVATORIES

The Orbiting Astronomical Observatories (OAO) are designed to provide an opportunity to explore those regions of the spectrum that are now inaccessible because of atmospheric absorption. The OAO is a precisely-stabilized satellite designed to accommodate various types of astronomical observing equipment. The primary experiments for the first three observatories are all concerned with stellar astronomy in the ultraviolet range (800 to 4000Å).

1. OAO-A will carry two prime investigations:

a. A mapping study of the celestial sphere in three ultraviolet ranges. This investigation will map the sky in ultraviolet down to a wavelength of 1100Å with three broad band television photometers and will record the brightness of at least 20,000 stars.

b. A broad band photometry study of individual stars and nebulae. These observations will be directed toward the determination of the stellar energy distribution in the spectral region from 800 to approximately 3000Å, and the measurement of emission line intensities of diffuse nebulae in the same spectral region. These investigations are expected to provide data which will not only be useful to the entire astronomical community but will also act as an aid in designing later instrumentation.

2. OAO-B will contain a system designed to obtain absolute spectrophotometric data on selected stars, nebulae and galaxies. The optical system will employ a relatively fast 36-inch Cassegrain telescope with a large aperture spectrophotometer and will use both the coarse (1 minute of arc) and the fine (1 second of arc) control systems. The usable spectral region will be approximately 912 to 4000Å.

3. The absorption investigation in OAO-C has, as its primary objective, quantitative observations of the absorption spectrum of the interstellar gas in the regions between 800 and 1500Å and 1600 to 3000Å.

It is expected that later satellites will be used for studies of the sun and planets. In addition, all observatories will have a limited amount of payload capacity for small secondary investigations.

The basic OAO structure is octagonally-shaped with a central tubular area containing the experiment equipment. The total weight of the spacecraft is expected to be about 3600 lbs., of which 1000 lbs. is allocated to the experimental apparatus.

The power supply for OAO is externally-mounted fixed arrays of silicon solar cells used in conjunction with rechargeable nickel-cadmium storage batteries. An average power of 330 watts is available from the arrays. The power available to the experimental equipment is to be 30 watts average and 60 watts peak.

The stabilization and control system consists primarily of star trackers, sun trackers, inertial wheels, and gas jets. The requirements imposed on the guidance and control system will permit determination of the absolute direction of the optical axis to an accuracy of 1 minute of arc and an orientation of the optical axis to 1 degree with respect to a know reference. Also, the control system will permit an ultimate guiding accuracy of 0.1 second of arc during observation of an individual star. The major function of the attitude control system may be categorized as follows:

1. To stabilize the spacecraft following booster separation and to establish its attitude with the required precision.

2. To slew the satellite to any desired attitude as dictated by the scientific objectives of the mission.

3. To enable the satellite to maintain a given attitude with the required accuracy for long periods of time.

The remainder of the basic system is comprised of data storage units and a communications system, including four radio links which are required to accomplish tracking, command, and telemetry.

The satellite will be launched by an Atlas-Agena from AMR into an approximately-circular orbit at an altitude of 500 statute miles, inclined to the equator at an angle of 32 degrees.

ORBITING ASTRONOMICAL OBSERVATORIES

OAO-A, OAO-B, OAO-C

Investigations and Investigators

OAO-A

Mapping in three ultraviolet ranges.

F. Whipple
Smithsonian Astrophysical Observatory

Stellar broad band photometry measurements in ultraviolet.

A. Code
University of Wisconsin

OAO-B

Absolute spectrophotometry measurements.

J. Milligan
Goddard Space Flight Center

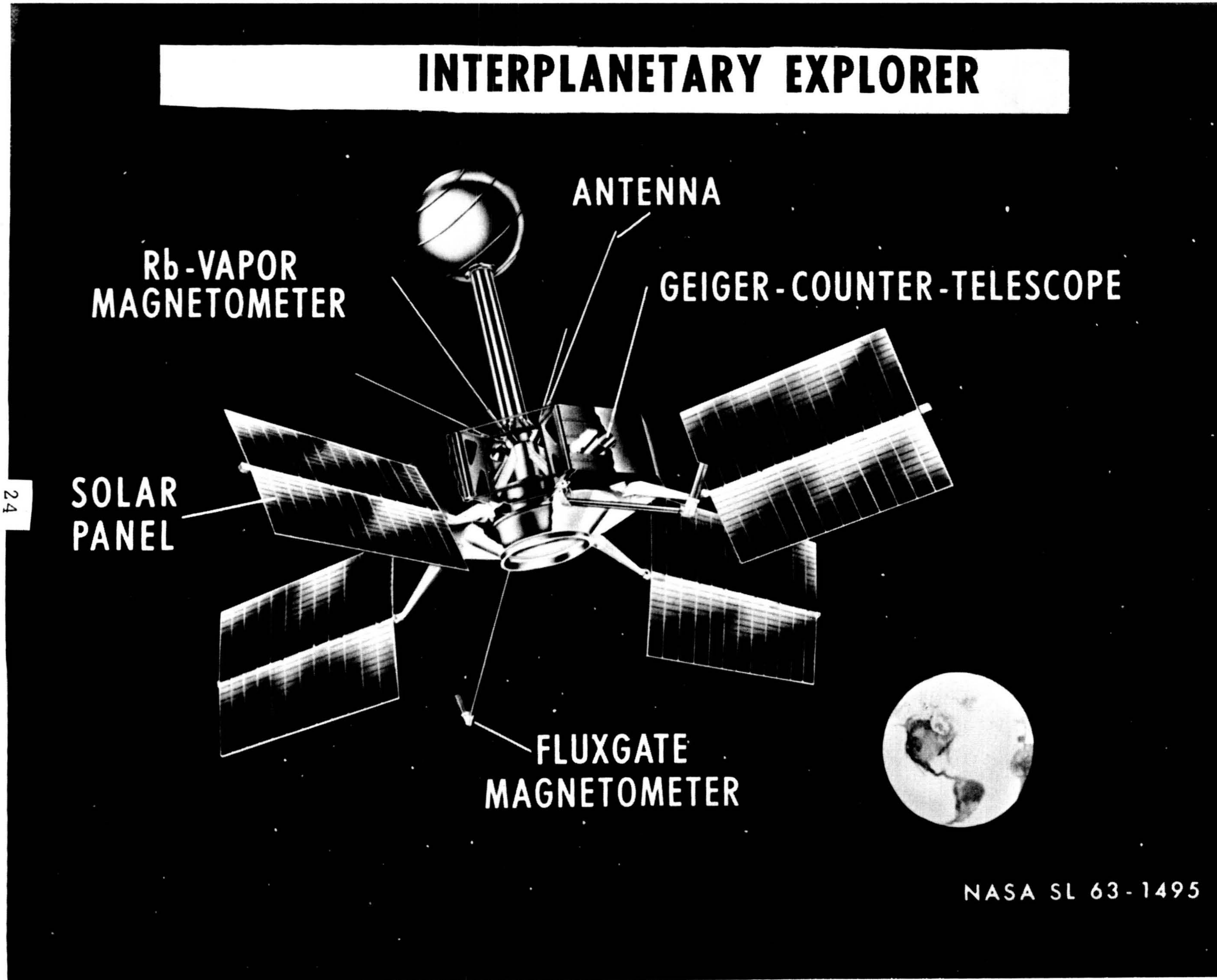
OAO-C

Interstellar absorption measurements.

L. Spitzer
Princeton University

X-ray Telescope

Prof. R. L. F. Boyd
University College London


INTERPLANETARY EXPLORER
ANTENNA
Rb-VAPOR MAGNETOMETER
GEIGER-COUNTER-TELESCOPE
SOLAR PANEL
FLUXGATE MAGNETOMETER
NASA SL 63-1495

INTERPLANETARY EXPLORER SATELLITES

The interplanetary explorer satellites have been developed for the purposes suggested by their name. They belong to the general group of small satellites and will be put in orbit with the Delta vehicle. The planned orbit calls for an apogee of 173,000 miles and a perigee of 125 miles and an angle of inclination (33°). The first three interplanetary explorers will carry equipment for the following investigations:

Investigations and Investigators

1. Magnetic field measured with rubidium vapor and fluxgate magnetometers.

   N. F. Ness
   Goddard Space Flight Center

2. Plasma measurements in energy range of a few electron volts to 8 Kev.

   H. S. Bridge
   Massachusetts Institute of Technology

3. Energetic particles in energy range, 10 to 200 Mev.

   J. A. Simpson and G. Gloeckler
   University of Chicago

4. Plasma measurements in thermal energy range (0-10 Ev).

   G. P. Serbu and R. Bordeau
   Goddard Space Flight Center

5. Total charged particle flux.

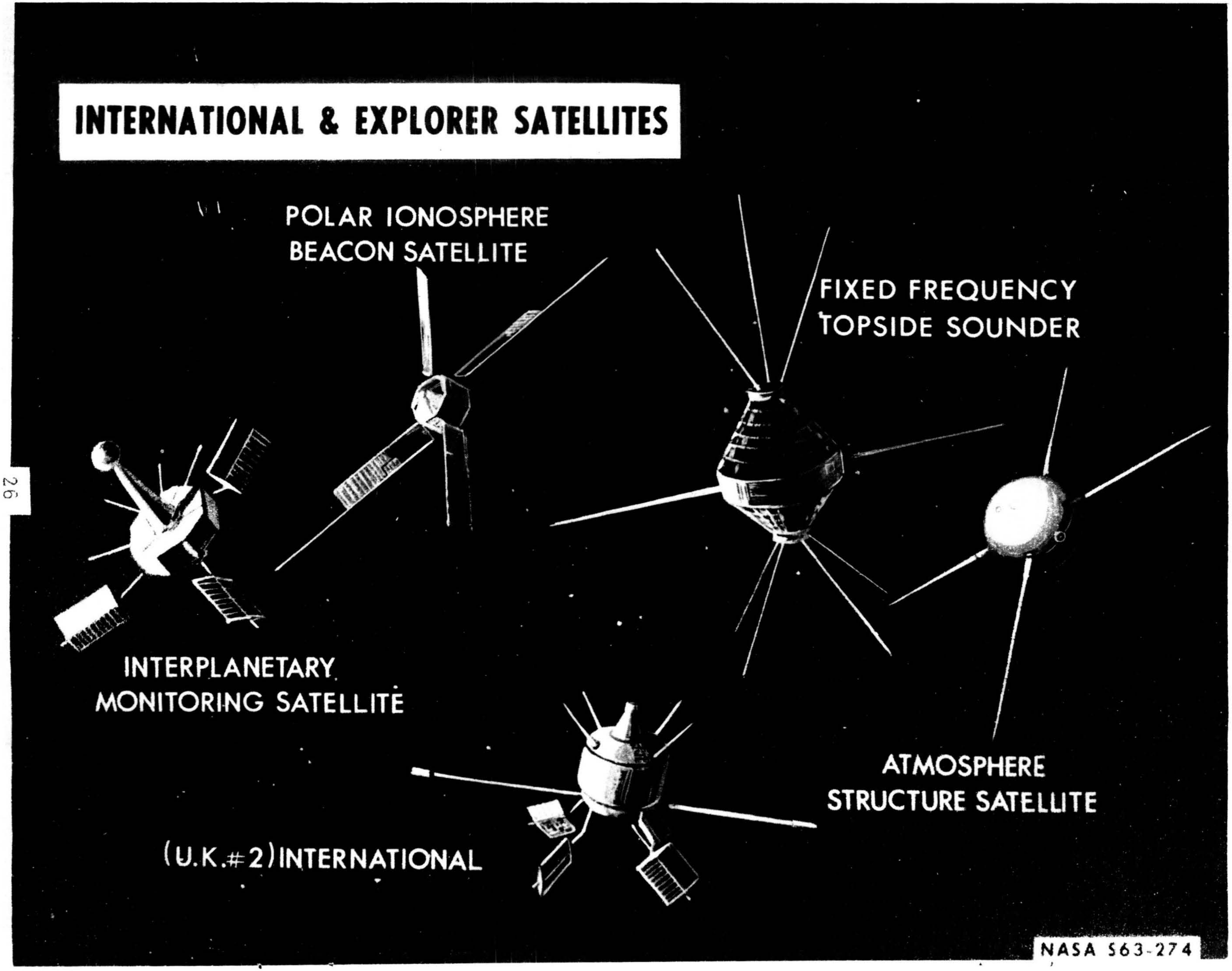
   K. A. Anderson
   University of California, Berkeley

6. Total energy of protons versus energy loss over range, 10 to 100 Mev.

   F. B. McDonald and G. Ludwig
   Goddard Space Flight Center

7. Proton analyzer

   J. H. Wolfe
   Ames Research Center



INTERNATIONAL & EXPLORER SATELLITES
POLAR IONOSPHERE BEACON SATELLITE
FIXED FREQUENCY TOPSIDE SOUNDER
INTERPLANETARY MONITORING SATELLITE
ATMOSPHERE STRUCTURE SATELLITE
(U.K.#2) INTERNATIONAL
NASA S63-274

INTERNATIONAL SATELLITES

A number of satellites are programmed that call for international cooperation with either national units of scientists or with individual scientists. These satellites are:

1. A second United Kingdom satellite (ARIEL, International Ionosphere Satellite, was the first). The studies to be conducted by the UK #2 are the following:

   a. A galactic radio noise study in the frequency range between 0.75 to 3.0 megacycles and exploration of the upper atmosphere.

      F. G. Smith
      University of Cambridge

   b. A study of the vertical distribution of ozone in the atmosphere using filtered photocells and a prism spectrometer in the region from 2500 to 4000A.

      R. Frith and K. A. Stewart
      UK Air Ministry

   c. A study of micrometeorite flux; the quantity and size of particles down to several microns studied by the holesformed in thin metallic films.

      R. C. Jennison and J. Bank
      Nuffield Radio Astronomy Laboratories

2. First releases of information concerning the third United Kingdom satellite list the following investigations:

   a. The vertical distribution of oxygen at levels of solar activity in the atmosphere.

      Dr. R. Frith
      Meteorological Office

   b. Radio noise from the galaxy

      F. G. Smith
      Mullard Radio Observatory of the University of Manchester

c. VLF radiation spectrum @ 3.2, 9.6, and 16 Kc.

T. R. Kaiser
University of Sheffield

d. Plasma probe measurements of the ionosphere above the F_2 maximum.

J. Sayers
University of Birmingham

e. Flux of radio frequency radiations arising from natural sources.

J. A. Ratcliffe
Radio Research Station

3. Polar Ionosphere Beacon - The primary objective of the satellite will be to determine the general profile of the ionosphere, its irregularities, and the propagation characteristics below the altitude of the satellite (about 1000 Km) as these characteristics affect radio communication frequencies. The prime observing stations will be the University of Illinois, the Pennsylvania State University, Stanford University, and the Central Radio Propagation Laboratory. The program offers an opportunity for world-wide cooperation, and about forty other investigators in twenty countries will take part in the program. Observers will be given the orbital data necessary to conduct experiments with the beacon frequencies.

In addition, a LASER test will be attempted.

4. The International Satellite for Ionospheric Studies will be a cooperative activity of Canadian and American scientists. The first satellite will use the existing ALOUETTE back-up spacecraft. An updated version of EXPLORER VIII Direct Measurements satellite will be launched piggyback with the ALOUETTE. The orbit will be closely polar. The investigations for this flight project have not yet been selected.

OTHER SATELLITES

The Air Density/Injun payload consists of two independent spacecraft to be launched simultaneously by a Scout into a near polar, eccentric orbit with perigee of 600 Km, apogee of 3000 Km, and inclination of 84°. The Air Density spacecraft is a 12-ft sphere of the same design as EXPLORER IX. Like EXPLORER IX it will be used to study changes in atmospheric density through the changes in drag as shown by orbital changes. The Injun spacecraft is designed to make direct measurements of the down flux of corpuscular radiation into the atmosphere with CeI and CdS detectors, geiger counters, and spherical retarding potential analyzers. The flux will be correlated with changes in atmospheric density.

The investigators are:

W. J. O'Sullivan, C. Coffee, G. Keating
(all of Langley Research Center)

L. Jacchia
(Smithsonian Astrophysical Observatory) - Air Density Spacecraft

J. Van Allen (State University of Iowa), R. Sagalyn (Air Force Cambridge Research Laboratories) - Injun Spacecraft

A second Atmosphere Explorer satellite, similar to EXPLORER XVII, is being planned which will carry equipment for the following investigations:

1. Electron temperature

   L. H. Brace
   Goddard Space Flight Center

2. Atmospheric pressure

   G. P. Newton and D. R. Tauesch
   Goddard Space Flight Center

3. Neutral gas concentration, including hydrogen

   C. Reber and J. Cooley
   Goddard Space Flight Center

Another Energetic Particle Explorer Satellite, identical to EXPLORER XV is also in the planning stage.

The Fixed Frequency Topside Sounder is similar in purpose to the Canadian swept frequency satellite, ALOUETTE, but will employ six fixed frequencies. The use of a fixed frequency will permit the following of rapid changes in the ionosphere. In addition to the sounder and the receiver, the satellite will carry the ion spectrometer of R. L. F. Boyd and A. P. Willmore that was on board the British satellite ARIEL.

