# *National Aeronautics and Space Administration*

# BUDGET ESTIMATES

**FISCAL YEAR 1970**

**Volume II**

RESEARCH AND DEVELOPMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1970 ESTIMATES

RESEARCH AND DEVELOPMENT

TABLE OF CONTENTS

VOLUME II


| | Page No. |
|---|---|
| General statement | SUM 1 |
| Summary of research and development budget plan by program by cognizant office | SUM 5 |
| Distribution of research and development budget plan by installation and fiscal year | SUM 6 |
| Justification by program: | |
| MANNED SPACE FLIGHT PROGRAMS | |
| Budget plan | MSF 1 |
| APOLLO | RD 1-1 |
| Spacecraft | RD 1-13 |
| Saturn V | RD 1-17 |
| Lunar exploration | RD 1-27 |
| Operations | RD 1-27 |
| Saturn IB | RD 1-33 |
| Engine development | RD 1-34 |
| SPACE FLIGHT OPERATIONS | RD 2-1 |
| Apollo applications | RD 2-4 |
| Space station | RD 2-15 |
| Operations | RD 2-15 |
| ADVANCED MISSIONS | RD 3-1 |
| Advanced missions studies | RD 3-1 |




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SPACE SCIENCE AND APPLICATIONS PROGRAMS


Budget plan..... SSA 1

PHYSICS AND ASTRONOMY..... RD 4-1

Supporting research and technology/Advanced studies.... RD 4-2
Data analysis..... RD 4-3
Sounding rockets..... RD 4-4
Solar observatories..... RD 4-5
Astronomical observatories..... RD 4-7
Geophysical observatories..... RD 4-10
Explorers..... RD 4-12

LUNAR AND PLANETARY EXPLORATION..... RD 5-1

Supporting research and technology/Advanced studies.... RD 5-3
Data analysis..... RD 5-5
Pioneer..... RD 5-6
Mariner..... RD 5-8
Viking..... RD 5-11
Planetary explorers..... RD 5-12

BIOSCIENCE..... RD 6-1

Supporting research and technology/Advanced studies.... RD 6-3
Planetary quarantine..... RD 6-7
Biosatellite..... RD 6-8

SPACE APPLICATIONS..... RD 7-1

Supporting research and technology/Advanced studies.... RD 7-3
Tiros/TOS improvements..... RD 7-5
Nimbus..... RD 7-6
Synchronous meteorological satellite..... RD 7-8
Meteorological soundings..... RD 7-8
Cooperative applications satellite..... RD 7-9
Applications technology satellites..... RD 7-10
Geodetic satellites..... RD 7-12
Earth resources survey..... RD 7-13

LAUNCH VEHICLE PROCUREMENT..... RD 8-1

Supporting research and technology/Advanced studies.... RD 8-3
Scout..... RD 8-4
Delta..... RD 8-4
Agena..... RD 8-5
Centaur..... RD 8-6
Titan III C..... RD 8-7

UNIVERSITY AFFAIRS


SUSTAINING UNIVERSITY PROGRAM..... RD 9-1

Research..... RD 9-4
Administration and management..... RD 9-5
Engineering systems design..... RD 9-6
Special training..... RD 9-7


ADVANCED RESEARCH AND TECHNOLOGY PROGRAMS


Budget plan..... ART 1

Space and aircraft technology summary..... ART 2

BASIC RESEARCH..... RD 10-1

SPACE VEHICLE SYSTEMS..... RD 11-1

Research and Technology:
Space vehicle aerothermodynamics..... RD 11-2
Space vehicle structures..... RD 11-4
Space environmental protection and control..... RD 11-5
Space vehicle design criteria..... RD 11-6
Aerospace safety research..... RD 11-7

ELECTRONICS SYSTEMS..... RD 12-1

Supporting research and technology..... RD 12-2
Flight projects..... RD 12-9

HUMAN FACTOR SYSTEMS..... RD 13-1

Supporting research and technology..... RD 13-3
Biotechnology flight projects..... RD 13-5

SPACE POWER AND ELECTRIC PROPULSION SYSTEMS..... RD 14-1

Supporting research and technology..... RD 14-2
Space electric rocket test (SERT)..... RD 14-9

NUCLEAR ROCKETS..... RD 15-1

Supporting research and technology..... RD 15-2
NERVA..... RD 15-4
Nuclear rocket development station operations..... RD 15-6

CHEMICAL PROPULSION..... RD 16-1

Supporting research and technology..... RD 16-2

AERONAUTICAL VEHICLES..... RD 17-1

Advanced research..... RD 17-2
General aviation aircraft technology..... RD 17-6
V/STOL aircraft technology..... RD 17-8
Subsonic aircraft technology..... RD 17-10
Supersonic aircraft technology..... RD 17-12
Hypersonic aircraft technology..... RD 17-15

TRACKING AND DATA ACQUISITION PROGRAM..... RD 18-1

Operations..... RD 18-2
Equipment..... RD 18-8
Supporting research and technology..... RD 18-13

TECHNOLOGY UTILIZATION PROGRAM..... RD 19-1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## RESEARCH AND DEVELOPMENT

## GENERAL STATEMENT

The National Aeronautics and Space Administration program of research and development and supporting activities is directed toward maintaining the United States in a position of world leadership in aeronautics and space. The major programs for achieving this objective are:

MANNED SPACE FLIGHT: A program for the development of a capability for peaceful manned space operations and the utilization of that capability for earth orbit and lunar missions.

SPACE SCIENCE AND APPLICATIONS: An unmanned space flight program directed toward scientific investigations of the earth, moon, sun, planets, stars and interplanetary space; and the development of technology and spacecraft systems which can be utilized for meteorology, communications and geodetic and earth resources observations.

ADVANCED RESEARCH AND TECHNOLOGY: An effort required to provide the fundamental knowledge and the technological base for future aeronautics and space programs.

TRACKING AND DATA ACQUISITION: The worldwide activity required to support the NASA manned and unmanned flight programs.

## MANNED SPACE FLIGHT

Manned Space Flight activities continue to comprise the largest portion of the budget request. Included are the development and demonstration of a capability for manned space operations and exploration. The readiness of the Saturn V launch vehicle and Apollo command and service module for manned lunar operations was demonstrated by the Apollo 8 mission in December 1968. Apollo planning calls for the initial lunar landing mission to be flown during calendar year 1969, after flight qualification of the lunar module. The budget also provides for several additional manned lunar missions using basic Apollo hardware and for definition of modifications to this hardware and of new systems and experiments needed for a comprehensive lunar exploration program.

The Space Flight Operations program involves application of the capabilities developed in Gemini and Apollo to manned missions of increasing duration and complexity. The program focuses on development of a manned

space station system for flight in the mid-1970's. An initial series of manned orbital missions designated Apollo Applications is scheduled to begin in FY 1971. The flight program consists of three basic missions: (1) initial operation of the Saturn I Workshop in orbit; (2) revisit and reactivation of the Workshop; and (3) a second revisit using the Workshop and the Apollo Telescope Mount as a basis for solar astronomy. This plan involves five launches using Saturn IB launch vehicles and Apollo spacecraft modified to meet mission requirements.

SPACE SCIENCE AND APPLICATIONS

The Space Science and Applications program is the second largest in the FY 1970 budget request. The scientific program is broad based; concentrating on studies of the solar system, stars, and space environment. Planetary exploration will receive increased emphasis in FY 1970. Efforts in progress will include analysis of data acquired from Mariner-Mars 1969 and the Pioneer series of spacecraft, preparation for the Mariner-Mars 1971, development of the Viking orbiter and lander spacecraft for the Mars 1973 opportunity, and continued development of Pioneer spacecraft for investigations of the interplanetary medium as far out as the orbit of Jupiter. Development of a series of relatively small planetary explorers for flight to Venus and Mars and of a Mariner spacecraft for a 1973 Venus/Mercury mission will begin. Research on the earth and its local environment is conducted through the use of balloons, sounding rockets, explorers, and the Orbiting Geophysical Observatories. Solar studies are carried out using the Orbiting Solar Observatory. The Orbiting Astronomical Observatory, explorers, and sounding rockets support a program of research in astronomy, including investigations in the optical, radio, x-ray and gamma ray regions of the spectrum. The Bioscience program continues to investigate the effects of the space environment on living organisms and to study methods of increasing knowledge on the origin, nature and distribution of life in the universe.

The Applications program is made up of activities for adapting space technology to the direct benefit of mankind. TIROS and Nimbus continue to support requirements of the atmospheric sciences research community and improvements in operational weather satellite systems. Meteorological sounding rocket launches will continue studies in the region of 20 to 60 miles above the earth. Development of a meteorological satellite for synchronous orbit is planned to begin in FY 1970. Applications Technology Satellites are being used to develop information and test techniques for new applications in the areas of communications, navigation, and traffic control. Geodetic satellites will continue to conduct measurements on a global basis. The Earth Resources Survey program will receive increased emphasis with expansion of the aircraft survey effort and initiation of an earth resources technology satellite to test remote sensing and data acquisition techniques.

## ADVANCED RESEARCH AND TECHNOLOGY

The Advanced Research and Technology effort is a continuing program aimed at providing the technological base for significant future aerospace missions. This effort covers the spectrum of activity from basic research to improve our fundamental scientific knowledge, through applied technology to improve our practical capability for developing advanced systems applicable to space and aeronautical activity. The specific areas of effort in the program are Basic Research, Space Vehicle Systems, Electronics Systems, Human Factor Systems, Space Power and Electric Propulsion Systems, Nuclear Rockets, Chemical Propulsion and Aeronautical Vehicles. It is proposed to start development of the nuclear powered rocket engine, NERVA, in FY 1970. The aeronautics program includes increased emphasis on aircraft noise reduction, flight test of V/STOL concepts, and a broad range of applicable research.

## TRACKING AND DATA ACQUISITION

The Tracking and Data Acquisition effort provides the support required by the NASA space flight programs. As in the current year, the largest part of the FY 1970 request is for operating the worldwide network of tracking and data acquisition facilities. This activity will increase in FY 1970 to meet the support requirements of the Apollo manned lunar landing program. Activity in support of the unmanned space flight programs will remain at approximately the same level as in the current year.

Funds in FY 1970 for replacement of equipment and maintaining the capability of the facilities will increase somewhat due to the requirements of new programs.

## SUSTAINING UNIVERSITY PROGRAM

The Sustaining University program is an integral part of NASA's program of university research and training. The major elements of the program in FY 1970 will be broadly based multidisciplinary research, engineering systems design, administration and management, and special training in high priority aerospace fields. These long range programs are largely locally controlled and provide the special benefit of contribution to the financial stability and educational needs of universities while supporting NASA.

## TECHNOLOGY UTILIZATION

The Technology Utilization program provides for expeditious public availability of scientific, technological and engineering information and concepts which result from NASA programs. This promotes a maximum return from public investment in NASA's research and development to the non-aerospace sector of the economy as well as benefitting the aerospace industry. To assure fulfillment of this objective, the program provides for establishing effective mechanisms for: (a) assuring that all new

knowledge is identified, collected and evaluated,and (b) announcing and disseminating this new knowledge to assure its wide application and utilization.

FINANCING

The FY 1970 Research and Development program plan discussed in this budget totals $3,168,900,000, a reduction of $24,659,000 below the FY 1969 program of $3,193,559,000. The appropriation request for FY 1970 is $3,051,427,000, reflecting the application of $117,473,000 of the FY 1969 appropriation, which has been reserved from apportionment pursuant to the Revenue and Expenditure Control Act of 1968 (Pub. L. 90-364, 82 Stat. 251).

Research and Development expenditures for the current fiscal year are estimated at $3,520,000,000 and at $3,235,000,000 for FY 1970, a reduction of $285,000,000.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1970 ESTIMATES

SUMMARY OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY PROGRAM BY COGNIZANT OFFICE

| BUDGET ACTIVITY | OFFICE/PROGRAM | Fiscal Year 1968 | Fiscal Year 1969 | Fiscal Year 1970 |
|---|---|---|---|---|
| | MANNED SPACE FLIGHT | $2,809,230,000 | $2,177,500,000 | $2,007,700,000 |
| 1b | Apollo | 2,556,030,000 | 2,025,000,000 | 1,651,100,000 |
| 1c&d | Space flight operations | 253,200,000 | 150,000,000 | 354,100,000** |
| 1d | Advanced missions | --- | 2,500,000 | 2,500,000 |
| | SPACE SCIENCE AND APPLICATIONS | 552,850,000 | 438,416,000 | 558,800,000 |
| 2a | Physics and astronomy | 139,500,000 | 125,116,000 | 119,600,000 |
| 2b | Lunar and planetary exploration | 147,500,000 | 81,800,000 | 146,800,000 |
| 2c | Bioscience | 41,800,000 | 32,700,000 | 32,400,000 |
| 3 | Space applications | 99,500,000 | 98,600,000 | 135,800,000 |
| * | Launch vehicle procurement | 124,550,000 | 100,200,000 | 124,200,000 |
| | UNIVERSITY AFFAIRS | 10,000,000 | 9,000,000 | 9,000,000 |
| 6b | Sustaining university program | 10,000,000 | 9,000,000 | 9,000,000 |
| | ADVANCED RESEARCH AND TECHNOLOGY | 315,022,000 | 285,171,000 | 290,400,000 |
| 4&5 | Basic research | 21,465,000 | 21,000,000 | 21,400,000 |
| 4 | Space vehicle systems | 34,100,000 | 31,700,000 | 30,000,000 |
| 4&5 | Electronics systems | 38,057,000 | 34,771,000 | 35,000,000 |
| 4&5 | Human factor systems | 19,828,000 | 19,700,000 | 23,600,000 |
| 4 | Space power and electric propulsion systems | 43,735,000 | 42,200,000 | 39,900,000 |
| 4 | Nuclear rockets | 54,000,000 | 32,000,000 | 36,500,000 |
| 4 | Chemical Propulsion | 37,037,000 | 28,900,000 | 25,100,000 |
| 5 | Aeronautical vehicles | 66,800,000 | 74,900,000 | 78,900,000 |
| 6a | TRACKING AND DATA ACQUISITION | 275,850,000 | 279,672,000 | 298,000,000 |
| 6c | TECHNOLOGY UTILIZATION | 4,000,000 | 3,800,000 | 5,000,000 |
| | TOTAL BUDGET PLAN | $3,966,952,000 | $3,193,559,000 | $3,168,900,000** |

*Funds for the procurement of launch vehicles are statistically distributed to unmanned flight programs (e.g., Physics and Astronomy, Space Vehicle Systems).
**Includes application of $117,473,000, which has been reserved from apportionment pursuant to the Revenue and Expenditure Control Act of 1968 (Pub. L. 90-364, 82 Stat. 251).



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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1970 ESTIMATES

DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of dollars)

| PROGRAM OFFICE | TOTAL | J. F. Kennedy Space Center NASA | Manned Spacecraft Center | Marshall Space Flight Center | Goddard Space Flight Center | Jet Propulsion Laboratory | Wallops Station | Ames Research Center | Electronics Research Center | Flight Research Center | Langley Research Center | Lewis Research Center | Space Nuclear Propulsion Office | NASA Headquarters | NASA Pasadena Office |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Office of Manned Space Flight** | | | | | | | | | | | | | | | |
| 1968 | 2,809,230 | 369,428 | 1,220,304 | 1,151,560 | 587 | 1,108 | 191 | 867 | 1,986 | --- | 2,095 | --- | --- | 61,104 | --- |
| 1969 | 2,177,500 | 383,645 | 1,071,624 | 668,550 | --- | 100 | --- | 605 | --- | --- | 450 | --- | --- | 52,526 | --- |
| 1970 | 2,007,700 | 340,400 | 920,800 | 690,700 | --- | --- | --- | 800 | --- | --- | 200 | --- | --- | 54,800 | --- |
| **Office of Space Science and Applications** | | | | | | | | | | | | | | | |
| 1968 | 552,850 | 4,566 | 6,550 | 1,022 | 223,365 | 118,069 | 1,538 | 40,127 | 3,483 | --- | 24,584 | 74,767 | --- | 53,113 | 1,666 |
| 1969 | 438,416 | 4,519 | 11,464 | 1,803 | 197,003 | 59,880 | 1,522 | 28,442 | 3,217 | --- | 15,485 | 58,125 | --- | 56,956 | --- |
| 1970 | 558,800 | 4,500 | 14,719 | 1,343 | 231,383 | 80,087 | 1,110 | 38,347 | 3,185 | --- | 47,091 | 69,200 | --- | 67,835 | --- |
| **Office of University Affairs** | | | | | | | | | | | | | | | |
| 1968 | 10,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 10,000 | --- |
| 1969 | 9,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 9,000 | --- |
| 1970 | 9,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 9,000 | --- |
| **Office of Advanced Research and Technology** | | | | | | | | | | | | | | | |
| 1968 | 315,022 | 75 | 4,220 | 16,797 | 9,779 | 24,410 | 712 | 24,960 | 21,348 | 21,543 | 55,654 | 60,150 | 50,400 | 19,575 | 5,399 |
| 1969 | 285,171 | --- | 5,411 | 11,622 | 9,866 | 23,538 | 790 | 24,569 | 20,850 | 16,965 | 57,299 | 60,864 | 30,080 | 19,718 | 3,599 |
| 1970 | 290,400 | --- | 7,080 | 13,620 | 10,910 | 23,085 | 300 | 28,705 | 22,150 | 11,330 | 54,975 | 68,220 | 32,800 | 13,675 | 3,550 |
| **Office of Tracking and Data Acquisition** | | | | | | | | | | | | | | | |
| 1968 | 275,850 | --- | --- | 400 | 201,302 | 52,368 | 5,000 | --- | --- | 2,000 | 1,625 | --- | --- | 13,155 | --- |
| 1969 | 279,672 | --- | --- | 300 | 209,522 | 50,400 | 6,000 | --- | --- | 2,000 | 1,350 | --- | --- | 10,100 | --- |
| 1970 | 298,000 | --- | --- | 400 | 220,100 | 54,200 | 6,000 | --- | 200 | 2,000 | 1,300 | --- | --- | 13,800 | --- |
| **Office of Technology Utilization** | | | | | | | | | | | | | | | |
| 1968 | 4,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4,000 | --- |
| 1969 | 3,800 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 3,800 | --- |
| 1970 | 5,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5,000 | --- |
| **Total Budget Plan** | | | | | | | | | | | | | | | |
| 1968 | 3,966,952 | 374,069 | 1,231,074 | 1,169,779 | 435,033 | 195,955 | 7,441 | 65,954 | 26,817 | 23,543 | 83,958 | 134,917 | 50,400 | 160,947 | 7,065 |
| 1969 | 3,193,559 | 388,164 | 1,088,499 | 682,275 | 416,391 | 133,918 | 8,312 | 53,616 | 24,067 | 18,965 | 74,584 | 118,989 | 30,080 | 152,100 | 3,599 |
| 1970 | 3,168,900 | 344,900 | 942,599 | 706,063 | 462,393 | 157,372 | 7,410 | 67,852 | 25,535 | 13,330 | 103,566 | 137,420 | 32,800 | 164,110 | 3,550 |

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1970 ESTIMATES

DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of dollars)

| PROGRAM | | TOTAL | J. F. Kennedy Space Center, NASA | Manned Spacecraft Center | Marshall Space Flight Center | Goddard Space Flight Center | Jet Propulsion Laboratory | Wallops Station | Ames Research Center | Electronics Research Center | Flight Research Center | Langley Research Center | Lewis Research Center | Space Nuclear Propulsion Office | NASA Headquarters | NASA Pasadena Office |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OFFICE OF MANNED SPACE FLIGHT, TOTAL | 1968 | 2,809,230 | 369,428 | 1,220,304 | 1,151,560 | 587 | 1,108 | 191 | 867 | 1,986 | --- | 2,095 | --- | --- | 61,104 | --- |
| | 1969 | 2,177,500 | 383,645 | 1,071,624 | 668,550 | --- | 100 | --- | 605 | --- | --- | 450 | --- | --- | 52,526 | --- |
| | 1970 | 2,007,700 | 340,400 | 920,800 | 690,700 | --- | --- | --- | 800 | --- | --- | 200 | --- | --- | 54,800 | --- |
| Apollo | 1968 | 2,556,030 | 368,851 | 1,140,464 | 992,490 | 184 | 166 | --- | 7 | 1,600 | --- | 1,162 | --- | --- | 51,106 | --- |
| | 1969 | 2,025,000 | 383,200 | 1,008,750 | 583,450 | --- | 100 | --- | --- | --- | --- | --- | --- | --- | 49,500 | --- |
| | 1970 | 1,651,100 | 324,700 | 779,900 | 503,700 | --- | --- | --- | --- | --- | --- | --- | --- | --- | 42,800 | --- |
| Space flight operations | 1968 | 253,200 | 577 | 79,840 | 159,070 | 403 | 942 | 191 | 860 | 386 | --- | 933 | --- | --- | 9,998 | --- |
| | 1969 | 150,000 | 245 | 61,924 | 84,200 | --- | --- | --- | 605 | --- | --- | --- | --- | --- | 3,026 | --- |
| | 1970 | 354,100 | 15,500 | 140,000 | 186,100 | --- | --- | --- | 800 | --- | --- | --- | --- | --- | 11,700 | --- |
| Advanced missions | 1968 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 1969 | 2,500 | 200 | 950 | 900 | --- | --- | --- | --- | --- | --- | 450 | --- | --- | --- | --- |
| | 1970 | 2,500 | 200 | 900 | 900 | --- | --- | --- | --- | --- | --- | 200 | --- | --- | 300 | --- |
| OFFICE OF SPACE SCIENCE AND APPLICATIONS, TOTAL | 1968 | 552,850 | 4,566 | 6,550 | 1,022 | 223,365 | 118,069 | 1,538 | 40,127 | 3,483 | --- | 24,584 | 74,767 | --- | 53,113 | 1,666 |
| | 1969 | 438,416 | 4,519 | 11,464 | 1,803 | 197,003 | 59,880 | 1,522 | 28,442 | 3,217 | --- | 15,485 | 58,125 | --- | 56,956 | --- |
| | 1970 | 558,800 | 4,500 | 14,719 | 1,343 | 231,383 | 80,087 | 1,110 | 38,347 | 3,185 | --- | 47,091 | 69,200 | --- | 67,835 | --- |
| Physics and astronomy | 1968 | 139,500 | --- | 739 | 86 | 112,949 | 373 | 1,093 | 2,267 | 140 | --- | 1,617 | --- | --- | 20,236 | --- |
| | 1969 | 125,116 | --- | 644 | 578 | 98,429 | 572 | 918 | 1,617 | 60 | --- | 1,155 | --- | --- | 21,143 | --- |
| | 1970 | 119,600 | --- | 644 | 578 | 91,888 | 847 | 630 | 1,617 | 60 | --- | 2,831 | --- | --- | 20,505 | --- |
| Lunar and planetary exploration | 1968 | 147,500 | 84 | 40 | 256 | 1,542 | 115,792 | --- | 7,098 | 75 | --- | 11,540 | --- | --- | 11,073 | --- |
| | 1969 | 81,800 | 119 | 275 | 540 | 4,141 | 56,381 | --- | 5,456 | 25 | --- | 260 | --- | --- | 14,603 | --- |
| | 1970 | 146,800 | --- | 1,775 | 115 | 10,820 | 75,140 | --- | 18,690 | 25 | --- | 27,260 | --- | --- | 12,975 | --- |
| Bioscience | 1968 | 41,800 | --- | --- | 55 | 134 | 1,545 | 40 | 30,662 | --- | --- | 85 | --- | --- | 9,279 | --- |
| | 1969 | 32,700 | --- | --- | 135 | 86 | 1,623 | 80 | 21,269 | --- | --- | 190 | --- | --- | 9,317 | --- |
| | 1970 | 32,400 | --- | --- | 150 | 75 | 1,600 | 80 | 17,940 | --- | --- | 100 | --- | --- | 12,455 | --- |
| Space applications | 1968 | 99,500 | --- | 5,771 | 565 | 77,886 | 179 | 405 | 100 | 1,605 | --- | 814 | 1,215 | --- | 10,960 | --- |
| | 1969 | 98,600 | --- | 10,545 | 350 | 71,747 | 1,104 | 524 | 100 | 1,832 | --- | 980 | 1,125 | --- | 10,293 | --- |
| | 1970 | 135,800 | --- | 12,300 | 300 | 96,400 | 2,300 | 400 | 100 | 1,800 | --- | 1,000 | 1,100 | --- | 20,100 | --- |
| Launch vehicle procurement | 1968 | 124,550 | 4,482 | --- | 60 | 30,854 | 180 | --- | --- | 1,663 | --- | 10,528 | 73,552 | --- | 1,565 | 1,666 |
| | 1969 | 100,200 | 4,400 | --- | 200 | 22,600 | 200 | --- | --- | 1,300 | --- | 12,900 | 57,000 | --- | 1,600 | --- |
| | 1970 | 124,200 | 4,500 | --- | 200 | 32,200 | 200 | --- | --- | 1,300 | --- | 15,900 | 68,100 | --- | 1,800 | --- |
| OFFICE OF UNIVERSITY AFFAIRS | 1968 | 10,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 10,000 | --- |
| | 1969 | 9,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 9,000 | --- |
| | 1970 | 9,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 9,000 | --- |

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1970 ESTIMATES

DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(Thousands of dollars)

| PROGRAM | | TOTAL | J. F. Kennedy Space Center, NASA | Manned Spacecraft Center | Marshall Space Flight Center | Goddard Space Flight Center | Jet Propulsion Laboratory | Wallops Station | Ames Research Center | Electronics Research Center | Flight Research Center | Langley Research Center | Lewis Research Center | Space Nuclear Propulsion Office | NASA Headquarters | NASA Pasadena Office |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY, TOTAL | 1968 | 315,022 | 75 | 4,220 | 16,797 | 9,779 | 24,410 | 712 | 24,960 | 21,348 | 21,543 | 55,654 | 60,150 | 50,400 | 19,575 | 5,399 |
| | 1969 | 285,171 | --- | 5,411 | 11,622 | 9,866 | 23,538 | 790 | 24,569 | 20,850 | 16,965 | 57,299 | 60,864 | 30,080 | 19,718 | 3,599 |
| | 1970 | 290,400 | --- | 7,080 | 13,620 | 10,910 | 23,085 | 300 | 28,705 | 22,150 | 11,330 | 54,975 | 68,220 | 32,800 | 13,675 | 3,550 |
| Basic research | 1968 | 21,465 | --- | --- | 824 | 131 | 4,175 | --- | 2,336 | 1,999 | --- | 2,818 | 2,702 | --- | 6,465 | 15 |
| | 1969 | 21,000 | --- | --- | 900 | 130 | 3,720 | --- | 2,450 | 2,380 | --- | 2,830 | 3,020 | --- | 5,570 | --- |
| | 1970 | 21,400 | --- | --- | 930 | 140 | 3,830 | --- | 2,520 | 2,450 | --- | 2,920 | 3,110 | --- | 5,500 | --- |
| Space vehicle systems | 1968 | 34,100 | --- | 755 | 4,103 | 2,615 | 2,045 | --- | 2,916 | 410 | 1,350 | 15,716 | 3,015 | --- | 1,175 | --- |
| | 1969 | 31,700 | --- | 947 | 3,562 | 2,451 | 1,810 | --- | 3,480 | 390 | 1,320 | 14,123 | 2,650 | --- | 967 | --- |
| | 1970 | 30,000 | --- | 450 | 3,140 | 2,200 | 1,485 | --- | 3,135 | 340 | 1,220 | 13,085 | 4,100 | --- | 845 | --- |
| Electronics systems | 1968 | 38,057 | --- | 150 | 2,655 | 2,878 | 3,405 | --- | 3,771 | 16,679 | 890 | 5,357 | 400 | --- | 1,872 | --- |
| | 1969 | 34,771 | --- | --- | 2,450 | 2,880 | 2,791 | --- | 3,589 | 15,675 | 830 | 4,931 | --- | --- | 1,625 | --- |
| | 1970 | 35,000 | --- | --- | 2,850 | 2,550 | 3,200 | --- | 3,250 | 16,500 | 800 | 4,220 | --- | --- | 1,630 | --- |
| Human factor systems | 1968 | 19,828 | --- | 2,243 | 300 | --- | 50 | 712 | 6,029 | 910 | 1,000 | 5,682 | --- | --- | 2,902 | --- |
| | 1969 | 19,700 | --- | 3,364 | 410 | --- | 50 | 790 | 5,990 | 995 | 900 | 5,310 | --- | --- | 1,891 | --- |
| | 1970 | 23,600 | --- | 5,550 | 700 | --- | 100 | 300 | 5,950 | 1,250 | 900 | 6,900 | --- | --- | 1,950 | --- |
| Space power and electric propulsion systems | 1968 | 43,735 | --- | 122 | 960 | 3,615 | 9,416 | --- | 345 | 1,350 | --- | 665 | 24,506 | --- | 2,596 | 160 |
| | 1969 | 42,200 | --- | 550 | 350 | 4,255 | 10,670 | --- | 310 | 1,410 | --- | 815 | 21,239 | --- | 2,601 | --- |
| | 1970 | 39,900 | --- | 580 | 430 | 5,770 | 9,270 | --- | 450 | 1,610 | --- | 1,480 | 18,510 | --- | 1,800 | --- |
| Nuclear rockets | 1968 | 54,000 | --- | --- | 1,400 | --- | --- | --- | --- | --- | --- | --- | 2,200 | 50,400 | --- | --- |
| | 1969 | 32,000 | --- | --- | 920 | --- | --- | --- | --- | --- | --- | --- | 1,000 | 30,080 | --- | --- |
| | 1970 | 36,500 | --- | --- | 2,200 | --- | --- | --- | --- | --- | --- | --- | 1,500 | 32,800 | --- | --- |
| Chemical propulsion | 1968 | 37,037 | 75 | 950 | 6,175 | 540 | 5,319 | --- | --- | --- | --- | 2,673 | 13,338 | --- | 2,743 | 5,224 |
| | 1969 | 28,900 | --- | 550 | 2,800 | 150 | 4,497 | --- | --- | --- | --- | 2,630 | 12,310 | --- | 2,364 | 3,599 |
| | 1970 | 25,100 | --- | 500 | 2,750 | 250 | 5,200 | --- | --- | --- | --- | 2,200 | 9,500 | --- | 1,150 | 3,550 |
| Aeronautical vehicles | 1968 | 66,800 | --- | --- | 380 | --- | --- | --- | 9,563 | --- | 18,303 | 22,743 | 13,989 | --- | 1,822 | --- |
| | 1969 | 74,900 | --- | --- | 230 | --- | --- | --- | 8,750 | --- | 13,915 | 26,660 | 20,645 | --- | 4,700 | --- |
| | 1970 | 78,900 | --- | --- | 620 | --- | --- | --- | 13,400 | --- | 8,410 | 24,170 | 31,500 | --- | 800 | --- |
| OFFICE OF TRACKING AND DATA ACQUISITION | 1968 | 275,850 | --- | --- | 400 | 201,302 | 52,368 | 5,000 | --- | --- | 2,000 | 1,625 | --- | --- | 13,155 | --- |
| | 1969 | 279,672 | --- | --- | 300 | 209,522 | 50,400 | 6,000 | --- | --- | 2,000 | 1,350 | --- | --- | 10,100 | --- |
| | 1970 | 298,000 | --- | --- | 400 | 220,100 | 54,200 | 6,000 | --- | 200 | 2,000 | 1,300 | --- | --- | 13,800 | --- |
| OFFICE OF TECHNOLOGY UTILIZATION | 1968 | 4,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4,000 | --- |
| | 1969 | 3,800 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 3,800 | --- |
| | 1970 | 5,000 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5,000 | --- |
| TOTAL BUDGET PLAN | 1968 | 3,966,952 | 374,069 | 1,231,074 | 1,169,779 | 435,033 | 195,955 | 7,441 | 65,954 | 26,817 | 23,543 | 83,938 | 134,917 | 50,400 | 166,547 | 7,065 |
| | 1969 | 3,193,559 | 388,164 | 1,088,499 | 682,275 | 416,391 | 133,918 | 8,312 | 53,616 | 24,067 | 18,965 | 74,584 | 118,989 | 30,080 | 152,100 | 3,599 |
| | 1970 | 3,168,900 | 344,900 | 942,599 | 706,063 | 462,393 | 157,372 | 7,410 | 67,852 | 25,535 | 13,330 | 103,566 | 137,420 | 32,800 | 164,110 | 3,550 |

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1970 ESTIMATES

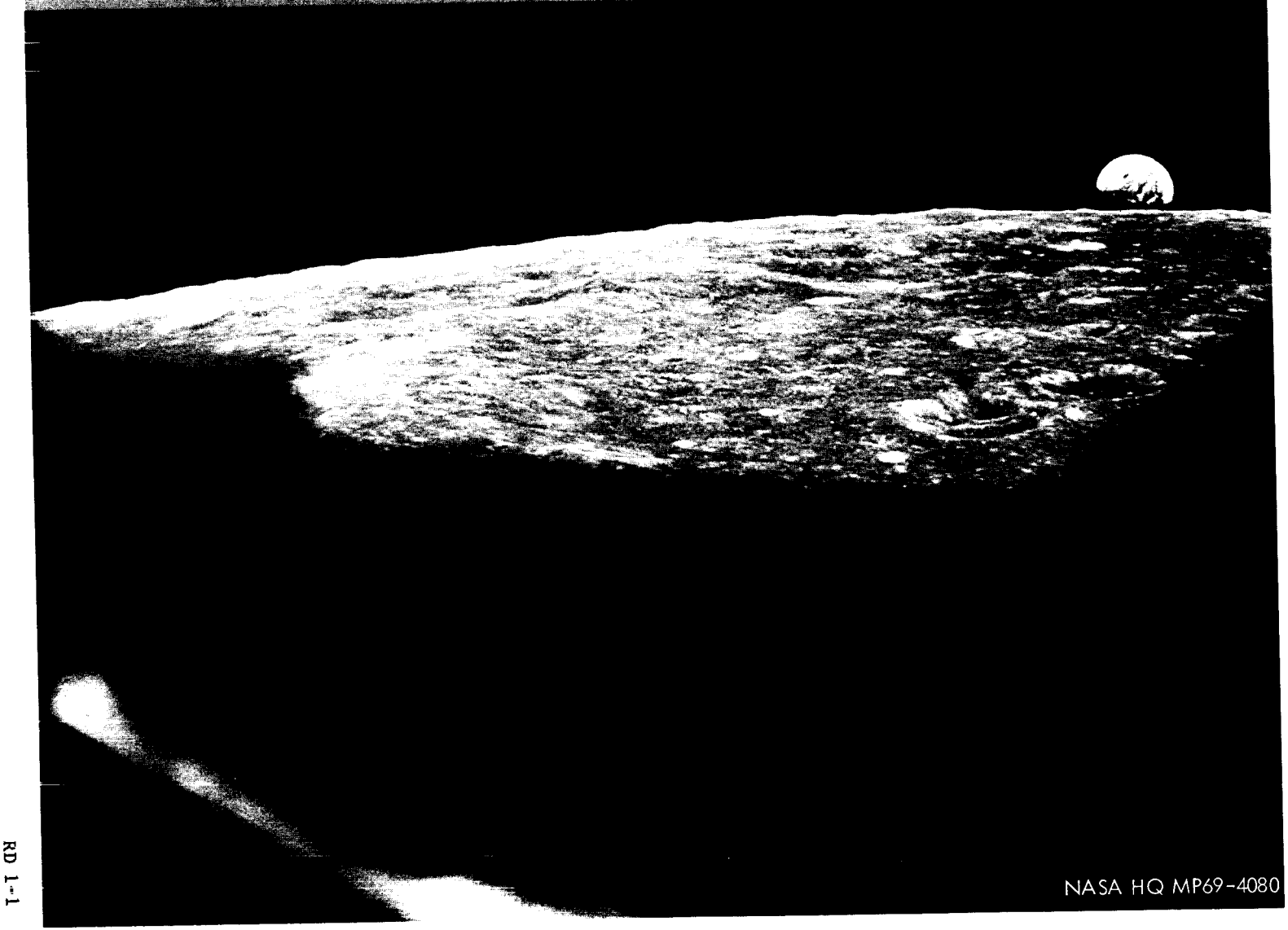
RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

MANNED SPACE FLIGHT PROGRAMS

| Program | Fiscal Year 1968 | Fiscal Year 1969 | Fiscal Year 1970 |
|---|---|---|---|
| Apollo | $2,556,030,000 | $2,025,000,000 | $1,651,100,000 |
| Space flight operations | 253,200,000 | 150,000,000 | 354,100,000* |
| Advanced missions | --- | 2,500,000 | 2,500,000 |
| Total | $2,809,230,000 | $2,177,500,000 | $2,007,700,000 |

* Includes $117,473,000 of FY 1969 funds applied to FY 1970 budget plan.

THE EARTH RISING ABOVE THE LUNAR SURFACE AS SEEN THROUGH COMMAND MODULE WINDOW OF APOLLO 8



OFFICE OF MANNED SPACE FLIGHT APOLLO PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

From its inception, the Apollo program has focused on developing and demonstrating a basic national capability to conduct manned space operations around the earth and moon, and on the moon. The development of the Apollo spacecraft, the Saturn launch vehicles and the associated operations base, with the construction of the ground facilities required to achieve this has brought together the largest and most varied scientific and engineering team ever assembled for a peaceful program. This partnership of industry, universities, and government has advanced the Apollo program to the point where the national goal of manned lunar landing and return during 1969 is within reach. The accomplishment of this goal will be a decisive demonstration of the nation's ability to conduct complex space operations, and will provide a sound foundation for a new and increasingly productive era in space flight.