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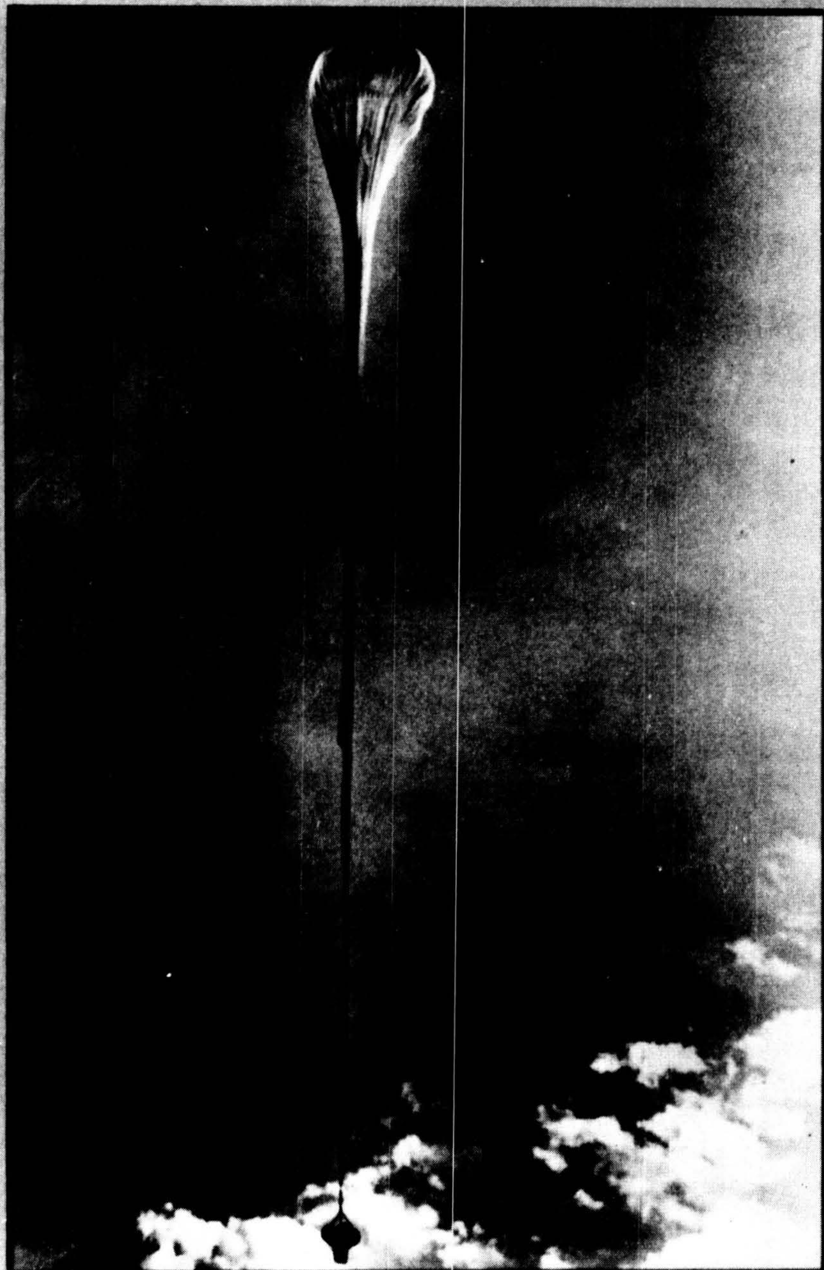

BALLOON OBSERVATORY

NASA S63-708

BALLOONS

The following investigations to be conducted from balloons during 1964 have been approved by NASA:

1. Collection of micrometeoroids at time of Perseid showers.

   C. L. Hemenway
   The Dudley Observatory

2. Charge spectrum of primary cosmic radiation

   E. C. Palmatier
   University of North Carolina

3. Anisotropies of cosmic radiation.

   K. G. McCracken
   Graduate Research Center of the Southwest

4. X-ray and gamma ray astronomy

   L. E. Peterson
   University of California at La Joaa, San Diego

5. Continuation of Stratoscope II flights.

   M. Schwartzchild
   Princeton University

6. Neutron detector

   C. P. Leavitt
   University of New Mexico

7. Cerenkov-scintillation telescope.

   E. P. Ney and J. R. Winckler
   University of Minnesota

8. Auroral light, particle flux, and ultraviolet and gamma ray flux.

   M. Almasi, W. B. Murcray
   University of Alaska

9. Cosmic ray investigations.

K. Anderson
University of California (Berkeley)

10. Cosmic ray investigations.

P. Meyer
University of Chicago

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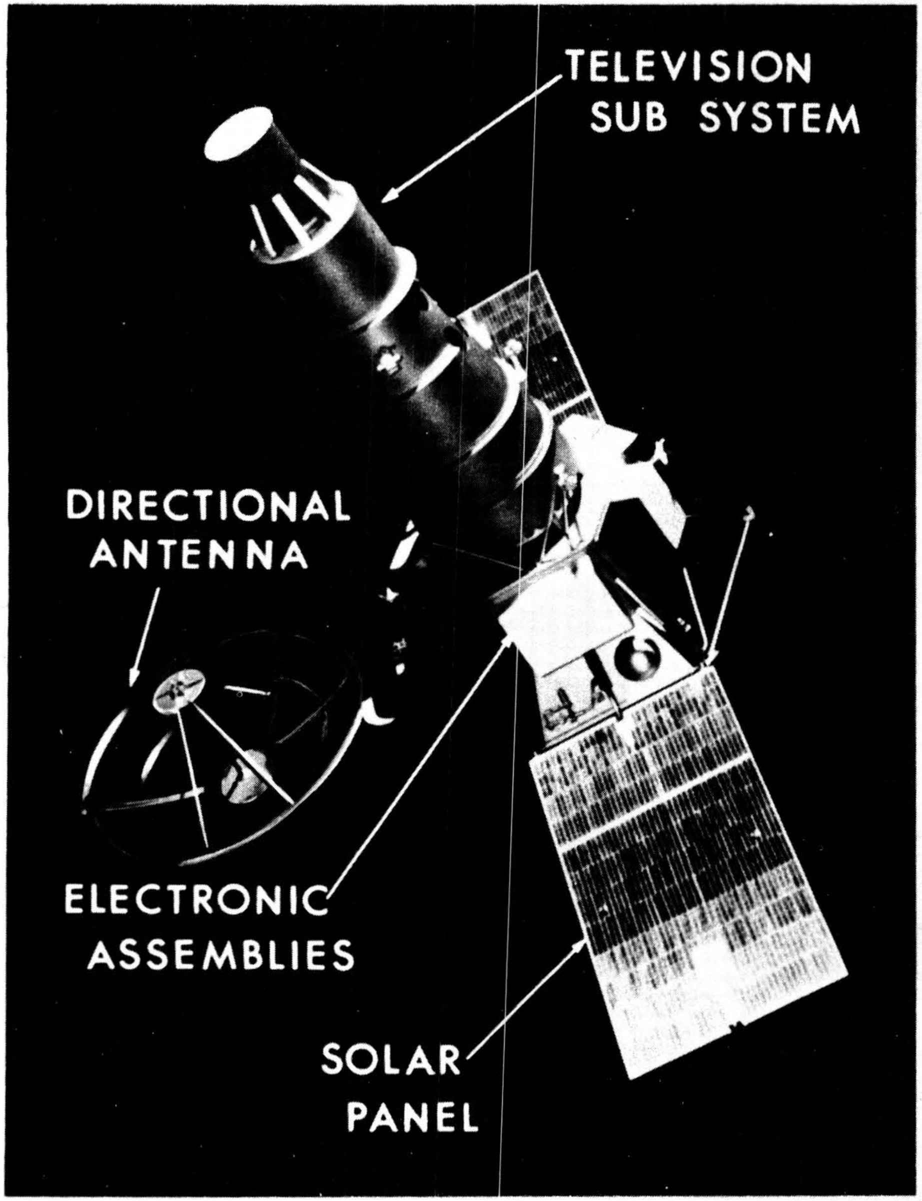
RANGER (6-9)



GROSS WEIGHT	- 807 LBS
INVESTIGATIONS	- TELEVISION (6 CAMERAS)
TELEVISION SUB-SYSTEM WEIGHT	- 371 LBS
POWER	- 170 WATTS
PROPULSION	- MIDCOURSE MOTOR- (LIQUID)
STABILIZATION	- ACTIVE 3 AXIS
LIFE	- 66 HR. TRANSIT
LAUNCH VEHICLE	- ATLAS AGENA-B
TRAJECTORY	- LUNAR IMPACT VIA PARKING ORBIT
STATUS	- NEXT FLIGHT, 1964

NASA SD63 - 1455

RANGER

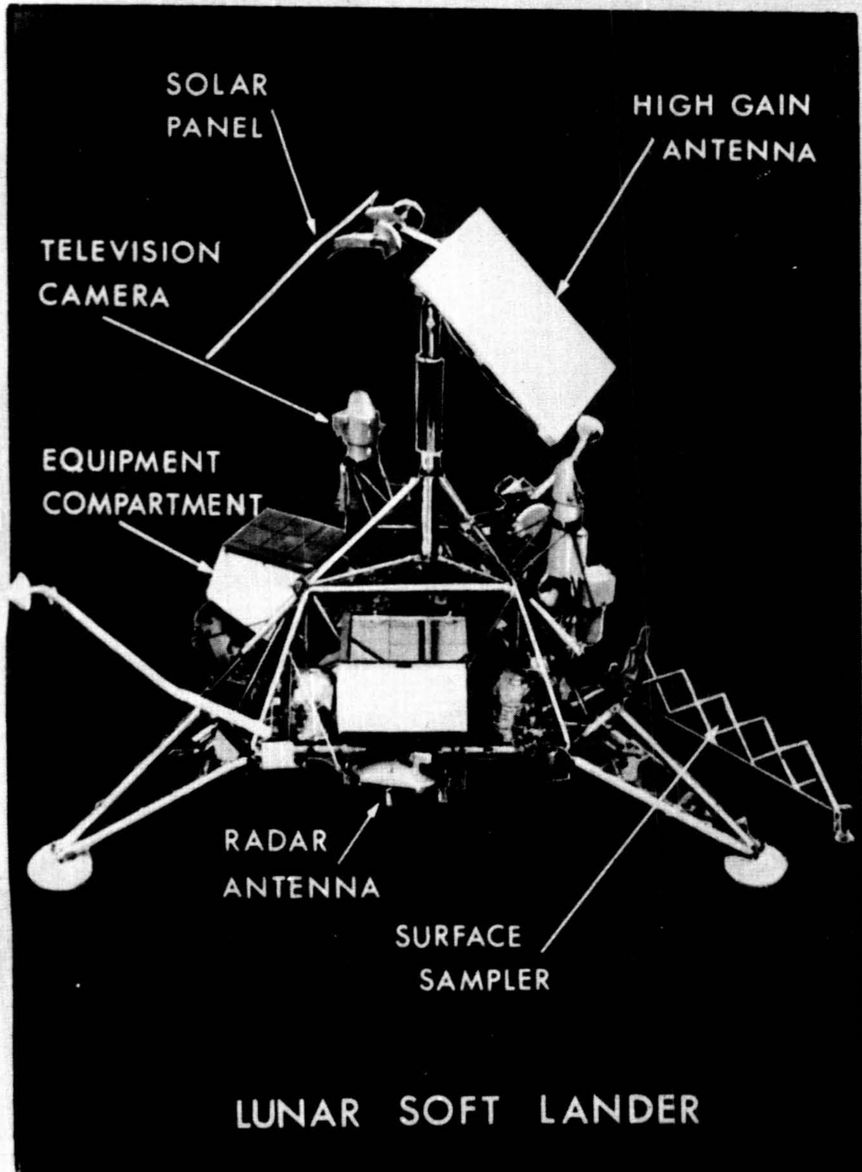
The first two RANGER flights were designed for spacecraft test and for measurement of interplanetary radiation and fields. The major accomplishments of these flights, which took place in 1961, was the proving out of complex spacecraft subsystems and the two-way deep space communications between the spacecraft and the earth. Due to a very short orbital life, only a small amount of scientific data was obtained.

RANGERS 3 through 5 included a hard-landing capsule as well as a main bus and were designed to obtain medium resolution TV photos of the lunar surface, to measure gamma-ray spectra, to land a seismometer on the lunar surface, and to measure lunar surface radar reflectivity characteristics. RANGER 3 was launched in January 1962 but failed to impact the moon as planned, owing to a small injection velocity error in the launch vehicle; it passed by the leading edge of the moon at a distance of about 37,000 kilometers. The RANGER 4 spacecraft, launched in April 1962, impacted the back side of the moon but, due to a spacecraft malfunction, no data was obtained. RANGER 5 was launched in October 1962 but missed the moon by 450 miles; significant gamma-ray spectra data was obtained before a power loss occurred.

The prime investigation on RANGERS 6 through 9 will be a wide bandwidth, high resolution television system for obtaining close-up pictures of the moon during the final approach before impact on the surface. The pictures are expected to be an order of magnitude better in resolution than those obtained by earth-based techniques. The RANGER system will begin taking pictures at about 1000 miles from the surface and will resolve lunar features as small as three feet in the last pictures before impact.

The prime investigation for RANGERS 10 through 14 will be a single-axis seismometer which will utilize a hard-landing impact limiter capsule similar to that used on RANGERS 3 through 5. In addition to the prime investigation, other main bus investigations are designed to obtain medium resolution TV photos of the surface, measure the gamma-ray spectra in cislunar space as well as near the surface and to measure lunar surface radar reflectivity characteristics.

SURVEYOR SPACECRAFT



LUNAR SOFT LANDER

GROSS WEIGHT	- 2,100 LBS
INSTRUMENT WEIGHT	- 100 LBS
INVESTIGATIONS	- 6
POWER	- 88 WATTS
STABILIZATION	- ACTIVE 3 AXIS
PROPULSION	
RETROROCKET	- SOLID
VERNIER ROCKETS	- LIQUID
DESIGN LIFE	- 30-90 DAYS
LAUNCH VEHICLE	- ATLAS-CENTAUR
TRAJECTORY	- DIRECT ASCENT OR PARKING ORBIT
STATUS	- FIRST FLIGHT 1964

NASA SD63 - 1456

SURVEYOR

Surveyor is the NASA lunar exploration program concerned with the soft landing of unmanned instrumented spacecraft on the Moon. The following list of investigations has been selected for the first several operational missions:

1. Television - visual surveillance of lunar surface topographic and terrain features.

    E. Shoemaker (USGS)

    G. Kuiper (Arizona)

    E. Whitaker (Arizona)

2. Micrometeorite Ejecta - determine flux, velocity, and mass distribution of material ejected from lunar surface by meteoric impacts.

    W. Alexander (GSFC)

    O. Berg (GSFC)

    L. Secretan (GSFC)

    C. McCracken (GSFC)

3. Seismometer - single-axis short-period seismometer to investigate lunar seismic activity on Moon.

    G. Sutton (Lamont)

    M. Ewing (Lamont)

    F. Press (CIT)

4. Alpha Scattering - elemental analysis of lunar surface material.

    A. Turkevich (Chicago)

    I. Patterson (Argonne National Laboratory)

    E. Franzgrote (JPL)

5. Surface Manipulator - determines surface structure and mechanical properties of lunar surface material.

R. Scott (CIT)

R. Haythornwaite (Michigan)

R. Liston (U. S. Army Land Locomotion Laboratory)

6. Touchdown Dynamics - determines mechanical properties of lunar surface material.

S. Batterson (Langley Research Center)

The Surveyor Program will assist the Apollo Program by providing topographic and lunar surface bearing strength information needed to certify suitable landing sites.

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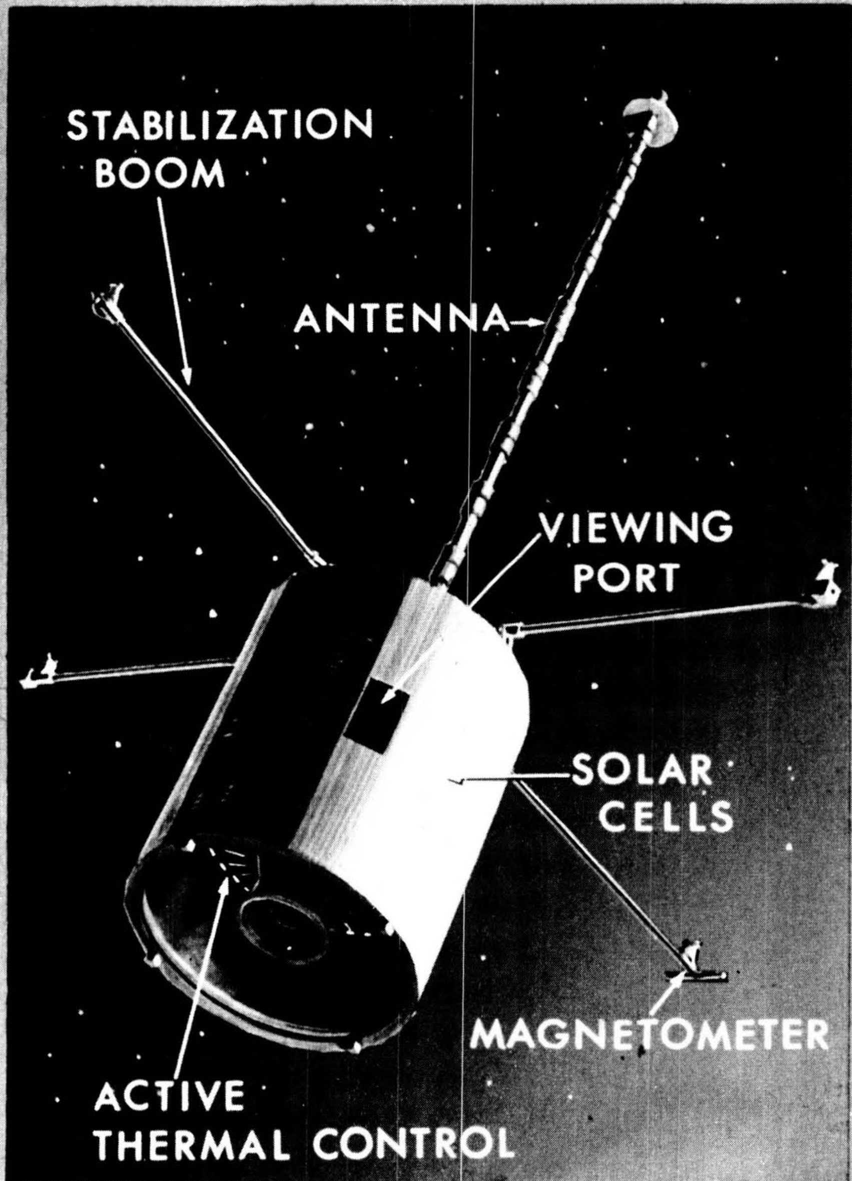
PIONEER



GROSS WEIGHT	- 115 LBS
INSTRUMENT WEIGHT	- 20 LBS
INVESTIGATIONS	- 4
POWER	- 50 WATTS
STABILIZATION	- SPIN
DESIGN LIFE	- 6 MONTHS
LAUNCH VEHICLE	- DELTA
TRAJECTORY	- INTERPLANETARY
STATUS	- FIRST FLIGHT 1965

NASA SD63 - 1453

PIONEER

NASA, beginning in 1965, will launch a series of spacecraft, designated Pioneer to monitor interplanetary space during and following the International Quiet Sun Year. The scientific payload for the first two flights has been approved and is as follows, listed according to priority:

Firm Payload

1. Magnetometer - measures the interplanetary magnetic field.

   N. Ness (GSFC)

2. Plasma Probe - measures the characteristics of the interplanetary plasma including the flux, energy spectrum, direction, and angular distribution of positive ions and electrons.

   H. Bridge (MIT)

   A. Lazarus (MIT)

   F. Scherb (MIT)

3. Cosmic Ray Telescope - measures proton and alpha particle fluxes and energy spectra.

   J. Simpson (Chicago)

   J. Lamport (Chicago)

   C. Fan (Chicago)

4. Radio Propagation Investigation - measures the interplanetary electron density and its variation.

   V. Eshleman (Stanford)

   O. Garriott (Stanford)

   R. Leadabrand (SRI)

   A. Peterson (SRI)

Tentative Investigations

5. Cosmic Ray Detector - studies the lower energy portion of cosmic ray spectrum to determine degree and variations of anisotropy.

K. McCracken (SW Graduate Res. Center)

W. Bartley (SW Graduate Res. Center)

U. Rao (SW Graduate Res. Center)

6. Plasma Probe - measures characteristics of the interplanetary plasma.

J. Wolfe (Ames)

R. Silva (Ames)

D. McKibbin (Ames)

7. Cosmic Dust - measures flux, direction, mass and velocity distribution of micrometeorites in interplanetary space--investigator to be selected.

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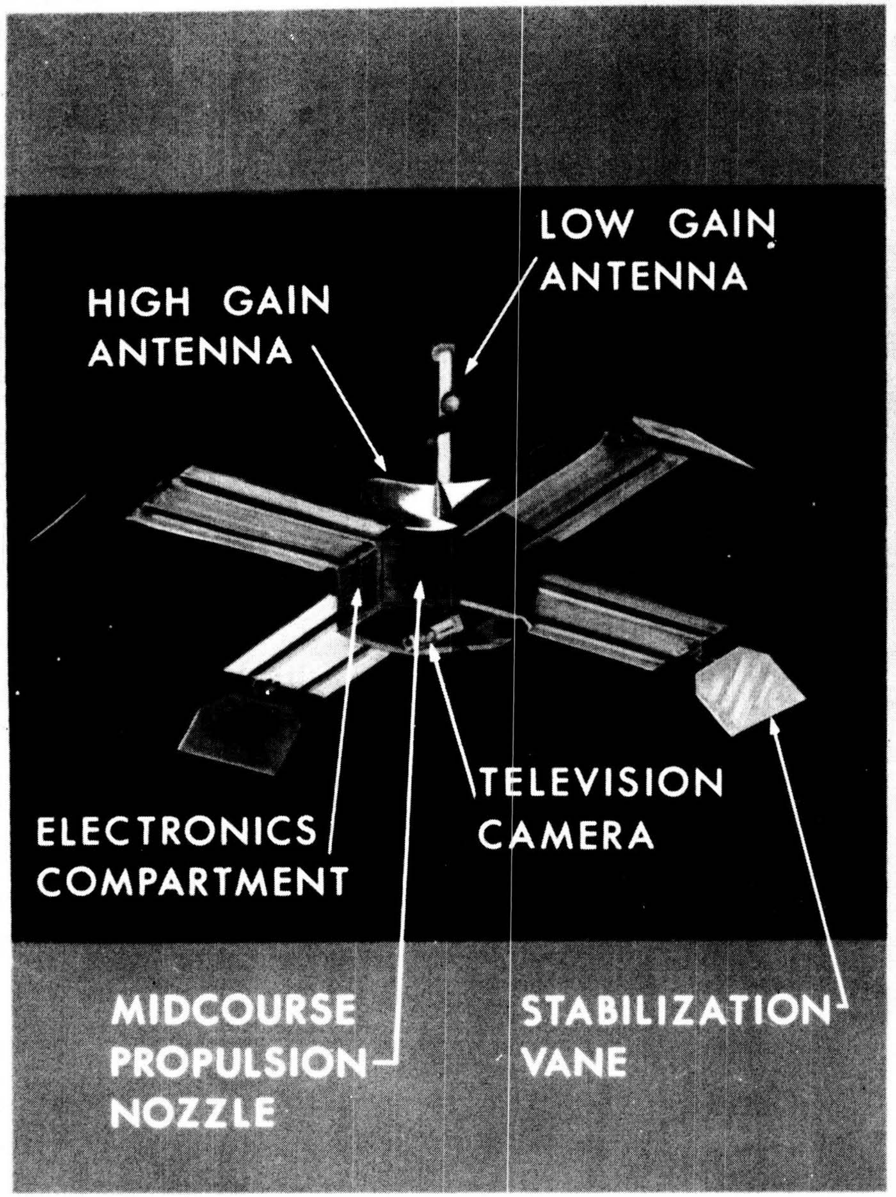
MARINER MARS



GROSS WEIGHT	- 570 LBS
INSTRUMENT WEIGHT	- 40 LBS
INVESTIGATIONS	- 8
POWER	- 120 WATTS
STABILIZATION	- ACTIVE 3 AXIS
DESIGN LIFE	- 8 MONTHS
LAUNCH VEHICLE	- ATLAS-AGENA
TRAJECTORY	- INTERPLANETARY, MARS FLY-BY
STATUS	- FIRST FLIGHT IN 1964

NASA SD63 - 1454

MARINER

The first MARINER spacecraft, MARINER II, flew within 22,000 miles of Venus in late 1962, instrumented to obtain information concerning the planet and the interplanetary environment. The successful mission provided data regarding the temperature of Venus and its atmosphere, as well as measurements of energetic particles, plasma, micrometeorites and magnetic fields in interplanetary space.

The next spacecraft in the MARINER series is called MARINER C and is designed to conduct a comparable exploration of Mars in 1964. The payload is comprised of the following investigations:

1. Television - photographs a band on the Martian surface near the equator with a number of overlapping alternately red and green filtered 5 kilometer resolution-pictures.

R. Leighton	(CIT)
B. Murray	(CIT)
R. Sharp	(CIT)

2. Magnetometer - measures the interplanetary magnetic field and the Martian field, if detectable at fly-by distance, using a sensitive 3-axis helium magnetometer.

E. Smith	(JPL)
P. Coleman	(UCLA)
L. Davis	(CIT)
D. Jones	(JPL)

3. Ultra-violet Photometer - determines the existence of atomic oxygen and atomic hydrogen in the exosphere of Mars.

C. Barth	(JPL)
J. Brandt	(Kitt Peak Natl. Obs.)
L. Wallace	(" " " ")
J. Pierce	(JPL)

4. Plasma Probe - measures the character of the interplanetary plasma including flux, energy, and direction of protons. The instrument is basically similar to that developed for EGO.

H. Bridge (MIT)

A. Lazarus (MIT)

C. Snyder (JPL)

5. Cosmic Ray Telescope - determines flux and energy spectrum of low, medium and high energy protons and alpha particles using silicon solid-state detectors.

J. Simpson (Chicago)

6. Low Energy Cosmic Ray - studies the angular distributions, energy spectra and time histories of solar cosmic rays and energetic electrons in interplanetary space and in the vicinity of Mars.

J. Van Allen (SUI)

L. Frank (SUI)

S. Krinige (SUI)

7. Cosmic Ray Ionization - measures flux and ionization rate of galactic cosmic rays.

H. Neher (CIT)

H. Anderson (JPL)

8. Cosmic Dust - measures flux, direction, mass and velocity distribution of micrometeorites in interplanetary space and in the vicinity of Mars.

W. Alexander (GSFC)

O. Berg (GSFC)

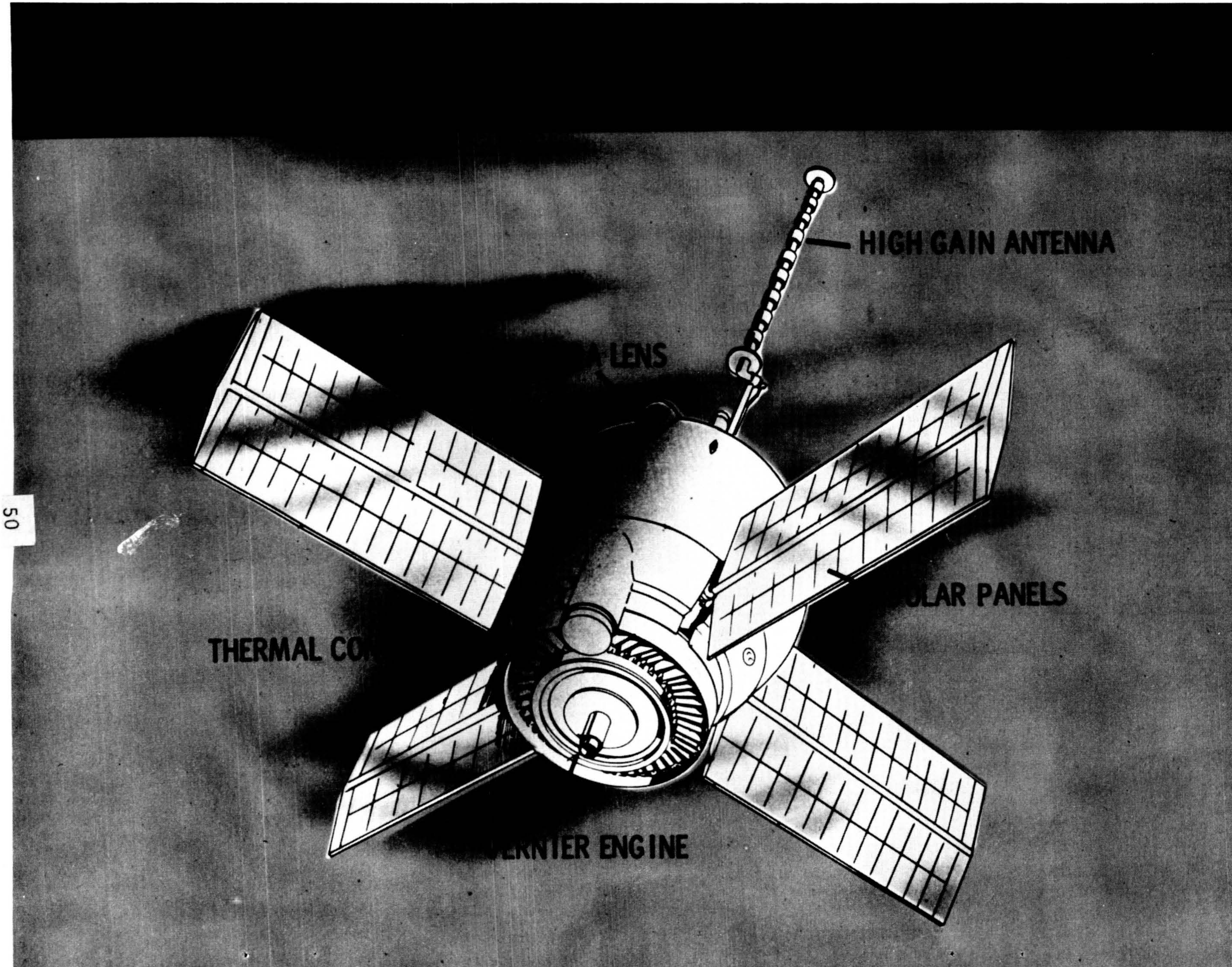
C. McCracken (GSFC)

L. Secretan (GSFC)

J. Bohn (Temple)

O. Fuchs (Temple)

Scheduled for the 1966 opportunity is a third type of MARINER spacecraft. It is planned to be a heavier version of MARINER C with the extra capability of carrying a capsule for entry into the Mars atmosphere. Investigations for the 1966 opportunity have not been selected.


HIGH GAIN ANTENNA
LENS
PANELS
THERMAL
ENGINE

LUNAR ORBITER

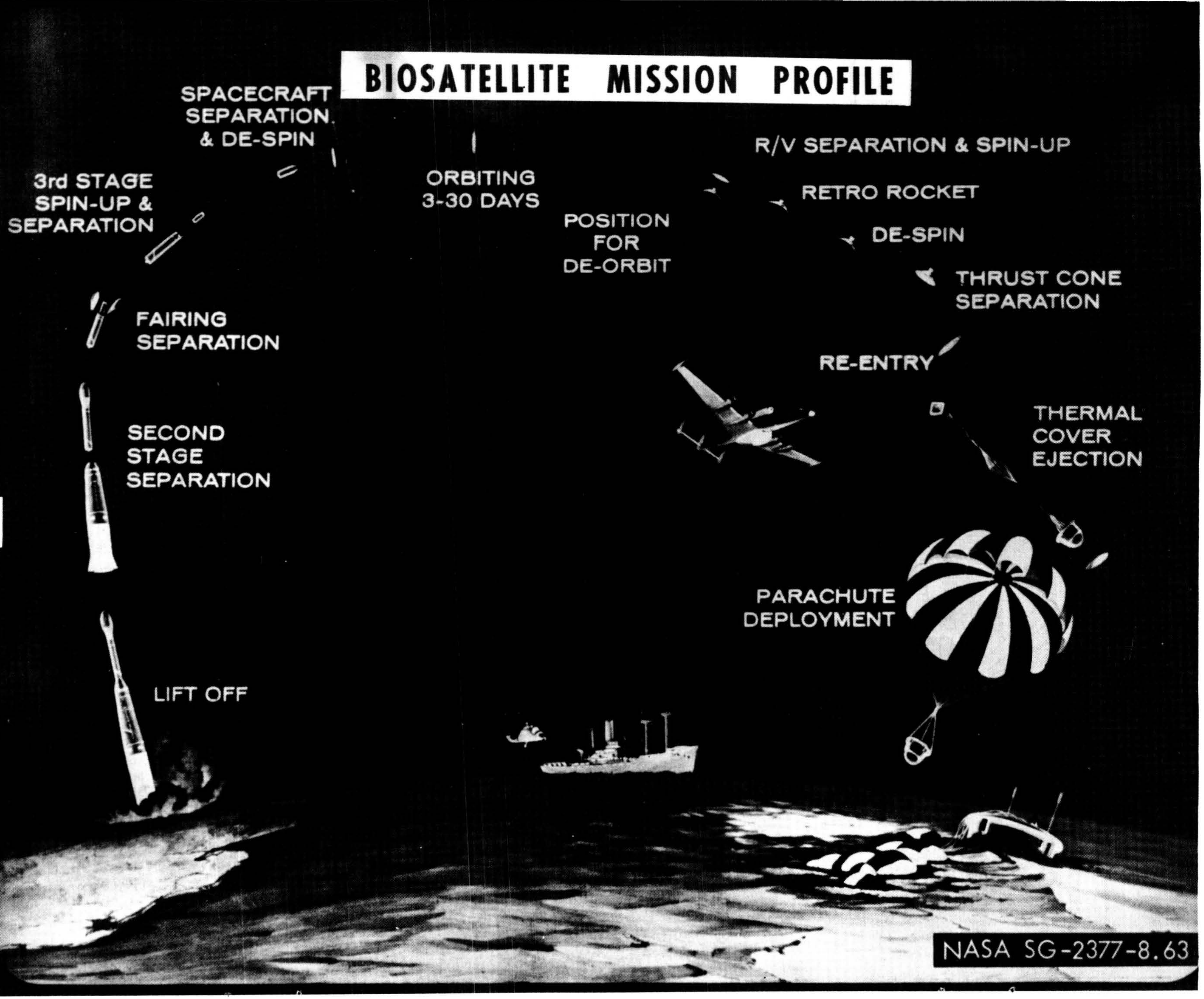
As of October 15, 1963, the Lunar Orbiter Program was in the midst of the evaluation of industry proposals to select the spacecraft contractor. NASA plans to launch a series of these spacecraft beginning in 1966.

The primary objective of the program is the detection and location of small-scale topographic features (such as protuberances $\frac{1}{2}$ meter in height) of selected areas of the lunar surface. A photographic payload will be an integral part of the spacecraft.

Secondary objectives are measurements of the lunar gravity field (by means of long-term tracking of the orbiting satellite) and investigation of the environment of a near-surface lunar orbit. The types of environmental investigation which can be accommodated will depend on the mode of stabilization selected and the available weight and power. Advice on the selenodesy is being provided by a working group chaired by G. MacDonald of UCLA. Investigators will be selected at a later date.

Liaison will be maintained to assure knowledge by the military agencies of advances in reconnaissance techniques that may result from this program which might be of use to them.

The Lunar Orbiter will join with the SURVEYOR in assisting APOLLO programs by providing lunar topographic information for selection of likely landing sites.


BIOSATELLITE MISSION PROFILE
SPACECRAFT SEPARATION & DE-SPIN
3rd STAGE SPIN-UP & SEPARATION
FAIRING SEPARATION
SECOND STAGE SEPARATION
LIFT OFF
ORBITING 3-30 DAYS
POSITION FOR DE-ORBIT
R/V SEPARATION & SPIN-UP
RETRO ROCKET
DE-SPIN
THRUST CONE SEPARATION
RE-ENTRY
THERMAL COVER EJECTION
PARACHUTE DEPLOYMENT
NASA SG-2377-8.63

ORBITING BIOLOGICAL OBSERVATORIES

The Biosatellite program is designed to study the unique environmental factors of space, which are the biological effects of zero gravity or weightlessness, and the effects on biological rhythms of removal of living organisms from the earth's rotation. The effects of weightlessness combined with a known source of radiation will be studies to determine if there is any antagonism, synergism, or no effect. It will then be possible to extrapolate to space conditions from the enormous amount of ground based data on biological effects of radiation.