Apollo represents a broad national capability to launch payloads of nearly 145 tons into earth orbit and 50 tons to the moon; to allow men to live and work in space for periods of up to two weeks; to sustain men on a round trip voyage of half a million miles into space and back to earth; and to conduct limited manned exploration of the moon. The flight hardware being produced, the specialized skills of the workforce, the nation-wide complex of laboratory, manufacturing, test, and launch facilities, and the technology created in Apollo establish a versatile and powerful national asset.

## Flight Chronology

Saturn/Apollo flights began in October 1961 when a Saturn I demonstrated the propulsion concept of clustering large liquid fueled engines. Seven years later, in October 1968, after fifteen successful flights, the Apollo phase of the Saturn I/IB series of launches was concluded with the completion of the Apollo 7 mission.

The Apollo 5 mission, using a Saturn IB, resulted in the initial flight test of the Lunar Module. This unmanned test, in January 1968, verified the ascent and descent stage propulsion systems, including restart and throttle operations, and qualified the lunar module for manned flight testing.

Apollo 7, the first manned Apollo mission, was launched from Cape Kennedy on October 11, 1968--within three minutes of the lift-off time set three months earlier. On October 22, after a journey of nearly 11 days, 163 orbital revolutions, and 4 1/2 million miles around the earth, the spacecraft splashed down to a safe recovery in the Atlantic Ocean. Apollo 7, piloted

by Astronauts Schirra, Eisele, and Cunningham, achieved all its primary test objectives and represented a major milestone in moving toward the goal of a manned lunar landing and return.

The Apollo 7 mission added a number of "firsts" to the history of manned space flight. It was the first American flight with a three-man crew in one spacecraft. It was the first manned mission where the spacecraft had its own propulsion system, a 20,500 pound-thrust engine, for major maneuvers in earth orbit. It was the first manned demonstration of the spacecraft and ground support communications system required for deep space operations; the first test of the television equipment planned for a manned lunar mission; and the first use of an advanced on-board computer capable of controlling the spacecraft's attitude and velocity.

A significant achievement of the flight of Apollo 7 was the first full use of the "open-ended" mission planning concept in manned space operations. In the Gemini program, flight experience was acquired and the design of the spacecraft tested in a series of steps--beginning with a three-orbit flight, followed by flights lasting four, eight, and finally fourteen days. In Apollo 7, the same basic approach was applied, but instead of stopping at each plateau and returning from orbit, real-time telemetry was used to evaluate the spacecraft's readiness to move forward to the next step. As a result of this inherent capability to capitalize on success, this first manned Apollo mission gained as much information about the reliability of the spacecraft design as was obtained in the first five manned Gemini flights.

With the built-in flexibility of "open-ended" mission planning, the total risks of moving forward to the next step can be weighed against the potential for significantly advancing the progress toward a safe and successful lunar landing. Accepting the fact that any space flight involves an element of risk, the Apollo philosophy of "open-ended" mission planning creates the capability to capitalize on success and minimize the total risks to the flight crews.

The completely successful flight of Apollo 7 and the successful development of the Saturn V permitted this country to undertake the Apollo 8 mission.

The first Apollo Saturn V, an unmanned development test flight designated Apollo 4, was launched on November 9, 1967 in a highly successful demonstration of the "all-up" concept. This "all-up" philosophy is designed to test as many new systems as practical in each flight, rather than having an individual flight for each new system. During this Apollo 4 mission, the Saturn V vehicle launched an Apollo Command and Service Module into a high elliptical orbit to test the systems and to verify the heatshield's ability to withstand the intense heat of re-entry from lunar distances. The major test objectives were achieved, and the 6 million individual parts in the complex Saturn V performed reliably.

The second unmanned flight test of the Saturn V occurred on April 4, 1968. During this Apollo 6 mission, the "POGO" phenomenon (longitudinal oscillations) developed, causing unacceptably high stresses in the space vehicle. Additionally, igniter fuel lines in the upper stages ruptured, resulting in a premature shutdown of two engines on the second stage, and the failure of the third stage engine to restart. Despite these difficulties, the Saturn V placed the Apollo spacecraft into orbit around the earth.

The resolution of anomalies that occurred in Apollo 6 by a government and industry task team under the direction of the Marshall Space Flight Center is considered an outstanding technical achievement. The POGO and fuel line rupture problems were resolved through an extensive program of flight data analysis, mathematical modeling using computers, and ground testing, and the Saturn V launch vehicle was determined to be ready for manned flight.

First Manned Mission to the Moon:

In the history of man, the flight of Apollo 8 will be chronicled as the first time man ever escaped the bondage of his planet, flew to another celestial body, orbited around it, and safely returned to earth.

On December 21, 1968, precisely on time, the first manned Saturn V launch vehicle sent the Apollo crew of Astronauts Borman, Lovell and Anders into a completely successful ten orbit mission around the moon.

The mission began with the ignition of the Saturn V 1st stage (S-IC). Burning 4.5 million pounds of kerosene and liquid oxygen propellant during its brief 2½ minutes of flight and generating over 7.5 million pounds of thrust at launch, the 1st stage lifted the two upper stages, the instrument unit, and an Apollo Command and Service Module to an altitude of 36 miles. Retro-rockets then separated it from the 2nd stage. After ignition, the five J-2 engines of the 2nd stage (S-II) burned for about six minutes, carrying the space vehicle to an altitude of nearly 115 miles above the earth. After jettisoning the S-II stage, the single J-2 engine in the 3rd stage (S-IVB) fired for about 2½ minutes to increase the velocity to the 17,500 miles per hour required to carry the three-man spacecraft into earth orbit. Propellants for later use in the mission remained in this stage after the S-IVB engine shut down.

As the Apollo spacecraft, combined with the S-IVB stage, circled the earth, the astronauts and the personnel monitoring the systems through the facilities of the worldwide tracking network examined and verified system readiness for the lunar mission. When the readiness of the crew and the equipment was confirmed, the 3rd stage engine restarted, burned for more than 5 minutes, and accelerated the spacecraft to the 24,300 mph velocity necessary to escape from the gravitational influence of the earth, and propelled the spacecraft out of earth orbit and onto a path to the moon. On the way to the moon, another check of the complex equipment was conducted. The astronauts separated the Apollo Command and Service Module from the S-IVB stage and the instrument unit, leaving the stage to go in orbit around the sun,



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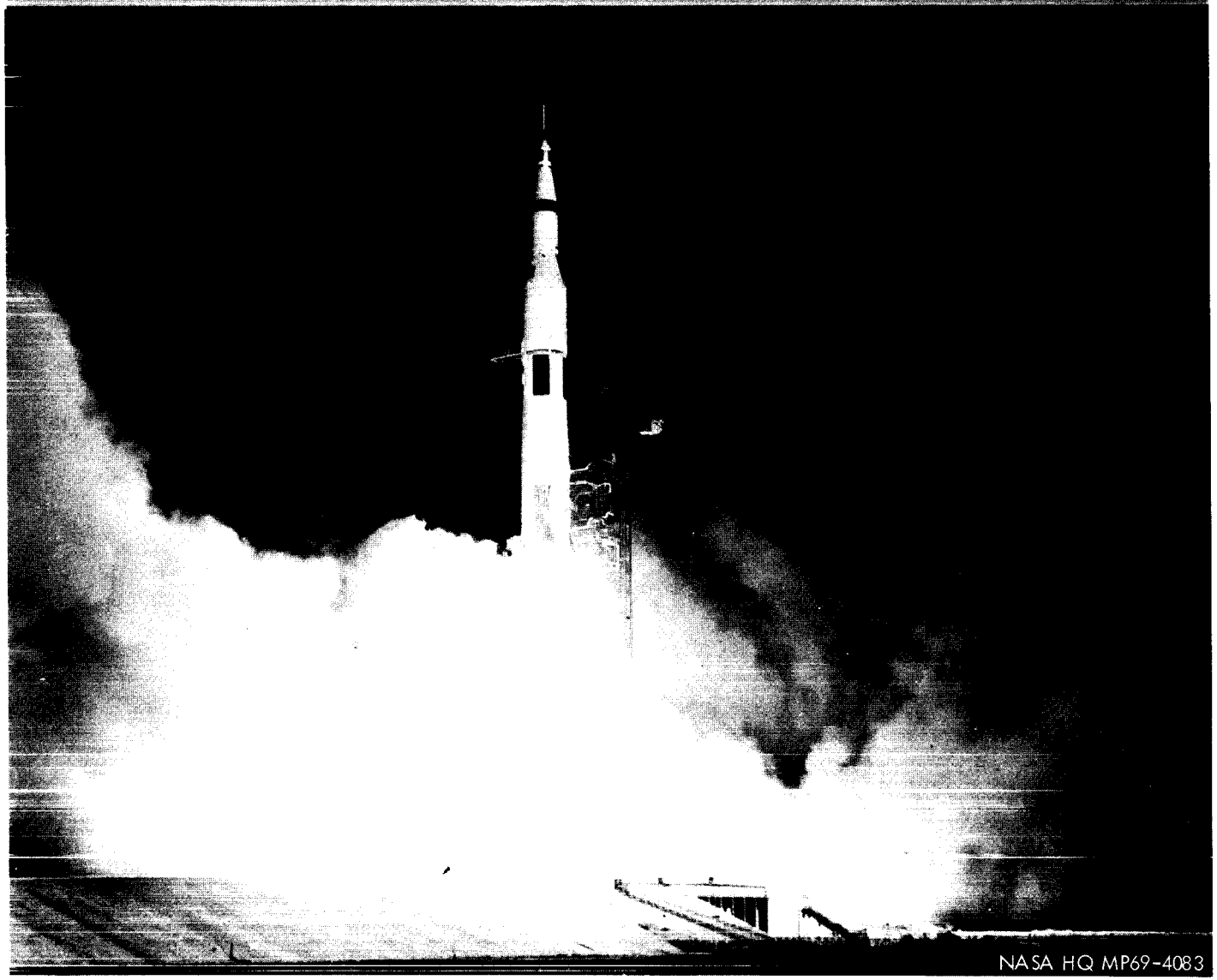
## DECEMBER 21, 1968-MEN, FOR THE FIRST TIME, ON THEIR WAY TO THE MOON



NASA HQ MP69-4083

and continued their voyage to the moon. As the spacecraft coasted closer to the moon, the service propulsion engine was used to make a midcourse correction. This same propulsion system was fired to slow the spacecraft down and carry it into orbit around the moon.

The lunar orbits at sixty nautical miles provided future Apollo crews with valuable information on lunar lighting, lunar features and landmarks, and confirmed man's ability to acquire reference points for guidance purposes. The mission tested the operation of the tracking and communication systems at lunar distances, and provided valuable data on perturbations in lunar orbit that are thought to be the consequence of concentrations of heavy metals beneath the lunar surface. The incorporation of these perturbations into the calculations for rendezvous and docking during later lunar missions will be of great assistance in assuring the success of these maneuvers.

On Christmas morning, the service propulsion engine was fired to increase the spacecraft's velocity for an escape from lunar orbit and to start the journey back to earth. On-board guidance and navigation data, verified by data transmitted from the worldwide tracking network, provided the Apollo crew with reference points for determining the return path. Shortly before earth re-entry, the Service Module was cast off and at nearly 25,000 miles per hour, the Command Module returned to earth, hitting the very narrow corridor which is designed to minimize the effects of the heat and gravitational forces of re-entry into the atmosphere. Three sets of parachutes slowed the rate of descent, bringing the spacecraft down to within three miles of the target point.

The flight was a demonstration of the capability of the spacecraft to function and support man in the hostile environment of space 233,000 miles from the earth; of the accuracy of the guidance and navigation systems; of its ability to maneuver and change course; and of the heatshield's and spacecraft's structures capacity to withstand the forces and heat at the high speed of earth re-entry from lunar distance.

On Apollo 9, the fourth Saturn V will launch an Apollo Command and Service Module and Lunar Module into orbit around the earth to perform the rendezvous and docking maneuvers that will be required for a landing mission. For the first time, the Command and Service Module will dock with the Lunar Module, and two of the three Apollo crew members will transfer to the Lunar Module. The reliability and performance of this module will be evaluated during these manned simulations of lunar operations. The following mission, Apollo 10, is planned as the last major step before a manned lunar landing may be attempted. This mission will be an operational checkout of the complete Apollo spacecraft in orbit around the moon, including rendezvous and docking. The success of these two missions, Apollo 9 and 10, will provide the experience to attempt the initial lunar landing, which is described below. It should be recognized that although this mission sequence leading to the initial lunar landing represents the primary plan, alternate Apollo planning recognizes that a requirement for additional missions prior to the landing attempt may become apparent as the program proceeds. For this eventuality,

## APOLLO 8, 60 NAUTICAL MILES ABOVE THE SURFACE OF THE MOON, LOOKS AT THE EARTH

the program has the capability to repeat any mission as required to establish a sound basis for moving to the next step in the mission sequence.

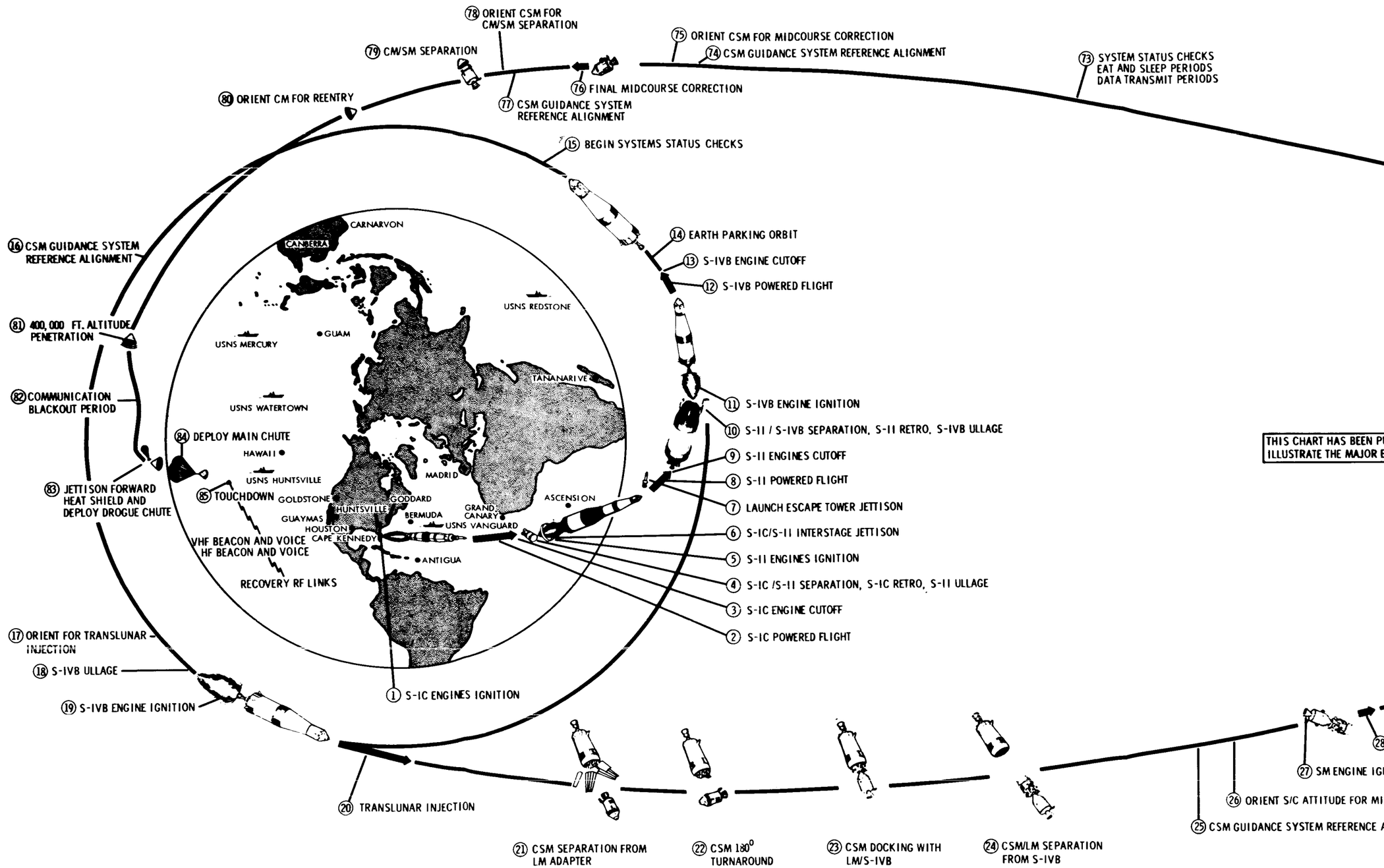
Lunar Landing Mission Profile:

The initial flight of the landing mission closely approximates the Apollo 8 mission until the space vehicle is inserted into a lunar trajectory. A check is made of the spacecraft equipment. If there is no problem with the systems, the astronauts separate the Apollo Command and Service Module from the combination of the Lunar Module, the adapter, the S-IVB stage, and the instrument unit, turn the craft around, and dock nose-to-nose with the Lunar Module. After this docking maneuver is completed, the adapter section, S-IVB, and instrument unit are released, and the spacecraft continues its journey to the moon. The voyage lasts from 2½ to 3½ days, depending on the date of launch, and on a planned trajectory that provides for a "free return" to earth; that is, if for any reason it is not possible or advisable to go into lunar orbit, the spacecraft sweeps around the moon and back to earth. If cleared for lunar orbit, the service propulsion system is fired to slow the spacecraft down and carry it into orbit around the moon. Once in lunar orbit, the astronauts again check the equipment, confirming that the Lunar Module is ready to be used for a landing. Two of the three Apollo astronauts then leave the Command Module and move through connecting hatches to the Lunar Module. After separating from the orbiting command craft, the two astronauts ignite the Lunar Module's descent engine, which slows down the vehicle and takes it into an elliptical orbit to within ten miles of the lunar surface. At this altitude, the descent engine is again fired in a braking maneuver to reduce the speed as the Lunar Module approaches the landing site. The final approach begins at 9,000 feet with a maneuver to bring the landing point into the astronaut's line of sight. The descent engine cuts off at about 15 feet, just before the Lunar Module touches down on the surface of the moon. The length of this first stay on the moon will be less than 24 hours. During the first landing, the astronauts will collect lunar soil and rock samples, conduct observations, place experiments and instrumentation on the surface, and take photographic and television pictures of the surrounding surface.

After completing these tasks, the astronauts return to the Lunar Module and prepare for the critical take off operation. The descent stage serves as a launching pad for the ascent stage with its cabin. The two astronauts fire the ascent engine and maneuver the craft for thirty minutes until they rendezvous and dock with the orbiting Command Module. After they re-enter the command craft, the ascent stage is jettisoned, and left in lunar orbit to relay additional information back to earth on the lifetime and operation of the equipment. The service propulsion engine, as it did in the Apollo 8 mission, will then fire to increase the spacecraft's velocity for an escape from lunar orbit and to start the journey back to earth.

A specific objective of the Apollo program will be attained with the first manned lunar landing and return to earth, and will herald a period of lunar exploration using, initially, hardware available in Apollo. The Apollo program includes the procurement of 12 Saturn IB's, 15 Saturn V's, 18 lunar mission configured Command and Service Modules and 14 flight Lunar Modules.

# LUNAR LANDING MIS

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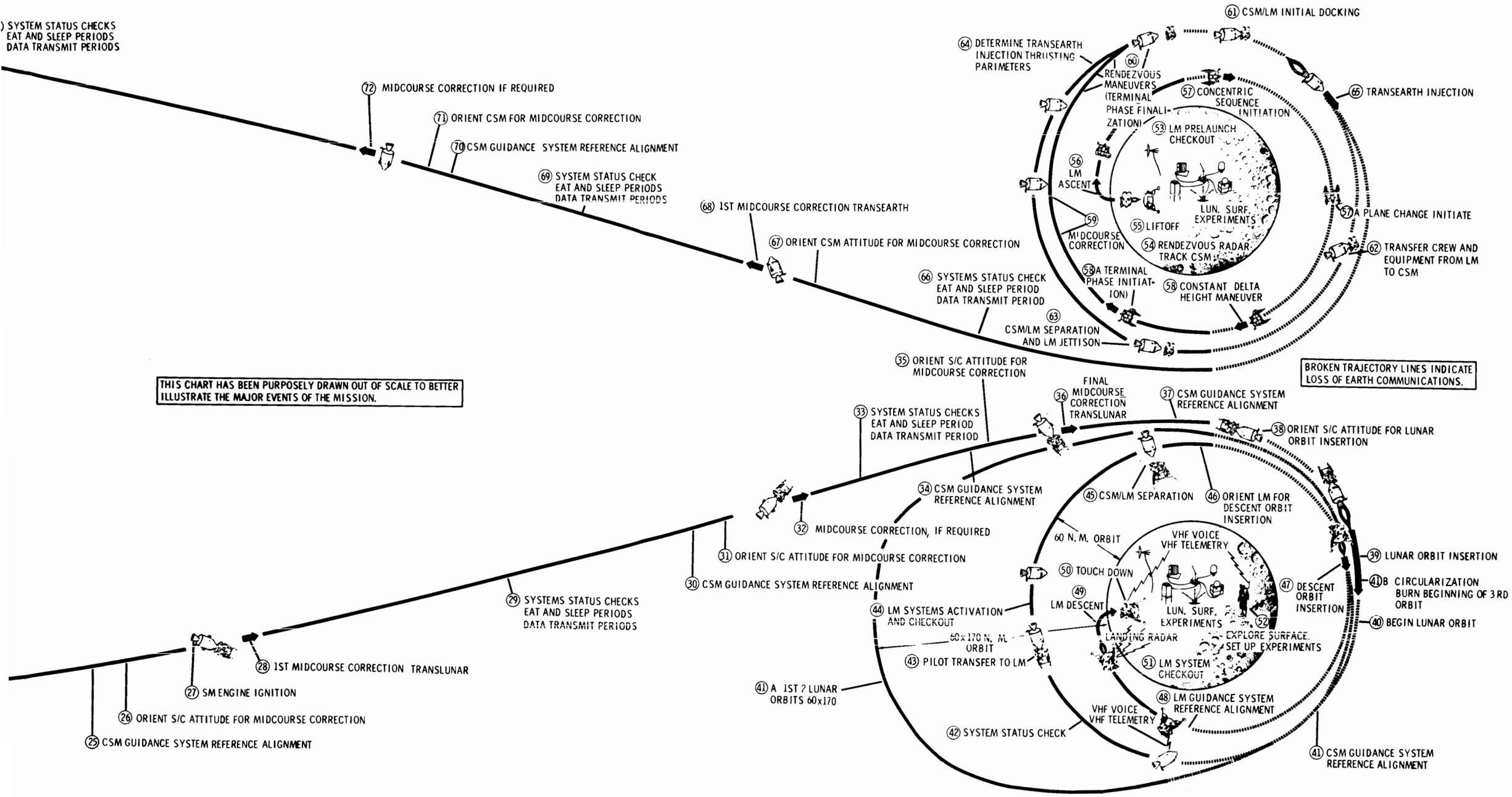
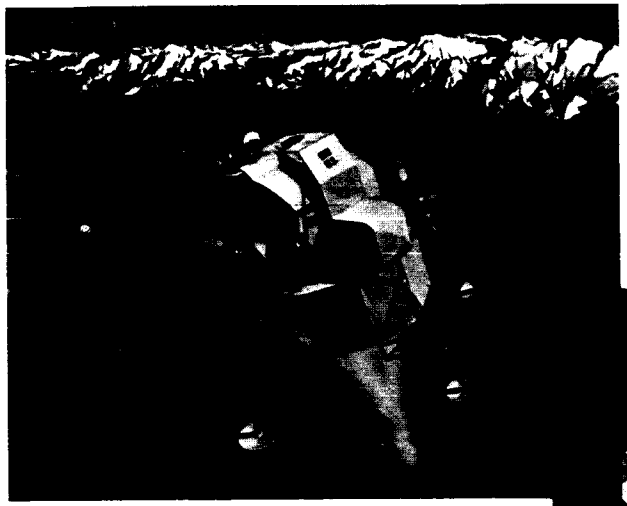
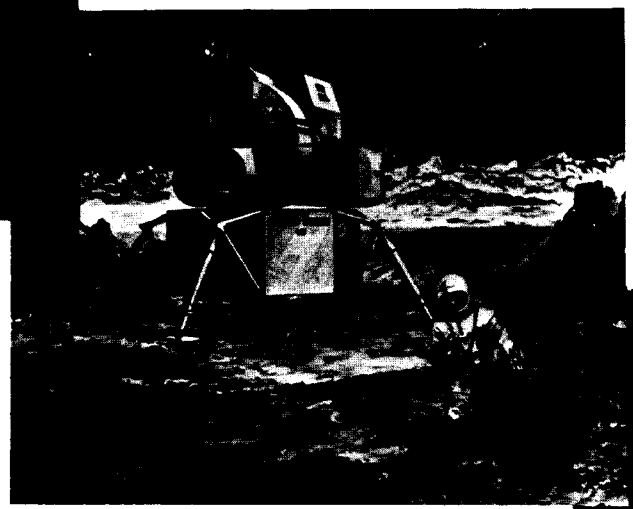
# LANDING MISSION PROFILE

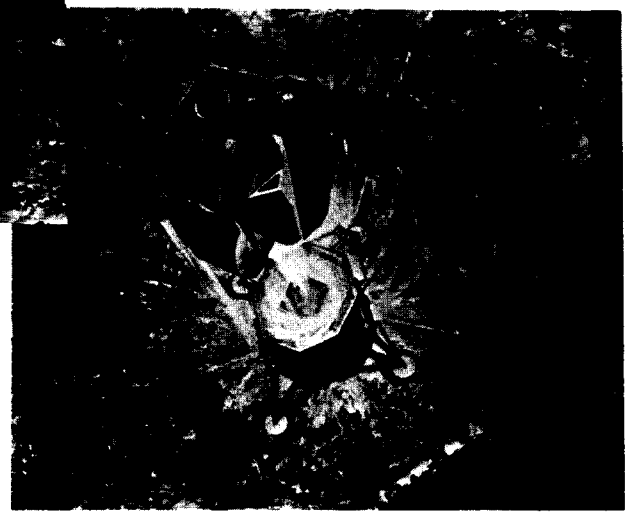




LUNAR MODULE DESCENT



ON THE MOON



# SATURN V APOLLO

ASCENT STAGE LIFT-OFF

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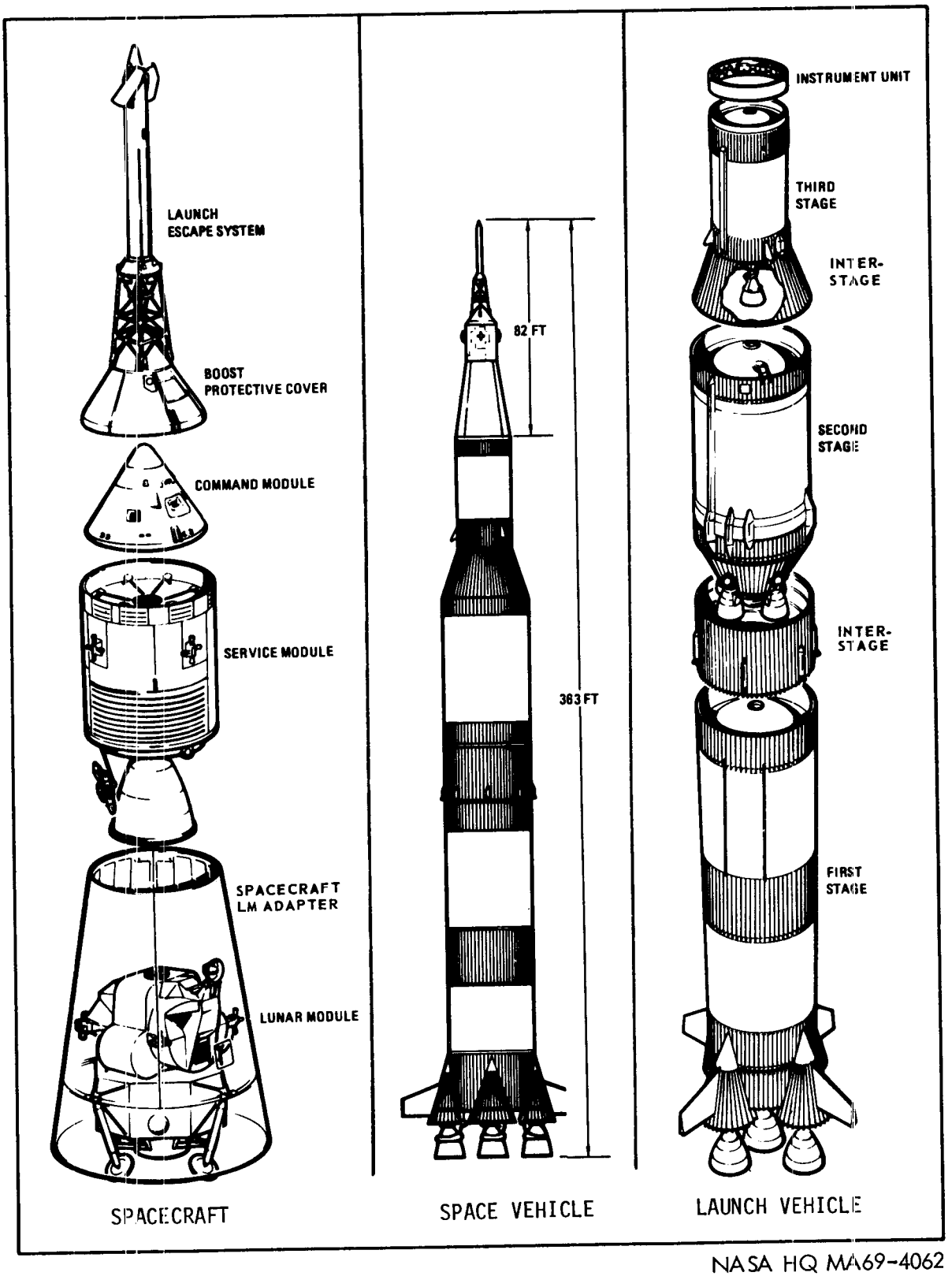
Subsequent missions after the initial manned lunar landing will position the Apollo Lunar Surface Experiments Package (ALSEP) on the surface of the moon. Using electrical power supplied by a radioisotopic thermoelectric generator, this series of ALSEP experiments will transmit data for a year or more on seismic activity on the moon, lunar heat flow, solar wind, and charged particles existing above the surface of the moon. The primary goal of continued lunar exploration is to determine how the moon can best serve our national interests and its potential for benefiting all the people of the earth. The principal scientific objectives include understanding the moon's origin, composition, formation, and evolution, and its relationship to the earth and the entire solar system. The basic Apollo systems provide for man's staytime on the moon up to one day, and provide a limited radius of exploration from the Lunar Module. Basic technical objectives will be to expand man's capability to explore the moon by increasing astronaut staytime and mobility, and developing surface vehicle and other mobility units for traverses to assist man in accomplishing an extensive survey of the moon.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft..... | $1,034,700,000 | $902,800,000 | $653,800,000 |
| Saturn V..... | 853,965,000 | 534,453,000 | 496,700,000 |
| Lunar exploration..... | --- | --- | 11,000,000 |
| Operations..... | 545,765,000 | 546,400,000 | 489,600,000 |
| Saturn IB..... | 101,100,000 | 41,347,000 | --- |
| Engine development..... | 20,500,000 | --- | --- |
| Total..... | $2,556,030,000 | $2,025,000,000 | $1,651,100,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| John F. Kennedy Space Center, NASA..... | $368,851,000 | $383,200,000 | $324,700,000 |
| Manned Spacecraft Center. | 1,140,464,000 | 1,008,750,000 | 779,900,000 |
| Marshall Space Flight Center..... | 992,490,000 | 583,450,000 | 503,700,000 |
| Goddard Space Flight Center..... | 184,000 | --- | --- |
| Jet Propulsion Laboratory | 166,000 | 100,000 | --- |
| Ames Research Center..... | 7,000 | --- | --- |
| Electronics Research Center..... | 1,600,000 | --- | --- |
| Langley Research Center.. | 1,162,000 | --- | --- |
| NASA Headquarters..... | 51,106,000 | 49,500,000 | 42,800,000 |

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BASIS OF FUNDING REQUIREMENTS:

Spacecraft

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Command and service module | $393,023,000 | $346,000,000 | $217,900,000 |
| Lunar module..... | 402,688,000 | 326,000,000 | 270,900,000 |
| Spacecraft support..... | 110,514,000 | 121,800,000 | 95,700,000 |
| Guidance and navigation... | 61,158,000 | 43,900,000 | 26,400,000 |
| Integration, reliability, and checkout..... | 67,317,000 | 65,100,000 | 42,900,000 |
| Total..... | $1,034,700,000 | $902,800,000 | $653,300,000 |

The Apollo spacecraft consists of three modules: the Command Module, the Service Module, and the Lunar Module. The Command Module is a double-shelled, conical shaped spacecraft containing systems for communications; environmental control; guidance and navigation, stabilization and control for in-flight and re-entry manuevering; thermal protection against the heat of re-entry; and earth landing systems. Providing the living and crew station quarters, it is the only hardware used during a mission that is recovered. The Service Module is a cylindrical structure storing most of the spacecraft consumables such as oxygen, hydrogen, and propulsion fuels. The Service Module contains the main spacecraft propulsion system providing 20,500 pounds of thrust; the reaction control system for secondary propulsion and manuevering; the electrical power system; and elements of the communication and environmental control systems. It is jettisoned from the spacecraft just prior to re-entry. The Lunar Module is a self-contained vehicle consisting of a descent stage and an ascent stage with a two-man cabin. The module serves as a base of operations on the surface of the moon. Each stage is equipped with its own engine - the descent stage engine provides the decelerating force necessary for a soft landing; the ascent stage engine launches the two astronauts up from the surface of the moon to the orbiting Command and Service Module.

Command and Service Module (CSM)

Command and Service Modules were developed by the Space Division of the North American Rockwell Corporation, and are produced at the Downey, California plant. Sixty-two major subcontractors in twenty states have supported North American Rockwell in this effort. Four unmanned CSMs were successfully flight tested before the first manned operational test during the Apollo 7 mission. The last unmanned spacecraft was launched by the second Saturn V vehicle in April 1968.

The Command and Service Modules used for all manned flights are configured for lunar missions, and incorporate changes resulting from the Apollo 204 accident. Principal changes include the replacement of the previous two-piece Command Module hatch with a single unified hatch and replacement of flammable nonmetallic cabin materials with new materials which have met the



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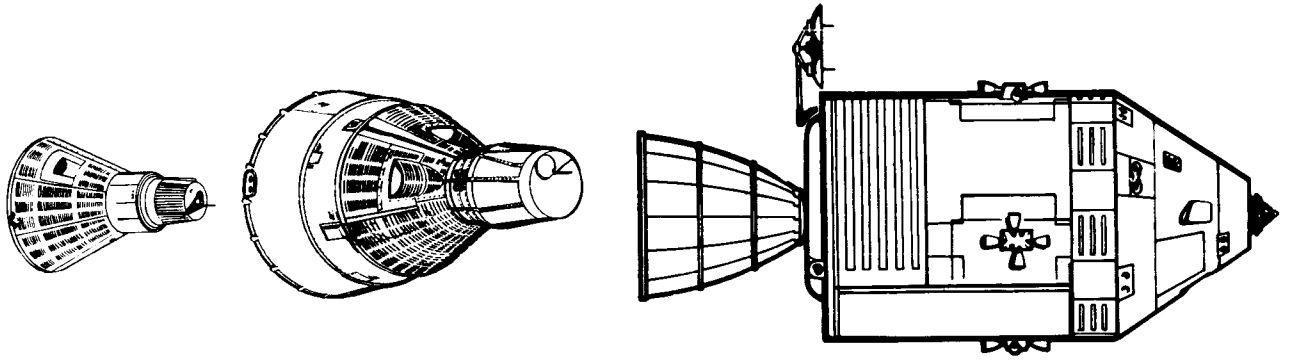
# U. S. MANNED SPACECRAFT



(LM NOT SHOWN)

| | MERCURY | GEMINI | APOLLO |
|---|---|---|---|
| CREW | 1 | 2 | 3 |
| DURATION | 2 DAYS | 14 DAYS | 14 DAYS |
| HABITABLE VOLUME | 72 $FT^3$ | 80 $FT^3$ | 526 $FT^3$ |
| WEIGHT AT LAUNCH | 4265 LB. | 8360 LB. | 109,500 LB. |

NASA HQ MT 68-5626

stringent noninflammability and nonpropagation standards that have been established. Any flammable materials required in the spacecraft are enclosed in fire resistent containers or are strictly controlled to small quantities. Metal covers encase all previously exposed plumbing and electrical equipment. Additional protective measures were taken to strengthen the plumbing by placing armored collars around joints. Eleven CMSs will be in various stages of production and factory checkout during FY 1970. The requested funding also supports the analysis of flight data and the necessary in-plant capability for the solution of problems which arise during test, pre-launch checkout and flight phases.