The Biosatellite investigations include studies at the cellular, tissue, organ, and organism levels and include studies on fundamental phenomena such as biochemical reactions, protoplasmic streaming, fertilization, embryological development, and growth investigations at the tissue level. The investigations involving organisms would include physiological (including fluid transport), behavioral, reproductive, genetic and over-all performance studies. They will include investigations with a wide variety of plants and animals from single cellular organisms to higher plants and animals including primates.

At the present time, over 160 biological proposals for investigations have been submitted by scientists from universities, government, and industry. Panels of scientists have reviewed these proposals and 100 are presently being considered. About 30 contracts and grants have been awarded to investigators with the highest priority experiments. No investigations have yet been assigned space in payloads. The Ames Research Center is cooperating with investigators to determine the engineering, life support, and telemetry requirements. Breadboard layouts are being made and integration of investigations is being studied.

The investigations are divided into six categories, including (1) primates, (2) mammalian (non-primate), (3) animal, cellular, and egg, (4) plant morphogenesis, photosynthesis and growth, (5) biorhythm, and (6) radiation experiments. The primate investigations include cardiovascular studies involving implants, neurological studies with deep brain probes, skeletal calcium loss, effects of weightlessness on urinary and gastro-intestinal systems, and performance. Pigtail, rhesus, and squirrel monkeys will be used, and the orbits will be 14-30 days.

Investigations on the effects of decreased gravity mainly involve cells and higher organisms which have known gravity sensing mechanisms, growth responses, polarization, behavior, or other responses to gravity, In reviewing proposed investigations the primary consideration is whether there is a valid scientific investigation involved and with some specific hypothesis to be tested. The choice of organisms to be used, engineering, weight, and life support requirements are also considered.

The radiation investigations will be exposed to weightlessness and a known source of radiation. Cesium 137 with a mono-energetic gamma radiation of 0.6 MEV will be used in a 9 inch cintered Tungsten sphere. The source can be rotated to the surface to provide from 5000 to 100 roetgens in 3 days orbit. Non-irradiated control investigations will also be flown in the same spacecraft, and a complete duplicate of the radiation investigation will be run on the ground.

Biorhythm investigations will be carried out to help determine whether various circadian and other rhythms are indigenous in the organism or whether they are externally caused by certain environmental factors connected with the earth's period of rotation.

The biosatellite will remove the organism from any day-night, magnetic, or gravitational cycles. The biorhythm specialists are also interested in putting investigations on interplanetary probes to assure complete removal from any fields surrounding the earth which might have any causal effects.

After completing a very careful study of the different possible launch vehicle and spacecraft systems available, and as a result of competitive industrial contract studies, a Thor-Delta launch vehicle and a modified Discoverer spacecraft have been selected.

The spacecraft contract is being negotiated with the General Electric Company.

Six biosatellites will be flown, with the first flight in late 1965 and additional flights at 3 month intervals. The launches will be from AMR in an easterly inclined 22^{o} equatorial orbit at an altitude of between 150 and 200 nautical miles for periods of 3 to 30 days. The spacecraft will be recovered by air snatch or sea recovery. During orbital flight there will be no more than 10^{-4}g acceleration. The spacecraft will have a 20% oxygen 80% nitrogen atmosphere at 14.7 psi to prevent any effects of unusual atmosphere. Certain investigations will be supplied with specialized temperture or other environmental conditions.

Investigations and Investigators

Plant Morphogenesis

1. Growth of a plant tissue culture in the gravity-free state.

   E. A. Ball
   North Carolina State College

2. Plant Morphogenesis under weightlessness.

   A. H. Brown
   University of Minnesota

3. Growth of a plant during an entire life-cycle in the gravity-free state.

E. A. Ball
North Carolina State College

4. Liminal angle of a plagiogeotropic organ under weightlessness.

J. C. Finn, Jr.
North American Aviation

5. The effect of weightlessness on growth of the wheat coleoptile.

S. W. Gray
Emory University

6. Growth form of leafy, branched plant under zero gravity.

C. J. Lyon
Dartmouth College

7. Emergence of seedlings with zero gravity.

C. J. Lyon
Dartmouth College

8. Effects of weightlessness on root growth.

J. D. Tiner
Melpar, Inc.

9. The effect of weightlessness on the orientation of root and shoot of corn (Zea Mays).

H. M. Conrad
North American Aviation

Photosynthesis and Growth

10. The effects of radiation and a gravity-free environment in space on cell division and growth

R. W. Krauss
University of Maryland

11. Effect of zero gravity on growth rate of yeast and E. Coli.

G. P. Welch
University of California

12. Measurement of photosynthetics and respiratory rates in outer space.

A. H. Brown
University of Minnesota

13. Photosynthetic gas exchange potentialities of Lemnaceae in G-free state.

S. S. Wilks
USAF School of Aerospace Medicine

14. Effect of Zero-G on photosynthetic gas exchange systems.

C. H. Ward
USAF School of Aerospace Medicine

15. Evaluation of the activated sludge technique for waste.

J. E. Moyer
USAF School of Aerospace Medicine

16. Algal life cycles.

J. A. Gross
Illinois Institute of Technology

Animal Investigations

17. Daphnia survival and feeding

F. B. Taub
University of Washington

18. Study of tissue regeneration and wound healing during weightlessness.

W. F. Scheich
North American Aviation

19. Respiratory movements in ambystoma in a zero gravity field.

G. R. Thurow
University of Kansas Medical Center

20. Ambystoma orienting behavior in a O-gravity field through tactile and proprioceptive cues.

G. R. Thurow
University of Kansas Medical Center

21. A comparison of morphogenic aspects of the effects of Low-g and Zero-G conditions on the larvae of (bull frog) Rana catesbeiana.

W. J. Mills
Ames Research Center

22. Effect of weightlessness on immune defenses against pathogenic agents.

C. C. Conley
Ames Research Center

23. Effect of space environment on tissue regeneration.

C. E. Miller
Dynamic Science Corporation

24. Discrimination and communication under weightless conditions.

R. P. Casey
North American Aviation

25. The effect of radiation and/or weightlessness upon frequency of cell division and differentiation of Hydra.

R. P. Casey
North American Aviation

26. A study of growth and differentiation of organs in a closed ecological environment under conditions of radiation and/or weightlessness.

H. M. Conrad
North American Aviation

27. Gravity sensitive organs and malaise.

R. P. Casey
North American Aviation

O-G Cellular and Eggs

28. Behavior and reproduction of paramecia in the weightless state.

M. L. Ferguson
Goodyear Aircraft Corporation

29. Effect of weightlessness on development of chick embryo

G. N. Hoover
North American Aviation

30. Nutrition and growth in Pelomyxa Carolinesis during weightlessness.

R. W. Price
General Electric Company

31. Effects of sub-gravity on cellular phenomena (P-1047)

R. S. Young
Ames Research Center

32. Effects of sub-gravity on cellular phenomena (P-1048).

R. S. Young
Ames Research Center

33. Determination of physiological responses of living cells to the space environment via satellite videomicroscopy.

C. F. Gell
Chance Vought Corp.

34. The role of gravity in the establishment of cytoplasmic localizations.

R. E. Huff
Michigan State University

35. Influence of zero gravity on isolated human cells.

P. O'B. Montgomery, Jr.
University of Texas

36. Zero-G growth chamber.

L. A. Irvine
USAF School of Aerospace Medicine

37. The effects of weightlessness on the replication and recombination of DNA.

R. H. Mattoni
North American Aviation

Cardiovascular

38. Primate hemodynamics and metabolism in an orbiting satellite.

    N. Pace
    University of California

39. Dynamic monitoring of the cardiovascular system in weightlessness (extensibility of vessel walls)

    G. Sullivan
    Spacelabs, Inc.

40. Analysis of renal and vascular changes produced in orbiting flight.

    W. D. Collings
    Michigan State University

41. Heart Vibration Monitor

    C. M. Agress
    Inst. Medical Research

42. Psychocardiovascular reactions during conditions of weightlessness in an orbiting satellite.

    J. Perez-Cruet
    John Hopkins University

43. Adaptation of cardiovascular nervous control system to space flight.

    J. U. Casby
    United Aircraft Corp.

44. Primate physiological performance during sustained satellite orbit.

    R. F. Shaw
    School of Engineering & Applied Science

Neurophysiological and Behavior

45. Monitoring brain functions and performance in the primate under prolonged weightlessness.

    W. R. Adey
    UCLA School of Medicine

46. Experimental psychophysical analysis of the sensation of gravity.

R. E. Belleville
NASA Headquarters

47. The pathophysiological effects of weightlessness on primates with initial attention to the role of the vestibular organs.

A. Graybiel
U.S. Naval School of Aviation Medicine

48. Interactions between metabolic rate, motivational levels and performance.

T. Verhave
Arizona State University

49. Electrophysiological performance

J. Huertas
Ames Research Center

50. Vigilance and manipulatory behavior of unrestrained animals in orbital flight.

D. S. Kimura
United Aircraft Corp.

Other Systems

51. Fundamental investigation of losses of mineral in young adult human males and collaterally in young adult male pig-tail monkeys (Macacus Nemestrima) through immobilization for varying periods of time, coupled with methods of preventing or reducing mineral loss.

P. B. Mack
Texas Woman's University

52. The effect of weightlessness upon urinary bladder function.

C. G. Battig
North American Aviation

53. Effect of weightlessness upon gastro-intestinal tract function.

C. G. Battig
North American Aviation

54. Urinary bladder intravesical pressure in Zero-G environment.

P. M. Wood
United Aircraft Corp.

55. The effect of OG on gastric secretion in monkeys.

S. Rigler
County Hospital

56. Blood volume determinations in the mouse at Zero-G.

P. G. Roofe
University of Kansas

57. The effect of weightlessness and other stresses associated with flight in space vehicles on pathogenicity and immunity.

D. T. Clark
Michigan State University

58. Nutritional & metabolic performance in space.

H. Z. Dymsza
Mass. Institute of Technology

59. Effect of weightlessness on immune defenses against pathogenic agents.

C. C. Conley
Ames Research Center

60. Effect of prolonged weightlessness on calcium and phosphorus metabolism.

G. N. Hoover
North American Aviation

61. Gravity sensitive organs and malaise.

R. P. Casey
North American Aviation

62. Effects of space flight on cerebral neuronal and glial chemistry.

R. G. Grenell
University of Maryland

63. Weightlessness and kidney stones

A. J. Getzkin
North American Aviation

64. Effect of weightlessness on gross body composition of the rat.

G. Pitts
University of Virginia

65. Analysis of blood glucose

W. J. Frajola
North American Aviation

66. Atmosphere movements in sealed environments

D. A. Keating
6570 Aerospace Medical Research Labs

Biorhythm Investigations

67. Effect of space environment on circadian rhythms of plants

T. Hoshizaki
UCLA School of Medicine

68. The effect of weightlessness on the rhythmicity of photosynthesis & bioluminescence in dinoflagellates grown in liquid media

R. W. Price
General Electric Company

69. Circadian rhythm of the Madeira Roach in orbit

W. N. Sullivan
Department of Agriculture

70. Hamster circadian rhythms during prolonged orbital flight

C. S. Pittendrigh
Princeton University

71. Spectra and cross-spectra of metabolic rhythms (circadian and other) in Inbred C Mice as a temporal guage of mammalian performance in extraterrestrial space

F. Halberg
University of Minnesota

72. Orbiting effects of light emission of luminescent fungi.

Berliner
Avco Corporation

73. Effect of space environment & weightlessness on periodicity of growth & conidial formation in neurospora "clock" mutants

Berliner
Avco Corporation

74. The effect of extraterrestrial residence on the circadian metabolic rhythm of pocket mice (*Perognathus logimembris*)

R. G. Lindberg
Northrop Space Laboratory

Genetic Effects

75. Chromosomal aberrations in human somatic cells

M. A. Bender
Oak Ridge National Laboratory

76. Genetic studies in the space environment (1) static cell experiments

A. G. DeBusk
Florida State University

77. Mutagenic effectiveness of known doses of gamma irradiation in combination with zero gravity

F. J. Deserres
Oak Ridge National Laboratory

78. Comparison of mutagenic effectiveness of equal Rad doses of penetrating Van Allen radiation with Co^{60} gamma rays

A. H. Sparrow
Brookhaven National Laboratory

79. Chromosomal damage induced by extraterrestrial radiation in mammals

M. A. Bender
Oak Ridge National Laboratory

80. Fine analysis of mutational events at the wx locus of maize in a space environment

D. L. Shaver
Brookhaven National Laboratory

81. Mutagenic effectiveness of known doses of gamma radiation in combination with weightlessness on Habrobracon

R. C. von Borstel
Oak Ridge National Laboratory

82. Bacterial lethal and mutagenic effect

G. E.Stapleton
Oak Ridge National Laboratory

83. Determination of influence of "space environment" on mutation process using controlled gamma ray exposures as a standard

A. H. Sparrow
Brookhaven National Laboratory

84. The interaction of weightlessness, radiation, & high oxygen environment on mutation rate in <u>Drosophila melanogaster</u>

R. H. Mattoni
North American Aviation

85. Growth rates & the accumulation of mutants in quasi-steady state populations of <u>E. Coli</u> in space environment

R. H. Mattoni
North American Aviation

86. Inhibition of mutations by antibiotics in <u>Drosophila</u>

W. J. Burdette
University of Utah

<u>Somatic Effects</u>

87. Effect of zero gravity and radiation on growth of tissues in vitro

B. F. Edwards
Emory University

88. An optimal biological dosimeter for use in retrievable space vehicles

D. F. Mitchell
Northrop Space Labs

89. Effect of the space environmental complex on insect growth and development

J. V. Slater
University of California

90. Effect of radiation in low gravitational fields on Spermatogonia and Oocytes of mice

E. F. Oakberg
Oak Ridge National Laboratory

91. Effect of space radiations and zero gravity on isolated human cells

P. O'B. Montgomery, Jr.
University of Texas

92. A study of the synergistic effect of space environment on radiation damage to an inert biological system

K. M. Hoalst
Avco/Tulsa & University of Oklahoma Research Institute

93. Effect of space environment on human red blood cell metabolism

C. E. Miller
Dynamic Science Corporation

94. The effects of radiation upon the physical and chemical properties of living membrane

A. T. Yahiro
Electro-Optical Systems, Inc.

95. Exposure of resistant isolates to space conditions

G. Silverman
Mass. Institute of Technology

96. The effect of radiation and/or weightlessness upon frequency of cell division and differentiation of Hydra

R. P. Casey
North American Aviation

97. The effect of weightlessness and/or radiation upon growth and development of multinucleate cells of coconut milk

S. P. Johnson
North American Aviation

98. Induction of lysogenic bacteria in the space environment

R. H. Mattoni
North American Aviation

MANNED SPACE SCIENCE

The Manned Space Sciences Division was created in July 1963 to coordinate technical support from unmanned programs to the manned space developmental and flight projects, and to manage all NASA activities concerned with defining and developing scientific experiments for manned space flight missions.

The Division is concerned with:

1. The APOLLO Project Science Program

The science program for the APOLLO Project is in the planning stage. Scientific guidelines for the APOLLO Project have been issued and detailed mission profiles compatible with the guidelines are being prepared.

2. The GEMINI Project Science Program

In August, a request for GEMINI experiments was sent out by the Office of Space Sciences. In answer to this request, approximately 70 proposals have already been received. These proposals are now under review by the subcommittees of the Space Sciences Steering Committee. A preliminary definition of the GEMINI scientific investigations will be ready in January 1964.

3. Scientific Support of OMSF

The Manned Space Sciences Division serves as the Office of Space Sciences coordinating point for receipt of requests from OMSF concerning scientific support of OMSF projects. The Division coordinates the efforts of other OSS Divisions in providing scientific support and, if necessary, provides for necessary scientific investigations.

4. Providing for Certain Joint OSS-OMSF Programs

The principle joint activity is the Lunar Mapping Program. The Division consolidates the requirements of both OSS and OMSF and determines whether existing programs are adquate and coordinated. The Division is supporting projects concerned with lunar triangulation networks (the measurements are made on photographs) and supporting the Air Force Aeronautical Chart and Information Center's 1:1,000,000 scale lunar mapping program. The Division is concerned with coordinating the OSS Lunar Orbiter program with OMSF requirements.

5. Selection of Lunar Landing Sites

The Division is responsible for the selection of possible lunar landing sites from the point-of-view of scientific value and engineering geology considerations. The Division will support work in terrain analysis that will choose areas to be photographed by the lunar orbiter this fiscal year.

6. Scientific Support for OMSF Advanced Studies

The Division is supplying data needed for the Advanced Manned Missions Program, OMSF. The Division has provided scientific guidelines for possible post-APOLLO projects and is managing studies of scientific equipment requirements for possible post-APOLLO lunar projects.

The Division is conducting an extensive survey of the scientific potentialities of a Manned Orbiting Laboratory (MOL).

The Division is providing a scientific rationale for manned Mars investigations.

7. Ad Hoc Committee on Scientific Tasks and Training for Man-in Space

This committee, one of the parent organizations of MSSD, was concerned with the scientific investigations made during the MERCURY Project flights.

8. MERCURY Project Scientific Activities

The MERCURY Project flights were completed before the organization of the MSSD; however, the OSS personnel most closely involved with the MERCURY Scientific investigations are now in MSSD, and it is appropriate to summarize three of the more important investigations in this summary.

a. General Purpose Photography on MA-9

On both MA-8 and MA-9, a hand-held 70 mm Hasselblad Camera was used for general purpose terrain photography. Owing to poor visibility, no useful terrain pictures were obtained on MA-8, although a number of the pictures may be useful for meteorological purposes.

Astronaut L. Gordon Cooper, however, took 29 color pictures of various land and sea areas, all of which are usable. In particular, several of these pictures show large areas with abundant resolvable geological detail. This success underlines the potential usefulness for geological reconnaissance of photographs taken from orbiting vehicles.

b. Ney Camera on MA-9

A camera used for the study of dim sky phenomena developed by Ney and Huch at the University of Minnesota was used on MA-9, and the first pictures of the airglow layer viewed from space were taken by an astronaut. The data gathered confirmed rocket measurements on the height and width of the layer. Furthermore, the measurements taken by the astronaut indicated that the airglow may vary with latitude and/or other factors.

Further studies of the airglow and zodiacal light are planned for GEMINI.

c. Solar Eclipse

Astronaut M. Scott Carpenter and Dr. Gill, Chief, In-Flight Sciences MSSD, participated in the National Geographic-Douglas Solar Eclipse flight. The purpose of Astronaut Carpenter's inclusion on this flight was to provide both astronomical experience for an astronaut, and a follow-on to Cooper's airglow experiment performed on MA-9.

Carpenter's dim sky photography at 40,000 feet in the jet aircraft was a useful supplement to the ground and balloon (University of Minnesota) measurements obtained during the eclipse.

UNIVERSITY PROGRAMS

Since its establishment, NASA has supported substantial numbers of basic and applied research projects by grants and contracts. This existing support, called sponsored research, is chiefly project-oriented and related to specific problems such as space flight probes, satellites or deep space experiments. While this research often encompasses fundamental research activities, its project orientation does not attack all the areas of fundamental research which are required to support a rapidly expanding space program. With the Presidential decision to expand and accelerate this effort, it became immediately apparent that sponsored research alone could by no means utilize fully the ability of our universities to help preserve and advance the role of the United States as a world leader in aeronautical and space science and technology.

Accordingly, the Sustaining University Program was initiated in January 1962 to increase significantly university participation in space science and engineering and to augment and complement sponsored research activities by:

<u>Training Grants</u> - which increase the future supply of scientists and engineers required in space-related science and technology.

<u>Facilities Grants</u> - which help universities provide facilities urgently needed for space research.

<u>Research Grants</u> - which strengthen universities as a whole and enable them to increase their role in support of NASA's program through encouragement of creative multidisciplinary investigations, development of new capabilities, consolidation of activities, and stabilization of funding.

The training grants will increase the supply of scientists and engineers in space-related science and technology. It has been estimated that by 1970 one-fourth of the nation's trained scientific and engineering manpower will be engaged in space activities. To help meet this demand, we have as a goal the support of about 4000 graduate students per year in 100-150 qualified universities, yielding an annual output of about 1000. With this magnitude of participation, the universities will be in a position to make a significant contribution to the space effort's manpower needs.

Training grants have been awarded to 88 universities to support the training of predoctoral graduate students in appropriate areas of space-related science and engineering. This program is designed to meet the future demands for scientific and technical personnel and is expected to increase considerably in the future in order to keep pace with the rapid expansion of the national space program.

Nearly 900 students are now in the program. In September of 1963, 786 new students began their training in addition to the 100 students who started in September 1962. The students may continue their training for a three-year period providing they meet the standards of the university.

The participating universities are:

Alabama
Arizona State
Arizona
Arkansas
Auburn
Brooklyn, Poly. Inst
California Inst. of Tech.
California, at Los Angeles
Carnegie Inst. of Tech.
Case Inst. of Tech.
Catholic
Chicago
Cincinnati
Clemson
Colorado
Colorado State
Columbia
Connecticut
Cornell
Delaware
Denver
Duke
Florida State
Florida
George Washington
Georgia Inst. of Tech.
Houston
Illinois Inst. of Tech.
Illinois
Indiana
Iowa, State University of
Iowa State
Johns Hopkins
Kansas State
Kansas
Kent State
Lehigh
Louisiana State
Maryland
Massachusetts Inst. of Tech.
Michigan State
Michigan
Minnesota
Missouri
Missouri School of Min. & Met.
Nevada
New Mexico
New York
North Carolina
North Carolina State
Northeastern
Northwestern
Notre Dame
Ohio State
Oklahoma State
Oklahoma
Oregon State
Pennsylvania State
Pennsylvania
Pittsburgh
Princeton
Purdue
Rensselaer Poly. Inst.
Rhode Island
Rice
Rochester
Saint Louis
Southern California
Stanford
Stevens Inst. of Tech.
Syracuse
Tennessee
Texas, A&M
Texas Tech.
Texas
Tulane
Utah State
Utah
Vanderbilt
Vermont
Virginia Poly. Inst.
Virginia
Washington (St. Louis)
Washington (Seattle)
West Virginia
Western Reserve
Wisconsin
Yale

In FY 1964, it is planned to expand the program to permit the entrance of additional 1250 students at about 110 universities.

Since the initiation of the Sustaining University Program, grants have been awarded to thirteen universities for the construction of research facilities. These grants provide facilities that are urgently needed to house research activities at universities which are making substantial contributions to the national space program. The first of these facilities was completed in mid-1963 and the others are scheduled for completion during the next two years. It is presently estimated that some 60-75 universities, which are closely involved in space-related research, have pressing needs for additional research facilities. The recipients of the facilities grants to date are: Rensselaer Polytechnic Institute, Stanford University, University of Chicago, University of Iowa, University of California at Berkeley, Harvard University, University of Minnesota, University of Colorado, University of California at Los Angeles, University of Wisconsin, University of Michigan, University of Pittsburgh, and Princeton University.

Research grants under the Sustaining University Program are issued to enable universities to develop and increase their capabilities to support the growing demands of the national space effort. Such grants are used to support broad multidisciplinary research programs, promote the consolidation of related projects, and encourage new research to fill existing research gaps. Grants are also provided to initiate and encourage the establishment of research programs within currently competent but non-participating groups and institutions. During each of the next few years, several large research programs will be supported, ten to fifteen research grants will be provided to augment existing efforts, and 15 to 20 new universities will receive initial grants.

Total NASA support of activities in the universities has approximately doubled each year since NASA was organized. During Fiscal Year 1963 nearly $100 million were committed for these activities. Of this $100 million, $15 million were utilized for the training grant program; $10 million has been utilized for the support of research facilities; $5.6 million were utilized for the special purpose research grants. The rest of the funds supported project type sponsored research.

During Fiscal Year 1964 the training grant program is expected to increase and $20 million has tentatively been allocated for this purpose; $12 million has been allocated for the support of research facilities; approximately $8 million will be committed to the special purpose research grant activity. Based on past experience, it is anticipated that at least an additional $50 to $100 million will come out of our program offices for the support of project type research in the universities. It is extremely difficult to predict the level at which this activity might ultimately stabilize. Obviously, it will not double each year, as it has in the past two years, however, it is probable it will continue to rise again following this year's program.

SATELLITE APPLICATIONS

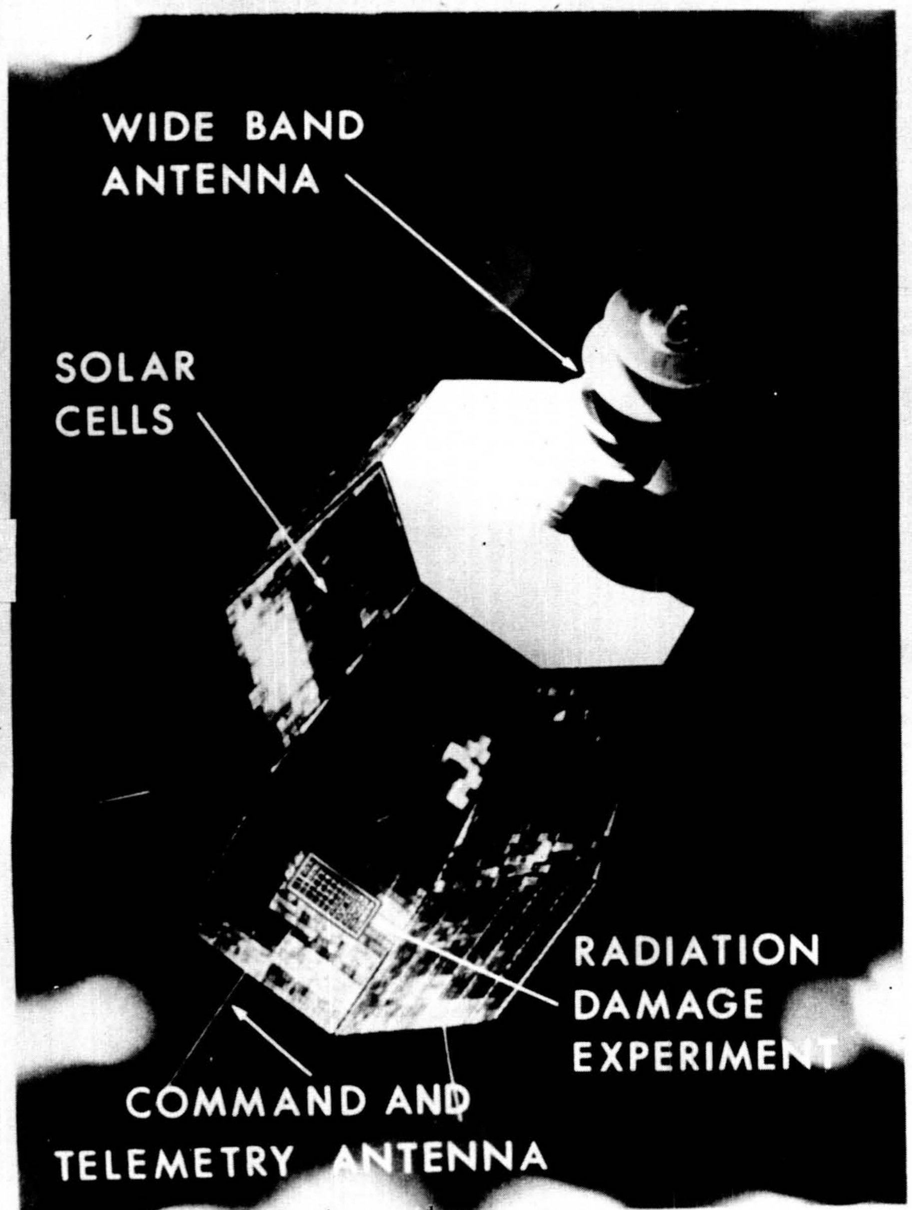
Communications Satellites

NASA is currently concerning itself with two basic types of communications satellites - active and passive. The active satellites carry their own power supplies, receivers, amplifiers, and transmitters. The passive satellites act as a device to reflect a signal transmitted by a ground station to be received by a second ground station.

The active satellites are studied in two basic altitudes, medium (up to 12,000 miles) and synchronous (22,300 miles). The passive satellites are studied in the low altitude regime (up to approximately 1000 miles).

A satellite placed into orbit at the synchronous altitude will have an angular velocity equivalent to the rotational velocity of the earth about its axis. If this satellite is placed into orbit over the equator, it will be stationary with respect to a point on the earth immediately below. If the satellite is launched into an orbit which is inclined to the equator, it will trace a figure 8 path on the earth below. The extremes in north and south latitude of the figure 8 will be that of the launch inclination.

RELAY SPACECRAFT



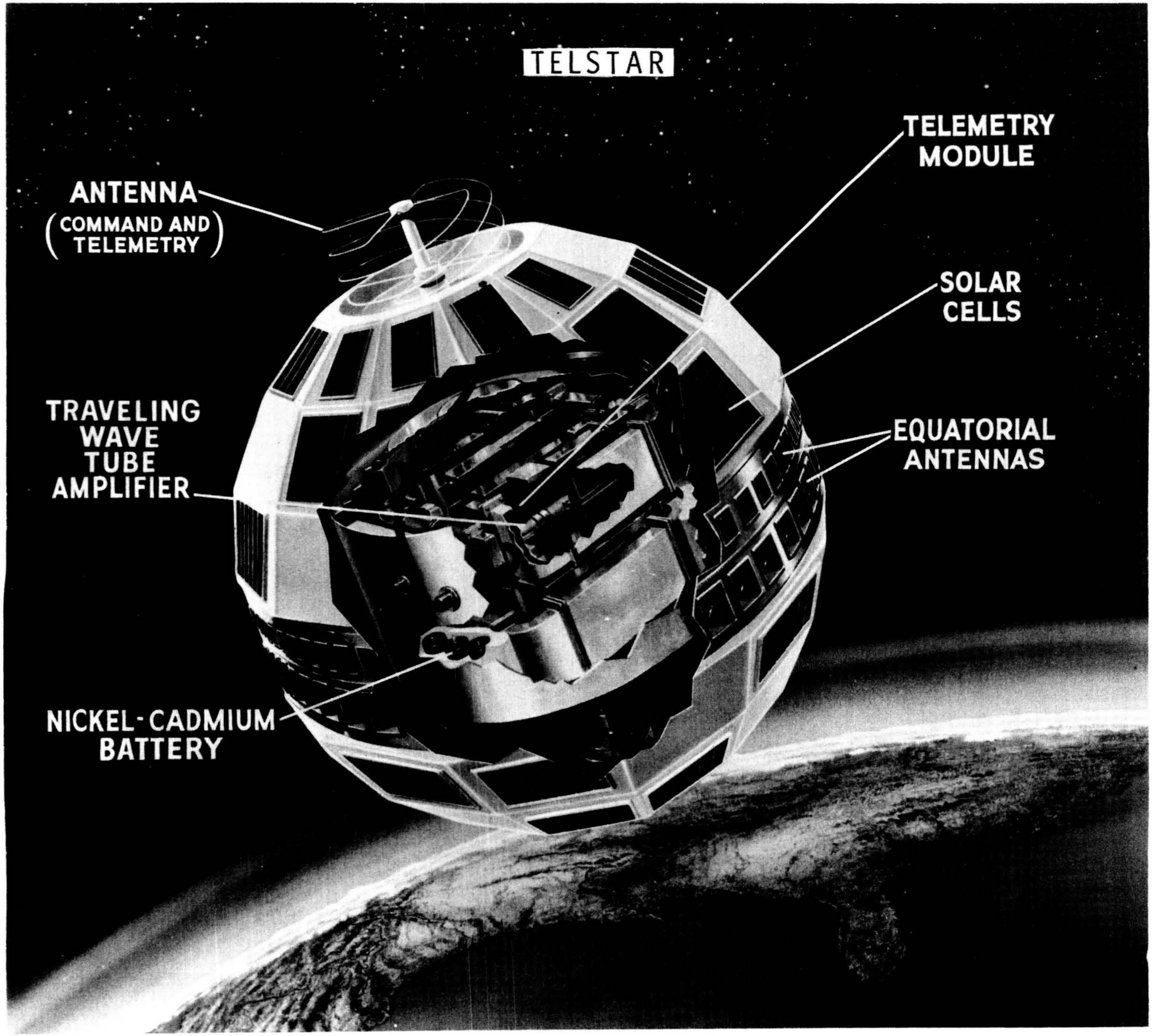
GROSS WEIGHT	- 172 LBS
INSTRUMENT WEIGHT	- 47 LBS
INVESTIGATIONS	- 4
POWER	- 45 WATTS
STABILIZATION	- SPIN
DESIGN LIFE	- 1 YEAR
LAUNCH VEHICLE	- DELTA
ORBIT	- APOGEE 4012 NM PERIGEE 714 NM INCLINATION 47.5°
STATUS	- RELAY I LAUNCHED 13 DEC 1962

NASA SD63-1443

Active Satellites

RELAY

RELAY is a medium altitude active repeater communications satellite which was launched from Cape Canaveral on December 13, 1962. Difficulties with a power supply voltage regulator in one of the wideband transponders appeared immediately after launch, and caused a power drain that for a while precluded the use of the satellite as a communications device. By January 3, 1963, the satellite temperature and power supply charge condition had changed sufficiently so that by exercising care not to use the defective wideband transponder, the redundant system could be utilized. Since that time RELAY has been operating satisfactorily and is now the longest lived active communications satellite. Since the beginning of the year RELAY has been used to perform a multitude of communications experiments linking the United States, Europe, and South America. There have also been many significant demonstrations of live intercontinental television and telephone relay. For example, RELAY was used in January to telecast to Europe the ceremony marking the opening of the Mona Lisa exhibition. In April the granting of honorary citizenship to Sir Winston Churchill was transmitted via RELAY to Europe. In May RELAY was used to transmit to Europe pre-launch activities of the 22 orbit flight of Astronaut L. Gordon Cooper. When ionospheric conditions prevented the use of normal radio communications between the United States and South America, RELAY was successfully used as the ground station link.


TELSTAR
TELEMETRY MODULE
ANTENNA (COMMAND AND TELEMETRY)
SOLAR CELLS
TRAVELING WAVE TUBE AMPLIFIER
EQUATORIAL ANTENNAS
NICKEL-CADMIUM BATTERY

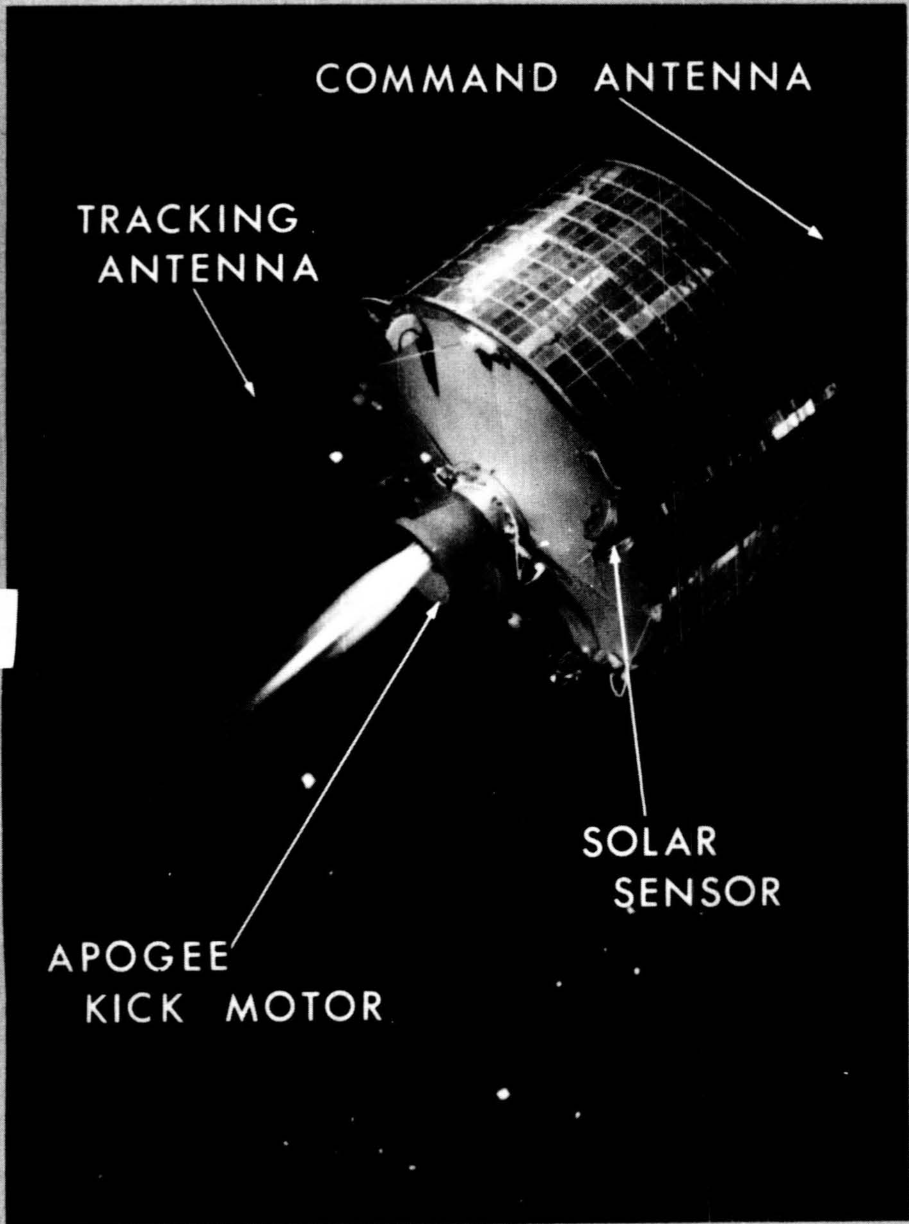
TELSTAR (AT&T)

TELSTAR is a cooperative project between NASA and the American Telephone and Telegraph Company. This medium altitude active repeater communications satellite was built by AT&T and launched, on a reimbursable basis, by NASA.