## Lunar Module (LM)

Study and design effort on the Lunar Module was initiated by Grumman Aircraft Engineering Corporation, Bethpage, New York, in early 1963. The first flight article, designated LM-1, was launched by a Saturn IB in January 1968 in an unmanned development mission. The flight verified the operational reliability of the systems and tested the LM propulsion systems and their capability to restart during flight. Two LM test articles were flown on the two unmanned Apollo Saturn V missions as part of the unmanned flight qualification test program and provided data on vibration, acoustics and structural integrity under a launch environment. Flammability tests were conducted in December 1967 when a series involving over 40 deliberately simulated ignitions was completed and demonstrated the Lunar Module's ability to meet the standards for nonpropagation of fire. During FY 1970, seven Lunar Modules will be in the process of subsystem and structural assembly, systems integration, and checkout at Grumman. The capability is also being maintained at Grumman for possible LM modifications and problem solving which may be necessary as a result of the test and flight programs.

## Spacecraft Support

Spacecraft support funds provide for test operations, crew equipment, space suits, logistics, instrumentation, and scientific equipment. Funds are required to conduct spacecraft development and analysis tests at the Manned Spacecraft Center and other government test laboratories. Activities at the facilities of the Manned Spacecraft Center include unmanned and manned thermal-vacuum testing; component and subsystem qualification; reliability and verification testing; and electronic systems compatibility tests. Service Module propulsion system testing and Lunar Module ascent and descent engine testing is conducted at White Sands, New Mexico. Lunar Module propulsion system and Service Module propulsion system testing is also conducted in special test cells at the Arnold Engineering Development Center, Tullahoma, Tennessee.

Spacecraft support funding also provides for development and procurement of space suits and related crew equipment; survival equipment; food; extravehicular activity umbilicals; personal hygiene systems; and bioinstrumentation. Major effort in FY 1970 is focused on manufacturing space suits and portable life support systems required for operating on the lunar surface, as well as manufacturing the recently designed noninflammable crew space suit.

Logistic funding for FY 1970 is required for transportation of spacecraft between installations and procurement of spacecraft fuels and propellants used in the test programs at NASA and other government facilities and at contractor sites.

Instrumentation and scientific equipment funding for FY 1970 provides for development and procurement of specialized flight research and test instrumentation. Typical equipment includes signal conditioners, sensors, transmitters, antennas, ground support equipment, cameras, and radiation measuring devices.

## Guidance and Navigation (G&N)

A guidance and navigation system unit is carried on both the Command and Service Module and the Lunar Module. The unit is composed of three subsystems. The inertial guidance subsystem measures changes in the spacecraft position and velocity and assists in generating steering commands. The optical subsystem is used to take precision navigational sightings and provide the computer with measured angles between the stars and landmarks. The computer subsystem consists of a digital computer which takes data from the inertial guidance and optical subsystems and calculates spacecraft position, velocity, and steering commands.

The guidance and navigation system units for the Apollo spacecraft were designed by the Massachusetts Institute of Technology. The General Motors/A. C. Electronics Division in Milwaukee, Wisconsin, is the prime contractor for production of the inertial guidance subsystem, including its associated electronics, ground support, and checkout; and for integrating and testing all subsystems of the guidance and navigation system. The on-board navigational computer subsystem is manufactured by the Raytheon Company, Waltham, Massachusetts; the optical subsystem is built by the Kollsman Instrument Corporation, Elmhurst, New York.

FY 1970 funding provides for the checkout of flight units; engineering and technical support for resolution of problems; and preparation, development, testing, and modification of computer programs. Because of the heavy launch schedule in FY 1970, the capability for analysis of flight data and resulting software reprogramming will be maintained.

## Integration, Reliability and Checkout

The integration, reliability, and checkout funding provides for automatic checkout equipment (ACE) stations and engineering support. The spacecraft ACE is used at the contractor plants and at NASA test and launch sites for separate and combined checkout of the spacecraft systems. The basic design of ACE ground stations was completed in FY 1964; 14 ACE stations are now operational.

Funding in FY 1970 provides for operation of the checkout stations, as well as related engineering changes and spare parts to maintain the operational equipment.

The funding also provides for the engineering support required for spacecraft specification maintenance and review; systems performance analysis; reliability and quality assurance; trend analysis; critical parameter studies and technical problem analysis; mission planning and analysis; post-flight data processing and documentation; simulation and training; and interface control.

Saturn V

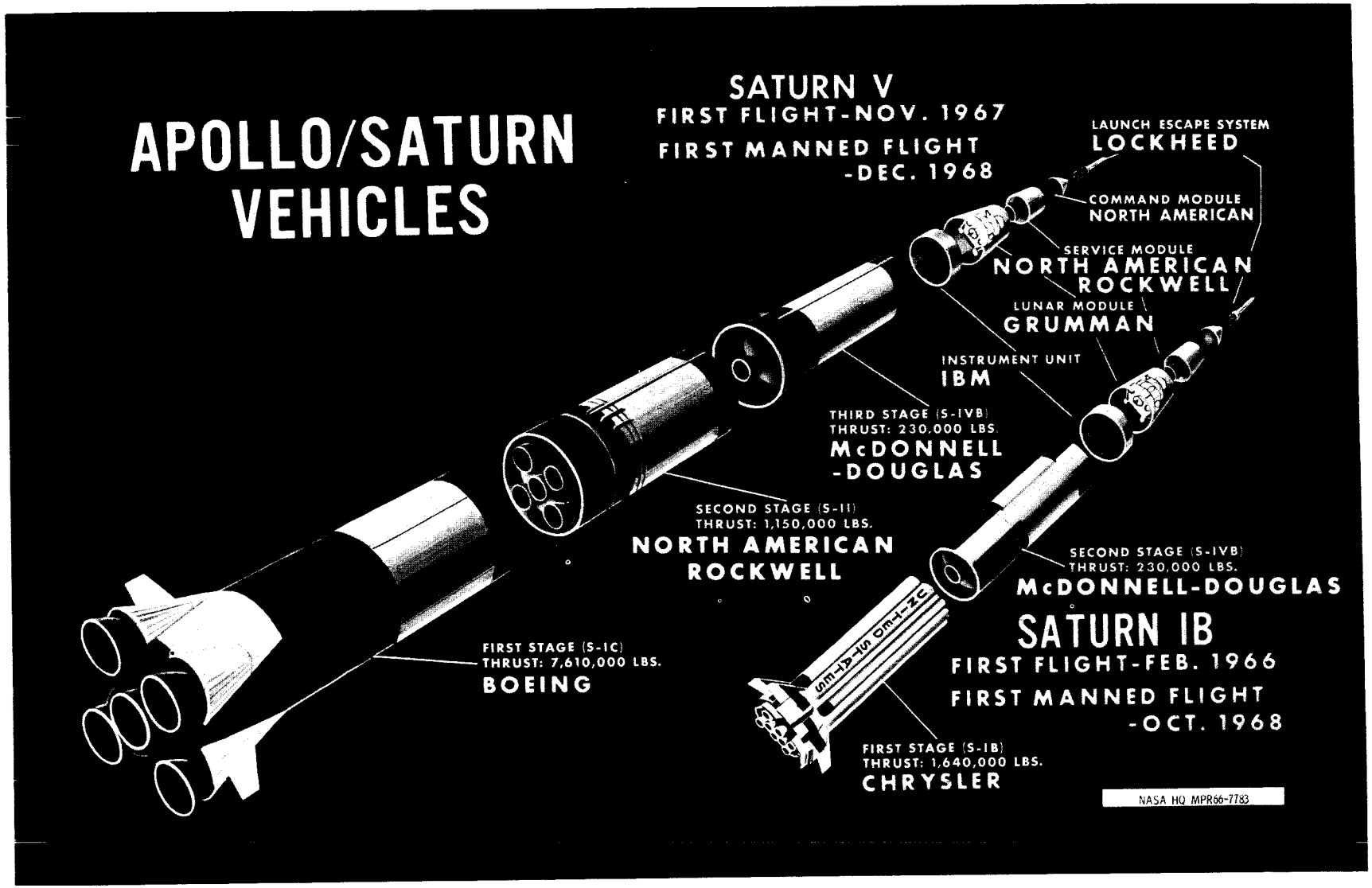
| | 1968 | 1969 | 1970 |
|---|---|---|---|
| 1st stage (S-IC)..... | $121,428,000 | $70,700,000 | $66,000,000 |
| 2nd stage (S-II)..... | 205,156,000 | 132,000,000 | 120,624,000 |
| 3rd stage (S-IVB)..... | 121,825,000 | 78,400,000 | 75,200,000 |
| Instrument unit..... | 62,642,000 | 39,500,000 | 33,600,000 |
| Vehicle support..... | 150,748,000 | 113,500,000 | 109,000,000 |
| Ground support equipment... | 38,974,000 | 20,200,000 | 18,000,000 |
| F-1 engine..... | 81,368,000 | 38,675,000 | 37,670,000 |
| J-2 engine..... | 71,824,000 | 41,478,000 | 36,606,000 |
| Total..... | $853,965,000 | $534,453,000 | $496,700,000 |

The Saturn V launch vehicle, this country's most powerful rocket, possesses nearly five times the thrust of the Saturn IB. Comprised of three propulsion stages and an instrument unit, the Saturn V can launch payloads of nearly 145 tons into low earth orbit, or payloads of 50 tons to the moon.

Fifteen flight vehicles are being produced for a planned series of unmanned qualification flights, manned lunar landing simulations, and manned lunar landings. The first two vehicles were delivered in FY 1967 and completed the unmanned qualification phase of the program. The first launch, in November 1967, was a fully successful demonstration of the "all-up" concept of hardware development, incorporating the initial flight test of the 1st and 2nd stages and the 1st stage engines. The 3rd stage, the 2nd and 3rd stage engines, and the instrument unit had been tested during earlier Saturn IB flights.

Anomalies occurred in the second Saturn V launch vehicle during the Apollo 6 mission in April 1968. During the "burn" of the 1st stage, the five F-1 engines began to pulse together, and a significant oscillation or "POGO" effect developed in the launch vehicle. These oscillations were similar to those caused by a troop of soldiers marching in step across a suspension bridge. Additionally, auxiliary fuel lines ruptured in the engines of the two upper stages during the later portions of the flight.

After the 2nd stage ignited, its five J-2 engines performed satisfactorily during the initial portion of the "burn", but a ruptured igniter fuel line in the number 2 engine resulted in a pressure loss, and the instrument unit commanded the engine to shut down. This signal was also received by the number 3 engine. The stage continued powered flight despite the shutdown


APOLLO/SATURN VEHICLES
SATURN V
FIRST FLIGHT-NOV. 1967
FIRST MANNED FLIGHT -DEC. 1968
LAUNCH ESCAPE SYSTEM
LOCKHEED
COMMAND MODULE
NORTH AMERICAN
SERVICE MODULE
NORTH AMERICAN ROCKWELL
LUNAR MODULE
GRUMMAN
INSTRUMENT UNIT
IBM
THIRD STAGE (S-IVB)
THRUST: 230,000 LBS.
McDONNELL -DOUGLAS
SECOND STAGE (S-II)
THRUST: 1,150,000 LBS.
NORTH AMERICAN ROCKWELL
FIRST STAGE (S-IC)
THRUST: 7,610,000 LBS.
BOEING
SECOND STAGE (S-IVB)
THRUST: 230,000 LBS.
McDONNELL-DOUGLAS
SATURN IB
FIRST FLIGHT-FEB. 1966
FIRST MANNED FLIGHT -OCT. 1968
FIRST STAGE (S-IB)
THRUST: 1,640,000 LBS.
CHRYSLER
NASA HQ MPR66-7783

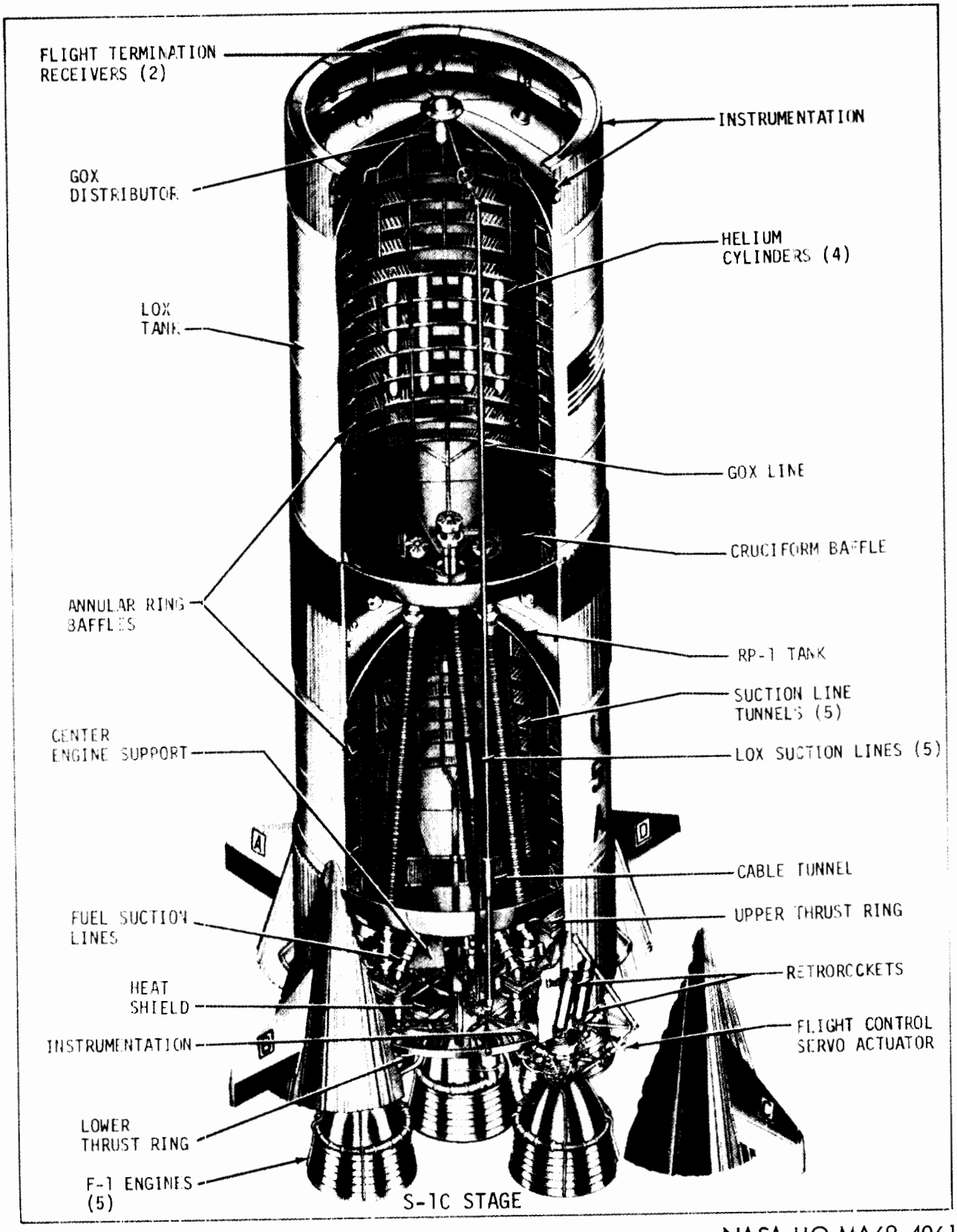
of these two engines. After the liquid hydrogen and liquid oxygen fuel had been depleted, the 2nd stage shutdown, and the 3rd stage with its single J-2 engine fired normally to place the spacecraft in earth orbit. After a coasting period, the 3rd stage engine was commanded to restart. The engine failed to restart because of a ruptured igniter fuel line similar to that which occurred in the 2nd stage.

An extensive test program was established and conducted by the Marshall Space Flight Center and a group of hardware and consultant contractors to determine the engine failure modes and to examine proposed corrective modifications for this problem and for the "POGO" produced by the engine phasing. Computer simulations indicated a possible sequence of events and the fuel line rupture conditions were then duplicated in the laboratory. The cause of the failure was then examined and found to be a vibration resulting from fuel flow in the vacuum of space. During engine testing at atmospheric levels, these vibrations were never severe enough to cause a rupture because liquid air condensing on the surface of the fuel lines had provided damping. These laboratory and test efforts resulted in a redesigned and restrengthened fuel line being installed on all J-2 flight engines. The "POGO" phenomenon was resolved by using helium in the liquid oxygen prevalves, thus providing accumulators to change the effective length of the liquid oxygen feed lines in the propulsion system. This lowered the natural frequency of the propulsion system, and moved it away from the natural frequency of the structure. The modifications to the F-1 and J-2 were successfully demonstrated during ground and static testing.

## 1st Stage (S-IC)

The Saturn V 1st stage is produced by the Boeing Company at the Michoud Assembly Facility near New Orleans, Louisiana. Boeing has been supported by fifty major subcontractors located in sixteen states. The stages are acceptance tested at the Mississippi Test Facility in Hancock County, Mississippi, before being shipped by barge to the Kennedy Space Center. The stage, weighing nearly 4.8 million pounds when filled with fuel, is 138 feet tall and 33 feet in diameter. Burning 535,000 gallons of liquid oxygen and kerosene fuel, its engines develop over 7.5 million pounds of thrust at launch, and, during its 150 seconds of flight, carry the space vehicle to an altitude of 38 miles and a velocity of 6,000 mph. Development of the stage began in 1962, with the first flight test of the stage occurring in November 1967.

FY 1970 funding provides for the completion of manufacturing and assembly of the S-IC stages procured for the Apollo program. Undelivered stages will be in various phases of checkout, acceptance test and post-test refurbishment and checkout. Five Saturn V launches are planned for FY 1970. A significant engineering capability will be maintained for solving technical problems which may arise and for analyzing the large amounts of flight data.

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## 2nd Stage (S-II)

The 2nd stage of the Saturn V uses a cluster of five J-2 engines to generate a total thrust of over one million pounds. Development of this stage also began in 1962. The development, production, and test of the stage is the responsibility of the Space Division of the North American Rockwell Corporation. Manufacturing, assembly and factory checkout of the stage is performed at Seal Beach, California, in government owned facilities. Twenty-seven major subcontractors assist in the production of the stage. Acceptance testing of the flight stages is conducted at the Mississippi Test Facility before delivery to the Kennedy Space Center.

The S-II stands nearly 82 feet high, has a diameter of 33 feet, weighs 95,000 lbs. and holds over 930,000 pounds of propellant. During its 6½ minutes of flight, the stage pushes the space vehicle to an altitude of 115 miles and a speed of 15,300 mph.

Five of the fifteen flight stages included in the S-II program have been delivered to the Kennedy Space Center. Three additional stages are scheduled to arrive at Kennedy Space Center by the end of FY 1969. Manufacturing, systems installation, test and checkout on the last seven S-II stages will be underway in FY 1970. In addition, a flight data analysis and problem solving capability will also be maintained at the plant.

## 3rd Stage (S-IVB)

The 3rd stage of the Saturn V (S-IVB) was developed and is produced by the McDonnell-Douglas Corporation at Huntington Beach, California. Ninety-one major subcontractors in eighteen states supply subsystems and components for this stage. The stage is powered by a single J-2 engine and generates a thrust of 230,000 pounds at altitude. The stage is used on both the Saturn IB and the Saturn V, but basic development costs were funded from this line item. McDonnell-Douglas performs stage acceptance testing at the Sacramento Test Operations Site in California. Fabrication of the first Saturn V S-IVB flight stages began in 1964. The stage achieved a significant and critical milestone during the first Saturn V mission when it successfully demonstrated its ability to restart in a space environment. A total of five Saturn V flight stages have been delivered to the Kennedy Space Center with three more scheduled to be transported to the Kennedy Space Center before the end of FY 1969.

FY 1970 funding will support the production efforts on the last of the fifteen flight stages included in the Saturn V procurement for Apollo. With the five Saturn V flights in FY 1970, a strong base of skilled manpower will be maintained to provide a quick and effective response to the problems which can occur during the pre-launch, checkout, and flight phases. The analysis of flight data will also be critical because of the heavy launch schedule.



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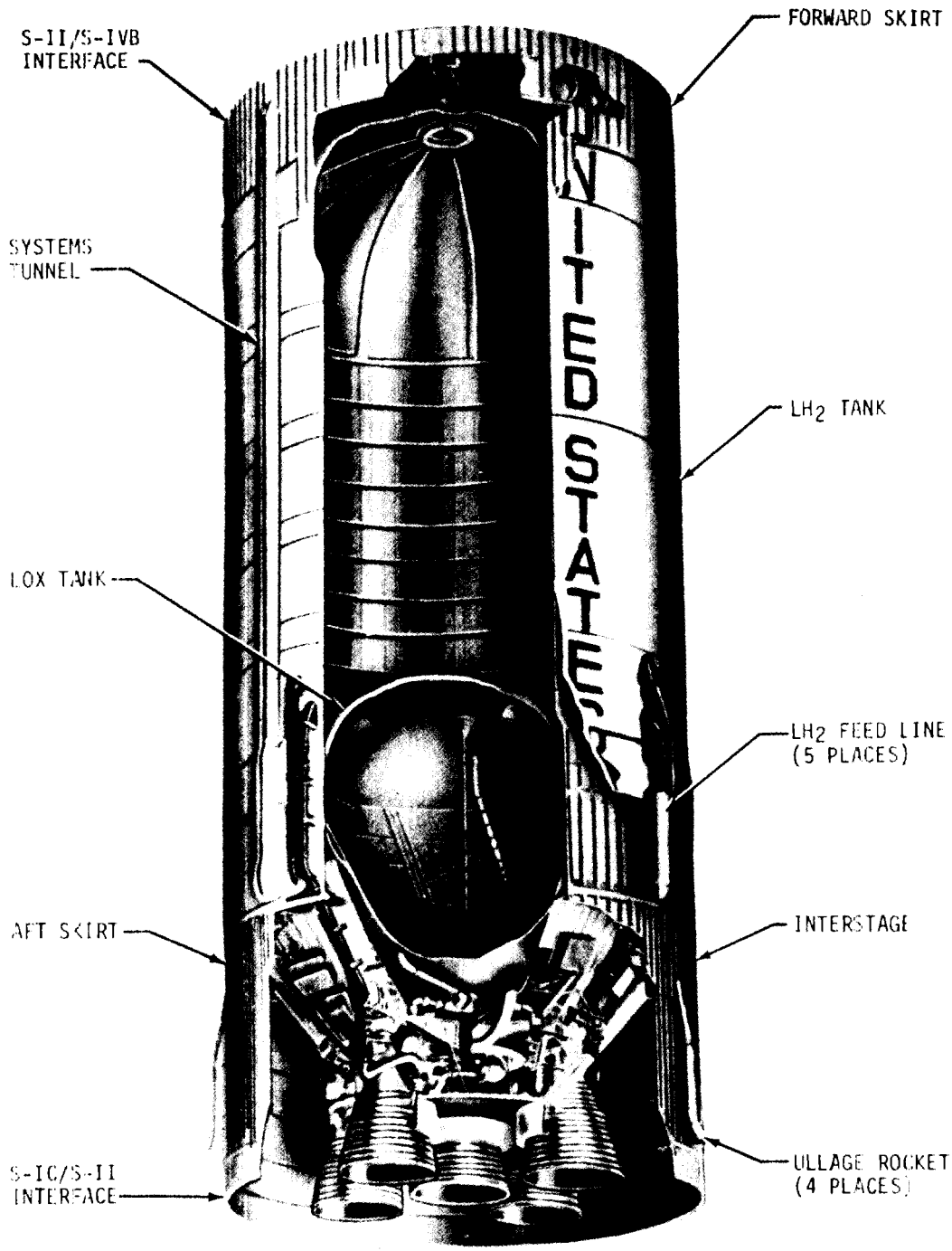


S-II STAGE

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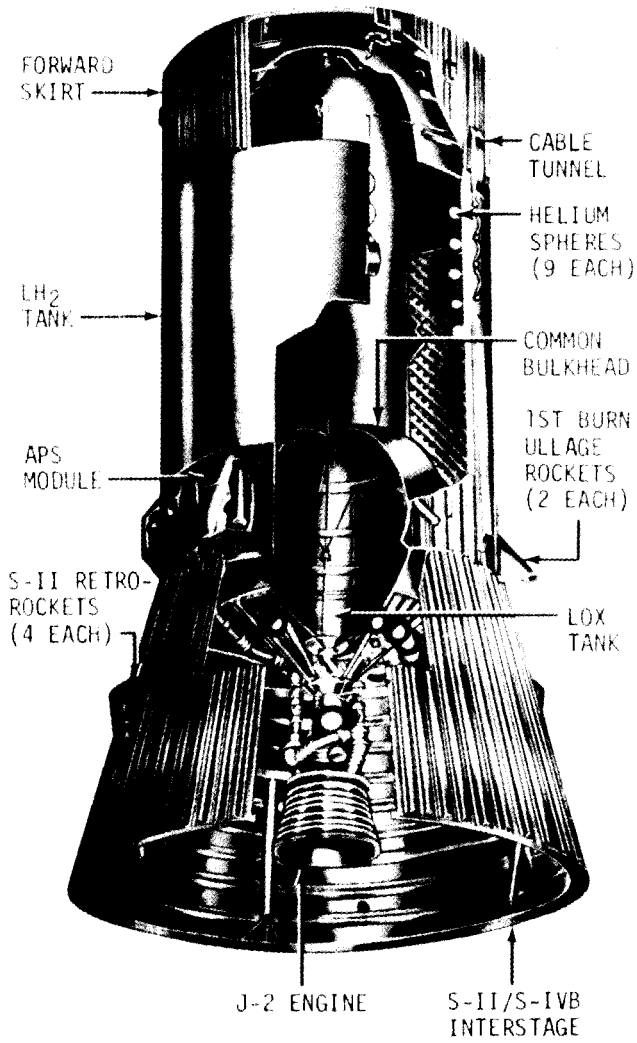
| | | |
|---|---|---|
| ENGINE: | J-2 | |
| PROPELLANT: | $LOX/LH_2$ | |
| THRUST: | 1st BURN | 232,000 LBS |
| | 2nd BURN | 211,000 LBS |
| WEIGHT: | DRY | 26,421 LBS |
| | AT IGNITION | 263,204 LBS |




S-IVB STAGE

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## Instrument Unit (IU)

The Saturn V instrument unit is essentially the same as the one used on the Saturn IB. The instrument unit contains the guidance and control system that issues commands to the attitude control devices of each stage during powered flight to guide the launch vehicle. The instrument unit also controls engine start and cutoff. The units are assembled and checked out by the International Business Machines Corporation in Huntsville, Alabama. Components and subsystems are supplied by fifty-two major subcontractors in seventeen states.

In FY 1970, the last seven remaining units will be in various phases of fabrication, assembly, and checkout. With five flights scheduled for FY 1970, these funds will also cover the capability for analysis of flight data and the subsequent software reprogramming of the instrument unit in the event of mission profile changes.

## Vehicle Support

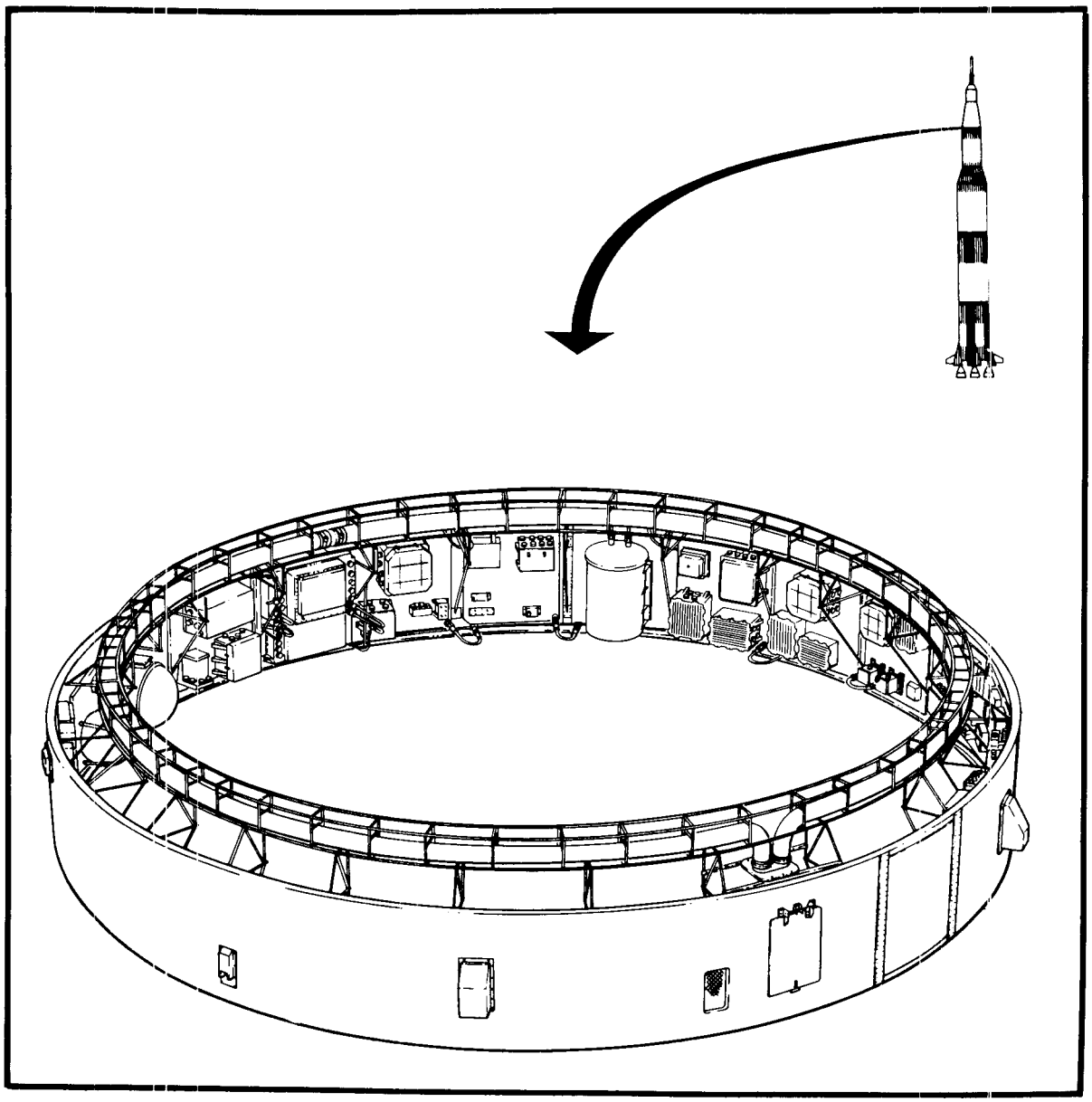
Vehicle support funds are utilized for services and equipment that are common to more than one stage of the vehicle. In FY 1970, the effort is concentrated on test operations at the Mississippi Test Facility; logistics, which include use of aircraft and marine vessels for transportation of stages, engines and components; operation of the Slidell Louisiana Computer Facility; range safety and tracking devices for the vehicles; propellants; systems integration, to assure proper configuration control of all stages, systems, and structures; computation services; engineering services, including quality control and inspection; reliability; and flight evaluation programs.

## Ground Support Equipment (GSE)

The Saturn V ground support equipment consists of the electrical and mechanical support equipment required to test and checkout the stages, instrument units, and associated hardware. The checkout procedures developed for the Saturn V are based on the principle that improved vehicle reliability and minimum time at the launch site can be attained by using a computer-controlled system in which the operational soundness of components is automatically verified. Automatic checkout equipment is used at the manufacturing, ground test, and launch sites.

The General Electric Company provides design, fabrication, checkout, and logistic support of the Saturn V electrical support equipment. The Boeing Company provides the Saturn V equipment management system, and is also responsible for the integration and logistic support of all mechanical support equipment. The Radio Corporation of America and Sanders Associates supply computer systems and display systems for use at Launch Complex No. 39.

# SATURN INSTRUMENT UNIT



NASA HQ MA69-4058

Funding during FY 1970 supports the operation of stage and vehicle ground support equipment, including mechanical and electrical support equipment to satisfy Saturn V requirements.

## F-1 Engine

The F-1 engine, this country's most powerful engine, was developed by the North American Rockwell/Rocketdyne Division at Canoga Park, California. Engine testing is conducted at Edwards Air Force Base, California. Five liquid oxygen/kerosene F-1 engines are clustered in the 1st stage of the Saturn V, with each engine generating over 1.5 million pounds of thrust at launch. The principal operating system of the F-1 engine includes a turbopump utilizing a 55,000 horsepower turbine to drive a pump supplying liquid oxygen at the rate of nearly 25,000 gallons per minute and another pump impelling kerosene at the rate of 15,500 gallons per minute, into the thrust chamber. The turbopump is subjected to extreme temperature conditions - one end operating at +1,500 degrees Fahrenheit, and the other at -300 degrees Fahrenheit.

Each engine, weighing almost ten tons, is 19 feet high and over 12 feet wide. The initial contract for the F-1 was awarded to Rocketdyne in January 1959.

Production of F-1 engines for Apollo will be concluded in FY 1970. The funds for FY 1970 also provide a quick response capability for evaluating and resolving any F-1 problems encountered in the flight missions. This effort covers field and engineering support; maintenance of the test engines; testing of the components and engine systems, including propellants; and periodic verification of flight worthiness to assure mission reliability and safety.

## J-2 Engine

The J-2 engine is also produced by North American Rockwell's Rocketdyne Division. These engines are used in the 2nd and 3rd stages of the Saturn V. The 2nd stage is powered by five J-2 engines, each producing over 200,000 pounds of thrust, while the 3rd stage is powered by a single 230,000 pound thrust J-2 engine with restart capability. The J-2 is a somewhat smaller engine than the F-1 being 11 feet high and nearly 7 feet wide. It is a high performance engine using liquid oxygen and liquid hydrogen fuel. The J-2 entered development in September 1960, and the first flight test was made in February 1966, when it powered the S-IVB stage on the first Saturn IB launch.

The funds in FY 1970 provide for completion of J-2 engine production and for the field and engineering support activity required for flight evaluation and problem solving. The funds assure maintenance of test engines in a configuration for rapid solution of problems through component and system testing, as well as for periodic verification of flight worthiness. The requirement for this problem solving capability was demonstrated during the recent investigation by the Marshall Space Flight Center of the auxiliary fuel line

rupture on the J-2 engine during the second Saturn V flight. This investigation required an extensive series of tests, initially to duplicate the failure, and then to verify the proposed modification to correct the situation. Much of the J-2 environmental testing is conducted at the Air Force Arnold Engineering Development Center in Tullahoma, Tennessee.

Lunar Exploration

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Lunar exploration..... | --- | --- | $11,000,000 |
| Total..... | --- | --- | $11,000,000 |

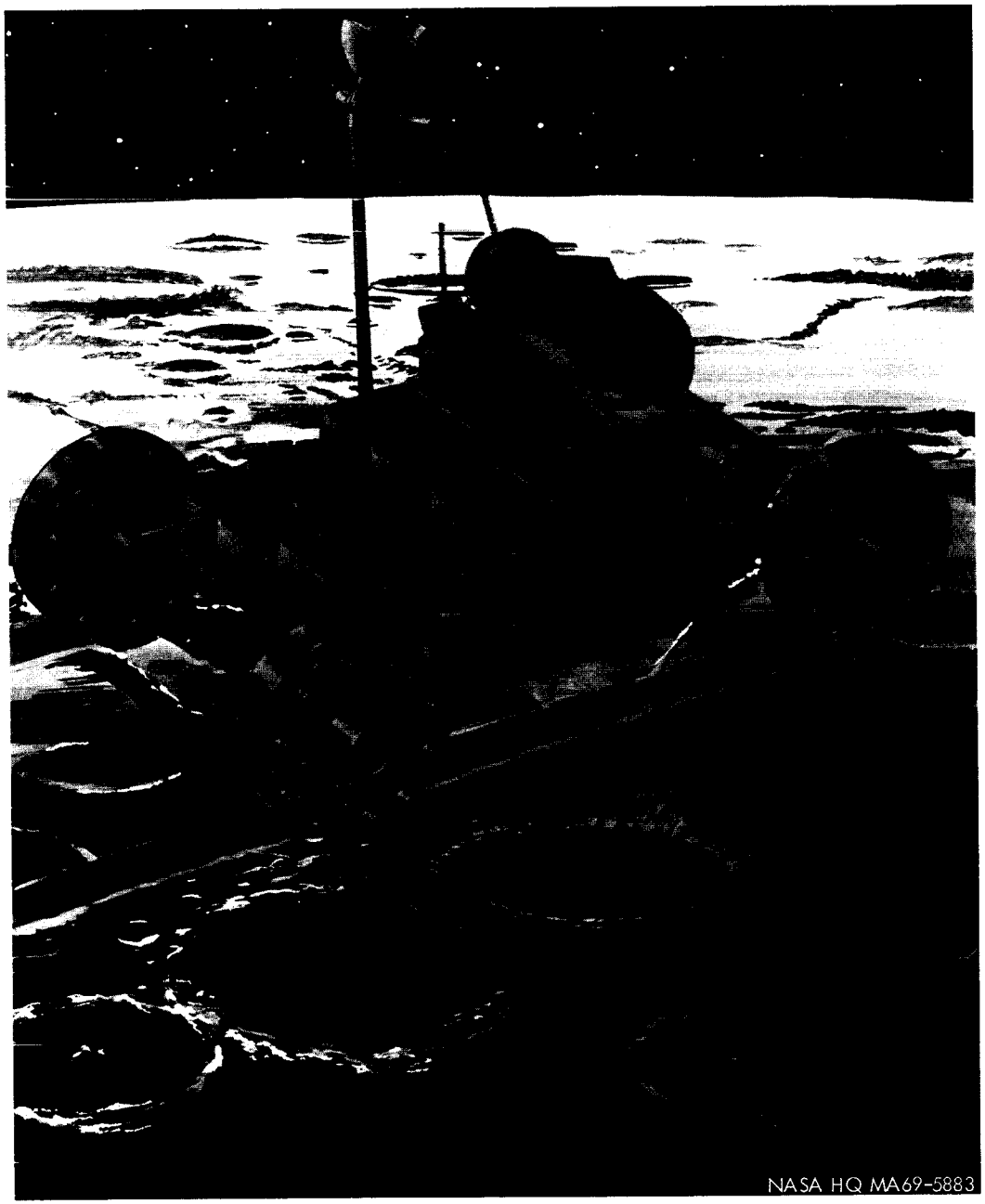
The activities and developments necessary to expand the capabilities and usefulness of basic Apollo hardware to conduct extended exploration of the moon are being studied intensively. FY 1970 funding will be used for the definition of modifications to Apollo hardware, new system requirements and experiments. The efforts to date have resulted in the broad outline of requirements. Over 15 distinctive types of geological features have been identified on the lunar surface. They have been grouped into five major classes, representing fundamental scientific questions associated with the nature of the moon. Manned landings at several features within each major class are necessary to complete a well balanced exploration. Man's capabilities, however, must be enhanced by extending his lunar staytime beyond the one day restrictions inherent in present Apollo hardware, and by expanding the radius of his exploration through the use of astronaut mobility aids and the development of lunar traverse vehicles. The traverse vehicle should be able to journey several hundred miles, collect samples, make measurements and deploy geophysical instruments. Deployment of instrument networks are essential in determining the internal structure and energy budget of the moon. At each site visited, the most significant activities must be the collection of samples, both on site, and from the traverse vehicle, and the observations made by an astronaut-geologist. Other complementary exploratory activities include orbital measurements of the moon through metric photography, compositional mapping, and electromagnetic radiation measuring.