TELSTAR I which was launched on July 10, 1962 had operated for $4\frac{1}{2}$ months when on November 23, 1962 it stopped responding to commands. By special procedures developed by AT&T engineers, TELSTAR I was reactivated and once more, on January 4, 1963 became operative. On February 21, 1963 TELSTAR I once more stopped responding to commands and has not operated since that time. Investigation of the first failure indicates that it resulted from the ionization of gas in the case of one of the transistors of a command decoder. The cause of the second failure has not been determined.

On May 7, 1963, NASA launched a second TELSTAR satellite for AT&T. As did TELSTAR I, TELSTAR II functioned as planned during the post launch period. The satellite performed well until July 16 when, for some unknown reason, it ceased operations. On August 13, again for some unknown reason, the satellite resumed operating and has been functioning since.

SYNCOM SPACECRAFT



GROSS WEIGHT - 146 LBS.

INSTRUMENT WEIGHT - 16 LBS.

POWER - 25 WATTS

STABILIZATION - SPIN

DESIGN LIFE - ONE YEAR

LAUNCH VEHICLE - DELTA

ORBIT - CIRCULAR 19,300 NM
INCLINATION 33°

STATUS - LAUNCHED
SYNCOM I - 13 FEB 1963
(NOT OPERABLE)
SYNCOM II - 26 JULY 1963

SYNCOM

SYNCOM I was launched from Cape Canaveral on February 14, 1963. The satellite attained an elliptical transfer orbit as planned. During this period tone, teletype, voice, and music transmissions were received by the satellite from the USNS Kingsport anchored in Lagos, Nigeria and retransmitted back to the ship. The apogee motor fired on command and burned for about 20 seconds after which all radio contact with the satellite was lost. Visual sightings of the satellite were made on February 24 and 25 and again on March 2 by an observatory located in Bloemfontein, South Africa operated by the Harvard College Observatory. These sightings indicate that SYNCOM I is in orbit at approximately the synchronous altitude.

SYNCOM II was launched on July 26, 1963 and became the world's first satellite to be placed and positioned in synchronous orbit. After injection into orbit at approximately the proper altitude, the satellite was found to be drifting eastward as expected. The positioning jets were fired to reverse the direction of this drift and the orientation jets were fired to turn the satellite approximately 90 degrees so the antenna pattern was directed towards the earth. When the satellite had drifted near the desired location, the positioning jets were again used to gradually reduce the drift rate and finally to fix the position of the nodes at 55° W. Longitude.

The final average drift rate is 0.03 degrees per day. This drift is in the opposite direction to the "pull" of the earth's triaxiality, therefore after the satellite drifts about 3/4° it reverses its direction and returns to 55° W. Longitude. This cycle takes about a month at which time another position correction is required. Because of the inclination of its launch the satellite traces a figure 8 path ranging from 33°N to 33°S Latitude. The satellite has an orbital period of 23 hours 56 minutes and is at an altitude of 22,235 miles.

The first live transoceanic voice demonstration via SYNCOM II was successfully achieved on August 23. This featured conversations involving the President of the United States, the Prime Minister of Nigeria, the Vice President of the United States, the Foreign Minister of Nigeria, the Secretary General of the United Nations, the Ambassador from Nigeria to the United States and other notable dignitaries.

Many communications demonstrations and experiments have since been conducted. In its relatively short lifetime SYNCOM II has already logged as much communications time as have all of the other communications satellites since their launch. In fact, although not designed to transmit television pictures, experiments were conducted late in September in which TV pictures were transmitted from Ft. Dix in New Jersey via the satellite 22,235 miles above the earth to the Andover, Maine receiving station.

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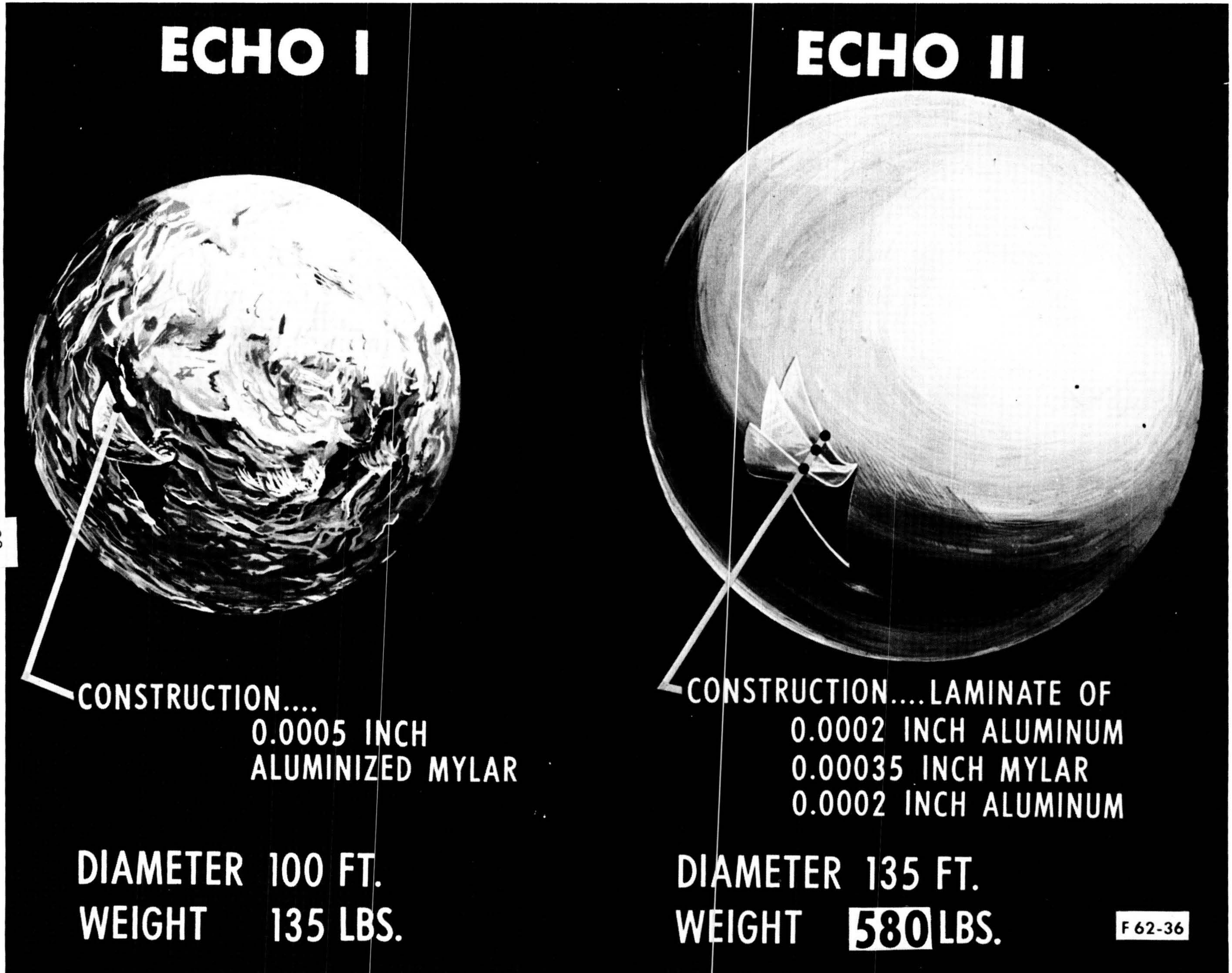

ECHO I
ECHO II
CONSTRUCTION....
0.0005 INCH
ALUMINIZED MYLAR
DIAMETER 100 FT.
WEIGHT 135 LBS.
CONSTRUCTION....LAMINATE OF
0.0002 INCH ALUMINUM
0.00035 INCH MYLAR
0.0002 INCH ALUMINUM
DIAMETER 135 FT.
WEIGHT 580 LBS.
F 62-36

Passive Satellites

ECHO

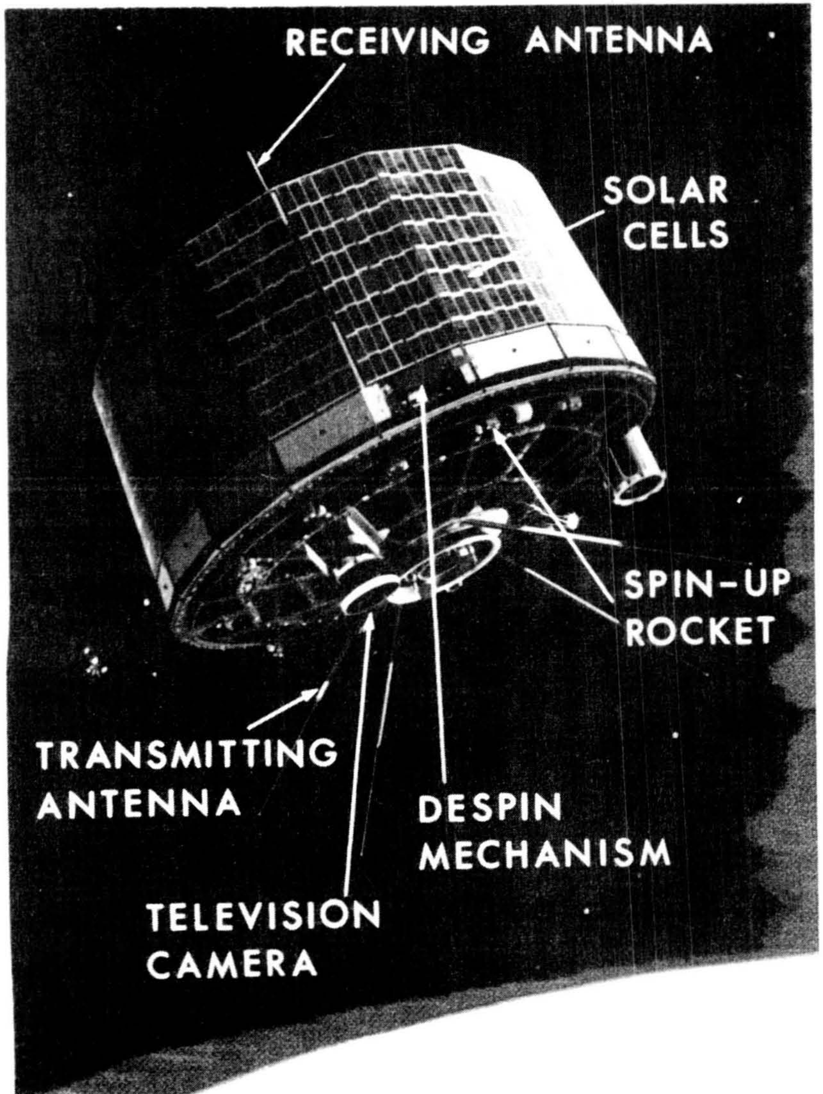
On August 12 the Echo I satellite completed its third year in orbit. The balloon is no longer spherical in shape and is in a wrinkled state. However, the satellite proved the inflation procedure and the capability of injecting such a balloon into orbit. In addition, valuable data was collected relating to the radio reflectivity in space of material of the type used, the effects of solar pressure on devices of this size (100 ft in diameter), and lifetime potential.

Scheduled for early next year is the launch of a balloon of heavier, stronger material to provide a more rigid structure and larger in diameter to provide more reflecting surface. This satellite, Echo II will be constructed of material 50 percent thicker than Echo I (0.0075" vs 0.00050"), will weigh 580 pounds as compared with 135 pounds for Echo I, and will be 135 feet in diameter. The technique for inflation will be similar to that of Echo I (use of a sublimating material) except that it will be over pressurized in an attempt to erase the memory of the folds thereby providing for a smoother surface for a longer period of time.

The sphere will be launched into a polar orbit from PMR at an altitude of approximately 700 nautical miles. Radio reflectivity and static inflation tests recently conducted at Goddard Space Flight Center, and the Naval Air Station at Lakehurst, New Jersey verify the promising nature of the project.

It is the Echo II balloon that will be used in the cooperative effort between the United States, England, and the Soviet Union that resulted from the exchange of letters between President Kennedy and Premier Krushchev in March 1962. An agreement for limited cooperation on three space projects, of which communications experiments is one, was announced on August 26, 1963.

TIROS VII



GROSS WEIGHT	- 297 LBS
INSTRUMENT WEIGHT	- 72 LBS
INVESTIGATIONS	- TELEVISION (2 CAMERAS) INFRARED (2 SYSTEMS) ELECTRON TEMP. PROBE (1)
POWER	- 20 WATTS (AVERAGE)
STABILIZATION	- SPIN
DESIGN LIFE	- 4 MONTHS
LAUNCH VEHICLE	- DELTA
ORBIT	- APOGEE 349 NM PERIGEE 335 NM INCLINATION 58°
STATUS	- TIROS VII LAUNCHED 19 JUNE 1963

NASA SD63-1442

Meteorological Satellites

TIROS

The TIROS program continued its unbroken record of success with the launch of the seventh in the series on June 19, 1963. TIROS VII, as did TIROS II, III, and IV, included infrared detectors as part of its experimental equipment. Of significance is the fact that due to the continued successful operation of TIROS V and VI, the launch date of TIROS VII was deliberately rescheduled twice in order to be of greatest value during the fall hurricane season.

The estimated design lifetime of the TIROS satellites was originally three months. So far, of the seven spacecraft placed into orbit only the first did not exceed this lifetime. TIROS I ceased operating after $2\frac{1}{2}$ months, TIROS II after 10 months, TIROS III - $4\frac{1}{2}$ months, TIROS IV - $4\frac{1}{2}$ months, TIROS V - $10\frac{1}{2}$ months, TIROS VI - 13 months, and TIROS VII is still operating after more than 4 months. As of the end of September, a total of more than 220,000 usable cloud cover pictures have been received, more than 7500 cloud cover analyses have been prepared, more than 1100 special storm advisories have been issued, and there have been more than 440 instances where weather analyses have been improved significantly through the use of TIROS data.

Current plans call for the future launch of four additional TIROS spacecraft. The next TIROS to be launched will include the newly developed Automatic Picture Transmission (APT) system. This will be the first flight test of this equipment. APT will enable meteorologists near the track of the satellite, and having a suitable ground station, to receive local cloud cover pictures. The ground stations to be used for this first test cost less than $50,000 each and are commercially available. Military and civilian agencies have acquired about 45 of these stations for distribution throughout the world.

Subsequent TIROS launches will include the "wheel" configuration in which the cameras point out the side rather than the bottom as is now the case. The satellite itself will spin like a wheel so that its side is always facing the earth. By canting the two cameras in opposite directions it may be possible to observe almost all of the sunlit portion of the earth daily from the 400 mile altitude.

Beyond the "wheel" TIROS, NASA plans on launching a TIROS in a highly eccentric orbit, from about 200 to 22,300 miles in altitude. Such satellites will provide valuable information relating to meteorological satellite observations at the synchronous altitude, as well as data that will be useful in the development of sensors for use at this altitude.

It is expected that other R&D uses will emerge for the highly reliable TIROS satellite.

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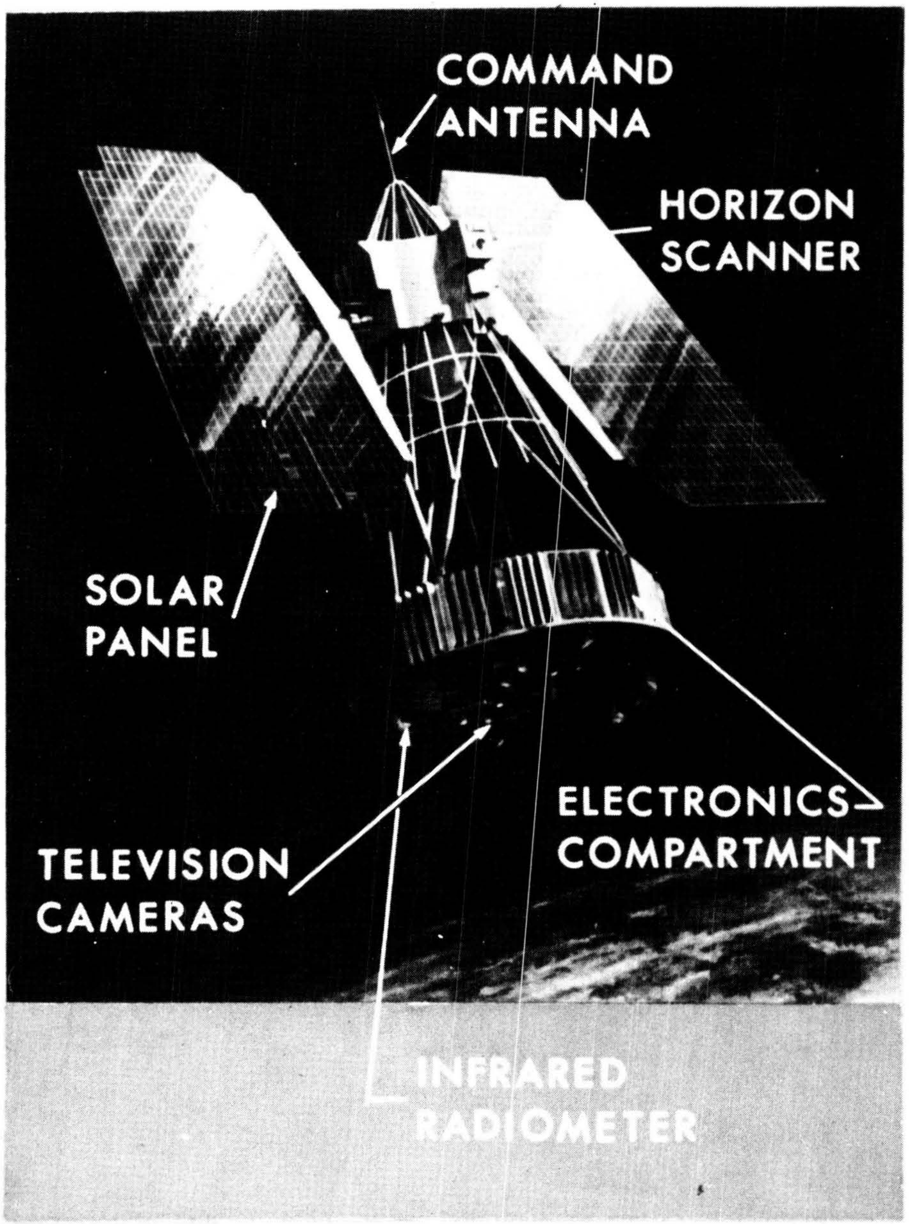
NIMBUS



GROSS WEIGHT	- 675 LBS
INSTRUMENT WEIGHT	- 116 LBS
SENSORS	- 3 SYSTEMS
POWER	- 400 WATTS
STABILIZATION	- ACTIVE 3 AXIS
DESIGN LIFE	- ONE YEAR
LAUNCH VEHICLE	- THOR-AGENA
ORBIT	- CIRCULAR 500 NM INCLINATION 80° RETROGRADE
STATUS	- FIRST FLIGHT 1964

NASA SD63-1451

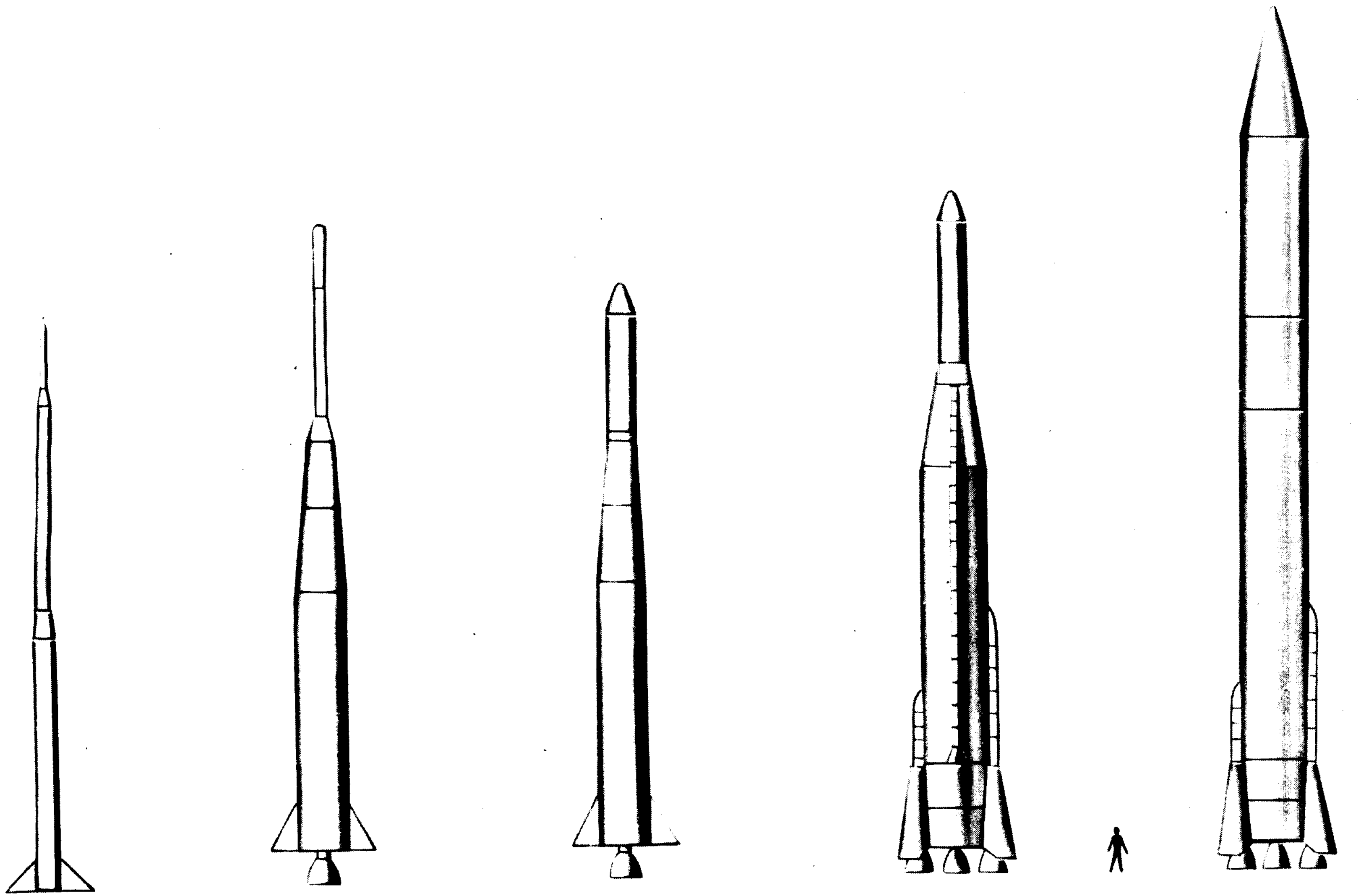
NIMBUS

NIMBUS is a second generation meteorological satellite scheduled for flight during the first half of next year. NIMBUS is designed to overcome some of the limitations of TIROS. Whereas TIROS is space oriented, NIMBUS will be earth oriented. Whereas TIROS is launched in an inclined orbit, NIMBUS will be launched in a near polar orbit. In addition, NIMBUS will have improved and new sensory equipment. This will include improved radiation sensory equipment, Automatic Picture Transmission (APT) equipment, advanced vidicon camera systems, and new experimental devices designed to provide improved and increased coverage.

NIMBUS was originally conceived as a program serving two objectives. The first was to provide a platform for the development of new devices, techniques, and increased coverage and to provide more refined and detailed information that will lead to a better understanding and interpretation of meteorological phenomena. A second objective of NIMBUS was to use the satellite as part of the operational meteorological satellite system under the sponsorship of the Weather Bureau.

On October 4 it was announced that the Weather Bureau had withdrawn its support of the current NIMBUS as the basis for the operational system. However, the Weather Bureau is continuing its cooperative program with NASA for the development of an operational satellite. Meanwhile NASA is continuing with the development of the NIMBUS R&D spacecraft for flight test.

LIGHT AND MEDIUM LAUNCH VEHICLES



SCOUT DELTA THOR-AGENA B ATLAS-AGENA B CENTAUR

AA 62-308

SUMMARY OF NASA LAUNCH VEHICLES

Introduction

The following summarizes the capabilities of NASA launching vehicles for space research and exploration. The vehicles fall into two general categories:

1. Sounding rockets
2. Satellite and space probe vehicles

The sounding rockets are relatively inexpensive and simple to operate but are limited to small payloads and vertical-or-near-vertical flights. The satellite and space probe vehicles are ranged from the Scout all-solid launch vehicle to very large vehicles capable of launching man-carrying spacecraft on missions to the lunar surface and return.

Sounding Rockets

Description: A family of six sounding rockets is used in the geophysical sounding program. These are relatively simple rockets that can be launched at precise times from several sites. About 90 are being launched each year from Wallops Island, Fort Churchill, White Sands, and foreign sites.

The types of programs in which these rockets are being used show a strong dependency of objectives or requirements of subsequent firings on the findings of the initial firings in a given family of observations. Consequently, sepecific long-range firing schedules are not practical for sounding rockets. Based on projected research program planning, a sufficient number of each rocket type is ordered to satisfy the various program needs foreseen.

Typical sounding rockets now utilized are listed in the following table with their nominal costs and capabilities:

Vehicle	Cost (Thousands of Dollars)	Capability Altitude (miles)	Capability Payload Wt. (pounds)
Nike-Apache	7.5	150	50
Aerobee 150,150A	30	150	150
Aerobee 300	38	230	50
Argo D-4	50	800	50

Vehicle	Cost (Thousands of Dollars)	Capability Altitude (miles)	Payload Wt. (pounds)
Argo D-8	140	1150	130
Nike-Cajun	6	100	50

The Scout is used as a sounding rocket as well as a satellite booster. Its description and capabilities are included in the section on Satellite and Space Probe Vehicles.

Satellite and Space Probe Vehicles

The objectives of the Launch Vehicles and Propulsion Programs are to provide vehicles with the capability to perform reliably and economically the unmanned orbital, lunar, planetary, and interplanetary missions. Satellite and space probe vehicles currently available in the program are Scout, Delta, Thor-Agena, Atlas-Agena. Vehicles under development to support future missions are Atlas-Centaur and Saturn.

The plan for Launch Vehicles to meet unmanned satellite and space probe mission requirements considers the following:

Mission	Spacecraft Weight Range
Orbital	150 to 20,000 lbs.
Lunar	900 to 9,000
Planetary	570 to 8,000

Weight ranges when considered from a Launch Vehicle point of view can be categorized into three groups: Small, medium, and large. The range of payload capability by vehicle class is:

Mission	Small	Medium	Large
	Scout, Delta	Thor-Agena Atlas-Agena Atlas-Centaur	Saturn C-1B (2 & 3 stages) & Saturn C-5
Earth Orbital	150-800 lbs.	5,000 to 10,000 lbs.	20,000 lbs.
Escape	50 lbs.	850 to 2,500 lbs.	8,000 lbs.
Planetary	0	570 to 1,500 lbs.	4,000 lbs.

A description of each launch vehicle, along with its capabilities is provided in the following paragraphs:

SCOUT

STAGES

1ST STAGE - SOLID (ALGOL)

2ND STAGE - SOLID (CASTOR)

3RD STAGE - SOLID (ANTARES)

4TH STAGE - SOLID (ALTAIR)

MISSION CAPABILITY

300 N. MI. ORBIT 220 LBS.

USE

ORBIT

HIGH ALTITUDE PROBE

RE-ENTRY

INITIATED

LATE 1958

1ST LAUNCHING

R & D
JULY 1960

OPERATIONAL
MAR. 1962

LAUNCH RATE CAPABILITY

WALLOPS IS.

1/MO. NOW
2/MO. OCT. 1963
PMR - 2/MO.

LAUNCH SITES

WALLOPS IS. - (2)

PMR - (1)

NASA S63-300

SCOUT

Description: Scout is the smallest of the launch vehicle family. All of its four stages use solid rockets. Because of its relative simplicity, the Scout can be launched from relatively inexpensive installations. It is a low-cost vehicle which can be used for a large variety of scientific payloads such as high velocity probes, reentry experiments and satellites. Its guidance and control system incorporates a digital programmer and 3-axis stabilization for all except the spin-stabilized fourth stage. Ling-Temco-Vought, Dallas, Texas, is the vehicle prime contractor and is responsible for all vehicle items except the motors. The motors are obtained from Aerojet, Sacramento, California; Thiokol, Huntsville, Alabama; and the Allegany Ballistics Laboratory, Cumberland, Maryland.

Mission Capability: The present Scout is capable of placing 240 pounds in a 300 n.m. easterly orbit. By next year this capability will be increased to 280 pounds.

Schedule: Starting with the first flight on July 1, 1960, eight developmental and fifteen operational vehicles have been flown to date. A well integrated Scout program has been established between NASA and DOD. Forty-nine vehicles will have been procured through CY 1964 to fulfill NASA, AEC, and DOD requirements. In addition, a fully integrated logistic support system for the two Scout launch sites (Wallops Island and PMR) has been established by NASA with joint funding.

DELTA

• STAGES

1ST LIQUID (LOX/RP)

2ND STAGE (UDMH / IRFNA)

3RD STAGE-SOLID (4TH STAGE OF SCOUT)

• MISSION CAPABILITY

350 MI. ORBIT - 800 LBS.

ESCAPE - 120 LBS.

• USE

COMMUNICATION SATELLITES

METEROLOGY SATELLITES

SCIENTITIC SATELLITES

SATELLITES SATELLITES

INTERNATIONAL SATELLITES

• INITIATED

EARLY 1959

• 1ST LAUNCHING

R&D - MAY 1960

OPERATIONAL - OCT.1962

• LAUNCH RATE CAPABILITY

18/YR./PAD

• LAUNCH PADS

2 C AMR

NASA S63-700

DELTA

Description: The Delta is a three-stage vehicle, in which the first stage consists of a production Thor with the nose cone and guidance removed. The second stage is a modified version of the Vanguard second stage. A radio guidance system (BTL) is installed in the second stage to provide velocity and attitude control This includes coast-phase attitude control which affords much higher orbits with Delta than with previous vehicles since a prescribed vehicle attitude can be maintained up to 2000 seconds after second-stage burnout. An NPP X-248 solid propellant rocket motor is used as the Delta third stage. Prior to ignition, this stage is spun up to 150 rpm to obtain spin stability after separation, since neither guidance nor autopilot is carried in the third stage.

Mission Capability: The Delta is capable of launching a 120-pound space probe or putting an 800-pound payload into a 300 n.m. circular orbit.

Schedule: The first Delta flight was scheduled for 1960 with flights extending to 1962. After a second stage coast-phase failure during the first launching in March 1960, Delta has had 19 consecutive fully successful launchings, placing each payload in an orbit very close to that planned.

An additional twenty vehicles have been ordered for use with scientific, meteorological and active communication satellite programs. These launches will continue well into calendar year 1965, and perhaps beyond, at a rate of eight to ten per year.

THRUST AUGMENTED DELTA (TAD)

Description: The Thrust Augmented Delta is a three and one half stage vehicle which differs from the Delta in that it utilizes the USAF developed, improved Thor Booster as a first stage. The improved Thor (SLV-2A) employs three (3) THIOKOL XM-33-#2 solid propellant rocket motors mounted around the base of the Thor Booster increasing the lift off thrust from 170,000 lbs. to 330,000 lbs. The solid motors are expended at approximately 40 seconds and are separated from the booster at an appropriate time thereafter. The upper stages are not changed from the standard Delta.

Mission Capability: This vehicle combination is capable of placing 1,000 lbs. into a 300 n.m. circular orbit and of placing 135 lbs. to escape.

Schedule: The Thrust Augmented Delta will be operational in the second quarter of CY 1964.

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THOR-AGENA B

- **STAGES**

  1ST STAGE - LOX/P-1 (THOR)

  2ND STAGE - IRFNA/UDMH (AGENA B)

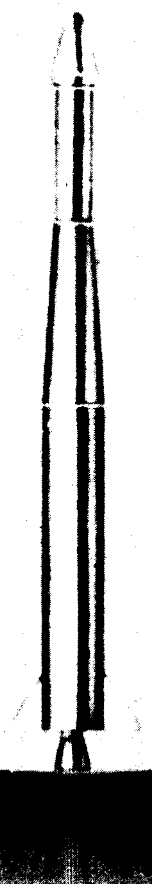
- **MISSION CAPABILITY**

  300 N. MI. ORBIT 1600 LBS

  1200 N. MI. ORBIT 850 LBS

- **USE**

  METEOROLOGICAL AND SCIENTIFIC SATELLITES



- **INITIATED**

  EARLY 1959 (DOD)

- **1ST LAUNCHING**

  LATE 1962 (NASA)

- **LAUNCH SITE**

  PMR

- **LAUNCH RATE CAPABILITY**

  10/YR

NASA S63-701
Rev. 8-1-63

THOR AGENA

Description: The Thor Agena is a two stage rocket consisting of a Thor first stage using liquid oxygen and RP-1 propellants and an Agena second stage using UDMH and IRFNA as the propellants. The vehicle is 8 ft. in diameter and weighs 125,000 pounds. The boos ter thrust is 170,000 pounds; the Agena second stage thrust level is 16,000 pounds.

Mission Capability: This vehicle is capable of launching a payload of 1600 pounds into a 300 n.m. circular orbit or an 850 pound Nimbus spacecraft into a 500 n.m. circular, polar orbit.

Schedule: Four (4) Thor Agena vehicles are currently scheduled for launch through 1964. All current Thor-Agena launches are for scientific and applications satellites which require polar orbits. No further launches after 1964 are now planned for the basic Thor-Agena vehicle since all follow-on missions require the capability of the Improved Thor Agena.

IMPROVED THOR AGENA (TAT)

Description: The Improved Thor Agena is a two and one half stage rocket consisting of a Thor booster with three (3) solid rocket engines mounted around the periphery of the Thor base and an Agena D as a second stage. The total lift-off thrust is increased to 350,000 pounds by the addition of the solid rocket engines. The solid rockets burn-out by approximately 40 seconds after lift-off and are designed to drop away from the basic Thor vehicle at approximately 60 seconds.