Operations

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Launch, flight and recovery... | $468,121,000 | $483,400,000 | $445,800,000 |
| Technical..... | 77,644,000 | 63,000,000 | 43,800,000 |
| Total..... | $545,765,000 | $546,400,000 | $489,600,000 |

This project provides for crew training, launch, flight and recovery and for the programwide technical and Department of Defense support required for manned space flights. Included in the Apollo portion of operations is funding of the basic capability to conduct manned flight, regardless of program,

# CONCEPTUAL LUNAR ROVING VEHICLE-MANNED MODE



together with activities necessary for specific Apollo missions. The associated operations project included in Space Flight Operations funds only those efforts unique to that program. The readiness and adaptability of this extensive capability to conduct manned earth orbit and deep space missions has been dramatically demonstrated in the Apollo 7 and Apollo 8 flights. Final checkout of all facilities in preparation for the initial lunar landing will be completed after the Apollo 9 and Apollo 10 missions.

## Launch, Flight and Recovery

The two principal centers for launch, flight control and recovery activities are the Kennedy Space Center, Florida and the Manned Spacecraft Center, Texas.

The Kennedy Space Center is responsible for checkout through system by system testing and analysis to determine if discrepancies exist during the preparation for launch of both the launch vehicles and the spacecraft; maintenance and operation of the launch facilities; final integration and integrated checkout of the space vehicle which includes the launch vehicle payload; the operation and coordination of supporting facilities, ground support equipment and logistics support; and the conducting of the launch. Over one billion dollars in land and facilities have been invested in this "spaceport" which occupies 87,800 acres, the center of which is the massive Launch Complex 39 used to assemble and launch the Saturn V space vehicle. This complex includes: (1) the Vehicle Assembly Building with a volume of 130 million cubic feet, where the space vehicle is assembled and checked out; (2) the three mobile launchers, 445 feet tall, upon which the vehicle is erected for checkout, and which later serve as the launching platform; (3) the mobile service structure, over 400 feet high, which provides access through work platforms to the space vehicle; (4) the two crawler transporters which carry the launch vehicle, mobile launcher, and mobile service structure to various positions at the launch complex; (5) the two launch areas (Pads A & B) containing the fuel storage and transfer system for the various cryogenic and hypergolic fuels and coolants; and, (6) the Launch Control Center which serves as the center of the ground system that monitors the checkout and launch of the space vehicle.

Major facilities involved in preparation for launch, other than Launch Complex 39, are contained in the Manned Spacecraft Operations Building (MSOB). This facility houses equipment associated with the checkout of the spacecraft; and includes altitude chambers, Automatic Checkout Equipment (ACE) Stations and flight crew training facilities and equipment.

The major operational costs of the Kennedy Space Center are associated with the checkout of the spacecraft and the launch vehicles, and the launch support requirements. During FY 1970 nearly two-thirds of the funding for launch operations is associated with the checkout and preparation of launch vehicles and spacecraft by the major hardware contractor workforce located at KSC. Five launches are planned for FY 1970. In addition, work will be underway on vehicles and associated spacecraft that can be launched in FY 1971.



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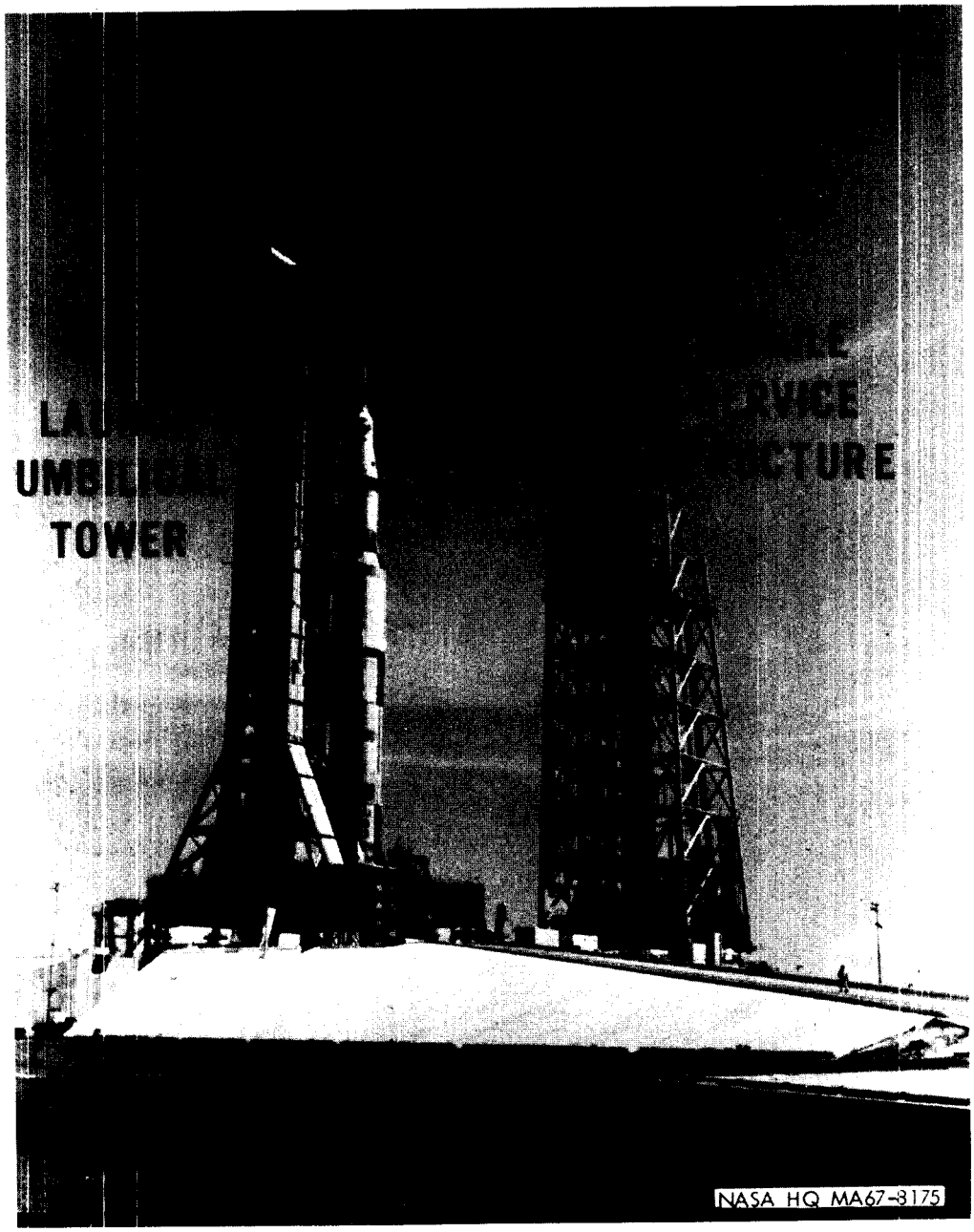


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Launch support is supplied by both NASA contractors and the Air Force Eastern Test Range (AFETR). The Department of Defense is reimbursed for AFETR costs incurred for NASA support based on a cost sharing formula developed by the Bureau of the Budget. Included in launch support is the management and operation of Launch Complex 39; systems engineering services; technical shop operations: propellant services and propellant systems laboratory operations; and ordnance storage. Also included are engineering design and fabrication services for the electrical and electronic systems that support the Apollo launch capability and the modification, installation and specialized maintenance of launch facilities; and post launch facility refurbishment.

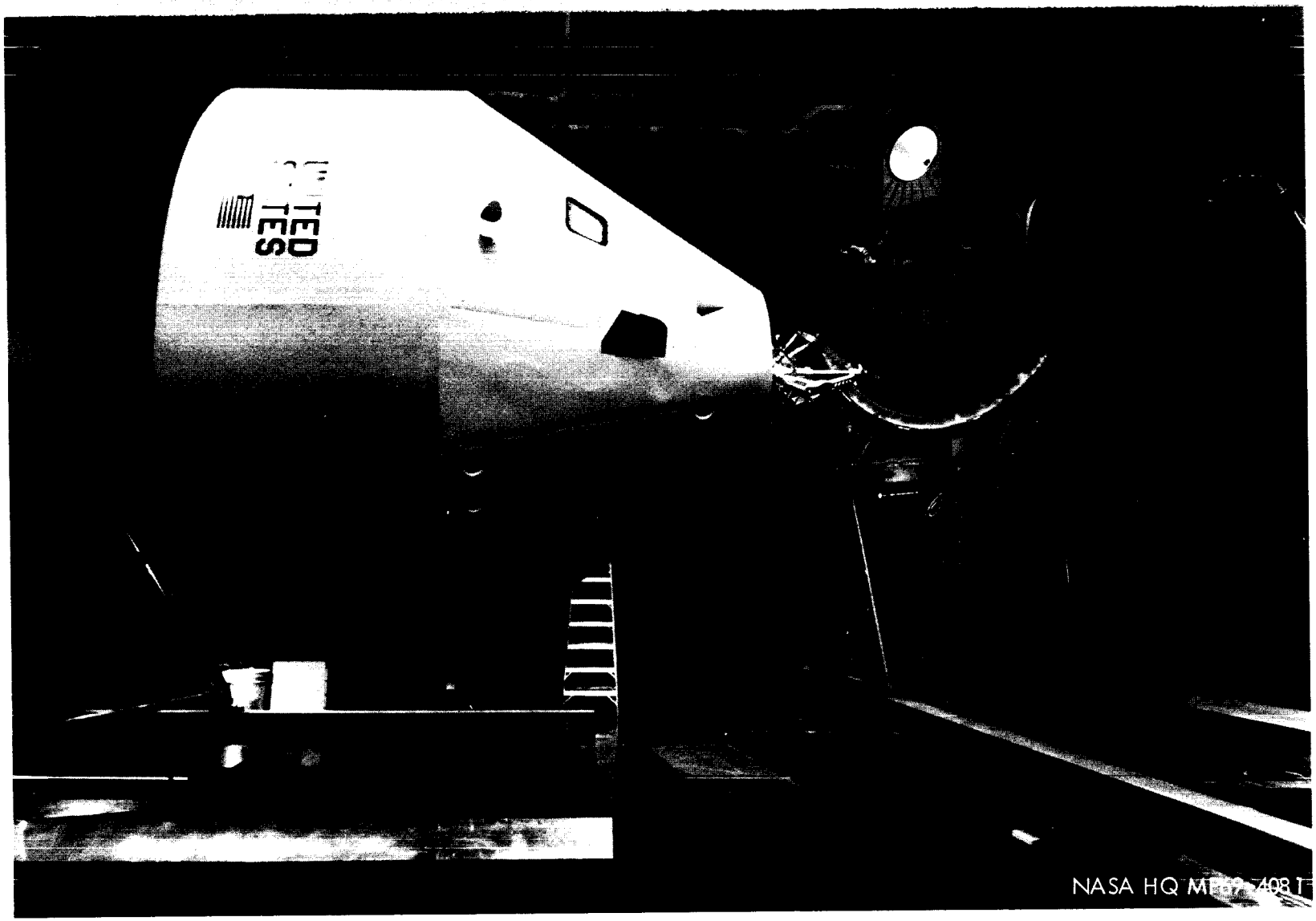
Other operational costs at KSC involve the computation and instrumentation support. This includes the operation and maintenance of the Central Instrumentation Facility (CIF), which houses the GE-635 computing systems, high speed plotters, magnetic tape data transmission equipment and computer peripheral equipment required to support two operations simultaneously. Other operational support provided under this category includes the operation and maintenance of telemetry, antenna, and tracking systems that receive and process data from pre-launch tests and launches of NASA space vehicles.

The Manned Spacecraft Center (MSC) in Houston is the headquarters for all crew, flight, and recovery operations. The astronauts are based at this Center along with most of their essential training equipment. This equipment includes proficiency aircraft, spacecraft mockups, procedures simulator, docking trainer, zero "G" simulator, systems trainer, lunar landing training vehicles and the mission simulators. The Manned Spacecraft Center is also responsible for mission simulation and other astronaut training equipment located at the Kennedy Space Center. Also at MSC is the Mission Control Center with its highly sophisticated computer complex and extensive communications links to the tracking network and other worldwide data sources. The Center controls flight operations from shortly after liftoff to recovery.

The major amount of the funding required in support of operations directed by the Manned Spacecraft Center is associated with maintaining a capability to provide the training and flight control required to conduct manned space flight missions. This includes the operation and maintenance of the Mission Control Center; the training of the astronaut crews through the use of the trainers, simulators and high performance aircraft; the maintenance and updating of recovery equipment; medical operations; computer support; and general technical and engineering support.

In addition to these basic expenses, there are requirements that are directly relatable to specific missions such as mission planning, including trajectory analysis: failure analysis and evaluation of operational performance; and the funding of recovery operations which encompasses the planning, development and operational phases of recovery activity including the location and retrieval of the astronauts and spacecraft following touchdown. The DOD provides most of the recovery operation elements required by NASA in this support category. Reimbursement is made for all DOD costs incurred based on the number of ships, aircraft, communications facilities and training

# COMMAND MODULE DOCKING SIMULATOR



personnel deployed and on the number of days that these resources are required.

Technical

Technical operations provide for the systems engineering needed for the integrated technical support, review, and analysis of the entire Apollo program; the supporting development necessary for product improvement; for the contractor administration, audit, and property administration services provided by the Department of Defense on a reimbursable basis; and for the nonrecurring maintenance and rehabilitation of government owned industrial plants. In FY 1970 systems engineering services provide functional and performance standards for Apollo developed hardware; technical integration and evaluation; technical documentation; and overall trajectory analysis primarily through the principal systems engineering contractors - Bellcomm, Boeing, and General Electric. Emphasis will continue to be placed on maintaining a quick response capability for analysis of Apollo flight missions. Funding for supporting development will concentrate on engineering efforts to improve Manned Space Flight hardware. The nature of these efforts vary widely, extending from alternative sub-systems to new material fabrication and testing. Effort in FY 1970 will be devoted to those promising areas highlighted in previous work with new tasks focusing on applied systems development.

Saturn IB

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Saturn IB..... | $101,100,000 | $41,347,000 | --- |
| Total..... | $101,100,000 | $41,347,000 | --- |

The Saturn IB is a two-stage launch vehicle with a capability of placing approximately 20 tons of payload into a low earth orbit, and was used to flight test the Lunar Module and to demonstrate the operational capability of the Apollo Command and Service Modules. The 1st stage, powered by eight H-1 engines, produced about 1.6 million pounds of thrust. The Chrysler Corporation produces this stage at the Michoud Assembly Facility in New Orleans, Louisiana. The second stage (SIV-B), which is basically the same as the third stage of Saturn V, was developed by the McDonnell-Douglas Corporation and is powered by a single J-2 engine capable of producing 230,000 pounds of thrust.

The Apollo program procured 12 Saturn IB vehicles. The vehicle was qualified for manned flight in 1966 after three successful development flights, which also qualified the major system of the 3rd stage of the Saturn V (S-IVB stage). A Saturn IB was scheduled to launch the first Apollo manned spacecraft in early 1967, but the Apollo accident and the subsequent requirements for significant spacecraft modifications delayed this flight until October 1968. The October flight was the last planned

flight in the Apollo phase of this series although in the event of problems with the Saturn V, the remaining seven vehicles can be used for Apollo earth orbital CSM/LM missions. No FY 1970 funding for the Saturn IB is being requested in the Apollo program.

Engine Development

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Engine development..... | $20,500,000 | --- | --- |
| Total..... | $20,500,000 | --- | --- |

FY 1968 was the last year of funding under the Engine Development project. Qualification of the H-1, F-1, and J-2 engines was accomplished during FY 1967.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1970 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — SPACE FLIGHT OPERATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Space Flight Operations program is directed toward increasing the scientific, technical, and economic return on this nation's investment in technology; launch, production, and operations facilities; the scientific, engineering and management skills and expertise; operational techniques; and hardware equipment developed in the Gemini and Apollo programs. Continued use of this national capability is an essential element as this nation continues its industrial and technical growth and maintains its role as a technological leader of the world.

The focus for the Space Flight Operations program is the development and operation of a manned space station that can be launched in the mid-1970's. The general requirements of the space station including logistic systems which will provide this country with the capability to conduct long-term space operations are now defined, and study efforts are being conducted on narrowing the range of alternatives. The station will be able to operate in earth orbit on a semipermanent basis, and its systems and configuration will be designed to accommodate payloads of varying size and complexity. The configuration will have a basic capability to incorporate complete experiment modules, to replace life support and other modules, and to take on new experiment modules after the station is in orbit. It will also accommodate increases in crew size from the initial complement. This adaptability will allow the space station to respond to technological advances and new operational techniques.

The development of a versatile space station is clearly the key toward developing more effective space operations and broadening the range of activities that can be conducted in the unique environment of space. The total system consists of a long duration, multipurpose space station where men can live and work for extended periods and a logistic system for carrying men, supplies, and experiment modules to and from the orbiting station. The productive long-term use of the space environment depends on the ability to reduce the high cost of putting payloads into orbit. The introduction of recoverable and reusable systems is a potential means of reducing these costs, simplifying the operational procedures, and providing convenient and economical round trip transportation to and from an orbiting space station.

The combination of a flexible base for earth orbital operation and an economical means for reaching the station and returning to earth will be the next major step in using the frontiers of space to maintain the vitality and forward progress of our society during the next decade. It will provide a natural focal point for advancement of science and technology and a platform for increasing the benefits of space to mankind.

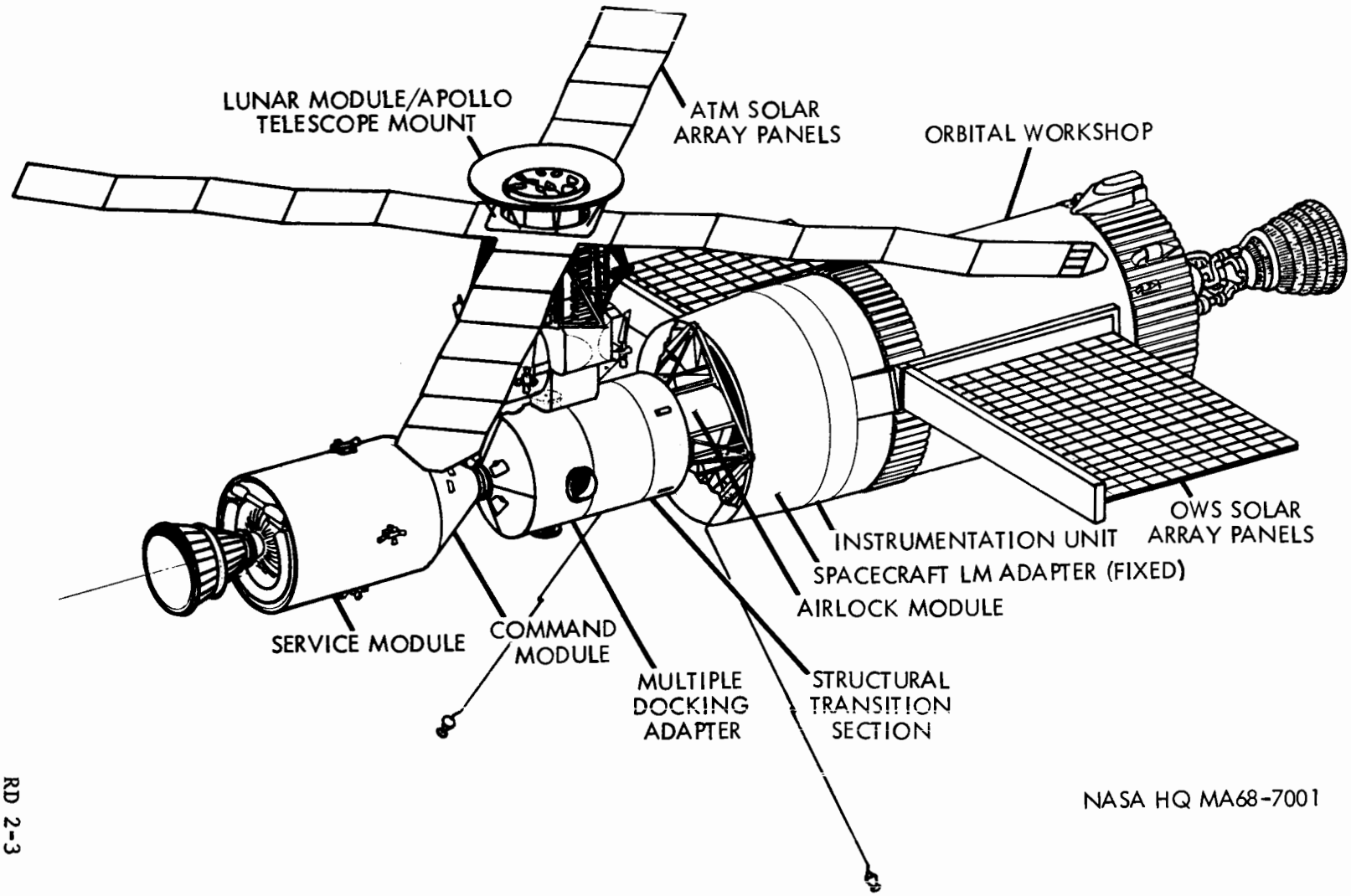
Once the space station system is established, its use for research, observations, and operational activities can be determined on the basis of priorities and resources available at a given point in time. With the advantages of added volume, operational flexibility, and built-in versatility, the space station system opens great opportunities for expanding and improving the quality and quantity of information obtained about earth resources, oceanography, weather prediction and control, disaster warnings, air and sea traffic control and safety, cartography, and scientific investigations. The lifetime and capabilities of the station will extend knowledge of the effects of long-term space operations on man's physiology and psychology. In addition, the space station will provide a base for continued development of the systems and technology required to increase man's ability to live and work comfortably in space and to progress toward practical solutions in establishing, operating, repairing, and maintaining permanent orbital stations. This body of knowledge will open the door to increased productivity and versatility in future space operations, including permanent bases which could be used as launching platforms, refueling stations, and sophisticated observatories and working laboratories.

Initial Space Flight Operations will be conducted in Apollo Applications, which is built on the strong base of flight experience, ground facilities, and trained manpower developed in the Apollo program. Apollo Applications employs the Saturn I Workshop, the Apollo Telescope Mount, and basic space vehicle hardware developed and procured in Apollo. This basic hardware is being modified to meet the unique requirements of the Apollo Applications missions and to capitalize on the Apollo-developed capability by accomplishing a limited but carefully selected spectrum of scientific, technological and medical investigations. The project is a progressive step toward the establishment of a long-term space flight operations capability in the Space Station, and furnishes information which will be used to reach sound decisions on the content and configuration of our future operations in the space environment.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Apollo applications..... | $253,200,000 | $150,000,000 | $308,800,000 |
| Space station..... | --- | --- | 9,000,000 |
| Operations..... | --- | --- | 36,300,000 |
| Total..... | $253,200,000 | $150,000,000 | $354,100,000 |
| Application of funds reserved from apportionment pursuant to the Revenue and Expenditure Control Act of 1968 (Pub. L. 90-364, 82 Stat. 251)..... | | | -117,473,000 |
| Budget authority requested..... | | | $236,627,000 |

# APOLLO APPLICATIONS CLUSTER

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Distribution of Program Amount by Installation:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| John F. Kennedy Space Center, NASA..... | $577,000 | $245,000 | $15,500,000 |
| Manned Spacecraft Center..... | 79,840,000 | 61,924,000 | 140,000,000 |
| Marshall Space Flight Center. | 159,070,000 | 84,200,000 | 186,100,000 |
| Goddard Space Flight Center.. | 403,000 | --- | --- |
| Jet Propulsion Laboratory.... | 942,000 | --- | --- |
| Wallops Station..... | 191,000 | --- | --- |
| Ames Research Center..... | 860,000 | 605,000 | 800,000 |
| Electronics Research Center.. | 386,000 | --- | --- |
| Langley Research Center..... | 933,000 | --- | --- |
| NASA Headquarters..... | 9,998,000 | 3,026,000 | 11,700,000 |

## Apollo Applications

Apollo applications consists of three basic missions and relies primarily on hardware developed and produced for the Apollo program. The mission objectives include:

1. Obtaining information on how best to sustain or improve the effectiveness of man in space in terms of biomedical considerations, living conditions, mobility, and work station designs.

2. Effecting long duration operations. Since the quantity of data return and other accomplishments is generally directly proportional to the duration of the flight, the value and economy of each mission can be greatly enhanced by increasing the amount of time that can be devoted to productive activities.

3. Conducting scientific, technical, and applications tasks with the purpose of assessing, experimenting with and increasing man's capabilities for performing these tasks; as well as the acquisition of useful data and results.

4. Providing information to support the effort in developing the long duration Space Station of the mid-1970's.

Saturn I Workshop Mission:

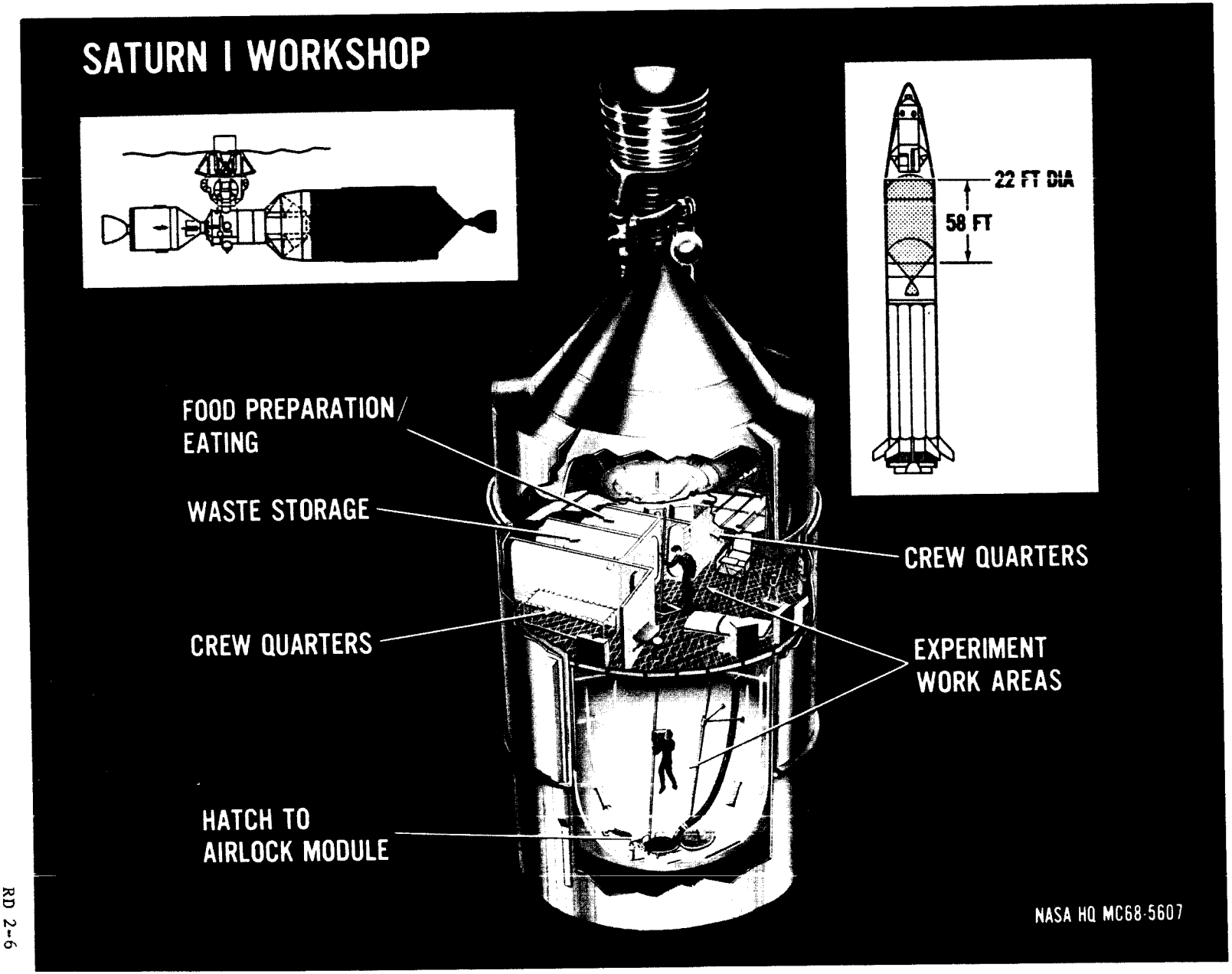
Initial Workshop operations are planned in 1971. The Workshop is set up inside the empty hydrogen tank of a spent S-IVB stage, after its actual use as a launch vehicle stage. The Workshop then serves as the nucleus of an embryonic space station. Operating subsystems for power, life support, thermal controls and experiments, together with Airlock and Docking Adapter are carried in the volume occupied by the spacecraft adapter in the normal Apollo configuration.

The Saturn I Workshop mission requires the launch of two Saturn IB vehicles to establish and begin operation of a large volume workshop in earth orbit. An unmanned flight, consisting of a Saturn IB with an Airlock Module, and a Docking Adapter, will be launched first. A second Saturn IB launch, occurring approximately one day later, will be manned and will rendezvous with the S-IVB stage of the first flight. The hydrogen tank of the S-IVB stage will be vented so that it is safe for crew occupancy. Following venting, the hydrogen tank will be repressurized with the two-gas atmosphere of oxygen and nitrogen. The crew will transfer from the Command Module through the Docking Adapter and the Airlock Module into the Workshop, and complete preparations for the crew quarters. Elements of the Workshop will have already been preinstalled in the S-IVB stage before launch. The Airlock Module will have a suitable hatch to permit access to space without depressurizing the orbital assembly.

The experiments planned on this mission are chiefly devoted to determining and evaluating task performance of men in space over extended periods of time. Habitability experiments include crew quarters evaluation, food and food preparation, personal hygiene provisions, evaluation of space suits, and mobility devices. Extensive medical evaluations of the effect of long duration space flight on the crew will be made. Engineering experiments, including tasks testing the feasibility of orbital assembly, measurement of heat flow, electron beam welding, tube joining, and controlled flammability in the zero gravity environment, will be conducted. Finally, various technology and scientific experiments, including earth science observations, are planned. The planned mission duration for the crew will be 28 days. After completion of experimental activities, the equipment in the Workshop, Airlock and Docking Adapter will be placed in a standby mode for orbital storage. The crew will return to the Command Module and separate from the Docking Adapter. The Service Module propulsion system will be used to place the Command Module on an earth return trajectory.

Workshop Revisit Mission:

The Workshop revisit mission uses a single Saturn IB launch of a three-man Command and Service Module to rendezvous and dock with the Workshop stored in orbit at the completion of the previous mission. This mission is the first flight test of the concept of reusing a habitable space structure after a period of several months of untended operation in orbit. Its planned duration of 56 days is the next step in the progressive extension of mission length to systematically test and evaluate the ability of both man and equipment to function effectively for long periods of time in space. For this reason, the primary in-flight experiment emphasis will be in the medical area. This will be the first mission in which a medical doctor is a member of the crew. Other crew activities will continue the experimental evaluation of the utility of the various habitability subsystems and accommodations of the Workshop itself, and


SATURN I WORKSHOP
22 FT DIA
58 FT
FOOD PREPARATION/
EATING
WASTE STORAGE
CREW QUARTERS
CREW QUARTERS
EXPERIMENT
WORK AREAS
HATCH TO
AIRLOCK MODULE
NASA HQ MC68-5607

of the extravehicular activity devices carried in the initial Workshop launch. The results of the initial Workshop mission will be used to refine the operating procedures used in the revisit mission. Similarly, the results of this mission will be used to improve equipment and operating plans for subsequent missions.

Solar Astronomy Mission:

The third mission, planned for early 1972, uses the Workshop as a base of operations for a manned solar observatory. This mission also requires the use of two Saturn IB launch vehicles. One Saturn IB will launch a three-man Apollo Command and Service Module configured for a 56-day mission. After the Command and Service Module rendezvous and docks with the Workshop, the crew enters and reactivates the Workshop and prepares for the operational phase of the mission. About five days later, a second Saturn IB launches the unmanned Apollo Telescope Mount (ATM) which will rendezvous and dock with the Workshop under a combination of automatic and remote control commands to perform the first flight test of equipment and operating concepts for future manned and man-tended astronomical observatories. The ATM incorporates high resolution solar telescopes and spectrographs for observing dynamic phenomena on the surface and in the corona of the sun. To maximize the scientific data return, an astronomer-astronaut will be a member of the crew. Crew activities are structured to allow the maximum possible time for operation of the observatory. Medical observations of the crew during this second 56-day mission will continue to add to the data based on man's reaction to the space environment.

Backup Flight Hardware:

Backup hardware will be provided for both the Workshop (with Docking Adapter and Airlock) and the Apollo Telescope Mount (ATM), including a second set of experiments for the Workshop and Solar Astronomy missions. The backup flight hardware will provide program assurance in the event of a malfunction or failure in the primary missions. Wherever feasible, development and prototype hardware will be refurbished for the backup missions.

Apollo Applications

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Budget plan..... | $253,200,000 | $150,000,000 | $308,800,000 |
| Prior year funds applied to FY 1969 financing plan..... | -127,010,000 | +127,010,000 | --- |
| Financing plan..... | $126,190,000 | $277,010,000 | $308,800,000 |

NASA HQ ML68-6244

Apollo Applications (Continued)

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Space vehicles..... | $29,629,000 | $93,600,000 | $138,400,000 |
| Payloads and experiments..... | 96,561,000 | 183,410,000 | 170,400,000 |
| Total..... | $126,190,000 | $277,010,000 | $308,800,000 |

Space Vehicles

All AAP missions utilize the Saturn IB as the launch vehicle. In addition to the vehicles procured in Apollo, two Saturn IB's 213 and 214, are being procured which will meet launch vehicle requirements in the event that repeat Workshop and Solar Astronomy missions are required to obtain primary mission objectives. Space vehicle requirements related to the Saturn IB launch vehicle include the design, development, and installation of peculiar systems for Apollo Applications missions and spacecraft systems modified to meet the long duration objectives of Apollo Applications missions. Funding in FY 1970 will cover storage and maintenance costs required for the Saturn IB's provided by Apollo and for continuing production effort on vehicles 213 and 214.

The duration of Apollo Applications missions requires modification of selected Apollo spacecraft systems to extend the lifetime of the equipment. The Apollo spacecraft, designed to provide for a 14-day operational capability, is being modified to support flight missions lasting 28 and 56 days. The capacity of the cryogenic tanks is being increased to provide the additional hydrogen and oxygen necessary for powering the fuel cells, and the additional nitrogen and oxygen supply for life support during the long duration flights. The capacity of the reaction control system is being increased to support the additional flight maneuvering time requirements. The communications and electrical control and distribution systems are being modified to expand the voice and data recording units as well as to provide for power regulation, current transfer, and interface controls between the Command Module and the space vehicle coupled to it.

Display and control systems for the astronaut crews are being changed to meet the new performance demands on the spacecraft. The Command and Service Modules used for Apollo Applications missions use a two-gas system of oxygen and nitrogen as the spacecraft atmosphere to avoid the possible adverse physiological effects of a pure oxygen atmosphere during prolonged periods

of flight. This change requires modification of the environmental control unit. The guidance and navigation system, both programming and hardware, is being modified to meet the technical requirements of the Workshop and Solar Astronomy missions.

Work on analysis and identification of the necessary spacecraft systems modifications was completed in FY 1969. Preliminary design was completed, and detailed design, together with development and qualification of cryogenic tankage and long duration fuel cells, began in FY 1969. Procurement of the cryogenic tanks has been initiated.