Mission Capability: This vehicle combination is capable of placing an 1100 pound payload into a 750 n.m. circular, polar orbit.

Schedule: An Improved Thor Agena (TAT) vehicle is scheduled to launch an Orbiting Geophysical Observatory from PMR into a polar orbit early in 1965. It is planned to use this vehicle for all Polar Orbiting Geophysical Observatories throughout 1965 and 1966 and probably will be used in the weather satellite programs.

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ATLAS-AGENA B

- **STAGES**

  1ST STAGE - LOX/RP-1 (ATLAS)

  2ND STAGE - IRFNA/UDMH (AGENA B)

- **MISSION CAPABILITY**

  300 N. MI. ORBIT - 5,800 LBS.

  LUNAR PROBE - 750 LBS.

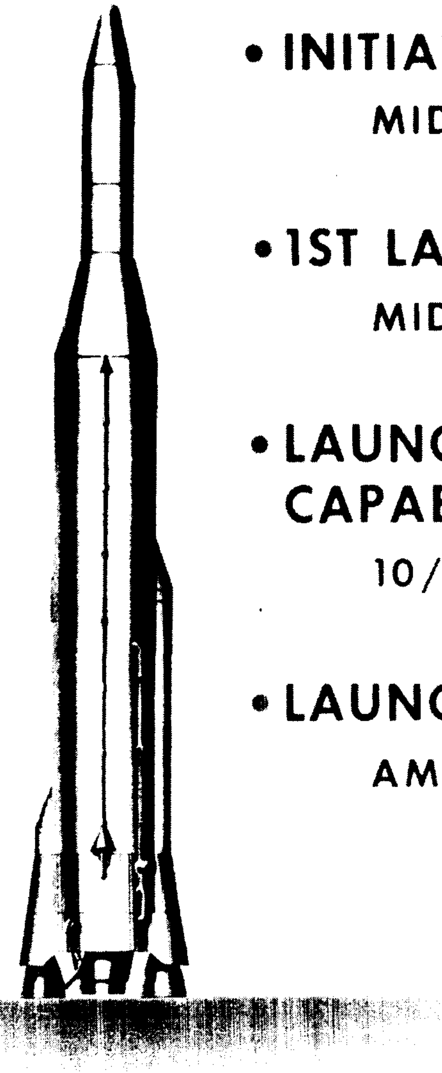
  PLANETARY PROBE - 450 LBS

- **USE**

  LUNAR PROBES

  COMMUNICATIONS SATELLITES

  SCIENTIFIC SATELLITES



- **INITIATED**

  MID 1959 (DOD)

- **1ST LAUNCHING**

  MID 1961 (NASA)

- **LAUNCH RATE CAPABILITY**

  10/YR./PAD

- **LAUNCH SITE**

  AMR - 1 PAD

  2 PADS AVAILABLE FOR BACK-UP

NASA S63-299

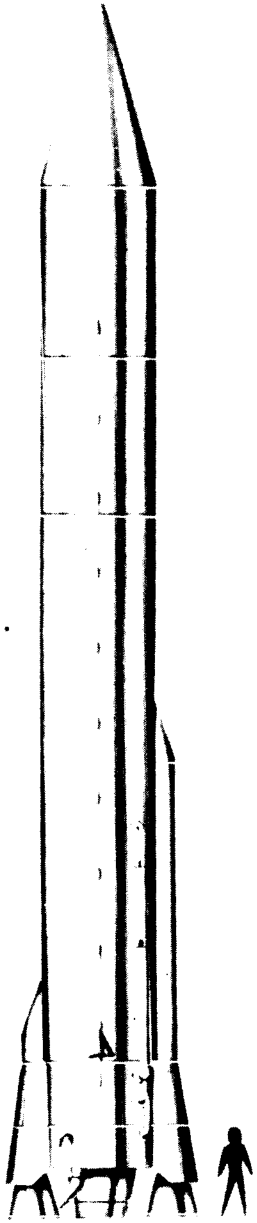
ATLAS AGENA

Description: Atlas Agena is a two-stage vehicle. The first stage is a D or standard model Atlas modified to accept a second stage. The Agena second stage is the stage described for the Thor Agena. The vehicle is approximately 91 feet high exclusive of payload and develops 367,000 pounds of thrust at sea level.

Mission Capability: The Atlas Agena is being employed to launch the Ranger series of hard lunar landing missions and the Mariner Planetary Probes and provides increased payload and orbit altitude capability for several earth satellite missions. It can place about 5,000 pounds into a 300 n.m. circular orbit, send over 850 pounds to the moon (Ranger), or inject 570 pounds to Mars (Mariner).

Schedule: Nine (9) Atlas Agena Launchings are programmed through 1964. Long range planning currently reflects a sustained rate of firing through 1965, 1966 and 1967 with a taper-off in 1968.

CENTAUR



STAGES

- 1st LIQUID
- 2ND LIQUID (HIGH ENERGY)

MISSION CAPABILITY

- 300 MILE ORBIT-8,500 LBS.
- LUNAR PROBE-2,300 LBS.

USE

- LUNAR AND PLANETARY EXPLORATION

INITIATED

LATE 1958

1ST LAUNCHING R&D

- MAY 1962

OPERATIONAL

LATE 1964

LAUNCH RATE CAPABILITY

- 6 PER YEAR PER LAUNCH PAD

LAUNCH PADS:

- 2 @ AMR

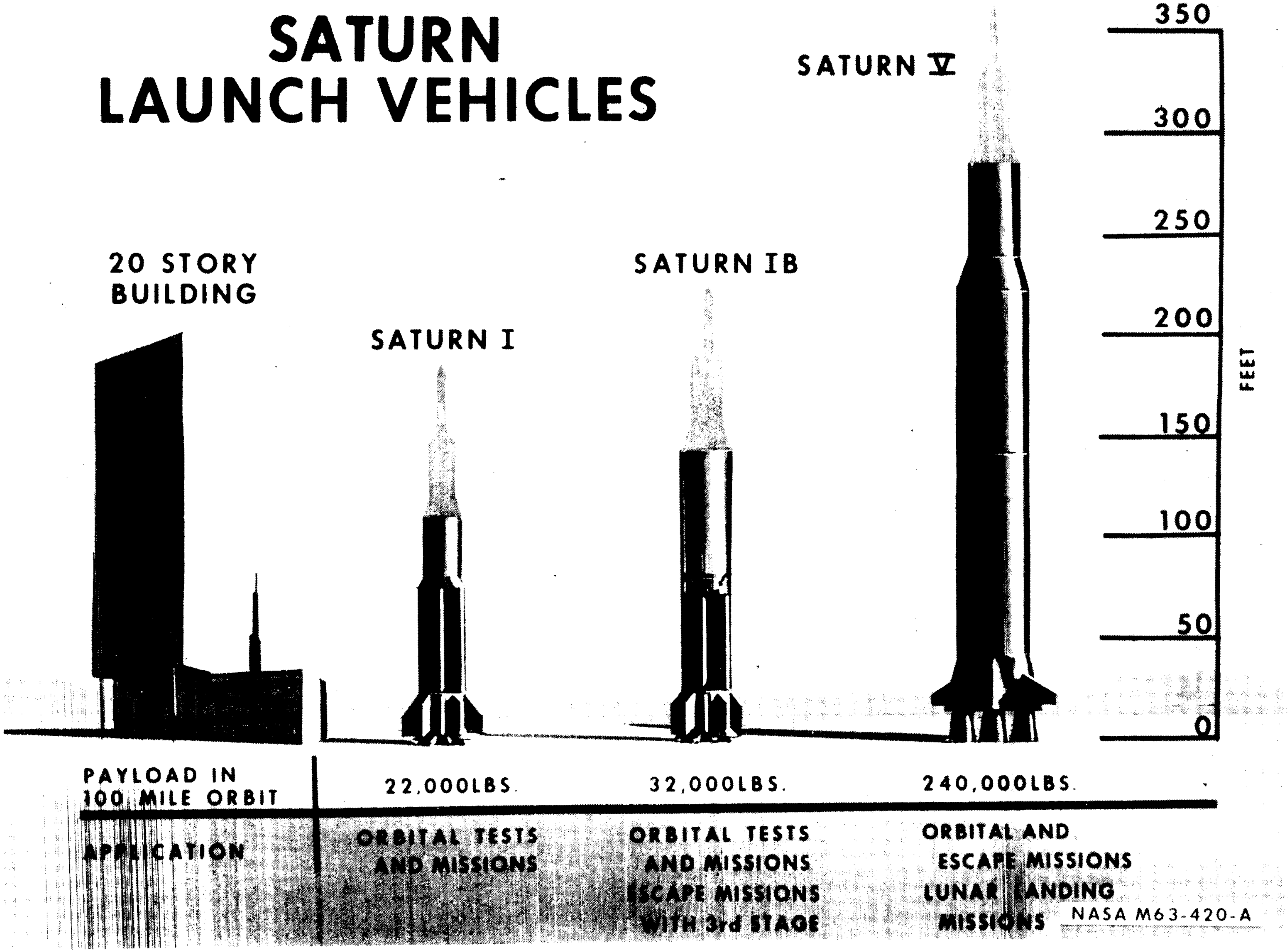
NASA S63 671

CENTAUR

Description: Centaur is a 10 ft. diameter high-energy upper stage powered by two Pratt and Whitney RL 10-A-3 liquid hydrogen-liquid oxygen engines of 15,000 pound thrust each. Centaur will use a modified Atlas-D as a first stage. This configuration is over 105 feet long and weighs about 300,000 pounds at launch.

Mission Capability: The high energy propellants used in Centaur give it a payload capability substantially above that of the Atlas-Agena-B. Atlas-Centaur can place a payload of over 8,500 pounds in a low earth orbit. Its performance advantages for high velocity missions is even more marked. It will be used by NASA principally for the Surveyor series of unmanned soft lunar landings and the Mariner planetary shots.

Schedule: The first development flight of Centaur took place on May 8, 1961. The vehicle failed during first stage flight, probably due to aerodynamic forces. The development test program extends to 1965 with the first Surveyor payload scheduled for early 1965. Centaur, as an upper stage for Atlas, is expected to remain operational throughout this decade.


SATURN
LAUNCH VEHICLES
20 STORY
BUILDING
SATURN I
SATURN IB
SATURN V
350
300
250
200
150
100
50
0
FEET
PAYLOAD IN
100 MILE ORBIT
22,000LBS.
32,000LBS.
240,000LBS.
APPLICATION
ORBITAL TESTS
AND MISSIONS
ORBITAL TESTS
AND MISSIONS
ESCAPE MISSIONS
WITH 3rd STAGE
ORBITAL AND
ESCAPE MISSIONS
LUNAR LANDING
MISSIONS
NASA M63-420-A

SATURN C-1

Description: The Saturn C-1 is a multi-purpose space booster vehicle of approximately 1.5 million pounds of initial thrust. The first stage, approximately 80 feet long, 257 inches diameter, weighing 103,000 pounds dry, is powered by eight Rocketdyne H-1 engines of 188,000 pounds thrust each. The four inner engines are fixed and the four outer engines are gimballed for pitch, yaw, and roll control. Of the nine propellant tanks, the center tank and four of the outer tanks contain liquid oxygen and the remaining four hold the hydrocarbon fuel.

The Saturn S-IV, approximately 41 feet long, 220 inches diameter, weighing 11,978 pounds dry, is powered by six Pratt and Whitney RL10-A-3 engines of approximately 15,000 pounds thrust each (Centaur engines) and will burn approximately 100,000 pounds of liquid oxygen and liquid hydrogen.

Mission Capability: The vehicle can be used for both manned and unmanned orbital missions, such as Dyna-Soar, Apollo space crew training, etc., with a payload capability of about 20,000 pounds in a 300 n.m. orbit.

SATURN C-1B

Description: The C-1B is a two-stage launch vehicle. The first stage (S-1) to be powered by a cluster of H-1 engines developing a total sea level thrust of approximately 1,500,000 pounds. The second stage (S-IVB) to be powered by a single J-2 engine developing a total vacuum thrust of approximately 200,000 pounds. The first stage will be a slightly modified version of the current S-1 stage being developed by MSFC. The second stage will be a slight modification to the S-IVB stage currently being developed by Douglas for use on the Advanced Saturn C-5 based on design concepts from MSFC.

Mission Capability: Primary Mission. The primary mission of the C-1B launch vehicle two-stage configuration shall be to place an Apollo spacecraft, weighing approximately 32,500 pounds, without lunar mission propellants, into an earth orbit of approximately 105 nautical miles.

Other Missions. The C-1B launch vehicle will provide an early means of demonstrating the capability of the S-IVB stage in support of the C-5 Apollo program. In addition, the following missions may be performed:

(a) Apollo re-entry.
(b) Voyager - Planetary Orbiter & Lander.

ADVANCED SATURN

Description: The Advanced Saturn first stage (S-1C) will be powered by five Rocketdyne F-1 engines, each of which develops 1.5 million pounds of thrust for a total thrust of 7.5 million pounds. The engines will be arranged in a square pattern of four gimballed engines with one fixed engine in the center of the square pattern. This basic configuration provides for maximum flexibility in that two of the outside engines can be eliminated without redesign, thus providing a more economical stage for missions which do not require the full 7.5 million pounds of thrust. The S-1C will have a propellant capacity of approximately 4.4 million pounds consisting of liquid oxygen and hydrocarbon fuel in two tanks, each approximately 33 feet in diameter. The total length will be approximately 138 feet.

The second stage (S-II) will be powered by five J-2 engines developing 200,000 pounds thrust each, for a total thrust of 1,000,000 pounds. The propellant (liquid oxygen and liquid hydrogen) capacity will be in excess of 900,000 pounds. The second stage will be approximately 33 feet in diameter and approximately 83 feet long. An engine-out capability will be provided.

The third stage (S-IVB) will use one J-2 engine for a total thrust of 200,000 pounds. It will carry 230,000 pounds of liquid oxygen and liquid hydrogen usable propellant loading and will be 260 inches in diameter and 58 feet long.

Mission Capability: The Advanced Saturn Launch Vehicle system will have sufficient payload capability to perform manned lunar-landing missions using a single-earth-orbital rendezvous. Also, provide a basic vehicle for manned circumlunar and lunar orbit missions, and for unmanned lunar and planetary explorations. This launch vehicle will have the capability of putting more than 100 tons in a low earth orbit and of sending more than 40 tons to the vicinity of the moon. Prime emphasis will be placed on the Apollo, Prospector, and Voyager missions.

COSTS OF LAUNCHED SPACECRAFT (MILLIONS OF DOLLARS)

Orbiting Astronomical Observatories

Spacecraft	(5)*	$ 216.5
Atlas-Agena	(5)	61.4
Total		$ 277.9

Unit cost $55.58 million

Orbiting Geophysical Observatories

Spacecraft	(9)*	$ 245.7
Atlas-Agena	(5)	36.4
Thor-Agena	(4)	23.7
Total		$ 305.8

Unit cost $33.98 million

Orbiting Solar Observatories

Spacecraft	(8)*	$ 53.7
Delta	(8)	19.5
Total		$ 73.2

Unit cost $9.15 million

Polar Ionosphere Beacon

Spacecraft	(2)*	$ 2.9
Scout	(2)	2.0
Total		$ 4.9

Unit cost $2.45 million

Atmospheric Explorers

Spacecraft	(4)*	$ 22.9
Delta	(4)	11.9
Total		$ 34.8

Unit cost $8.7 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

Ionosphere Explorers

Spacecraft	(2)*	$ 5.4
Scout	(2)	2.1
Total		$ 7.5

Unit cost $3.75 million

Air Density Explorers

Spacecraft	(2)*	$ 1.2
Scout	(2)	2.0
Total		$ 3.2

Unit cost $1.6 million

Geodetic Explorers

Spacecraft	(5)*	$ 19.2
Delta	(5)	13.8
Total		$ 33.0

Unit cost $6.6 million

Radio Astronomy Explorers

Spacecraft	(4)*	$ 14.0
Delta	(4)	11.0
Total		$ 25.0

Unit cost $6.25 million

University Explorers

Spacecraft	(7)*	$ 8.8
Scout	(7)	7.0
Total		$ 15.8

Unit cost $2.25 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

International Satellites

Spacecraft	(28)	$ 29.4
Scouts	(23)	23.0
Delta	(3)	8.3
Thor-Agena	(2)	16.5
Total		$ 77.2

Unit cost $2.76 million

Does not include spacecraft cost funded by International Groups.

Energetic Particles Satellites

Spacecraft	(4)*		$ 7.5
Delta (Develop. Vehicles)		(2)	5.5
(Proc. Vehicles)		(2)	6.3
Total			$ 19.3

Unit cost $4.8 million

Probes

IMP

Spacecraft	(10)	$ 26.2
Delta	(10)	29.2
Total		$ 55.4

Unit cost $5.5 million

BIOSATELLITES

Spacecraft	(6)*	$ 40.2
Delta	(6)	17.7
Total		$ 57.9

Unit cost $9.65 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

Probes

PIONEER

Spacecraft	(7)*	$ 50.0
Delta	(7)	21.4
Total		$ 71.4

Unit cost $10.2 million

RANGER

Spacecraft	(15)	$ 247.4
Atlas-Agena	(15)	126.2
Total		$ 373.6

Unit cost $24.9 million

SURVEYOR Lander

Spacecraft	(17)*	$ 358.0
Centaur	(17)	204.7
Total		$ 562.7

Unit cost $33.1 million

SURVEYOR Orbiter

Spacecraft	(10)*	$ 120.6
Atlas-Agena	(10)	78.7
Total		$ 199.3

Unit cost $19.9 million

MARINER R

Spacecraft	(2)*	$ 30.9
Atlas-Agena	(2)	18.7
Total		$ 49.6

Unit cost $24.8 million

*Costs include experiment design and fabrication, spacecraft assembly, and test, and data analysis.

MARINER B

Spacecraft	(6)*	$ 294.5
Centaur	(6)	70.6
Total		$ 365.1

Unit cost $60.8 million

MARINER C

Spacecraft	(4)*	$ 145.0
Atlas-Agena	(4)	45.8
Total		$ 190.8

Unit cost $47.7 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.