FY 1970 funding provides for the detailed engineering, fabrication, and certification testing of the modified subsystems to qualify them for long duration missions. Assembly of flight spacecraft with these modified systems will be initiated in FY 1970.

## Payloads and Experiments

Apollo Applications experiments cover a wide range of objectives in the fields of space medicine, science, applications, technology, and engineering. The definition and development of experiment payloads to meet these objectives includes activity by principal investigators within NASA, other government agencies, and the scientific and industrial communities. FY 1969 funds have been used for initial definition of post-Apollo payloads including possible approaches to lunar exploration and earth orbiting space stations as well as those payloads that became the Apollo Applications core program.

Apollo Applications will achieve its primary objectives through the careful selection and accomplishment of specific experiments. Formal review and approval of proposed experiments are conducted by the Manned Space Flight Experiments Board, composed of representatives from senior NASA and DOD management. This Board bases its decisions on the information developed in the process of defining the experiment. Funding for this definition phase of experiments to be flown in Apollo Applications has been completed.

A measure of success in Apollo Applications will be the degree to which the planned experiments meet the overall objectives of investigating, demonstrating, and utilizing man's effectiveness in space, extending his useful staytime in space, and contributing to human knowledge. The key to extending the time man can spend in space is the Saturn I Workshop.

The modifications to the basic S-IVB stage to convert it into the Workshop are being accomplished by the McDonnell-Douglas Corporation, Missile and Space Systems Division, Huntington Beach, California. FY 1969 funding is providing for the necessary design, definition, procurement and fabrication of test articles, as well as the initiation of preliminary development test effort. FY 1970 funds will be used in extensive development and qualification tests of components and subsystems and will include "zero-g" simulation, and design verification testing.

The Airlock Module is under development by McDonnell-Douglas Corporation, Astronautics Division, St. Louis, Mo. In FY 1969, the basic design was established; test plans were formulated; and fabrication of the structural test article was initiated. FY 1970 effort will emphasize the development and qualification tests of components and subsystems, completion of fabrication of the structural test article and completion of major static, dynamic and acoustic tests, and start of fabrication of the initial flight unit.

The Multiple Docking Adapter is being developed in-house at the Marshall Space Flight Center, Huntsville, Alabama. During FY 1969, activity is focusing on the basic design, definition, test plans, fabrication of an engineering mockup, and initiation of a structural test article. FY 1970 efforts will concentrate on the development and qualification test of the components and subassemblies; completion of the structural test article; completion of static, dynamic and acoustic development tests; and the start of fabrication of the first flight article.

The other major segment of Apollo Applications is the development of the Apollo Telescope Mount (ATM) and associated scientific instruments for the scientific study of the sun. The surface of the sun, the observable sunspot cycle, and the nature and pattern of the solar flare activity, may hold the key to understanding the basic forces and elements which control the solar system. The unmanned Orbiting Solar Observatory (OSO) spacecraft provided the first opportunity to study the sun without the interference of the earth's atmosphere. The ATM will provide a significant increase in the quality and depth of our knowledge of the sun by providing greater pointing accuracy than was possible with the smaller OSO; a capability of film return which can provide better quality pictures than has previously been possible; and a selective discrimination capability provided by the crew member who will manage the instruments to permit the gathering of data on phenomena of the greatest scientific interest.

The substantial scientific benefits of the Solar Astronomy mission will make a significant contribution to the knowledge required to plan future space operations activities. It will test the effectiveness of man's combined capabilities of scientific judgment, reasoning, and motor response in the orbital operation of complex scientific instruments to a greater degree than any previous manned experiment. It will provide a much more extensive and valid understanding of the future utility of manned space flight. The Solar Astronomy mission also incorporates a number of technological and operational concepts which are under active consideration as integral elements of the Space Station. These include: launch, rendezvous, and docking of a sophisticated unmanned experiment payload; the use of control moment gyros for stabilization and control; the use of gravity gradient torque in momentum management; and the use of a large gimballed system for precise pointing and stabilization of major instruments.

The ascent stage of an Apollo Lunar Module will be modified and will serve as a command post for two astronauts conducting the solar experiments. The LM descent stage is replaced by a structural rack with associated power



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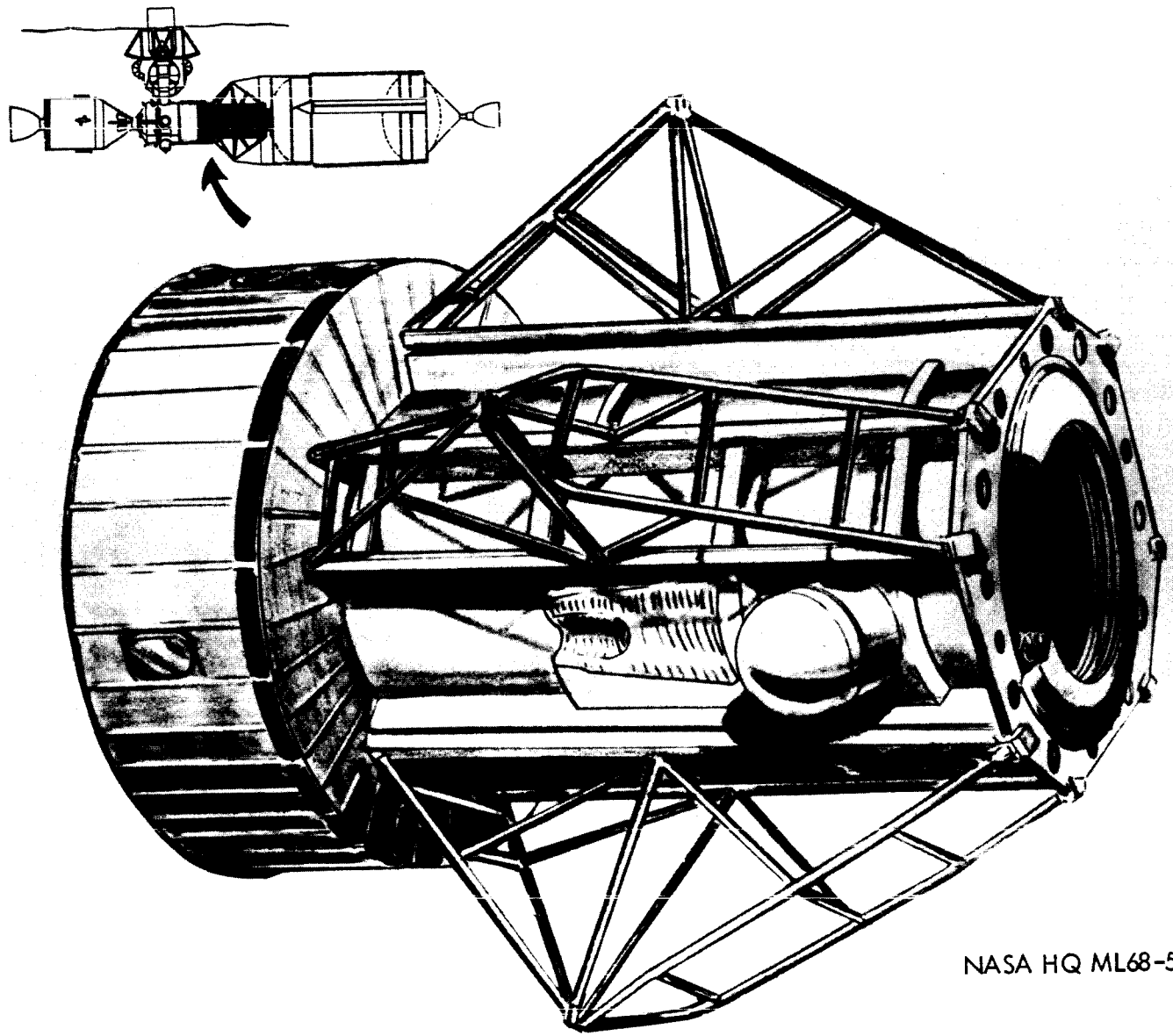
# AIRLOCK MODULE



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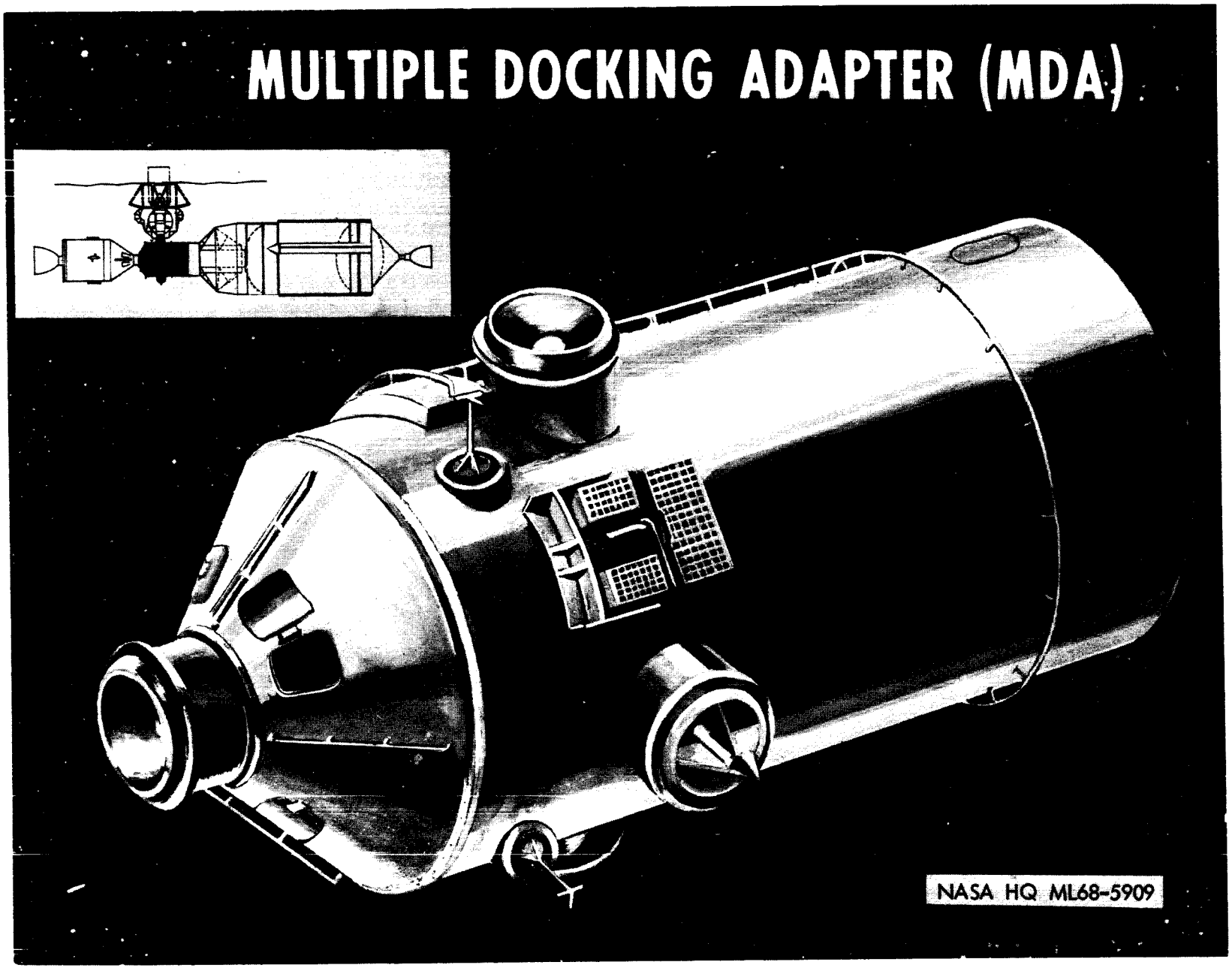

MULTIPLE DOCKING ADAPTER (MDA)
NASA HQ ML68-5909

and pointing equipment. The rack also contains the various experiments to be flown.

The Marshall Space Flight Center is responsible for major subsystem development of the ATM. Fabrication and assembly of a preliminary mockup was completed in FY 1967. The article was recently updated to incorporate results of the continuing design work. Fabrication of a structural test unit is currently in process with testing scheduled to begin in late FY 1969. In FY 1970, the testing effort will be continued. Prototype unit fabrication will be initiated early in FY 1970, with flight unit fabrication starting later in the year. Five specific experiments involving 13 major instruments have been selected for flight on the ATM and are currently in the process of fabrication. These include:

| Experiment | Developer | Location |
|---|---|---|
| White Light Coronagraph | High Altitude Observatory | Boulder, Colorado |
| Ultraviolet Spectro-Heliograph | Naval Research Laboratory | Washington, D.C. |
| X-ray Spectrographic Telescope | American Science and Engineering Company | Cambridge, Mass. |
| Dual X-ray Telescope | Goddard Space Flight Center | Greenbelt, Md. |
| Ultraviolet Scanning Spectrometer | Harvard College Observatory | Cambridge, Mass. |

Considerable emphasis is being placed on the integration of payloads so that the various experiments and flight modules will result in a properly functioning system. This payload integration effort includes mission payload analysis and systems engineering, and program management support for the incorporation of experiment payloads into Apollo Applications space vehicles. It provides requirements, plans and program data for the proper interfacing of payloads; performance and interface specifications; design, test, and checkout plans and procedures; and ground and in-flight support equipment. Engineering analysis and design of the incorporation of spacecraft and payloads into a coordinated space system qualified for flight is also included. FY 1967 efforts were related to preliminary definition of the payload integration requirements. FY 1968 funds supported studies, mission planning and the implementation of design and development on the control and display panel for ATM. FY 1969 and 1970 funding will support continued efforts in integration of the mission and hardware elements of the cluster from the point of orbital insertion through post-flight data evaluation; verification of technical performance; efforts associated with the design, development and fabrication of mission hardware; and studies and analyses to define the requirements of mission alternatives. The Martin Company, Denver, Colorado, is the prime contractor for payload integration.

## Space Station

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Space Station..... | --- | --- | $9,000,000 |
| Total..... | --- | --- | $9,000,000 |

The Space Station system will consist of the station itself, experiments, supporting modules and logistic systems for personnel transfer and resupply. Based on the findings of completed advanced studies, a selection of detailed objectives and program constraints is being made and industry is being asked to prepare preliminary designs of station and logistic system configurations. After completion of these contractual efforts, a comprehensive in-house analytical review will be conducted, to refine alternative concepts, develop preliminary design specifications, define support requirements, and assess preliminary manufacturing and test requirements. Funds requested in 1970 are for continuing definition studies, preliminary engineering and necessary supporting work.

## Operations

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Launch, flight and recovery.. | --- | --- | $30,100,000 |
| Technical..... | --- | --- | 6,200,000 |
| Total..... | --- | --- | $36,300,000 |

### Launch, Flight, and Recovery

This activity funds only the unique project requirements of Space Flight Operations. The basic support for manned space flight launch, flight, and recovery operations, is funded under Apollo.

Operations include efforts at the Kennedy Space Center and the Manned Spacecraft Center that are directly involved with prelaunch, launch, flight, crew, and recovery planning activities. FY 1970 funds are required for mission planning and analysis; initiation of procurement for an ATM simulator; trainer modifications to Apollo Application configurations; maintenance of Saturn IB launch capability including equipment and systems in storage, by keeping it in a condition of good repair to permit reactivation to support Apollo Applications launches; modification of launch check-out equipment to accommodate Apollo Applications unique hardware; test planning and procedures for check-out of previously deactivated equipment and systems as well as Apollo Applications unique hardware and documentation planning for reactivation of launch complexes for Apollo Applications.

## Technical

Technical operations provides for integrated technical support, review, and analysis of the Apollo Applications missions. These services include the development of functional and performance standards consistent with mission objectives; mission planning; technical integration and evaluation test objectives and integration; mission and systems specifications; trajectory analysis; checkout effectiveness; and technical documentation.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1970 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — ADVANCED MISSIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Advanced Missions program is to examine advanced manned space flight program concepts, including logical extensions of the national space capability through analysis of present hardware systems for growth potential; to develop requirements for future systems; to provide guidance for research and technology activities; and to provide technical information and cost data upon which future program decisions can be based.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Advanced missions studies..... | --- | $2,500,000 | $2,500,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| John F. Kennedy Space Center, NASA..... | --- | $200,000 | $200,000 |
| Manned Spacecraft Center..... | --- | 950,000 | 900,000 |
| Marshall Space Flight Center.. | --- | 900,000 | 900,000 |
| Langley Research Center..... | --- | 450,000 | 200,000 |
| NASA Headquarters..... | --- | --- | 300,000 |

BASIS OF FUND REQUIREMENTS:

Advanced Missions Studies

| | | | |
|---|---|---|---|
| Advanced studies..... | --- | $2,500,000 | $2,500,000 |

Advanced studies provide for future manned space flight program planning. The studies utilize the capabilities of industry to perform conceptual designs and provide technical trade-off data to supplement our in-house activities. During FY 1969, emphasis is being placed on support of the Space Station definition effort.

Areas that are being examined in support of the Space Station definition effort include study and evaluation of all aspects of the Space Station information management systems, launch implications to the Eastern Test Range when launching payloads for the Space Station, and investigation of

space logistic systems. Definition of payload packages and the support requirements to achieve the objectives of the Space Station is underway. The payload investigations are designed to obtain information about man's capability to live, to function, and to perform useful tasks in a zero or partial "G" environment for periods of long duration, and to use this capability to perform experiments in several scientific areas.

FY 1970 funding will be used as follows:

a. Rescue and Escape - Studies will be undertaken to examine and identify methods and systems for astronaut escape and rescue on lunar orbit and lunar surface missions. Conceptual design of manned and unmanned earth based rescue systems will be studied for low earth and geosynchronous orbit missions. The impact of the projected use of such systems on the design and operation of space stations and lunar surface shelters and vehicles will be assessed.

b. Advanced Lunar Studies - Studies will be conducted on advanced studies which have the potential for utilization in the latter half of the 1970's. The studies will be concerned with spacecraft systems required to transport personnel and cargo to the moon and systems to provide shelter and support for exploration activities. System synthesis studies will provide planning data applicable to development of an early lunar station using Apollo system derivatives.

c. Advanced Space Station Studies - Advanced Space Station studies will include identification of advanced mission requirements and operational modes for a semipermanent space station. New modules required for second generation payloads and systems required for missions in synchronous orbit will be examined. The implications of deep space missions for these modules and systems may also be examined.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1970 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

SPACE SCIENCE AND APPLICATIONS PROGRAMS

| Program | Fiscal Year 1968 | Fiscal Year 1969 | Fiscal Year 1970 |
|---|---|---|---|
| Physics and astronomy..... | $139,500,000 | $125,116,000 | $119,600,000 |
| Lunar and planetary exploration..... | 147,500,000 | 81,800,000 | 146,800,000 |
| Bioscience..... | 41,800,000 | 32,700,000 | 32,400,000 |
| Space applications..... | 99,500,000 | 98,600,000 | 135,800,000 |
| Launch vehicle procurement.. | 124,550,000 | 100,200,000 | 124,200,000 |
| Total..... | $552,850,000 | $438,416,000 | $558,800,000 |



332-276 O - 69 - 9

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1970 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PHYSICS AND ASTRONOMY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Physics and Astronomy program is primarily directed to increase human knowledge of the earth's space environment, the sun, the stars, and more distant celestial bodies. Research is being conducted under this program to investigate the earth's upper atmosphere and ionosphere; the magnetosphere and the interplanetary medium; the sun, the stars, and galaxies; cosmic dust; cosmic rays and other physical and astronomical phenomena found beyond the earth's atmosphere.

A broad range of techniques to gather information on these phenomena is used ranging from theoretical and laboratory research through aircraft, balloon and sounding rocket flights to small Explorer spacecraft, large automated observatories in earth orbit, and manned spacecraft. Research groups involved in this program are located at NASA field centers, other government laboratories, universities, and industrial laboratories. Opportunities are also extended to scientists in other nations to participate in the program through flight experiments on NASA spacecraft and cooperative sounding rocket and satellite projects.

The data generated in this program are made widely available to the scientific and technical community in order to further advance future scientific research, and to contribute to education and the advance of technology.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology/advanced studies.. | $22,904,000 | $19,900,000 | $19,600,000 |
| Data analysis..... | 2,900,000 | 3,400,000 | 3,700,000 |
| Sounding rockets..... | 20,000,000 | 20,100,000 | 20,100,000 |
| Solar observatories..... | 11,332,000 | 12,000,000 | 14,800,000 |
| Astronomical observatories..... | 44,768,000 | 36,900,000 | 28,600,000 |
| Geophysical observatories..... | 20,064,000 | 13,200,000 | 6,800,000 |
| Explorers..... | 17,532,000 | 19,616,000 | 26,000,000 |
| Total..... | $139,500,000 | $125,116,000 | $119,600,000 |

Distribution of Program Amount by Installation:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Manned Spacecraft Center.... | $739,000 | $644,000 | $644,000 |
| Marshall Space Flight Center | 86,000 | 578,000 | 578,000 |
| Goddard Space Flight Center. | 112,949,000 | 98,429,000 | 91,888,000 |
| Jet Propulsion Laboratory... | 373,000 | 572,000 | 847,000 |
| Wallops Station..... | 1,093,000 | 918,000 | 630,000 |
| Ames Research Center..... | 2,267,000 | 1,617,000 | 1,617,000 |
| Electronics Research Center. | 140,000 | 60,000 | 60,000 |
| Langley Research Center..... | 1,617,000 | 1,155,000 | 2,831,000 |
| NASA Headquarters..... | 20,236,000 | 21,143,000 | 20,505,000 |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

| | | | |
|---|---|---|---|
| Space physics..... | $12,704,000 | $10,800,000 | $10,300,000 |
| Astronomy..... | 10,200,000 | 9,100,000 | 9,300,000 |
| Total..... | $22,904,000 | $19,900,000 | $19,600,000 |

In the Supporting Research and Technology project, we support the research required to provide for a firm foundation for space physics and astronomy. This project provides for advanced technological development of experiments and spacecraft components for future flight programs, the support of theoretical and laboratory research, and the conduct of flight scientific research using balloons and aircraft. It provides partial support for the Goddard Institute of Space Studies, the Space Science Board, and the Research Associate Program. Advanced mission studies to establish the concepts, characteristics and feasibility of future missions are also funded in this project. Nearly 300 research tasks are carried out by universities, nonprofit and industrial research centers, NASA centers and other government agencies. Specific areas of research tasks include the following:

Space Physics

Work in this area is primarily devoted to support of research related to physics of the earth's environment. It includes study of the sun-earth environmental factors as well as extra solar factors such as cosmic rays. In general these tasks may be categorized in the traditional disciplines of particles and fields, ionospheres, and interplanetary dust. Particles and fields tasks include research in magnetodynamics, plasma studies, solar wind and the magnetosphere, mass spectroscopy, magnetometer and plasma detector development. Research on cosmic rays and the radiation belt are carried out under this area.

Tasks included in the Ionospheres area cover ionospheric theory, plasma physics, radio propagation, electromagnetic waves, ionospheric electron content, electron density and electron temperature, plasma and langmuir probe observations, antenna impedance, solar/terrestrial relations and ionospheric and magnetic storms and disturbances.

Under the category of interplanetary dust is included the study of meteorites and micrometeorites, micrometeorite simulation, development of instrumentation, theoretical studies, interplanetary gas and dust, noctilucent clouds, cometary physics, and physical and chemical analysis of dust particles. Also included in this area are problems relating to chemical releases, Zero G physical phenomena, airglow and zodiacal light observations.

## Astronomy

Research supported in this area involves the study of the sun and other stars and objects outside the solar system. Research tasks include studies of the sun, solar spectrum, influence of the sun on interplanetary and planetary environment, instrument development, and laboratory and theoretical studies of basic physical processes peculiar to the sun. Also included are solar radio astronomy, and solar radar.

Research tasks related to objects outside of the solar system include observation by ground based and balloon-borne telescopes, radar and radio astronomy and instrument development. Theoretical studies of stars and stellar physics, physics of interstellar material, of intergalactic material, and of the galaxies, and advanced development work on experimental tests of the validity of Einstein's theory of relativity are also supported in this area.

## Data Analysis

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Data center operation..... | $600,000 | $1,000,000 | $1,300,000 |
| Space physics research tasks.. | 2,200,000 | 2,200,000 | 2,100,000 |
| Astronomy research tasks..... | 100,000 | 200,000 | 300,000 |
| Total..... | $2,900,000 | $3,400,000 | $3,700,000 |

The project supports research tasks involving the use of data acquired from space flight investigations and the operations of the National Space Science Data Center (NSSDC) located at the Goddard Space Flight Center.

Following the successful launch of a spacecraft, a principal investigator is allowed an adequate period of time to perform the reduction and analysis of the data. Depending on the type of data, this time varies from six months to two years and is generally funded as part of the flight project. At the completion of his analysis, the investigator places his reduced data in the NSSDC.

The NSSDC was established to serve as a central repository for space science data and provide a mechanism for the dissemination, utilization and analysis of the data. The amount of data from space flight experiments has increased steadily each year and is expected to make its full impact on NSSDC capability during FY 1971-72. In order to accommodate this workload, a phased buildup of the NSSDC is required. The FY 1970 funding provides for a start towards the necessary buildup.

Resources will be used to fund correlative studies from several separate investigations as well as new approaches to the analysis of available data. Resources will also be used for prime analysis of data from flight experiments on spacecraft launched prior to FY 1968 that are still transmitting worthwhile scientific data. All proposals for research are competitively evaluated and support is provided for those efforts which are expected to contribute most to the total advancement of knowledge.

The trend in the Astronomy amounts reflects the availability of data from the Orbiting Solar Observatories and the increased demands for use of the data for analysis and studies.

Sounding Rockets

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Space physics..... | $10,500,000 | $9,600,000 | $9,400,000 |
| Astronomy..... | 9,500,000 | 10,500,000 | 10,700,000 |
| Total..... | $20,000,000 | $20,100,000 | $20,100,000 |

Sounding rockets have continued to be a most effective means of making scientifically valuable studies of the upper atmosphere at altitudes between 80 and 1,000 miles. These relatively small and inexpensive vehicles are capable of carrying wide varieties of instrumentation for the study of the atmosphere, ionosphere, energetic particles, the stars, and the sun. The relatively low cost and short lead times associated with sounding rocket flights make them extremely useful for carrying out exploratory experiments and testing new instruments, including many of those being developed for satellites, observatories and probes.

Sounding rockets have been used to measure atmospheric density and temperature; to analyze the various gases present in the upper atmosphere, and responses of the atmosphere to varying solar activity. Chemicals released from sounding rockets for wind and temperature measurements launched from various sites all over the world have improved our knowledge about the dynamics of the ionospheric region and the nature of the earth's magnetic field. Recoverable sounding rocket payloads have been used to collect extraterrestrial dust originating in meteor streams, comets, and asteroids. Noctilucent clouds formed by the condensation of ice about this dust have been probed.

Incoming cosmic radiation and energetic particles, and their relationship to the aurora and airglow, have been studied by rocket probes containing spectrophotometers, filter photometers, and particle detectors.

Ionospheric experiments carried out with sounding rockets have been extremely valuable for scientific investigations of the physics of the D-, E-, and F-Regions of the ionosphere. Instruments have been developed to measure electron concentrations and temperature, electromagnetic waves, ionic and neutral mass spectra, magnetic fields, and E-Region currents.

Sounding rockets are now being effectively utilized for astronomical observations of the sun and the stars in the X-ray and ultraviolet regions of the spectrum. These experiments were made possible by the development of improved attitude control systems with pointing accuracies on the order of a few arc seconds.

Responsibility for flight support activities has been assigned to the Goddard Space Flight Center. NASA Headquarters has responsibility for experiments developed by scientists at universities, in industry, at other agencies, and in other countries. Ames Research Center has responsibility for high accuracy solar pointing control systems. Responsibility for flight support activities for certain special projects is assigned to Wallops Station.

One hundred and twenty-seven physics and astronomy sounding rockets, primarily of the Nike Cajun/Apache/Tomahawk, Aerobee, and Javelin types were launched during CY 1968 from sites in the United States, Canada, Brazil, India, Sweden, and Norway.

NASA plans to continue the sounding rocket flight program in FY 1970 at the current level. Forty to fifty scientific teams will be supported by this program effort. Increased emphasis will be placed in the astronomy and solar physics disciplines and will utilize the recently improved attitude control system capability which maintains control to "jitter" accuracies of a few arc seconds. Increased use will also be made of the Aerobee 350 and Aerobee 170 which will allow us to obtain more viewing time with heavier payloads of multiple and complementary experiments.

Solar Observatories

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Orbiting Solar Observatory (OSO): | | | |
| Spacecraft..... | $5,015,000 | $5,869,000 | $7,486,000 |
| Experiments..... | 6,317,000 | 6,131,000 | 7,314,000 |
| Subtotal OSO..... | $11,332,000 | $12,000,000 | $14,800,000 |
| Delta (Launch Vehicle Procurement Program)..... | ($1,100,000) | ($700,000) | ($2,100,000) |
| Total (including Launch Vehicles)..... | ($12,432,000) | ($12,700,000) | ($16,900,000) |

The Orbiting Solar Observatory (OSO) is a spin-stabilized satellite consisting primarily of a sail which during the daylight part of the orbit continuously points at the sun, and a wheel which rotates beneath the sail to provide stability. Mounted in the sail section are solar pointing and solar scanning scientific instruments which measure the ultraviolet, X-ray and gamma ray emissions of the sun, and observe other solar phenomena. The wheel section houses scientific instruments which are generally full sun or sky-mapping experiments; these instruments scan the sun once every two seconds during rotation of the wheel. All of the instruments provide scientific information which would be impossible to obtain with earth based telescopes. OSO's are gathering scientific data during significant portions of the eleven-year solar cycles. They are also providing solar and astronomical information continuously during shorter periods of from 30 days to two years.

OSO-I and OSO-II were successfully launched in 1962 and 1965 during a period of minimum solar activity and met their mission objectives. OSO-I clearly established the capability to successfully orbit a complex scientific observatory containing numerous independent solar and astrophysical instruments. OSO-I provided the first long duration observations of the X-ray and ultraviolet spectrum of the sun.

OSO-III and OSO-IV were launched in 1967 during a period of increasing solar activity and are still operating. Each observatory is providing 7.5 hours a day of useful scientific data. On OSO-III, an extremely significant observation has been made for the first time; the center of our galaxy is a source of high energy (50 Mev) gamma rays. This measurement is important for models of galactic structure and evolution, and theories on the energies of cosmic radiation. OSO-IV has obtained over 4,000 spectroheliograms of the solar atmosphere between 300 and 1,300 Å. These data will permit the development and assessment of realistic models of the solar atmosphere and will provide insight into the problem of energy transport through the chromosphere and corona.

The remaining OSO's, F, G and H, will be launched during and after a period of maximum solar activity. OSO-F, which will be designated OSO-V after it has been placed into orbit, is expected to be launched in the early part of 1969. This spacecraft will carry eight experiment instruments to observe solar and astrophysical phenomena. Two of the Principal Investigators are from the Naval Research Laboratory, two from the Goddard Space Flight Center, and one each from the University of Minnesota, University of Colorado, University College, London, and University of Paris. Data gathered by the instruments will continue to advance our knowledge about solar radiation and the processes which produce it.

The OSO-G spacecraft is being assembled and experiment instruments will be integrated during early 1969. After successful completion of the

acceptance testing, it is expected to be launched in the latter part of 1969. The principal scientific investigations will be high resolution X-ray spectra of flares and activity centers.

The payload for OSO-H will consist of six experiment instruments emphasizing high resolution X-ray and coronal studies. The spacecraft and instruments are in various stages of design and development. It is expected that this observatory will be launched in 1971.

All OSO's are launched from the Eastern Test Range by the Delta launch vehicle into a nominal 550 kilometer circular orbit inclined 33 degrees. Planning is currently underway for three additional missions and the spacecraft for these missions will be improved to provide additional support for more solar instruments having increased resolution capability.

Project management of the OSO is assigned to the Goddard Space Flight Center (GSFC). The Ball Brothers Research Corporation is the spacecraft prime contractor with responsibility for integration and test of experiments and other equipment into the observatory. In-orbit operations are controlled from the GSFC OSO Control Center through the STADAN/Tracking Network.

Fiscal Year 1969 funds provided for final preparation and launch of OSO-F, for the development, manufacture, and test of the OSO-G spacecraft and experiment instruments, for the definition and initial design of the OSO-H experiment instruments, and primary design of the OSO-H spacecraft.

Fiscal Year 1970 funds will provide for continued analysis and publication of data from OSO-IV; for orbital operation and data analysis for OSO-F; for completing test for launch preparations and initial data analysis for OSO-G; for design and hardware effort on OSO-H; and for initial development on OSO-I, J, and K.

Fiscal Year 1967 and prior funding for these missions was $65,686,000, including launch vehicles. Fiscal Year 1971 and subsequent years' funding needed to complete an eleven flight program is estimated to be $75,500,000 including launch vehicles.

Astronomical Observatories

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Orbiting Astronomical Observatory (OAO): | | | |
| Spacecraft and support | $36,609,000 | $28,803,000 | $22,365,000 |
| Experiments..... | 5,012,000 | 5,300,000 | 3,700,000 |
| Ground operations..... | 3,147,000 | 2,797,000 | 2,535,000 |
| Subtotal OAO..... | $44,768,000 | $36,900,000 | $28,600,000 |
| Centaur (Launch Vehicle Procurement Program)..... | ($7,900,000) | ($12,842,000) | ($2,058,000) |
| Total (including Launch Vehicles)..... | ($52,668,000) | ($49,742,000) | ($30,658,000) |

The Orbiting Astronomical Observatories (OAO) project requires the development of space-borne hardware and operational capability which must meet the most advanced scientific and technical requirements of the space program. This major advance in the state of the art is essential in realizing the potential of space astronomy. It will provide opportunities to obtain astronomical observations of celestial objects and phenomena in those regions of the electromagnetic spectrum that are inaccessible to ground based instrumentation because of atmosphere absorption. Experiments selected for the OAO missions will: perform exploratory sky mapping surveys in the ultraviolet region, obtain moderate resolution spectrometer data of stars down to tenth magnitude, and carry out high resolution ultraviolet spectral analysis of fainter objects.

The OAO spacecraft is designed to point in any direction with an accuracy of one minute of arc. Pointing accuracy of 0.1 second of arc will be obtained using sensors associated with the experiment instrumentation. The attitude control system performs five functions: stabilization and solar orientation subsequent to orbital injection or following loss of stabilization; roll search to acquire guide stars; slew to and hold at attitudes required for scientific observation; hold in inertial space without star trackers; and sun bathing, which provides a safe observatory holding mode while providing for maximum recharge of the spacecraft batteries.

The Goddard Space Flight Center is responsible for the management of the OAO project including the procurement of the spacecraft and experiments. The Grumman Aircraft Engineering Corporation, the spacecraft prime contractor, has designed and is fabricating the spacecraft. Goddard Space Flight Center will integrate the experiments in the spacecraft, perform the environmental tests, and operate the observatory in orbit.

Extensive ground facilities in the United States and in four other countries (Ecuador, Chile, Australia, and Madagascar) are provided for control of the mission in orbit and to receive telemetry for transmission to the OAO Control Center at the Goddard Space Flight Center.

The first OAO (OAO-I) was launched on April 8, 1966. Although the spacecraft failed on April 10, 1966, it achieved orbit, performed planned functions for a short period of time, and demonstrated the design objectives in a number of complex areas. The problem areas identified with the OAO-I operations were thoroughly analyzed and reviewed. Based on knowledge gained from the first flight, several modifications were made to the OAO spacecraft subsystems. Changes were made in the testing procedure for the subsequent observatories and the ground operations and facilities were expanded. In addition, a significant number of improvements were made to the OAO system to enhance the prospects for mission success.

The second OAO (OAO-II) was launched successfully on December 7, 1968. The operation of the spacecraft has verified modifications made to assure satisfactory operation of the power subsystem; provide better thermal



332-276 O - 69 - 10

environment; prevent arcing in the star trackers; minimize noise susceptibility and generation; and provide a safe holding mode independent of the star trackers. The improved and expanded ground systems have supported this mission by increasing the real-time knowledge of the in-orbit operation. Measurements have been made of the emission characteristics of diffuse nebulae and the extension of the opacity of the interstellar medium into the ultraviolet by the Wisconsin Experiment Package. The Smithsonian Astrophysical Observatory Celescope has provided sky mapping and brightness characteristics of faint nebulae and of hot stars.

The third OAO (OAO-B), to be launched in late 1969, will carry the Goddard Space Flight Center 36-inch telescope to obtain absolute spectrophotometry data on stars, nebulae, and the brighter galaxies. This mission will be the first to include the Inertial Reference Unit, under development by the Massachusetts Institute of Technology.

The fourth OAO (OAO-C), scheduled for launch in 1971, will carry a major experiment for Princeton University and a small piggy-back experiment for the University College, London. The Princeton Experiment Package is a 32-inch Cassegrainian reflecting telescope with a concave grating experiment. Studies will be made of spectra of interstellar gas and of composition and physical characteristics of interstellar gas and dust, as well as stars. The London experiment consists of three telescopes with paraboloidal reflectors, photon detectors, and gas counters to study X-ray emissions and to search for interstellar absorption.

Development of the OAO spacecraft was initiated in 1960. Funding prior to FY 1969 provided for the complete design, fabrication, integration, and test of the observatory (spacecraft and experiments) system as well as the ground support equipment for the OAO-I mission, launched in 1966, and the partial development and modifications of the systems for the three additional approved OAO missions. During this period, work was initiated on an inertial reference unit at the Massachusetts Institute of Technology to augment the star trackers in the stabilization and control subsystem of OAO-B and OAO-C. Following the OAO-I problem, efforts were curtailed on the third and fourth missions in order to concentrate critical resources on the second flight observatory.

Fiscal Year 1969 funding completed the OAO-II development and the observatory was launched successfully on December 7, 1968. Other major requirements for FY 1969 funds include: OAO-II operation and data processing; continued development, integration and test of the OAO-B spacecraft and Goddard Experiment Package; and the reinitiation of the equipment development for the OAO-C mission, including the Princeton Experiment Package.

In FY 1970, the funding will provide for continued analysis and publication of data from OAO-II and the prelaunch, launch, and post-launch support of the OAO-B mission. In addition, the subsystems for the OAO-C

spacecraft and experiment instruments will be developed and the subsystem fabrication, integration, and test for the OAO-C spacecraft and experiment instruments will be completed; the observatory system will be assembled and tests will be underway for an early 1971 launch.

Fiscal Year 1967 and prior funding for these missions, including launch vehicles, was $227,975,000. Fiscal Year 1971 and subsequent years' funding needed to complete a four flight program is estimated to be $12,500,000 including launch vehicles.

Geophysical Observatories

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Orbiting Geophysical Observatory (OGO): | | | |
| Spacecraft..... | $12,130,000 | $7,105,000 | $1,563,000 |
| Experiments..... | 7,934,000 | 6,095,000 | 5,237,000 |
| Subtotal OGO..... | $20,064,000 | $13,200,000 | $6,800,000 |
| Thor-Agena (Launch Vehicle Procurement Program)..... | ($881,000) | ($233,000) | (---) |
| Total (including Launch Vehicles).... | ($20,945,000) | ($13,433,000) | ($6,800,000) |

The Orbiting Geophysical Observatory (OGO) project has as a primary objective the accomplishment of a series of coordinated scientific studies of the earth's environment and the effect of solar activity on that environment.

Five OGO missions, each including 20 or more experiments, have been launched, one each year starting in 1964. These missions have alternated between high altitude, low-inclination orbits for magnetospheric and interplanetary studies and low altitude, nearly polar orbits, for global studies of atmospheric and related phenomena.

OGO-I, launched near the minimum period of solar activity in 1964, continues to operate on a periodic basis and is providing data from the 12 experiments which are still operating. Operation of OGO-II was terminated in November 1967 after two years of data acquisition. OGO-III provided satisfactory three-axis stabilization for an extended period, and has provided continuous data acquisition for magnetospheric studies. Most notable of these has been the first detailed observation of the solar storm ring current particles by the Van Allen experiment. The OGO-IV mission, launched July 1967, continues to operate satisfactorily and has exceeded the long-sought design goal of more than one year of three-axis stabilization. The

OGO-IV experiments have provided valuable data on atmospheric composition, airglow and auroral phenomena. As of November 1968, the 105 experiments placed in orbit aboard OGO missions had accumulated over one million operating hours.

The most recent mission, OGO-V, was launched March 4, 1968, into a highly elliptical orbit. It has met all major objectives and continues to perform well with active three-axis stabilization and 20 of the 24 experiments operating. This mission includes a number of new and challenging experiments and is capable of detecting particle energies from a few electron volts to 10 billion electron volts.

Initial results from OGO-V include discovery of electric field discontinuities in the solar wind and surveys of the spatial and temperature distribution of the earth's hydrogen cloud (Geocorona).

Four of the experiments flown on OGO-V were provided by foreign countries and include the first satellite-borne spark chamber (University of Southampton, England).

The timing of the initial OGO missions and their long lifetime has provided good coverage from solar minimum through the period of maximum solar activity. The sixth OGO (OGO-F) is scheduled for launch in early 1969 and will extend this coverage through solar maximum. This mission, the last OGO planned, will carry 25 experiments into a low altitude polar orbit for detailed studies of atmospheric physics.

Management of the OGO project is the responsibility of the Goddard Space Flight Center. Development of the spacecraft system and fabrication and testing of flight observatories is under contract to TRW, Inc.

Funding prior to FY 1968 provided for design and development of the basic spacecraft, launch of the first four observatories, beginning work on OGO-E and OGO-F, and support of data analysis for the first three missions.

Fiscal Year 1968 funds provided for launch of OGO-E, for continuation of preparation of the OGO-F mission, and for continued data support for four operational missions.

Fiscal Year 1969 funds are providing for launch of OGO-F, operational support for four OGO's and support of data analysis.

Funds in FY 1970 will provide for operational support for data acquisition, and for data analysis support for OGO-IV, OGO-V, and OGO-F.

Fiscal Year 1967 and prior funding for these missions, including launch vehicles, was $216,195,000. Fiscal Year 1971 and subsequent years' funding required to complete this six flight program is estimated to be $2,500,000.

## Explorers

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Space physics..... | $12,029,000 | $12,660,000 | $17,900,000 |
| Astronomy explorers..... | 5,503,000 | 6,956,000 | 8,100,000 |
| Subtotal Explorers..... | $17,532,000 | $19,616,000 | $26,000,000 |
| Scout (Launch Vehicle Procurement Program)..... | ($1,900,000) | ($1,300,000) | ($5,200,000) |
| Delta (Launch Vehicle Procurement Program)..... | (4,700,000) | (4,000,000) | (6,000,000) |
| Total (including Launch Vehicles)..... | ($24,132,000) | ($24,916,000) | ($37,200,000) |

The Explorer project utilizes relatively small Scout and Delta class spacecraft to conduct a coordinated program of experimental research on the environment of the earth, earth-sun relationships, and the nature of the interplanetary medium, and to conduct astronomical observations. These spacecraft are smaller and less complex than the observatories and can be designed and configured especially for the requirements of the particular mission. The program also provides for cooperative projects with other government agencies and with foreign governments.

During FY 1968, Explorer XXXV (IMP-E) was launched into lunar orbit to measure particles and fields data in the vicinity of the moon. This orbit was selected to gain further information on the earth's magnetosphere and magnetic tail, since the moon sweeps through this region monthly. This mission was successful and is still providing useful data. Explorer XXXVII (Solrad-B) was launched for the Naval Research Laboratory as a cooperative project. This spacecraft was designed to monitor energetic solar X-ray emissions to provide real time solar data to the scientific community. This mission was also successful. International Radiation Investigation Satellite I was successfully launched in a cooperative project with the European Space Research Organization (ESRO). The IMP-G spacecraft, originally scheduled for launch in 1968, was deferred one year because Explorer XXXIV, which carried the same scientific payload, was still operating satisfactorily. Development of the Small Scientific Satellites (SSS), Small Astronomical Satellites (SAS), and IMP spacecraft were continued, as were the Aurora, International Satellite for Ionospheric Studies (ISIS), Azur, and San Marco cooperative projects. The Air Density/Injun and Radio Astronomy Explorer (RAE) spacecraft were flight qualified and prepared for launch.

During FY 1969, Explorer XXXVIII, (RAE-A) was successfully launched. This spacecraft is designed to make the first observations of very low frequency radio waves from above the atmosphere. Although the spacecraft weighs only 607 pounds it is the largest spacecraft ever launched in terms of overall dimensions. The extendible antenna booms, configured in an X shape, measure over a quarter of a mile tip to tip. Boom extension was successfully completed in October 1968, and excellent data are being received. Explorers XXXIX and XL, the Air Density/Injun, were successfully orbited in a dual payload Scout launch. The Air Density Explorer, a twelve foot sphere to measure the density of the upper atmosphere, and the Injun, which carries a radiation measurement payload, are both operating satisfactorily. Aurora, the second ESRO cooperative satellite, was successfully launched to conduct an integrated study of the ionosphere at high latitudes. The ISIS-A spacecraft has successfully completed flight qualification testing and is awaiting launch. This is a cooperative project with Canada and will continue the successful ionospheric studies begun in 1962 by the Alouette I, which is still providing useful data. The IMP-G will be requalified and prepared for launching early in FY 1970. The SAS prototype spacecraft and experiments will be completed and undergo prototype testing. The RAE-B will complete integration. The SSS prototype will be tested and fabrication of the first flight spacecraft will begin. Detail design of the Sunblazer spacecraft and experiment will be started as will procurement of long-lead-time flight hardware. The structure of the IMP-I spacecraft will be completed. Development of other approved Explorers and various cooperative spacecraft will continue. Data analysis from earlier missions will also be carried out.

Fiscal Year 1970 funds will provide for the launching of IMP-G, RAE-B and SSS-A will be flight qualified and prepared for launch, as will the San Marco-C, Azur, ISIS-B, Barium Vapor Probe, and Air Force Cambridge Research Laboratory cooperative satellites. The SAS-A and IMP-I will complete development and be flight qualified. Another Naval Research Laboratory Solrad spacecraft will also be readied for launch. Fabrication of the Interplanetary Explorer Sunblazer prototype will begin. Detail design of the SAS-B experiment and procurement of long-lead-time items for the spacecraft will be completed and fabrication will begin. Development of SSS-B and IMP H&J will continue. We propose to initiate Atmosphere Explorer missions deferred in FY 1969. These missions will employ on-board propulsion needed to maintain the low altitude necessary to investigate that portion of the atmosphere where most of the incoming solar radiation is absorbed. Experiment selection will be completed for SSS C&D and SAS C&D, and development will be initiated. Agreements with foreign governments for two new cooperative satellites are expected to be completed which will include American experiments. Planning for follow-on missions will continue using IMP spacecraft with on-board computer capability. This effort will include studies of follow-on magnetospheric boundary missions and small piggy back satellites.

OFFICE OF SPACE SCIENCE AND APPLICATIONS

LUNAR AND PLANETARY EXPLORATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Lunar and Planetary Exploration program is the scientific exploration of our solar system utilizing manned and automated spacecraft supported by earth based research. The current program places emphasis on planning the further exploration of the moon by manned systems and on the exploration of the planets and the interplanetary medium using automated spacecraft. Intermediate and long range objectives encompass a broad exploration of the solar system and interplanetary space through more comprehensive missions to the outer planets and to the asteroids and comets. The ultimate achievement of these objectives will provide the data to better explain the origin, history, and mechanisms of development of our solar system, thereby increasing our understanding of the evolution of the earth and the processes that control its environment.

The fundamental scientific objectives of the lunar exploration program are to understand the moon's origin, evolutionary history, relationship to the earth and the solar system, and processes of formation. Projects now completed have advanced considerably our knowledge of the moon and provided a wealth of data which have aided and will continue to aid in unraveling the mysteries of our nearest neighbor. The Ranger project, the first step in this effort, provided the first closeup picture of the moon's surface through the thousands of lunar photographs its spacecraft transmitted to earth. The subsequent Lunar Orbiter project provided the large scale detailed photographs of the moon required for the selection and certification of sites for the Apollo manned lunar landing missions. The Surveyor project, by demonstrating the soft landing of a complex spacecraft, verified the ability of Apollo to land on the lunar surface. In addition, Surveyor made valuable contributions to our knowledge of the moon by taking hundreds of high resolution photographs of the lunar terrain, measuring lunar surface bearing strength and by making the first rudimentary chemical analysis of lunar materials. The initial phase of lunar exploration came to a close with the successful completion of the Surveyor project.

The next phase of our exploration of the moon will be conducted by men in the Apollo program currently approaching fruition. The initial landings and the subsequent modifications to the systems necessary for comprehensive exploration of the moon are funded under the Manned Space Flight program. However, a manned exploration of this scope requires a very solid foundation of scientific research if it is to be an effective program. Funding requested under the Supporting Research and Technology and Data Analysis programs will provide the scientific planning which will serve as the base for conducting meaningful exploration of the moon.

The planetary and interplanetary programs have experienced a high degree of success beginning with the Mariner II flyby of Venus and continuing with the most recent successful launching of the Pioneer IX spacecraft into an orbit around the sun. The Mariner II mission in 1962, the first flyby missions to Venus, provided new data on the magnetic and atmospheric characteristics of the planet. The Mariner IV mission to Mars in 1965 provided the first closeup photography of the planet's cratered surface and showed that its atmospheric density was very low compared to the earth. Mariner V, launched in June 1967, made more precise measurements of Venus' ionosphere, magnetosphere, and atmosphere. Pioneer IX, launched in November 1968, is the latest in the current series of spacecraft designed to measure the interplanetary medium. Earlier missions provided data enabling a better understanding of the mechanisms related to the propagation through space of solar disturbances, the effect of these disturbances on terrestrial phenomena, and the relationship between solar activity and solar and cosmic rays.

The next phase of the Planetary program includes a series of missions to Mars, Venus, and Mercury, and the first mission to the vicinity of Jupiter. Two Mariner flyby missions of Mars are scheduled for 1969 to be followed by two Mariner orbiters in 1971. In 1973, a single Mariner spacecraft will be used to study both Venus and Mercury.

The Viking project, utilizing the orbiter/lander team approach found so successful in exploring the moon will be used to explore Mars. This project, combining a lander and a Mariner class orbiter, will be launched to Mars by the Titan/Centaur launch vehicle in 1973. Pioneer E is scheduled for launch in 1969 for further interplanetary studies. Modification of the successful Pioneer spacecraft design will permit missions beyond Mars to the vicinity of Jupiter; Pioneer F and G launches are scheduled for the 1972 and 1973 Jovian opportunities.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology/advanced studies | $19,800,000 | $20,600,000 | $24,600,000 |
| Data analysis..... | 600,000 | 2,600,000 | 2,700,000 |
| Pioneer..... | 6,000,000 | 5,000,000 | 18,200,000 |
| Mariner-Mars 1969..... | 62,850,000 | 27,200,000 | 4,900,000 |
| Mariner-Mars 1971..... | --- | 18,300,000 | 45,400,000 |
| Mariner-Mercury 1973..... | --- | --- | 3,000,000 |
| Viking..... | --- | 8,100,000 | 40,000,000 |
| Planetary explorers..... | --- | --- | 8,000,000 |
| Advanced planetary missions technology..... | 12,000,000 | --- | --- |
| Surveyor..... | 33,000,000 | --- | --- |
| Lunar orbiter..... | 9,500,000 | --- | --- |
| Mariner-Venus 1967..... | 3,400,000 | --- | --- |
| Voyager..... | 350,000 | --- | --- |
| Total..... | $147,500,000 | $81,800,000 | $146,800,000 |

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Distribution of Program Amount by Installation: | | | |
| Kennedy Space Center..... | $84,000 | $119,000 | --- |
| Manned Spacecraft Center.... | 40,000 | 275,000 | $1,775,000 |
| Marshall Space Flight Center | 256,000 | 540,000 | 115,000 |
| Goddard Space Flight Center. | 1,542,000 | 4,141,000 | 10,820,000 |
| Jet Propulsion Laboratory... | 115,792,000 | 56,381,000 | 75,140,000 |
| Ames Research Center..... | 7,098,000 | 5,456,000 | 18,690,000 |
| Electronics Research Center. | 75,000 | 25,000 | 25,000 |
| Langley Research Center..... | 11,540,000 | 260,000 | 27,260,000 |
| NASA Headquarters..... | 11,073,000 | 14,603,000 | 12,975,000 |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

| | | | |
|---|---|---|---|
| Lunar science..... | $3,750,000 | $4,800,000 | $9,400,000 |
| Lunar advanced studies..... | 250,000 | --- | --- |
| Planetary science..... | 8,250,000 | 8,100,000 | 8,000,000 |
| Planetary advanced technical development..... | 6,800,000 | 6,000,000 | 6,000,000 |
| Planetary advanced studies.... | 750,000 | 1,700,000 | 1,200,000 |
| Total..... | $19,800,000 | $20,600,000 | $24,600,000 |

Supporting Research and Technology and Advanced Studies programs are the research activities which provide support to the flight missions by providing the base for defining the scientific objectives of future missions, and establishing the scientific and engineering capabilities essential to the performance of these missions.

The activities of the Lunar Science program are devoted to increasing our scientific knowledge of the moon, continuing laboratory investigations and theoretical studies related to the moon by drawing on basic data derived from ground based research and from Ranger, Surveyor, Orbiter, Apollo 8 and subsequent Apollo missions. These activities are required if the Nation is to take full advantage of the Apollo capability to explore the moon and exploit the discoveries made in the earlier phases of lunar exploration.

FY 1970 effort in Lunar Science planning will cover such items as: continued production of geologic maps of currently selected and future landing sites; plotting traverse routes; selection of future landing sites; and the investigation of instrument concepts for remote chemical analysis. FY 1970 will be the first year that the Lunar Science Institute is fully operational at the Manned Spacecraft Center in Houston, Texas.

Planetary science provides for research in the three disciplines: Planetary Atmospheres, Planetary Astronomy, and Planetology.



332-276 O - 69 - 11

The Planetary Atmospheres program funds research in atmospheric phenomena including the upper atmosphere of the earth, the atmospheres of the planets, and the gaseous phenomena associated with comets. In FY 1970, research into design and development of experiments and the development and modification of instruments for use in the Planetary Explorers will be stressed. The area of direct measurement experiments and instrumentation for exploration of the lower atmospheres of Venus will also be stressed.

The Planetary Astronomy program funds research for obtaining as much information as possible about the planets from the vicinity of earth. The use of rockets, balloons, airplanes, and ground based observations provides valuable data, which enhances the scientific value of the Planetary Exploration program. The FY 1970 Astronomy program will emphasize observations of Mars which will be at its closest point to earth since 1956. Investigators are preparing to study the planet to determine its atmospheric composition more accurately; to determine its topographical contours; and to study changes in surface and atmospheric features.

A new area under Planetary Supporting Research and Technology is the Planetology program which funds research in the increasingly important area of planetary geology. As the planetary program progresses from earth based observational data to flyby and orbiter data, and in 1973 to data from landers, planetology research will play a more and more important role in determining the nature and properties of the planets. In particular, the research toward the development of scientific instruments for Project Viking (soft landing of an instrument package on, and orbiting the planet Mars in 1973) is one of the major goals of the Planetology program in FY 1970. Expansion of the Planetology program has become necessary to prepare adequately for the expected data return from the Mariner Mars 1969 and future Mars missions as well as studies of Venus and Mercury missions.

In the area of engineering technology, the Advanced Technical Development (ATD) program supports the development of new and improved design of spacecraft hardware. In the recent past, the ATD program has concentrated approximately one-third of its efforts in the advancement of planetary lander heat sterilization to prevent contamination of the planets by terrestrial life. The remaining effort in the ATD program has been focused in the following areas: (1) extending the nominal lifetime of the systems for missions such as a Jupiter flyby, with approximately 1½ years of spacecraft transit, and the outer planets or Grand Tour mission which may be up to 12 years in duration; (2) developing power sources which use nuclear energy and allow a spacecraft to operate for extended periods without dependence on solar energy; (3) developing instruments and subsystems which will survive in the hostile environments of the asteroid belts, the magnetosphere of Jupiter and the temperature extremes; (4) developing the ability to communicate up to three billion miles; and (5) perfecting the techniques and subsystems for swingby trajectories which require great precision in spacecraft control and tracking. In FY 1970, research in the ATD program will concentrate in the areas of Jupiter flyby and Grand Tour missions; provide more emphasis to the critical technologies for Venus probes and buoyant Venus stations; and develop concepts for an advanced Mars lander in the late 1970's.

In the Planetary Advanced Studies program, surveys of potential future scientific planetary missions are made and an up-to-date catalogue of mission opportunities, their general system requirements, and their value in fulfilling established goals and objectives of NASA are defined. Alternate mission approaches, including the utilization of existing systems are evaluated and resource requirements determined and advanced technology requirements examined. In FY 1969, Advanced Studies funds were used to continue the work on (1) multiple planet Grand Tour and other outer planet flybys; (2) surface sample return from Mars; (3) buoyant stations and atmospheric probes of Venus; (4) Jupiter orbiters; and (5) comet flybys. In FY 1970, it is planned to continue the investigation of the more promising missions and to fund additional studies: (1) orbiters of Mercury and the outer planets; (2) atmospheric probe of Jupiter; and (3) comet rendezvous.

Data Analysis

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Lunar data analysis..... | --- | $2,000,000 | $2,100,000 |
| Planetary data analysis..... | $600,000 | 600,000 | 600,000 |
| Total..... | $600,000 | $2,600,000 | $2,700,000 |

The primary purpose of spacecraft missions to interplanetary space or to the moon and the planets is to conduct experimental investigations which will advance our knowledge and understanding. Data are obtained by scientific instruments aboard the spacecraft and are transmitted to earth for analysis by the scientists conducting the experiments. The initial data reduction and analysis is funded by the flight project as a part of its project responsibilities. Very often the time required to reduce and analyze the data, and to publish the results, is longer than the period of support provided by the project. In addition, the full scientific value of space flight data requires detailed and continuing analysis. The Data Analysis project was established in order to meet this need.

The Lunar Orbiter project has photographed the entire moon, providing geologic and topographic information in great quantity and detail. Analysis of this Lunar Orbiter data has almost exclusively been focused toward Apollo landing zone photographs as candidate sites were examined in every possible way before the final selection of five sites. There is now every confidence that the initial Apollo lunar landing sites have been chosen well.

In the future, in-depth analysis must be made on the photographic data from outside the Apollo landing zone. Later missions will have scientific objectives which will require landings in regions outside the Apollo landing zone. Approximately one-half of the funds requested for FY 1970 will support continuing Lunar Orbiter photographic analysis. This analysis will emphasize geographical areas outside the Apollo landing zone, primarily for scientific interest.

The first Apollo flights should yield an abundance of scientific and engineering data that is highly relevant to subsequent lunar exploration missions. The balance of the funds requested will support analysis of data obtained in early Apollo lunar orbital and landing missions. The purpose of these analyses will also focus on planning for potential lunar exploration mission requirements.

In FY 1970, the Planetary Data Analysis program will continue to support the reduction of data from the Mariner IV, Mariner V, and Pioneer missions and from earth upper atmosphere experiments, and will provide the results for the use of the scientific community and in advancing the knowledge of mankind in general.

Pioneer

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft and support..... | $2,924,000 | $2,328,000 | $12,100,000 |
| Experiments..... | 3,076,000 | 2,672,000 | 6,100,000 |
| Subtotal, Pioneer..... | $6,000,000 | $5,000,000 | $18,200,000 |
| Delta (Launch Vehicle Procurement Program)..... | ($2,500,000) | ($1,452,000) | (---) |
| Centaur (Launch Vehicle Procurement Program)..... | --- | --- | ($7,839,000) |
| Subtotal, launch vehicles... | ($2,500,000) | ($1,452,000) | ($7,839,000) |
| Total (including launch vehicles)..... | ($8,500,000) | ($6,452,000) | ($26,039,000) |

The objectives of the Pioneer project are to provide for the continuing investigation of the interplanetary medium and the propagation of solar and galactic phenomena in this medium; and to provide initial exploration of the remote regions of the solar system in order to increase knowledge of the origin and evolution of the earth, sun, and planets, and the dynamic processes that shape the terrestrial environment.

The current series of Pioneer spacecraft weigh about 140 pounds each and are launched by the Thrust-Augmented Improved Delta. The first three of these, Pioneers VI, VII, and VIII, were launched successfully in 1965, 1966, and 1967 respectively; all three continue to operate successfully. Pioneer IX was successfully launched on November 8, 1968. All spacecraft subsystems are performing normally, and all on-board scientific instruments are transmitting valuable scientific information on the interplanetary medium. Pioneer IX and Pioneer E, to be launched in 1969, are essential elements of our network of deep space "weather stations". The experiments of these Pioneers are designed to measure the solar wind flow, magnetic fields, and the electron density in space; and to observe the energy spectra, fluxes, and direction of solar and

galactic cosmic rays. The opportunity to perform these experiments on widely separated spacecraft in deep space is providing unique and valuable scientific information about the sun and its influence on the solar system. The combination of measurements from the four widely separated stations enable us to detect and estimate the paths of solar storms. This information helps forecasters to provide advance warning of radiation dangers to spacecraft and of variations in the protective magnetic envelop of the earth which affects the long range radio communications of the world.

In FY 1969, the development of Pioneer F and G was initiated to be launched into trajectories permitting the exploration of the environment of interplanetary space between one and five astronomical units (AU) from the sun, including the asteroid belt and the magnetosphere of Jupiter. (One AU is equal to the mean earth-to-sun distance, 92,000,000 miles.) With this type of trajectory, we should be able to study the hazardous region of the asteroid belt and measure the gradient of the sun's influence on interplanetary space and the penetration of galactic cosmic radiation into the solar system. While the spacecraft is in the vicinity of Jupiter, instruments will measure the properties of charged particles, magnetic fields, and radio frequency emissions. Data from these measurements will be used to study the composition and dynamics of the atmosphere surrounding the planet and its interaction with the interplanetary medium. It will also be used to analyze the thermal balance of Jupiter and the source of energy which the planet seems to have. These missions will require modifications to the spacecraft to compensate for the lessening of solar radiation as a power source and the more demanding communications and thermal conditions. New experiment instrumentation will also be required to make measurements in the asteroid belt and near Jupiter. These spacecraft will be launched in the 1972-73 time period by Centaur launch vehicles. The change from the Delta launch vehicles used on earlier missions is required to provide the velocity necessary to reach Jupiter. In FY 1969, NASA initiated, as part of the Pioneer program, a cooperative project, Helios, with West Germany for measurements of the interplanetary medium to within 0.3 AU of the sun.

Management of the Pioneer project is the responsibility of Ames Research Center. TRW Incorporated, is the prime spacecraft contractor for the first five spacecraft. Tracking and data acquisition systems management is the responsibility of the Jet Propulsion Laboratory, and Goddard Space Flight Center has responsibility for Delta launch vehicle systems management. Lewis Research Center will be responsible for Centaur launch vehicle systems management.

Funds in FY 1969 provided for the continued operation of Pioneer VI-VIII, the launch and post-launch operations for Pioneer IX, and the assembly, integration, testing and launching of Pioneer E. Funds are also being used to initiate experiment design activities for Pioneer F and G. FY 1970 funds will be used for design and development work on the spacecraft and the selected experiments for Pioneer F and G. Operational support for the five active Pioneer spacecraft and for data analysis will continue. U.S. experiments for Helios will be selected and development begun.

FY 1967 and prior funding, including launch vehicles, was $57,740,000. FY 1971 and future years' funding requirements for this project, including launch vehicles, are estimated to be about $107,119,000.

Mariner

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Mariner-Mars 1969..... | $62,850,000 | $27,200,000 | $4,900,000 |
| Mariner-Mars 1971..... | --- | 18,300,000 | 45,400,000 |
| Mariner-Mercury 1973..... | --- | --- | 3,000,000 |
| Mariner-Venus 1967..... | 3,400,000 | --- | --- |
| Total Spacecraft and Support | $66,250,000 | $45,500,000 | $53,300,000 |
| Atlas Centaur (Launch Vehicle Procurement Program)..... | ($6,874,000) | ($14,518,000) | ($11,512,000) |
| Total (including launch vehicles)..... | ($73,124,000) | ($60,018,000) | ($64,812,000) |

Over the past six years, the Mariner spacecraft has evolved from the 450 pound Mariner II used for man's first successful mission to another planet to the 2,200 pound (including 900 pounds of propellant) Mariner 1971 to be used for our first orbiting mission of another planet. The Mariner spacecraft represents the tool in the planetary program for remote observations, from an attitude controlled spacecraft, of the other planets in the solar system.

Accomplishments to date include the December 14, 1962, Mariner II flyby of Venus which provided the first direct temperature and magnetic field measurements from near the planet. This was followed by the Mariner IV flight past Mars on July 14, 1965. Mariner IV's primary objective was to conduct initial closeup scientific observations of Mars and its environment. The objective was achieved and included pictures of the planet showing a cratered surface similar to that of the moon. Although closeup pictures of Mars were the primary goal, valuable information on the planet's atmosphere and ionosphere was also acquired. On October 19, 1967, Mariner V flew past Venus some 2,600 miles from the planet's surface and made measurements to determine the properties of the Venusian atmosphere and the interaction between the planet and interplanetary medium, improving and significantly augmenting the data acquired five years earlier by Mariner II. Scientists are still analyzing data telemetered back by Mariner V. According to Mariner V, Venus is a hot planet with a thick lower atmosphere - mostly carbon dioxide. The heavy atmosphere is surrounded by a sphere of hydrogen analogous to that of earth.

The next step in the scientific exploration of the planets consists of two Mariner spacecraft to flyby Mars in early August 1969 to provide data on the planet's physical, chemical, and thermal properties. These spacecraft

will be instrumented to transmit more data from scientific instruments during this one opportunity than has been transmitted by all previous planetary missions combined.

The basic spacecraft looks much the same as earlier Mariners although it is larger and heavier (approximately 850 pounds as compared to Mariner IV which weighed 570 pounds) to accommodate a vastly improved scientific payload. The scientific instruments consist of two television cameras, an infrared spectrometer, infrared radiometer, and an ultraviolet spectrometer. In addition to these flight instruments, it is also planned to conduct a planetary occultation experiment making use of the spacecraft's radio equipment, and a celestial mechanics experiment using the tracking data. Present plans call for having both spacecraft encounter the planet within a five-day period. As each spacecraft approaches the planet, one of the two TV cameras on board will commence a picture taking sequence permitting full photographic coverage of Mars at increasing resolution. During the near encounter phase, the other TV camera will be turned on along with the IR and UV instruments. Data will be collected and stored on magnetic tapes, and after the spacecraft exits from occultation, the tapes will be played back to the earth tracking stations.

The scientific investigation of Mars using orbiting spacecraft will begin in 1971. The Mars 1971 spacecraft, which will use many of the proven subsystems of the Mariner IV and Mariner 1969 exploratory flyby missions, will begin detailed studies of the atmosphere and environment of the planet, and provide a closeup look at large areas of the surface. This 1971 mission will provide broad topographic and thermal coverage; seasonal variations in the atmosphere and on the surface; and other long term dynamic observations.

Some of the scientific instruments for the Mariner-Mars 1971 missions will be improved versions of those carried on the Mariner-Mars 1969 flyby. However, the scientific data return will be increased significantly. This increase in data return results from the spacecraft being in orbit about the planet allowing multiple measurements and observations over a period of several months. From orbit, it will observe approximately 70% of the planet's surface including the wave of darkening, cloud movements and any other dynamic and seasonal changes in the planet atmosphere or on the planet's surface. In addition, the low point of the orbit will be about 1,200 miles as compared with the nominal 1,800 mile closest approach distance of the Mariner-Mars 1969 flyby. This closer distance to the surface will allow higher resolution measurements from all instruments, and will increase the value of the occultation and celestial mechanics experiments.

The Mariner-Mars 1971 orbiter design is based on existing Mariner technology which resulted in successful planetary investigations of Venus during 1962 and 1967, and of Mars during 1965, and was used to develop the spacecraft which will be launched to Mars in early 1969. The actual hardware to be used for the 1971 orbital missions will make extensive use of spare hardware and test equipment from the Mariner-Mars 1969 project.

A single modified Mariner spacecraft will be used to study both Venus and Mercury in 1973. Although the similarities between Mars, Venus, and Earth make the study of these planets important to our knowledge of Earth and its place in the solar system, the knowledge of other planetary bodies can also make a significant contribution. In 1973, using the same rocket required to go to Venus, a spacecraft can be accelerated by Venus' gravity and orbital velocity so that the same spacecraft can also swing by Mercury and begin the exploration of this the closest planet to the sun. The Mariner spacecraft, which will be launched by an Atlas/Centaur, will return both ultraviolet and visual television pictures, atmosphere and ionosphere data, as well as thermal maps from both Venus and Mercury. In addition, it will monitor the space environment in the unexplored regions between Venus and Mercury.

A modified Mariner spacecraft will be used as the orbiter for the 1973 Viking project. This orbiter will make maximum use of the technology and hardware developed for the Mariner 1971 orbiter project. Additional details and funding required for the Viking orbiter are included under the Viking project.

The Office of Space Science and Applications, NASA Headquarters, is responsible for overall management of the Mariner program. The responsibility for project management has been assigned to the Jet Propulsion Laboratory. The Jet Propulsion Laboratory will perform the systems integration function of the prime contractor for the Mariners under development; subcontracting will be for complete subsystems. The Lewis Research Center is responsible for the launch vehicles.

Current year funds will cover the cost of completion of fabrication, assembly, test, and launch of Mariner-Mars 1969. FY 1969 funds for Mariner-Mars 1971 will be used to establish the functional specifications for the mission and to complete systems design. Flight experiments and subsystem contractors will be selected.

The funds requested for FY 1970 will support post-launch operations for Mariner-Mars 1969 through encounter, and initial analysis of scientific and engineering data. FY 1970 funds requested for Mariner-Mars 1971 will be used to procure flight hardware, to provide for tests of prototype subsystems, and to permit environmental systems tests of the prototype spacecraft to be carried out. FY 1970 funds will also be used to prepare functional specifications for Mariner-Mercury 1973 spacecraft and to permit initial flight hardware procurement activities. FY 1971 and future years' funding requirements for this project, including launch vehicles, are estimated to be about $118,200,000.

Viking

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Orbiter - spacecraft and experiments..... | --- | $4,300,000 | $13,000,000 |
| Lander - spacecraft and experiments..... | --- | 3,800,000 | 27,000,000 |
| Total..... | --- | $8,100,000 | $40,000,000 |

The exploration of Mars initiated in 1965 by the Mariner series of spacecraft will be continued in 1973. While these prior missions were to study the planet from orbital or flyby distances, the 1973 mission will be the first opportunity to obtain data from direct measurements in the Mars atmosphere and on its surface.

The objectives established for the Viking project are to obtain, through the use of two lander/orbiter missions to Mars in 1973, scientific data which will significantly increase our knowledge of the Mars atmosphere and surface with particular emphasis on providing information relevant to life on the planet. Entry objectives include measurements of atmospheric composition and structure. Post-landing objectives are to visually characterize the landing sites, search for organic compounds, and investigate the ability of the environment to support life. Orbiter objectives are to study the dynamic characteristics of the planet and its atmosphere from orbit, to provide pictures of the landing area, and to relay data from the lander on the Mars surface to earth. This teamwork between the orbit and lander should yield scientific results which would not be attainable from independent lander and orbiter missions.

The lander to be used for this mission will be a soft lander similar to those used in the Surveyor program. Technology developed for Surveyor and the Apollo Lunar Module will be directly applicable to the Viking lander. This lander will be mated with a modified Mariner 1971 orbiter, which will have the capability to insert the lander into orbit prior to landing. This will permit orbital entry for the lander which has the advantage of smaller surface dispersions for the lander, lower entry velocities, and better control of entry angles. The launch vehicle to be used will be a Titan/Centaur.

The Office of Space Science and Applications, NASA Headquarters, is responsible for overall management of the Viking project. The responsibility for project management is assigned to the Langley Research Center (LRC). LRC will also be responsible for the lander system. The Jet Propulsion Laboratory, which has had responsibility for all Mariner projects, will be responsible for the Mariner class orbiter.

Current year funds are being used to complete mission definition studies and to begin preliminary development work on long-lead items, such as the lander scientific instruments and the landing radar and propulsion systems. A



332-276 O - 69 - 12

large number of the country's leading scientists have volunteered to participate actively in the science definition effort for this project.

The requested FY 1970 funds will provide for the completion of functional specifications, selection of the prime contractor for the lander system, initiation of detailed system design for the lander and orbiter, and will provide for continued development work on long lead items. During FY 1970, the specific scientific instruments to be flown will be selected after the results of the Mariner 1969 mission are known and development work on these instruments will begin. FY 1971 and future years' funding requirements for this project, including launch vehicles, are estimated to be about $354,500,000.

Planetary Explorers

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft and support..... | --- | --- | $6,450,000 |
| Experiments..... | --- | --- | $1,550,000 |
| Total..... | --- | --- | $8,000,000 |

The Planetary Explorers are relatively small, low cost, spin-stabilized spacecraft designed for a Thor/Delta launch and to orbit the near planets. The five-shot program includes launches to Venus in 1972, 1973, and 1975 and to Mars in 1973 and 1975.

The Planetary Explorers will team with the larger Mariner spacecraft to produce a highly efficient program to explore the near planets, just as the most efficient program to explore the earth and its environment proved to be a mix of small Explorer orbiters with larger satellites such as Nimbus and OGO. As part of its role on the team, the magnetically-clean Planetary Explorers will make those sensitive readings of the particle and field environments around Venus and Mars which are difficult to make aboard the higher-powered Mariners with their strong internal magnetic fields. The Planetary Explorers will thus free the Mariners to concentrate on conducting those high priority experiments which require stable and precise pointing, high-power, and high data rate.

The Planetary Explorer design is based on previous Explorer spacecraft such as Explorer XXXV, which is in orbit about the moon; and the program is directed by the NASA Goddard Space Flight Center team which successfully developed the IMP Explorers. Effort during FY 1970 will include completion of the detailed design, fabrication, and test of a structural test model and a thermal control model. Funding requirements for future years for this project, including launch vehicles, are estimated to be about $125.0 million.

OFFICE OF SPACE SCIENCE AND APPLICATIONS BIOSCIENCE PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Bioscience program has three principal objectives: (1) the attainment of a thorough understanding of the effects of the space flight environment on terrestrial organisms; (2) the search for extraterrestrial life, with the primary emphasis directed initially to the moon and nearest planets; and (3) prevention of the transfer of terrestrial organisms to the planets, so that their scientific value for studying hypotheses on existence of extra-terrestrial life will not be destroyed.

The first objective has three areas of effort: (a) to study the effects of space environmental factors on living earth organisms, especially weight-lessness and effective dissociation from factors related to the earth's rotation; (b) to exploit the unique space environment to analyze organism-environment relationships, especially the role environment plays in establishing and maintaining normal organization in living systems; and (c) to study the physiological, behavioral, and genetic responses and adaptations of living organisms to the space environment.

The biological effects of the space flight environment are being studied in the Biosatellite project. During flights of Biosatellite I and II the engineering design and integrated operation of the spacecraft systems were thoroughly checked out. The Biosatellite II experiment results showed that there was an interaction between radiation and weightlessness and other factors encountered in space flight. This interaction varied between greatly increasing the effects of radiation-induced damage, to decreasing the effect significantly depending upon the type of organism studied. The plant experiments studying the biological effects of weightlessness showed a close correspondence to results obtained by rotation on the horizontal clinostat. Post-flight laboratory control studies, in addition to those performed before and during flight, are being conducted to clarify any ambiguities in the results as well as to study biologic mechanisms involved.

The next Biosatellite flights, with more complex forms of life and flight duration of up to 30 days, will be used to determine the effects of weight-lessness on mammalian systems. Two primate flights are scheduled.

The specific aims of the second objective - the search for extraterrestrial life include: (a) physical and chemical evaluation of planetary surfaces as a possible environment for life; (b) determination of whether or not life exists, or has existed; (c) if life in some form exists, determination of its characteristics; and (d) if no life exists, investigation of the pattern of chemical evolution in order to evaluate the probability of its future

occurrence either spontaneously or by contamination, and the reason for its present nonexistence.

The development of prototype instrumentation for exobiological studies on the Martian surface is needed as a precursor to flight instrument development for an early Mars lander. The life detection and organic analytical techniques developed in various laboratories must now be converted into flight instruments which in turn must be tested and integrated into the payload required to achieve the scientific objectives of the exobiology program. Such work must be done in FY's 1969 and 1970 in order to support Viking, a 1973 Mars lander, and later missions. The development of this instrumentation is considered to be the most import single item in the Bioscience Supporting Research and Technology (SR&T) project and is extremely critical to the Viking mission. For this reason the entire increase in the Bioscience SR&T project has been requested for this purpose.

The third objective of the Bioscience Program (Planetary Quarantine) is shown as a separate line item because of its direct relationship to the planetary flight program. Continuing efforts are being made, before initiation of space flights destined to land on the planets, to assure adequate technology development in the solution of the complex problems related to the planetary quarantine constraints. The funding increase requested is in direct support of the Viking mission.

The objectives of the advanced programs and technology activity of the Bioscience program are to advance technology for application in new and improved spacecraft hardware and experiment hardware, and to provide better alternative designs that will successfully enable the accomplishment of biological experiments on a variety of automated and manned spacecraft.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology/ advanced studies..... | $10,122,000 | $ 9,900,000 | $11,400,000 |
| Planetary quarantine..... | 1,678,000 | 1,300,000 | 3,000,000 |
| Biosatellite..... | 30,000,000 | 21,500,000 | 18,000,000 |
| Total..... | $41,800,000 | $32,700,000 | $32,400,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| Marshall Space Flight Center.... | $55,000 | $135,000 | $150,000 |
| Goddard Space Flight Center..... | 134,000 | 86,000 | 75,000 |
| Jet Propulsion Laboratory..... | 1,545,000 | 1,623,000 | 1,600,000 |
| Wallops Station..... | 40,000 | 80,000 | 80,000 |
| Ames Research Center..... | 30,662,000 | 21,269,000 | 17,940,000 |
| Langley Research Center..... | 85,000 | 190,000 | 100,000 |
| NASA Headquarters..... | 9,279,000 | 9,317,000 | 12,455,000 |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Exobiology | $ 3,449,000 | $3,000,000 | $ 4,500,000 |
| Environmental biology | 1,825,000 | 2,000,000 | 2,000,000 |
| Behavioral biology | 1,800,000 | 1,900,000 | 1,900,000 |
| Physical biology | 1,673,000 | 1,800,000 | 1,800,000 |
| Bio-communications | 941,000 | 800,000 | 800,000 |
| Advanced programs and technology | 434,000 | 400,000 | 400,000 |
| Total | $10,122,000 | $9,900,000 | $11,400,000 |

Exobiology

An integral and perhaps inevitable event in the origin and evolution of the universe was the origin of life. An understanding of the controlling factors in the origin of life and determination of the uniqueness of life on the earth are the primary objectives of the Exobiology project. The research areas considered basic to the project area are:

1. Chemical Evolution - study of the chemical events on the primitive earth or on any primitive planet with a similar history which preceded and led to the origin of life. There are two approaches to chemical evolution: (a) by the application of energy (electrical discharge, ultra violet radiation, heat, etc.) to the simple components (methane, ammonia, water) of the primitive atmosphere, and (b) organic geochemistry which includes analysis of ancient rocks and sediments of the earth, moon and other planets, for fossils (both chemical and biological), providing a record of the events taking place at the time of the origin of life. Extraterrestrial analysis can be done *in situ* or on returned samples.

2. Biological Adaptation - a study of the response of terrestrial organisms (primarily microorganisms) to extremes of environment (temperature, radiation, pressure, atmospheric composition, water availability etc.) likely to be characteristic of extraterrestrial environments. Two basic problems are being explored -- survival and growth. Are terrestrial organisms accidently landed on an exterrestrial surface likely to survive and be detected inadvertently by our life detection experiments and are terrestrial organisms likely to grow and destroy indigenous life forms? What are the limits of environmental extremes which carbon-based life can tolerate, so that we may estimate the likelihood of life on any given planet? Are there other chemistries which could produce a "living" system capable of tolerating quite different environments than we ordinarily consider?

3. Life Detection - the development of techniques which will allow us to determine the presence or absence of past, present, or potential life elsewhere in the universe.

The emphasis is on automated systems performing relevant environmental measurements and chemical analysis early in the program. These evolve to more complex payloads making more integrated and sophisticated measurements and ultimately to unmanned and even manned laboratories. The most likely techniques seek the more basic attributes of terrestrial life-organic chemical, metabolic, and growth analyses, as well as imaging systems for visual detection and morphology. Ultimately, data on all of these basic attributes will be required, hopefully on a single sample.

4. Flight Experiments and Return Sample Analyses - lunar samples should be available for analyses in FY 1970. They will be studied for evidence of biologically significant organic matter and for evidence of all living or fossil biota.

## Environmental Biology

Living organisms, from microbial forms to man, are extremely responsive to their environment. Life forms have successfully adapted their life forms and life cycles to an inconceivable variety of biologic environments. The space environment provides still another variety of unique environmental factors to which living earth systems are being exposed.

A better understanding of the variables of the space environment and their effects on life processes is mandatory and will provide valuable base line information for planning and evaluating experiments for space flight. For instance, the rigors of space flight and individual physical factors (accleration, vibration, radiation, weightlessness) impose stresses which the organism must withstand through conditioning and adaptive processes.

Experience to date, in plants and animals (Biosatellites) and humans, indicates that space flight induces a variety of changes in life processes. The specific causes of these transient or permanent alterations, and the mechanisms by which they are brought about are unknown and must be verified experimentally. We must recognize and understand factors which directly or indirectly influence cellular function, either at the molecular level of interaction, or in the process of some more integrated function such as cell development.

Earth life with which we are familiar generally requires sufficient quantities of water, warmth, atmosphere, mineral and organic nutrient, and energy. Looking beyond our familiar habitat and into the world of extremes takes us into an area of biologic exceptions. This minority of living systems that exists under extreme ranges of the physical and chemical environments permitting growth, reproduction and other physiologic processes of earth organisms is under study to determine absolute limitations of life by the environment and the mechanisms by which normal levels of metabolic function are maintained within these limits.

## Behavioral Biology

The role of behavioral biology in space bioscience is twofold: (1) to explore the ways in which the extreme conditions of space flight affect the behavior of organisms, and (2) to use the unique features of the space environment to advance the analysis of behavior. In addition to weightlessness, which represents the principal unique factor in space, important effects upon behavior include drastic reductions in familiar modes of sensory stimulation, the removal or alteration of ordinary day-night cycles and, particularly for higher forms, a rather severe kind of social isolation.

A major area of endeavor is the border region between perception and control of movement. The origin and maintenance of eye-hand coordination is an extremely promising topic for current research in behavioral biology. The various feed-back and feed-forward mechanisms involved in manipulatory behavior have become susceptible to laboratory experimentation. If there is any deterioration in the performance of high-level motor skills it is important to learn about this from the standpoints of astronaut safety and a deeper understanding of mechanisms in sensorimotor coordination.

Orientation in space is engaging the attention of investigators interested in understanding and controlling those functions which are essential to extravehicular activity and those other maneuvers in space which require complex behavior. Both ground based and in-flight studies on the sensation of gravity, such as the determination of thresholds for angular and linear acceleration and responsiveness of the otoliths, semicircular canals, and other gravi-receptors to both transient and prolonged stimulation will contribute to this understanding.

Absence of the day-night cycle and other periodic aspects of the earth environment make space an ideal laboratory for learning about the origin and nature of circadian rhythms. Interest in this subject extends to a concern for behavioral and other biological events, observed by man, with a periodicity of approximately twenty-four hours, exemplified by the cycle of sleep and wakefulness. Studies of various stages of sleep, particularly those dealing with neurohpysiological and biochemical changes during that stage associated with rapid eye movement promises new knowledge equally relevant to man in space and his normal environment. The relationships between the requirements for sleep, the process of fatigue, and the effects of gravity remain almost totally unexplored.

## Physical Biology

Broad experimental and theoretical research provides a strong background of knowledge for planning and development of experiments for space flight. This includes comparative physiology, bioinstrumentation and biophysics, and molecular biology, including theoretical biology.

Biorhythmicity and oscillatory phenomena in physiological activity has long been recognized.

All living organisms demonstrate some degree of biological periodicity. These persistant rhythms can be accounted for by either the hypothesis that they are timed by an autonomous, endogenous oscillator system, or the hypothesis that these are dependent for their timing on an exogenous rhythmic input. The ultimate goals for studying these phenomena are the understanding of basic life processes and the monitoring and evaluating the physical condition and well-being of animal and man during space flight missions.

Crucial to conducting successful biological experiments in space is the need for advanced instrumentation and methods for measuring and analyzing behavioral and physiological reactions. Recent advances in solid state technology and theory have created a unique opportunity to develop new and especially miniaturized methods for obtaining biological information. Accordingly, basic research and preliminary development of experiments are sponsored for the acquisition of devices and techniques unique for the special problems arising out of space flight activities. These devices and methods are sought on the basis of their potential and/or immediate use to the Bioscience program.

Coincident with biological experimentation in space environments and with the search for extraterrestrial life is the need for an understanding of the form and function of cells, their relationship to one another, and of their constituents. This also includes an understanding of the evolutionary relationship of cells and their parts; and of cellular phenomena. Both experimental and theoretical studies are supported in order to develop an insight into the kind of response living organisms will have during space flight and also for the kind of life and/or life-related chemistry and physiology that might be found and should be sought on other planets.

## Bio-Communications

The Bio-Communications project was established to improve communication and understanding between life scientists and physical scientists. As the body of scientific knowledge expands in size as well as scope, it becomes increasingly difficult for a scientist to keep abreast of knowledge in his own field, and pertinent advances outside his field. The goal is to make the scientist more aware of advances in his own specialty, and open the door for a greater exchange of ideas and dissemination of information between and among scientific disciplines.

The Bio-Communications project provides:

(1) Partial support of the Space Science Board of the National Academy of Sciences and its subcommittees,

(2) Training of scientists through research associates and summer institutes,

(3) Consultation to administrative program scientists,

(4) Cross-disciplinary communication between physical and biological sciences,

(5) Research literature, report analyses, current status reports, and

(6) Conferences, symposia, and informal meetings.

## Advanced Programs and Technology

The role of this project is twofold: (1) to define a Bioscience flight experiment program which is feasible and appropriate to meet the Bioscience program objectives and (2) to study mission requirements to support the experimental work and develop specific future mission plans compatible with experiment requirements and within reasonable manpower and budget constraints.

Specific experimental programs have been recommended by the biological scientific community through the American Institute of Biological Sciences (AIBS) Regional Councils. An experiment proposal survey resulting from this activity is in progress and will form the basis for developing specific mission payloads.

A preliminary analysis of the survey shows that four types of future flight missions are required: (1) Automated, Earth-Orbital, Recoverable; (2) Automated, Earth-Orbital, and Heliocentric Orbit, Nonrecoverable; (3) Manned Earth-Orbital; and (4) Sub-Orbital. These are in addition to the experiments planned for the biological exploration of the moon and planets.

Requirements for the support of experiments utilizing a manned space station will be included in the OART Biotechnology Laboratory study. The objective of this study is to define a maximum utility laboratory facility for life sciences experiments to be carried out in a future manned space station. Separate studies are being conducted within the Bioscience program to more clearly define both general and specific experiment support requirements for manned flight experiments that will be flown prior to the availability of an integrated laboratory facility.

Wallops Station and Ames Research Center are conducting in-house and contracted studies relative to the feasibility of utilizing small inexpensive spacecraft to accommodate those experiments not requiring payload recovery.

Ames Research Center is also conducting an in-house study of recoverable spacecraft preliminary to a contract supported effort in FY 1970.

## Planetary Quarantine

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Planetary quarantine..... | $1,678,000 | $1,300,000 | $3,000,000 |
| Total..... | $1,678,000 | $1,300,000 | $3,000,000 |



332-276 O - 69 - 13

The absolute prerequisite in the search for extraterrestrial life is the requirement that all possible measures to be taken to prevent the transfer of earth forms to the planets and to keep them free of terrestrial contamination until the question of existence of planetary life is answered. The knowledge of environmental factors gained by both Venus flybys in 1967 has permitted a reassessment of the possibility of contaminating that planet. Early flybys of Mars should assist in the design of effective planetary quarantine measures. Missions for later landing probes to date neither confirmed nor denied the possibility of the existence of life in the outer atmosphere of Venus, on Mars, or on or below the surface of the moon.

Major launching nations have subscribed to the objective that there must not be more than one chance in a thousand of contaminating a planet during the period of biological exploration. This level of safety has required decontamination procedures and sterilization methods of the spacecraft by dry heat before the development of launch and protection of the sterile capsule from recontamination during launch. These requirements impact the design of the spacecraft as well as procedures for assembly, testing and checkout during the preflight period. Research results now assure that we can obtain reliable mission hardware performance together with positive sterilization. Investigations in FY 1970 are directed toward further simplifying the sterilization requirements.

In the operational area all lunar flights have been monitored to provide an inventory of the microorganisms landed on the moon. These operations are being extended to Apollo in order that any life on the returned lunar samples may be more quickly identified and the quarantine period of returned astronauts and lunar material be shortened.

Biosatellite

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft | $22,897,000 | $15,600,000 | $12,900,000 |
| Experiments | 6,910,000 | 5,400,000 | 4,700,000 |
| Operations | 193,000 | 500,000 | 400,000 |
| Total Spacecraft Operations | $30,000,000 | $21,500,000 | $18,000,000 |
| Thor-Delta (Launch Vehicle Procurement program) | ($1,000,000) | ($1,600,000) | ($1,600,000) |
| Total (including launch Vehicles) | ($31,000,000) | ($23,100,000) | ($19,600,000) |

The Biosatellite is the only automated spacecraft devoted to biological research. Management responsibility for the Biosatellite project has been assigned to the Ames Research Center. Spacecraft development and fabrication is under contract to the General Electric Company, Re-entry Systems Division, located at Philadelphia, Pennsylvania.

The entire Biosatellite is 6 feet 10 inches long, about 4 1/2 feet in maximum diameter, and weighs about 1500 pounds. It is launched by the Thor-Delta vehicle and is a laboratory for conducting experiments in orbit under conditions of controlled temperature, very low accelerations, and with a normal oxygen/nitrogen atmosphere at sea level pressure. All experiments are recovered in the air by the U.S. Air Force after the re-entry vehicle has separated from the adapter section and de-orbited and the capsule is descending by parachute.

Thirteen experiments were orbited on Biosatellite II for two days using specially selected plant cells, animals, and simple forms of life to study the effects of the space environment upon biochemical processes in cells, their development and growth, the transmission of hereditary characteristics, and the structure of living tissues. As an example of the results from one of the 13 experiments, the exposure to weightlessness in combination with controlled gamma radiation produced a significantly greater number of abnormalities than controls on earth when exposed to radiation alone. Many interesting and significant conclusions were reached as to how plants and animals grow in a weightless state. All of these results are published in detail in scientific journals, and many have been reported at national and international scientific meetings such as the XIIth International Congress of Genetics, Tokyo, 1968, and the 1968 COSPAR meeting in Tokyo. Studies of the effect of weightlessness upon more complex life forms are planned for the subsequent Biosatellite missions.

During this coming year the first of the two Biosatellite missions which use a primate will be flown. This mission is planned to stay in earth orbit for approximately 30 days prior to recovery, and the experiment will investigate the effects of weightlessness and isolation upon (1) the central nervous system through measurement of brain waves, (2) the cardiovascular system by means of continuous electrocardiograms, and (3) alertness, memory, and eye-hand coordination through the use of a behavioral task panel and rewards of food. Pre-flight and post-flight X-ray photographs of the primate skeleton will determine the loss of bone calcium and correlate this with the measurements made of calcium excreted in the urine. Other measurements will be made with a miniaturized, automated wet-chemistry laboratory system to determine changes in body metabolism.

FY 1967 and prior years' funding for the Biosatellite project, including launch vehicles, amounted to $85,731,000. Funding for FY 1968 provided for the primate mission experiment developments, and the engineering design, fabrication of components, system development and component testing of the Biosatellite D and F spacecraft for this mission. Funding for FY 1969 provided for the experiment development, the fabrication of Biosatellite D and F spacecraft, the system qualification testing of the prototype spacecraft for the primate mission (D and F), acceptance testing for the Biosatellite D flight spacecraft, and the field testing in preparation for launch, the launch, and orbital operations for Biosatellite D.

Funding for FY 1970 will provide for the continuation of experiment development as well as data analyses of the Biosatellite D flight results, and the acceptance testing and preparations for the launch of Biosatellite F. Funding requirements subsequent to FY 1970, for the completion of this effort, are estimated to be $8.8 million.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — SPACE APPLICATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Space Applications program are to: (1) conduct a broad program of research and technical development oriented toward the application of space techniques for the benefit of mankind; (2) expand the knowledge of atmospheric and space phenomena; (3) develop and test procedures, instruments, subsystems, spacecraft, and interpretive techniques for the various applications; (4) fulfill NASA's responsibilities under the Communications Satellite Act of 1962; (5) develop and implement for the Environmental Science Services Administration (ESSA), Department of Commerce, the operational meteorological satellite system; and (6) cooperate with the user government agencies such as the Departments of Agriculture, Commerce, Interior, and the Department of the Navy through the Earth Resources Survey Program Review Committee to achieve the practical benefits to mankind in earth resources.

Within the Space Applications program objectives, a number of current goals have been established which should be achieved in the near term. One or more goals have been established in each disciplinary area. In Meteorology the goals are: (1) to use infrared and microwave sounding techniques for global measurement of the vertical structure of the atmosphere via satellites, and (2) to develop, based on our successful experimentation with the Applications Technology Satellites (ATS), a first generation prototype operational Synchronous Meteorological Satellite (SMS) to permit continuous viewing of the global atmosphere and weather conditions. Achievement of the first goal will start to provide the three dimensional meteorological data which are needed for the fuller understanding of meteorological processes which can ultimately lead to long-term forecasting based on atmospheric models simulated numerically by computers. Achievement of the second goal will permit the continuous monitoring of cloud patterns associated with short-term, severe atmospheric disturbances such as thunderstorms and tornadoes; monitoring the tropics to detect hurricane development; and estimation of wind velocities by short-term tracking of small scale clouds.

In Communications a goal is to determine the many factors which affect efficient space use of the frequency spectrum, including the extension of that use into the millimeter wave region and ultimately up to optical wavelengths. It also includes study of the factors influencing allocation of positions in the geosynchronous orbit in order to minimize mutual interference between terrestrial and space communications systems sharing the same frequencies. A second communications goal is the development and test of improved technology for accurate stabilization and pointing of the large space erectable antennas which will be required on spacecraft. The purpose of these antennas is to improve the efficiency of radiated power in useful directions and to minimize interference radiation. A third goal is to

develop efficient satellite techniques for collecting data from many remote, unattended platforms. These remote platforms may include such devices as river guages, meteorological balloons, ocean buoys, and perhaps eventually large animals.

In navigation, which includes traffic control, a goal is to determine the utility of satellites for serving the aviation and maritime community needs for improved position determination, traffic control, and collision avoidance.

In geodesy the first goal is to complete the achievement of the National Geodetic Satellite program objectives which were established in 1964: the accurate determination of the shape of the earth and of the anomalies in its gravitational field. A second goal is to explore the utility of geodetic satellite technology and techniques to the solid earth sciences and oceanography. Satellite altimeters will be used to measure the shape of the ocean's surface, and to better determine and understand such things as the "wobble" of the earth's axis of rotation.

In the emerging area of Earth Resources Survey from space three goals have been established: (1) to establish the relative roles of aircraft and spacecraft for operational remote sensing of the earth's resources; (2) to provide systematically and simultaneously acquired data from a number of sensors on a single experimental spacecraft which will permit the user scientists to determine the potential of obtaining earth resources data from space; and (3) to develop efficient techniques for data processing, analysis, storage, and dissemination.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology/advanced studies. | $19,300,000 | $19,600,000 | $22,400,000 |
| TIROS/TOS improvements..... | 9,100,000 | 5,800,000 | 5,200,000 |
| Nimbus..... | 33,700,000 | 31,800,000 | 29,200,000 |
| Synchronous meteorological satellite..... | --- | --- | 3,600,000 |
| Meteorological soundings..... | 3,000,000 | 3,000,000 | 3,000,000 |
| Cooperative applications satellite..... | 100,000 | 100,000 | 100,000 |
| Applications technology satellites..... | 25,600,000 | 24,700,000 | 44,200,000 |
| Geodetic satellites..... | 3,400,000 | 2,400,000 | 3,000,000 |
| Earth resources survey..... | 5,300,000 | 11,200,000 | 25,100,000 |
| Aircraft program..... | (5,300,000) | (9,200,000) | (11,000,000) |
| Earth resources technology satellite..... | (---) | (2,000,000) | (14,100,000) |
| Total..... | $99,500,000 | $98,600,000 | $135,800,000 |

Distribution of Program Amount by Installation:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Manned Spacecraft Center..... | $5,771,000 | $10,545,000 | $12,300,000 |
| Marshall Space Flight Center. | 565,000 | 350,000 | 300,000 |
| Goddard Space Flight Center.. | 77,886,000 | 71,747,000 | 96,400,000 |
| Jet Propulsion Laboratory.... | 179,000 | 1,104,000 | 2,300,000 |
| Wallops Station..... | 405,000 | 524,000 | 400,000 |
| Ames Research Center..... | 100,000 | 100,000 | 100,000 |
| Electronics Research Center.. | 1,605,000 | 1,832,000 | 1,800,000 |
| Langley Research Center..... | 814,000 | 980,000 | 1,000,000 |
| Lewis Research Center..... | 1,215,000 | 1,125,000 | 1,100,000 |
| NASA Headquarters..... | 10,960,000 | 10,293,000 | 20,100,000 |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

| | | | |
|---|---|---|---|
| Applications technology..... | $730,000 | $915,000 | $900,000 |
| Communications..... | 2,745,000 | 3,090,000 | 3,100,000 |
| Earth resources..... | 7,361,000 | 7,060,000 | 9,800,000 |
| Geodesy..... | 999,000 | 1,530,000 | 1,500,000 |
| Meteorology..... | 5,163,000 | 4,800,000 | 4,900,000 |
| Navigation..... | 1,152,000 | 1,210,000 | 1,200,000 |
| Interdisciplinary applications. | 1,150,000 | 995,000 | 1,000,000 |
| Total..... | $19,300,000 | $19,600,000 | $22,400,000 |

Nearly every technique and space system in Space Applications must be preceded by Supporting Research and Technology (SR&T) effort. This effort includes supporting activities in all disciplines (Applications Technology, Communications, Earth Resources, Geodesy, Meteorology, and Navigation), and a number of interdisciplinary activities. The SR&T emphasizes activity in four major areas: (1) theoretical and applied research, (2) sensor and instrumentation development, (3) spacecraft technology, and (4) data processing and management.

The largest area is theoretical and applied research. Here, the main activity is in examining the feasibility of applications of space, through studies such as investigations of ERS signatures and development of inversion techniques of radiation measurements in meteorology. In sensors and instrumentation development, effort is on potential future spacecraft remote sensors, such as microwave radiometer and multispectral scanners. In spacecraft technology, work continues on subsystems for support functions, such as advanced tape recorders and phased array antennas. In data processing and management, effort continues in improving techniques for processing and analyzing space acquired data and their integration with data obtained from other sources. Such efforts include studies in multispectral correlation of images and indexing and storage of sensors and associated data.

The Space Applications SR&T project is a cohesive, integrated effort; assured by a system of reviews and evaluations of all tasks from a technological as well as from a disciplinary viewpoint. Significant examples of effort by discipline area are listed below.

In Applications Technology, effort continues in control systems directed at stabilization of spacecraft in orbit; spacecraft equipment developments to improve amplification and antenna system capabilities and increase the reliability and useful lifetime of satellite elements.

In Communications, effort is primarily in the active satellite area, and consists of system comparison and trade-off studies to determine the merits of advanced concepts, techniques applicable to small terminal multiple access communications; evaluation and development of components and subsystems required for broadcast applications; propagation studies and component development in the frequency region between 10 to 100 GHz where frequencies are more available for space communications, but much less understood; and interference analysis and prediction methods needed for developing sharing criteria.

In Earth Resources, studies will be continued in coordination with the user agencies to determine the spectrum of remote sensor requirements and the data processing techniques necessary to apply space technology to the fields of agriculture, forestry, geography, cartography, geology, hydrology, and oceanography. These studies will lead to improved interpretation and data reduction techniques for space acquired data; and the definition of user agency requirements in the various earth resources disciplines. Studies will continue in the definition of specific potential remote sensors and instrumentation that will be required to meet the needs of the participating user agencies. In FY 1970 new effort will emphasize the initiation of a major multidisciplinary effort which will lead to the development of an automatic data processing (ADP) capability including the definition of required software programs and ADP hardware. Identification of adequate data acquisition and handling systems are vital to the early and full realization of benefits to be gained from extension of space technology to earth resources. Data acquisition and handling problems requiring solution involve both high volumes of data and unique signatures of data.

In Geodesy emphasis is placed on conducting: (1) conceptual studies, feasibility analysis and configuration definition of geodetic spacecraft, (2) analysis of geodetic requirements by various disciplines in terms of spacecraft mission, (3) analysis of feasibility and effectiveness of geodetically optimized ground based spacecraft observation systems, and (4) research into geodetic effectiveness and feasibility of advanced observations systems and techniques, to provide more precise and densified measurement of geodetic data, and to calibrate geodetic observation methods intended for extraterrestrial use.

In Meteorology effort is concentrated on: (1) the development and evaluation of components for potential meteorological satellite system application; (2) investigation of scientific techniques and tools for the systematic observation, analysis and subsequent interpretation of meteoroligical

atmospheric phenomena; and (3) optimization system analyses.

In Navigation, studies and experiment development will be conducted on data and voice transmission via satellite to ships, aircraft, and other mobile platforms; position determination techniques; future navigation and traffic control satellite concepts.

The purpose of the Interdisciplinary Applications is to conduct interdisciplinary studies and research relating to several of the applications disciplines, such as the Space Applications Summer Study effort conducted in coordination with the National Academy of Sciences, and study and support to the Barbados Oceanographic/Meteorological Experiment (BOMEX).

TIROS/TOS Improvements

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| TIROS M spacecraft..... | $7,818,000 | $4,300,000 | $1,200,000 |
| TOS improvements..... | 1,282,000 | 1,500,000 | 4,000,000 |
| Total Spacecraft and Support | $9,100,000 | $5,800,000 | $5,200,000 |
| Delta (Launch Vehicle Procurement Program)..... | ($1,100,000) | ($1,100,000) | (---) |
| Total (including launch vehicles)..... | ($10,200,000) | ($6,900,000) | ($5,200,000) |

The objectives of this project are to: (1) provide research and development toward advanced meteorological satellite systems, particularly in support of the TOS program; (2) provide maximum interim operational data for use in weather analysis and forecasting; (3) measure emitted infrared and reflected solar radiation in selected spectral regions; and (4) observe cloud cover and patterns, and measure the earth-atmosphere heat balance.

Nine TIROS research and development spacecraft funded by NASA and nine operational spacecraft funded by ESSA have been successfully launched. Current development effort by NASA is to complete the advanced TIROS M spacecraft for launch in second quarter of calendar year 1969. This spacecraft contains Automatic Picture Transmission (APT), Advanced Vidicon Camera System (AVCS) and High Resolution Radiometer (HRR) system, flat plate radiometer and solar proton monitor. Flight test of these sensors in a single spacecraft will provide the technology for incorporating this combination of sensors in future operational meteorological satellites. This improvement will provide for global imaging both day and night into a single spacecraft effecting a corresponding improvement in weather forecasting ability. Under TIROS Operational System (TOS) improvements effort will be continued in the development of advanced sensors and subsystems such as high resolution radiometers and attitude determination systems which will be incorporated into future



332-276 O - 69 - 14

operational spacecraft. In FY 1970 effort will be initiated on a system definition study (TIROS N) to determine the requirements for a third generation operational spacecraft. A study of this type is required in FY 1970 to permit the proper time phasing of the system developments necessary to provide the technology for global operational coverage in the 1973-74 time period.

The Office of Space Science and Applications is responsible for the overall management of this project. Responsibility for project management is assigned to the Goddard Space Flight Center. The major spacecraft contractor is Radio Corporation of America.

FY 1967 and prior year NASA funds for TIROS I through IX, TIROS M and TOS Improvements, including launch vehicles, amounted to $48.2 million. FY 1969 funds are being utilized to complete the TIROS M spacecraft and sensors, integration, test and launch of this spacecraft and initial data acquisition and for continued development of sensors under TOS Improvements. FY 1970 funds are required for post launch support and data acquisition and handling for TIROS M, for continued sensor and subsystems development for TOS Improvements, and for a systems definition study for a future spacecraft system. Subsequent years' funding requirements for TIROS M are estimated to be about $.4 million.

Nimbus

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft | $21,600,000 | $23,600,000 | $17,400,000 |
| Experiments | 9,700,000 | 6,900,000 | 8,800,000 |
| Ground operations and support | 2,400,000 | 1,300,000 | 3,000,000 |
| Total | $33,700,000 | $31,800,000 | $29,200,000 |
| TAT - Agena and Delta (Launch Vehicle Procurement Program) | ($2,232,000) | ($4,743,000) | ($4,901,000) |
| Total (including launch vehicles) | ($35,932,000) | ($36,543,000) | ($34,101,000) |

The objectives of this project are to develop a significantly improved meteorological satellite to provide data for use by the scientific community; to carry out flight tests to prove the applicability of the instrumentation; to fulfill special data requirements of the atmospheric sciences research community which can be provided uniquely by this instrumentation functioning as a space meteorological observatory, and to provide the basis for further significant technological advances in meteorological satellites for operational as well as scientific uses. These objectives will be extended in the Nimbus E and F missions to develop an applications observatory in polar orbit at low to medium altitude that will flight test technology and experiments for meteorology and other applications disciplines.

This project includes development, launch, and operation of a series of meteorological satellites exhibiting evolutionary advances in operating characteristics, and testing in orbit sophisticated experiments for atmospheric research and operational demonstration. The satellite serves as a flexible space observatory on which a variety of advanced concepts for measuring atmospheric parameters can be tested. The satellite consists of three major subsystems, namely power, stabilization, and a sensory ring which can accommodate a number and variety of advanced sensors.

Seven spacecraft are in the series of which two have been successfully launched: Nimbus I, August 28, 1964, and Nimbus II, May 15, 1966. A third spacecraft, launched May 18, 1968, was lost due to a launch vehicle failure. In June 1968, NASA approved launch of a replacement spacecraft by largely using flight spares or updated prototype subsystems and experiments. This mission, identical to the Nimbus B configuration, has been designated B2 and is scheduled for launch in the spring of 1969. This replacement was necessary in order not to delay the flight test of that group of selected experiments and technological advances vital to the meteorological research and development program and required for long range weather forecasting. In addition, Nimbus D is scheduled to be launched in CY 1970, E in 1972, and F in 1973. Nimbus B2 will flight test experiments to determine the vertical temperature structure of the atmosphere, remote sensors to measure radiation reflected and emitted by the earth and its atmosphere, an improved cloud cover imaging system, and a worldwide data collection system. Nimbus D, using the same basic spacecraft design, will test advanced concepts of some of these experiments for determining the vertical temperature structure as well as additional experiments such as a temperature/humidity infrared radiometer, a monitor of the water content of the atmosphere, and a more refined worldwide data collection system that will include the first meaningful spacecraft wind measurement experiment. Nimbus E and F will test passive microwave and spectroscopy experiments designed to allow penetration of cloud layers for the global determination of the vertical structure of the atmosphere from ground or sea level.

The Office of Space Science and Applications is responsible for overall management of this project. Responsibility for project management is assigned to Goddard Space Flight Center. The major contractor for spacecraft structure and integration and test of spacecraft is the General Electric Company and the Radio Corporation of America for power and data storage subsystems.

FY 1967 and prior year funding, including launch vehicles, amounted to $177.5 million. FY 1968 and prior year funds were utilized for design, development, and launch of the first three spacecraft, data acquisition and analysis from Nimbus I and II, continued development of the Nimbus D spacecraft and design studies for the Nimbus E and F spacecraft. FY 1969 funds are being utilized to develop, test and launch the Nimbus B2 spacecraft and associated experiments and for initial data acquisition; continue development of the Nimbus D spacecraft and to initiate hardware development in the Nimbus E and F spacecraft program to include the selected experiments. FY 1970 funds are required for continued data acquisition and analysis of the Nimbus B2

spacecraft in orbit; complete the development, test and launch of Nimbus D, and continue the development of Nimbus E and F spacecraft and selected experiments. Subsequent years' funding requirements for this project, including launch vehicles, are estimated to be $58.6 million.

Synchronous Meteorological Satellite

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft and support..... | --- | --- | $3,600,000 |
| Total..... | --- | --- | $3,600,000 |

The objectives of the Synchronous Meteorological Satellite (SMS) are to (1) demonstrate a prototype operational SMS, (2) permit continuous observation of major weather systems routinely thus enhancing the ability to predict and locate severe short-lived storms, (3) derive important wind field data over considerably large areas and in much less time than heretofore possible, and (4) provide capability for rapid dissemination of processed meteorological data to local meteorologists.

A feasibility study and a project definition study were completed by GSFC in-house in FY 1968. In FY 1970 it is planned to undertake the design and development of two SMS satellites capable of continuous weather observation routinely, analysis of cloud motions through observations to permit derivation of important wind fields, and for obtaining other significant meteorological data from synchronous altitude. Two Delta launch vehicles will be utilized to launch the SMS into synchronous orbit, one planned for launch in 1971, and one in 1972.

No FY 1969 and prior year funds were utilized for this project. FY 1970 funds will be used for initiating the design and development of two SMS spacecraft. Funding requirements for future years, including launch vehicles, are estimated to be about $18.8 million.

Meteorological Soundings

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Large research sounding rockets..... | $2,091,000 | $2,050,000 | $2,050,000 |
| Small sounding rocket systems. | 714,000 | 730,000 | 730,000 |
| Field experiment support..... | 195,000 | 220,000 | 220,000 |
| Total..... | $3,000,000 | $3,000,000 | $3,000,000 |

The objectives of this project are to determine the structure and characteristics of the atmosphere in the 30 to about 100 km region through the use of research and development type sounding rockets and to develop a meteorological sounding rocket system amenable to research, range support, and routine operational requirements.

Three areas of effort are involved:

(a) Large research sounding rockets to explore the characteristics and phenomena of the atmosphere between 30 and about 100 km. This region is important to meteorological science, and cannot be reached except by sounding rocket. Nike Apache and occasionally Aerobee class rockets are used to explore the relations and mechanisms operating between and within the various regions of the atmosphere, the effects of solar energy and its variations upon the structure and circulation in the atmosphere.

(b) Small sounding rocket systems are utilized to obtain measurements in the region of approximately 30 to 60 kilometers above the earth. Included in this effort is the development of an inexpensive operational meteorological sounding rocket system capable of reliable launches amenable to the requirements for range support, research and network operations.

(c) The sounding rocket field experiment support, which through cooperation with other countries, provides for the establishment of self-sustaining capabilities for coordinated meteorological sounding rocket launches from sites that will contribute mutually valuable data.

The Office of Space Science and Applications is responsible for the overall management of the project. Project management for large research rockets is assigned to Goddard Space Flight Center, for small sounding rocket system development to Langley Research Center, and for field experiment support to Goddard Space Flight Center and Wallops Station.

FY 1967 and prior year funding amounted to $12.0 million of which $9.3 million was utilized for large research rockets, $2.3 million for small rocket development and $.4 million for field experiment support. Approximately 50 large research rockets and about 125 small development rockets are launched each year. FY 1969 and prior years' funds were utilized to launch large research and small developmental sounding rockets, develop and improve sounding rocket systems, and for continuation, extension, and development of field experiment projects in cooperation with countries in South America, Europe and Asia. FY 1970 funds are required to procure additional large research and small developmental rockets, flight test various payload experiments, improve rocket performance and to continue field experiment projects with other cooperating countries to obtain additional atmospheric research data. Subsequent year funding requirements will continue at approximately $3.0 million per year.

Cooperative Applications Satellite

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft and support..... | $100,000 | $100,000 | $100,000 |
| Scout (Launch Vehicle Procurement Program)..... | (---) | (---) | ($2,000,000) |
| Total (including launch vehicles)..... | ($100,000) | ($100,000) | ($2,100,000) |

This project was entitled International Applications Satellite in the FY 1969 budget. This cooperative project between the United States and France in space meteorology consists of developing instrumented balloon techniques to be utilized in conjunction with an earth orbiting satellite for the purpose of obtaining the characteristics of air masses, particularly in-situ measurement of speed and wind direction at various altitudes. The meteorological data obtained will be used by the U.S. and French scientists to assist in understanding the structure of the atmosphere and extending weather forecasting capability.

One spacecraft and one backup with instruments will be provided by France. The spacecraft will be launched by NASA in 1970 using a Scout vehicle from Wallops Island into a 900 km circular, 47 degree inclination orbit to gather data from approximately 500 balloons. The instrumented balloons will be developed and launched by France in the Southern Hemisphere. Satellite tracking and data acquisition, reduction and analysis will be by France, after initial tracking by NASA. The U.S. will provide the Scout launch vehicle, and back-up if required, launch services, initial satellite tracking, and analysis along with France, of the reduced data.

The Office of Space Science and Applications is responsible for the overall management within NASA. Responsibility for project management is assigned to Goddard Space Flight Center.

This project was initiated in FY 1967. FY 1968 and prior year funds were utilized for balloon subsystem studies and analysis of balloon and spacecraft antenna, and electronics and for general project support. The FY 1969 funds were utilized to continue this effort. FY 1970 funds are required to continue technical support and provide for launch and post launch support and for a Scout launch vehicle.

Funding requirements for future years are estimated to be about $.3 million for support and launch vehicle funding.

Applications Technology Satellites

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft | $12,300,000 | $13,400,000 | $19,100,000 |
| Experiments | 12,200,000 | 8,400,000 | 21,200,000 |
| Operational support | 1,100,000 | 2,900,000 | 3,900,000 |
| Total | $25,600,000 | $24,700,000 | $44,200,000 |
| Atlas Centaur and Titan IIIC (Launch Vehicle Procurement Program) | ($6,500,000) | ($596,000) | ($5,900,000) |
| Total (including launch vehicles) | ($32,100,000) | ($25,296,000) | ($50,100,000) |

The overall objectives of this project are to design, develop, flight test and evaluate a variety of scientific and technological experiments in the space applications disciplines by use of a series of spacecraft, most of which are launched into synchronous orbit. Seven spacecraft are in the series of which four have been launched. Due to launch vehicle anomalies, the planned medium altitude orbit for ATS II launched April 6, 1967, and synchronous orbit planned for ATS IV launched August 10, 1968, were not achieved and the spacecraft have been of limited experimental value. ATS I, launched December 7, 1966, and ATS III, launched November 5, 1967 into synchronous orbits have performed very successfully. Three additional spacecraft are being developed: ATS-E for launch in CY 1969, F in 1972 and G in 1974. Planned effort in FY 1970 includes the completion and launch of ATS-E. This spacecraft will flight test an experimental three-axis gravity gradient stabilization system for spacecraft in geostationary orbit. It will also flight test in synchronous orbit, a variety of experiments such as millimeter wave, L-band communication, measurements of the geostationary environment, and heat pipe technology.

Effort in FY 1970 for ATS F&G will include completion of the detailed design, and initiation of the fabrication phase of the spacecraft and of the experiments for ATS-F. The design of experiments for ATS-G will also be initiated. Modifications of the three ATS ground stations will be initiated in order to permit operation with the additional frequencies required by the experiments in ATS F&G. ATS F&G, utilizing three-axis active spacecraft stabilization, will be launched into synchronous orbit and will flight test a space erectable parabolic antenna of approximately 30 feet in diameter and capable of accurate pointing to about .1 degree of arc. In addition, a number of additional scientific and technological experiments will be flight tested on these missions. Effort will continue in FY 1970 to develop promising advanced experiments which have been defined but have not been assigned to a specific flight mission. These efforts will be largely directed toward demonstrating proof of concept for such applications as community TV broadcasting, navigation and traffic control, and orbiting data relay systems.

The Office of Space Science and Applications is responsible for overall program management. Responsibility for project management is assigned to Goddard Space Flight Center. The major contractors for the first five flight ATS missions are Hughes Aircraft Company for spacecraft development and General Electric Company for gravity gradient stabilization system development.

ATS F&G design effort is being performed by Fairchild Hiller and General Electric Company.

FY 1967 and prior year funding for this project, including launch vehicles amounted to $133.7 million. FY 1968 and prior years funds were utilized to design, develop, launch, test, and evaluate the experiments on the first three spacecraft. FY 1969 funds were utilized for final assembly, launch, test and evaluation of the fourth spacecraft. FY 1970 funds are required to complete development of the ATS-E spacecraft and associated experiments in preparation for launch in the third quarter CY 1969 and to complete the

spacecraft design for ATS F&G and initiate development of these spacecraft and selected experiments, and for continuation of advanced applications experiment effort. Subsequent years' funding for this project, including launch vehicles, is estimated to be approximately $92.2 million not including the continued advanced applications experiment effort.

Geodetic Satellites

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft and support..... | $3,400,000 | $2,400,000 | $3,000,000 |
| Delta (Launch Vehicle Procurement Program)..... | ($1,000,000) | (---) | (---) |
| Total (including launch vehicles)..... | ($4,400,000) | ($2,400,000) | ($3,000,000) |

The objectives of this project are to support the National Geodetic Satellite Program (a joint NASA/DOD/DOC program under NASA management) and to develop the application of geodetic satellite techniques to solid-earth geophysics and oceanography.

Three geodetic satellites have been launched, PAGEOS I, June 23, 1966; GEOS I, November 6, 1966; and GEOS II, January 11, 1968. Both GEOS I and II carried similar geodetic instrumentation which included optical beacons, geometric and gravimetric instrumentation, range and range rate transponders, laser retro-reflectors and Doppler beacons. In addition GEOS II carried two C-Band transponders, a radar passive reflector and a laser detector. Data obtained from these launches are utilized in the establishment of a unified worldwide geodetic datum. Effort will be initiated in FY 1970 for an additional mission (GEOS-C) for launch in late CY 1970, to obtain the additional data required to meet the gravimetric objective of the National Geodetic Satellite Program, and to demonstrate the feasibility of employing a geodetic satellite radar altimeter to measure the mean sea level of the oceans.

The Office of Space Science and Applications is responsible for the overall program and for project management.

FY 1967 and prior year funds including launch vehicles amounted to $19.4 million. FY 1968 and prior year funds were utilized to design, develop, launch, and obtain data from the three spacecraft. FY 1969 are utilized for continued data acquisition and analysis of data from these spacecraft and for refurbishment of the GEOS-B backup spacecraft for the GEOS-C mission. Fiscal Year 1970 funds are required for continued data acquisition and analysis, and for preparations for the GEOS-C mission. Funding requirements for future years, including launch vehicles, are estimated to be $9.0 million.

## Earth Resources Survey

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Earth resources survey/aircraft | | | |
| Operations | $500,000 | $1,300,000 | $1,800,000 |
| Data processing | 1,600,000 | 1,900,000 | 2,650,000 |
| Sensors | 3,200,000 | 6,000,000 | 6,550,000 |
| Subtotal | $5,300,000 | $9,200,000 | $11,000,000 |
| Earth resources technology satellites | | | |
| Spacecraft | --- | $2,000,000 | $6,500,000 |
| Experiments | --- | --- | 5,900,000 |
| Ground operations | --- | --- | 1,700,000 |
| Subtotal | --- | $2,000,000 | $14,100,000 |
| Total, Earth Resources Survey | $5,300,000 | $11,200,000 | $25,100,000 |

The objectives of this project are to: (1) assess the practical value of remote sensing of earth resources from space, (2) compare the capabilities in earth resources data acquisition of a space system vs aircraft, (3) determine whether or not, and in what configuration an operational space-assisted and user-oriented earth resources survey system should be pursued, (4) determine which remote sensors are most effective for earth resources surveying, (5) develop and improve data handling procedures, and (6) ensure full understanding of operational system requirements and costs.

This project consists of two activities in the earth resources disciplines: (1) an aircraft program to develop and test remote sensing techniques, sensors, and data handling systems and to conduct aircraft flights at altitudes of from 500 feet to above 50,000 feet altitude and (2) to design, develop, launch, and evaluate experiments by Earth Resources Technology Satellites.

The objectives of the Earth Resources Technology Satellite (ERTS) are to design, develop, launch and test a series of spacecraft capable of conducting a variety of predetermined experiments in the earth resources disciplines. In FY 1969, a definition and preliminary design study is being conducted. Starting in FY 1970, effort will be initiated on procurement of two spacecraft and associated sensors for launch in CY 1971 and 1972. These missions will result in a major advancement in our understanding of the overall subject of earth resources survey from space. Instruments operating in the visible, infrared, and microwave frequencies will be flight tested.

The objectives of the aircraft project are to promote the development, modification, calibration, and testing of remote sensors planned for future space missions and to contribute to the development of data handling and analysis techniques needed before earth resources space hardware becomes available. Three aircraft are utilized in this activity, each equipped with



332-276 O - 69 - 15

a variety of sensors and data handling subsystems to obtain earth resources data. Aircraft flights are conducted over a number of domestic and foreign test sites.

FY 1968 funds were utilized for operation of two aircraft, for sensor procurement and data handling systems. FY 1969 funds are being utilized to continue this effort, procure additional sensors, and modify a high altitude aircraft to obtain a better understanding of atmospheric effects on remote sensing capability.

The Office of Space Science and Applications is responsible for the overall management of this project. Responsibility for execution of the ERS/Aircraft project is assigned to Manned Spacecraft Center. Responsibility for management of the ERTS project is assigned to Goddard Space Flight Center. Effort in the earth resources survey is coordinated with other user agencies through the Earth Resources Survey Program Review Committee which includes representatives from Departments of Agriculture, Commerce, Interior, and Navy, and is chaired by NASA.

FY 1970 funds are required to continue aircraft operations, sensor procurement, and data processing to conduct about 50 flights over 60 test sites, and to initiate spacecraft and sensor hardware procurement for two ERTS spacecraft. Funding requirement to complete the ERTS, including launch vehicles, is about $31.6 million.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1970 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS LAUNCH VEHICLE PROCUREMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Launch Vehicle Procurement program is to provide launch vehicles for space missions. The program includes the procurement of vehicle hardware, launch services, engineering and maintenance support, in addition to providing for the product improvement of vehicle and ancillary ground support equipments. The program also includes Supporting Research and Technology/Advanced Studies effort to analyze future mission requirements and investigate new technological developments. Those vehicles currently being procured are: Scout, Delta, Thor Agena and Centaur. In addition to these vehicles, the Titan III C will also be procured in FY 1970.

NASA's goal is to provide launch vehicles in the most efficient and economical manner possible. One of the most important considerations in the management of this program is that of trying to determine the optimum number of vehicles to be ordered on each production contract. Before such an order is placed, the following factors are considered: (1) current and projected inventories, (2) launch schedules, (3) procurement lead times required for vehicle delivery, and (4) the most economical production rates for NASA's vehicle contractors.

The FY 1970 budget for the Launch Vehicle Procurement program is subdivided as follows: (1) Vehicle Hardware, (2) Supporting Activities, and (3) Major Product Improvement. This approach to budget presentation is a change from prior years.

Funding related to Vehicle Hardware can be identified and prorated to specific missions. It is, therefore, shown parenthetically in the budget requests of the various spacecraft missions in addition to being presented in the Launch Vehicle Procurement request in total. Funding requirements for Supporting Activities and Major Product Improvement are not included in the parenthetical notations shown with spacecraft projects since these efforts are not readily proratable to specific missions.

The Supporting Activities category includes funds to cover recurring costs, which are operational in nature, such as launch services, guidance services, engineering support, launch complex maintenance, and range support. Unlike the cost of hardware, these costs are relatively insensitive to launch rate and are based more on the establishment of a capability rather than upon a series of fixed end items.

Major Product Improvement efforts are also conducted to update our launch vehicle reliability and performance to support mission objectives adequately.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology/advanced studies | $4,350,000 | $4,000,000 | $4,000,000 |
| Scout | 10,200,000 | 12,600,000 | 15,700,000 |
| Delta | 33,696,000 | 24,000,000 | 33,700,000 |
| Agena | 7,999,000 | 11,900,000 | 7,300,000 |
| Centaur | 68,305,000 | 47,700,000 | 57,600,000 |
| Titan III C | --- | --- | 5,900,000 |
| Total | $124,550,000 | $100,200,000 | $124,200,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| John F. Kennedy Space Center | $4,482,000 | $4,400,000 | $4,500,000 |
| Marshall Space Flight Center | 60,000 | 200,000 | 200,000 |
| Goddard Space Flight Center. | 30,854,000 | 22,600,000 | 32,200,000 |
| Jet Propulsion Laboratory... | 180,000 | 200,000 | 200,000 |
| Electronics Research Center. | 1,663,000 | 1,300,000 | 1,300,000 |
| Langley Research Center..... | 10,528,000 | 12,900,000 | 15,900,000 |
| Lewis Research Center..... | 73,552,000 | 57,000,000 | 68,100,000 |
| Headquarters..... | 1,565,000 | 1,600,000 | 1,800,000 |
| NASA Pasadena Office..... | 1,666,000 | --- | --- |

The overall plan for launches during this period is:

| Vehicle | Calendar Year 1968 | Calendar Year 1969 | Calendar Year 1970 |
|---|---|---|---|
| Scout | 6 | 2 | 8 (+2 B/U) |
| Delta | 3 | 7 | 5 |
| Agena | 2 | 3 | 1 |
| Centaur | 3 | 4 | - |
| Titan | - | - | - |
| Total | 14 | 16 | 14 (+2 B/U) |

Above table includes Advanced Research and Technology missions but excludes reimbursable launches and vehicles procured for other agencies.

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Advanced studies..... | $648,000 | $800,000 | $800,000 |
| Propulsion and energy conversion..... | 249,000 | 700,000 | 800,000 |
| Guidance, control and navigation..... | 1,562,000 | 1,500,000 | 1,600,000 |
| Instrumentation and electronics | 690,000 | 200,000 | 100,000 |
| Structures and materials..... | 470,000 | 400,000 | 600,000 |
| Vehicle engineering..... | 731,000 | 400,000 | 100,000 |
| Total..... | $4,350,000 | $4,000,000 | $4,000,000 |

Launch vehicle requirements in support of future missions are assured through this advanced studies and research and technology program. This program is established to define the vehicles most suitable to accomplish our current and future missions and to further insure that new technology required for advanced missions is developed in a timely and orderly manner.

In FY 1969 advanced studies are being done on the Saturn S-IVB/Centaur Integration and the Multi-Mission Solar-Electric Propulsion Spacecraft System. Supporting research and technology work is being continued on the development of a strapdown inertial guidance system for small and medium class launch vehicles. Effort is also being continued on aerospace propulsion system and mission analysis research, computation of performance of low-thrust propulsion systems, development of computer programs for trajectory analysis, water injection for solid rocket motor velocity trim, and throttling techniques for hydrazine reactors and a variety of other related tasks.

In FY 1970 advanced studies will be continued in the areas of high-energy upper stages, including both chemical and electric propulsion systems. Supporting research and technology work that will be conducted in FY 1970 includes continuation of work on development of throttling techniques for hydrazine reactors, the development of a strapdown inertial guidance system for small and medium class launch vehicles, evaluation of astrionics systems requirements for automated missions, trajectory analysis research, electro-explosives test technique improvement, and evaluation of nozzle materials for a small launch vehicle. Effort will be initiated on a study of improved methods of design and fabrication of solid fuel rocket motors, investigation and improvement of a solid propellant motor for use on a small launch vehicle package, planetary spacecraft propulsion module, flightweight end-burning rocket motor demonstration, study to determine the feasibility of reducing control system thrust levels, solid state switching system for use in space vehicles, development of an improved material for use in space vehicles, development of an improved material for use in solid rocket nozzle inserts, study of pressure rise and heat transfer characteristics of hydrogen in space

vehicles, and demonstration of full-scale thermal protection system for storage of liquid hydrogen.

Scout

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Hardware procurement..... | $3,800,000 | $3,900,000 | $7,700,000 |
| Supporting activities..... | 5,900,000 | 7,900,000 | 7,200,000 |
| Product improvement..... | 500,000 | 800,000 | 800,000 |
| Total..... | $10,200,000 | $12,600,000 | $15,700,000 |

Scout is the smallest launch vehicle in the NASA vehicle family and the only one utilizing all solid propellants. It has launched a variety of small scientific satellites, space probes, and high speed re-entry experiments. From the launching of the first Scout vehicle on July 1, 1960 thru December 1968, there have been 65 launches. NASA has primary responsibility for the management of the Scout project, which is also utilized to support missions for the DOD, AEC, foreign countries, and international organizations.

The Langley Research Center has managed the Scout project for NASA since its inception. The prime contractor for the production, checkout, and launch of Scout vehicles is Ling-Temco-Vought (LTV), Dallas, Texas. Scout vehicles are launched by NASA from the Western Test Range, California or Wallops Station, Virginia. A Scout vehicle has also been launched from the Italian San Marco platform in the Indian Ocean off the coast of Africa, where additional launches are planned.

In FY 1969, funds for procurement of Scout vehicles are being utilized for the production, assembly, checkout, and launch of the vehicle. In addition, funds are being expended for contractor systems management, vehicle adaptation for individual missions, maintenance of ground equipment at the two U.S. launch sites, logistics, transportation, management and engineering support, and minor improvements in the Scout vehicle. Major product improvements being accomplished include uprating the Algol first stage by increasing its diameter four inches.

In FY 1970, Scout funds will be utilized to procure vehicle hardware, production systems engineering and management, vehicle checkout and launch services, and system maintenance and engineering. In addition, the improvement efforts on the Algol first stage will be continued.

Delta

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Hardware..... | $11,400,000 | $8,852,000 | $12,000,000 |
| Supporting activities..... | 18,516,000 | 10,883,000 | 16,700,000 |
| Product improvement..... | 3,780,000 | 4,265,000 | 5,000,000 |
| Total..... | $33,696,000 | $24,000,000 | $33,700,000 |

The Delta vehicle family has proven to be one of the most economical, versatile, and reliable members of the NASA launch vehicle stable. Its flight configuration consists of the Thor booster, the Delta second stage, and a third stage, if necessary. If the third stage is required, a United Technology FW-4 or a Thiokol TE-364 motor may be utilized depending upon mission requirements. These configurations are capable of lifting a wide variety of payloads into earth orbit or launching small spacecraft into lunar orbit or deep space. To date the Delta vehicle has successfully launched more meteorological, communications, and scientific spacecraft than any other NASA vehicle. Through December 1968 there have been 63 Delta vehicle launches of which 58 have been scored as successful.

Management responsibility for the Delta project is assigned to the Goddard Space Flight Center. The prime contractor for the Delta vehicle is the McDonnell-Douglas Astronautics Company, Santa Monica, California. NASA procures the first stage Thor boosters through the Air Force, which has management responsibility for the production of this vehicle stage. The Delta vehicle is launched from the Eastern Test Range, Cape Kennedy, Florida and the Western Test Range, California.

FY 1970 funds for procurement of Delta will be used to complete the purchase of first and second stage vehicles for which contracting was initiated in FY 1969, and to procure associated vehicle hardware, launch services, and other supporting services at the launch sites and production facilities.

During FY 1970, support funding is required for the maintenance of ground support equipment at the two launch sites, for vehicle-related engineering support, and for minor product improvement efforts. Major product improvement planned for FY 1970 includes a continuation of effort initiated in FY 1969 for incorporation of an updated guidance system, adaptation of the booster for additional solid motors for thrust augmentation, conversion to S-band telemetry, modification of Pad 17-B to accommodate the long tank Thor (Thorad) booster, and the flight qualification of the uprated TE-364 motor. There are no plans to initiate any new product improvement efforts in FY 1970.

Agena

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Hardware procurement..... | $5,279,000 | $5,770,000 | $2,751,000 |
| Supporting activities..... | 2,720,000 | 6,130,000 | 4,549,000 |
| Total..... | $7,999,000 | $11,900,000 | $7,300,000 |

The Thor Agena launch vehicle is used for polar orbital missions which exceed the capability of the Delta vehicle. The Agena project previously included funding for the Atlas Agena launch vehicle which was phased out of NASA usage following the successful launch of the OGO V satellite from the Eastern Test Range on March 4, 1968. Atlas Agena launch facilities at the

Eastern Test Range have since been returned to Air Force custody. The Thor Agena continues to be launched from the Western Test Range, California. During CY 1969, the Nimbus B2, OGO-F, and SERT II missions will be launched by the Thor Agena.

Within NASA the management of the Agena project is assigned to the Lewis Research Center. Lockheed Missiles and Space Corporation, Sunnyvale, California is the prime contractor for the Agena stage. McDonnell-Douglas Astronautics Company, Santa Monica, California is the prime contractor for the Thor booster. The Agena and the booster stages are purchased from these contractors through the U.S. Air Force, which has primary management responsibility of these vehicles.

FY 1969 funds support the procurement of vehicle hardware, mission peculiar adaptation, launch services and other support required for planned launches.

FY 1970 funds for procurement of Agena vehicles are required for the purchase of upper stages and Thor boosters. In addition, funds will be required for mission peculiar adaptation, launch services, and other support activities including maintenance of ground support equipment, engineering services, and minor improvements in support of the continued utilization of the Thor Agena launch vehicle.

Centaur

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Hardware..... | $21,274,000 | $27,956,000 | $21,409,000 |
| Supporting activities..... | 40,341,000 | 15,373,000 | 13,841,000 |
| Product improvement..... | 6,690,000 | 4,371,000 | 22,350,000 |
| Total..... | $68,305,000 | $47,700,000 | $57,600,000 |

The Atlas Centaur is the largest launch vehicle currently employed by NASA exclusively for automated space missions. It consists of the Atlas booster and the Centaur upper stage. Centaur was the first rocket in the national launch vehicle family to utilize liquid hydrogen/liquid oxygen propellants. These high energy propellants and the Centaur's capability to restart in space make this vehicle uniquely qualified to perform a variety of high velocity deep space missions as well as relatively large earth orbit and lunar missions. Since development was completed in 1966, the Centaur has been launched nine times in support of the Surveyor, the Orbiting Astronomical Observatory (OAO), and the Advanced Technology Satellite (ATS) missions. All flights were successful except for the ATS mission when the Centaur stage failed to ignite for its second burn. Future Atlas Centaur missions include Mariner-Mars, Pioneer, follow-on OAO and ATS missions, Helios, and several proposed space probe missions.

The Lewis Research Center has primary management responsibility for the Centaur project. The prime contractor for both the Atlas booster and the Centaur stage is General Dynamics/Convair, San Diego, California. The Pratt and Whitney Division of United Aircraft, West Palm Beach, Florida is an associate contractor for Centaur's liquid hydrogen engines. Honeywell, Inc., St. Petersburg, Florida is an associate contractor for the Centaur guidance system. The Atlas Center is launched from the Eastern Test Range, Cape Kennedy, Florida.

FY 1969 funds include vehicle procurement to support OAO, ATS, Mariner '69 and Mariner '71 missions. In addition, contractor launch services and vehicle support funds are required to continue vehicle improvements initiated in FY 1968.

During FY 1970, continued funding is required for supporting activities such as launch services, management and engineering services at the contractor plant, and for a variety of other program and field support services. Included in this budget are the vehicle improvement and vehicle integration efforts which were carried on in FY 1969. In particular, the Centaur improvements include a new guidance computer, pulse code modulation telemetry equipment, a standard forward adapter, fixed insulation, and a changed pressurization system. This modernization will enhance the reliability and flexibility of this vehicle.

FY 70 funds are included to provide for the introduction of the Titan family of boosters into the NASA launch vehicle stable. Integration of the Centaur stage with the Titan booster is being initiated to support the Viking mission. This effort will provide for the detailed design, hardware, testing, and documentation required to establish and qualify this launch vehicle configuration for flight. In addition, funds will be required for the activation of one operational launch site at the existing USAF Eastern Test Range Titan III launch complex compatible with the NASA program requirements. It is currently planned to fly the first Titan Centaur vehicle configuration in early 1972 in support of the Pioneer F mission.

| | Titan III C | | |
|---|---|---|---|
| | 1968 | 1969 | 1970 |
| Hardware procurement..... | --- | --- | $5,900,000 |
| Total..... | --- | --- | $5,900,000 |

The Titan launch vehicle family development is managed by the United States Air Force. The Titan III C vehicle consists of three liquid propellant stages and a solid propellant stage. The solid stage consists of two five-segment, 120-inch rocket motors strapped onto the liquid propellant core. The first two liquid propellant stages are common to all Titan III vehicles. The third liquid propellant stage is the transtage which possesses a multi-start capability useful for a wide variety of mission applications.



332-276 O - 69 - 16

The performance of the Titan III C vehicle is somewhat higher than that of the Atlas Centaur vehicle at the synchronous velocity and the initial NASA use is planned for Applications Technology Satellites F and G, scheduled for launch in 1972 and 1974. Future plans include the possible use of Titan III C vehicles for other synchronous orbit satellites exceeding the Atlas Centaur weight capability.

The Lewis Research Center has primary NASA management responsibility for the Titan III C project. Vehicles will be procured through the USAF, with Martin Marietta Corporation, Denver Division, Denver, Colorado as the prime contractor. The United Technology Corporation, Sunnyvale, California and Aerojet General Corporation, Sacramento, California are associate contractors providing solid boosters and core stage engines, respectively. Martin will provide mission integration services; Martin, with UTC and AGC, will also provide launch services. Launches will be from the Titan ITL (Integrate-Transfer-Launch) facilities at the Eastern Test Range.

During FY 1970, funds are required to initiate procurement of vehicles and services for the ATS F and G missions.

OFFICE OF UNIVERSITY AFFAIRS SUSTAINING UNIVERSITY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

NASA-University Programs

The NASA-university programs have made major contributions to the national aeronautics and space effort. They have generated new concepts, developed new technology, supported graduate education, and have created special university facilities for further education and research. The university community has provided policy, scientific, and engineering advice to NASA at all levels. These contributions demonstrate that NASA's university programs have been successful in their first and most important objective - obtaining the expertise of the university community to help meet the aeronautics and space goals of NASA, while at the same time strengthening the universities' ability to contribute to other national needs.

Space flight experimentation represents an area of significant accomplishment in NASA supported university programs. University scientists have been eager to take advantage of the opportunities made available by NASA to conduct experiments in space. More than 98 percent of balloon-borne experiments, more than 40 percent of sounding rocket experiments, and more than half of satellite experiments flown on NASA vehicles had principal investigators or co-investigators in universities. For the satellite experiments, this is five times the level of participation of industry and about the same as the participation of all government laboratories.

NASA-university programs have had a significant impact on the nation's universities. About 200 universities have been responsive to opportunities to become involved in the aeronautics and space program. They have used NASA support to strengthen and build research and education capabilities. Centers of excellence exist that were created with NASA support. Entire departments and graduate degree programs have grown out of NASA involvement, many new courses have been developed, and countless science and engineering and management courses have had their content altered as a result of NASA programs. The national capability for education and research has been both broadened and strengthened.

About 70 percent, or $480 million, of funds obligated to universities since 1959 has been for project research. These supporting research and technology projects have provided the solution to many high priority problems and opened avenues for experiments and advanced development while involving large numbers of faculty and graduate students in the effort. The policy of supporting the research and flight experiments of university faculty on

campus is serving both NASA and the universities well. NASA is making a major effort to provide funding stability in project grants through forward funding. About 50 percent of the project grants will be step-funded by the end of FY 1969. A step-funded grant is one which obligates funds for the support of a research project at the full level for the first year, 2/3rds of that level for the second year, and 1/3rd of full level for the third year, the aggregate of these obligations being made during the first year. At the beginning of the second year supplemental funds equal to one year of full support are awarded and spread over the following three years. When a decision is made to cease support of a step-funded grant no further funds are added, but the project still has a two year phaseout period at reducing levels, which enables the research to be concluded in an efficient and orderly manner. There are now a total of 200 grants, operating on a step-funded basis.

Despite the contribution of these supporting research projects to the nation's aeronautics and space goals, overall budgetary constraints are expected to result in a reduction in their number during FY 1969. Of some 1300 sponsored projects in universities early in FY 1969, it is estimated that less than 1000 can be continued if we are to have sufficient funds for initiating new studies in critical areas developing during 1969. Part of this reduction will be natural, i.e., projects which have been completed. Unfortunately, others are meritorious projects deserving continuation, but which cannot be extended as the research is of lesser priority than other work competing for research funds. Total support to university programs, including an estimate for FY 1969, is shown in Figure 1. To a limited extent, the Sustaining University program, in one of its roles, may be able to offset somewhat the effects in universities particularly hard hit in this manner, thus preserving the potential of such universities for future contributions to the national aerospace effort.

Sustaining University Program

The Sustaining University program is an integrated part of NASA's program of university research and training. Its goals, however, are broader and longer-range than the typical project activity. Grants are made to universities in a way that provides extensive local control over research approaches and task selection. Funding stability is provided through "step-funding" of all research activity and full funding for training and other special programs. Since 1959, 30 percent, or $204 million, of NASA's support to universities has been for research, training, and facilities sponsored under the Sustaining University program. This broad support balances the effect of closely defined project and flight activity and provides for the local development of stronger aerospace educational and research programs.

During the years 1959-1967, a large number of university trained experts were needed to develop scientific experiments and spacecraft. The universities of the nation were rapidly brought into the space program and

given resources and opportunities to conduct research and training in aerospace fields. These demands were met in part through the research, training, and facilities elements of the Sustaining University program, which were able to rapidly respond with support that filled special university and NASA needs in these areas.

In FY's 1968 and 1969 the flight and research programs were cut back. The FY 1970 need is to utilize, to the greatest extent possible, the national scientific and technical capability that has been developed. NASA must also maintain an active advanced technology research program within the scientific community if it seeks to retain a position of leadership in space exploration. The current shortage of flight opportunities should be offset by a more intensive laboratory research and study program. This can be done effectively by universities working cooperatively with NASA.

NASA's technological and managerial experience should be made available for university research and educational programs. Many of the major problems of the nation, such as transportation, pollution, health care, and the rebuilding of our urban centers, require talented people who understand the development and use of advanced systems approaches. A need exists to expose students and faculty to the broad and complex problems that involve science, engineering, and conflicting social priorities and policies. A goal of the Sustaining University program in FY 1970 is to make the NASA experience available to the academic community through multidisciplinary research programs, special training grants, internships, exchange programs, and study activities of mutual interest. Hopefully, this knowledge and experience will be combined with existing university strengths into innovative educational and research programs.

The Sustaining University program request in FY 1970 represents less than 20 percent of the amounts allocated to this program during its peak years. These funds provide a flexible source of research and training support that allows universities from many regions to participate in the nation's aeronautical and space activities. The support provides opportunities for universities to conduct multidisciplinary research and to establish special high priority educational programs, such as engineering systems design and administration and management. The Sustaining University program encourages participants to take a broader look at the effects and implications of advanced technology on society and identify ways that this knowledge can be applied to contemporary human needs.

It is also important in FY 1970 that opportunities for creative research be made available to emerging colleges and universities in order for them to attract and develop high quality faculty and students. NASA Centers, with their research facilities, managerial competence, and research needs, provide an excellent base from which to extend research and training opportunities to developing colleges. Experimental programs aimed at upgrading the aerospace related research capability of a few developing colleges will be initiated under the Sustaining University program. They will be continued by the Centers on the basis of their contributions to NASA research objectives.

In FY 1970 the Sustaining University program will encourage and support cooperative ventures within NASA and with universities to ensure the full consideration of the social, economic, and educational implications and application of NASA research. The technological research in such areas as satellite communication, weather modification and aeronautics must be paralleled by the consideration of the social, policy and legal implications of these technological advances. The benefits of these technological and managerial developments can be then put to use in our society in a productive and positive way.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Research..... | $6,000,000 | $5,000,000 | $5,000,000 |
| Administration and management... | 1,500,000 | 1,500,000 | 1,500,000 |
| Engineering systems design..... | 1,000,000 | 1,000,000 | 1,000,000 |
| Special training..... | 1,500,000 | 1,500,000 | 1,500,000 |
| Total..... | $10,000,000 | $9,000,000 | $9,000,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| NASA Headquarters..... | $10,000,000 | $9,000,000 | $9,000,000 |

BASIS OF FUND REQUIREMENTS:

Research

| | | | |
|---|---|---|---|
| Research..... | $6,000,000 | $5,000,000 | $5,000,000 |

The $5.0 million requested in FY 1970 for the research element of the Sustaining University program will continue research support to university programs that are broader in scope and longer range in nature than the usual project oriented tasks. Emphasis will be placed on activities which are multidisciplinary in nature, and seek innovative ways to bring the full range of university expertise and competence, including appropriate nontechnical considerations, to bear on space related problems.

The research element of the Sustaining University program supports university programs of a highly interdisciplinary character. "NASA," according to Dr. Frederick Seitz, President of the National Academy of Sciences, "is essentially unique in the way it binds scientific and engineering disciplines together for peaceful purposes." During the past decade the Sustaining University program has supported the creation of university research groups in such aerospace fields as aeronautics, materials, bioengineering, earth sciences, and astrophysics. The program has successfully encouraged universities to conduct research and train graduate research assistants in advanced multidisciplinary fields.

New university approaches to research and study that bring together the faculty and students of diverse disciplines must be developed to increase our understanding of the problems our new technology is bringing.

In FY 1970 the Sustaining University program will further encourage the inclusion of the universities' extensive social and behavioral research capabilities in multidisciplinary efforts. The understanding of the policy and economic and social implications of advanced developments is essential if advanced technology is to continue to contribute to the national purposes.

Attention will be given to those research programs which are related to the interest and future planning efforts of NASA Centers. Strong Center-university relationships provide NASA with increased flexibility and human resources to initiate programs of national interest, such as the application of space technology to earth problems and the response to new opportunities in manned and unmanned space flight. An intensive effort will be made in FY 1970 to strengthen university programs which make use of government research facilities and provide opportunities for faculty and students to participate with NASA in advanced research of mutual interest. A few special research initiation opportunities will be made available to developing institutions in regions near the NASA Field Centers. This is essential if these colleges are to recruit and develop qualified faculty in science, engineering, and administration, and train students in these fields. Major contributions can be made with the addition of limited new resources and strong involvement at the laboratory level.

The Sustaining University program research programs are individually tailored to the strengths and interest of the participating institutions. The grants are largely locally controlled to ensure that the programs contribute to both the educational needs of the university and research needs of NASA. The commitments are long-term in nature and each grant is "step-funded" over three years to assure financial stability for the participating universities.

With a budget of $5 million in FY 1970, the research element of the Sustaining University program will support multidisciplinary programs at about 25 universities. This number is down from 50 in FY 1968 and 35 in FY 1969. In addition, the program will establish task-level research opportunities for individual faculty at about 20 developing institutions near NASA Centers.

## Administration and Management

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Administration and management... | $1,500,000 | $1,500,000 | $1,500,000 |

The $1.5 million in FY 1970 will be allocated to continue support for administration and management research and graduate training programs at 10 universities.

The rationale for support of these activities is the belief that the evolution of public issues -- particularly those having to do with science and technology -- has been so swift and so complex that there has been an increasing shortage of trained persons coming from the universities who understand how to work with the new and expanding dimensions of science and technology. There is an increasing need for professional managers who understand the broader implications of managing advanced research and development as implementation of public policy. The success of future programs in space and aeronautics, as in other national concerns, will become increasingly dependent on the education and training of individuals with a much broader base of understanding of management and public administration, as well as science and technology. NASA and the university community have a common responsibility in the development of such managers. This program is aimed at continuing support for those universities that have undertaken a responsibility for education in the complex fields of administration and management.

The program, as presently defined, provides support to universities for pilot programs in research and training in public administration and management. Each of the research programs is structured around a number of major research areas of interest to one or more NASA organizations. The university faculty and graduate students involved in the program are encouraged to use the facilities and managerial staff of NASA as a research laboratory. This enables them to gain insight into the realistic problems of management in a public agency and to have access to data, systems, and management experiences which might not otherwise be available. This also brings the university researchers into close contact with professionals within the agency which helps sharpen and focus their research and makes it more relevant.

During FY 1970 ten universities will continue to receive research support from this program. In addition, 15 Public Administration Traineeships will be awarded to three of these universities. These traineeships will be awarded to outstanding students who are interested in the management or socio-economic aspects of large scale, technology-based programs.

## Engineering Systems Design

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Engineering systems design..... | $1,000,000 | $1,000,000 | $1,000,000 |

Industry, government, and academic institutions need graduates with integrated, interdisciplinary design experience who can conceive, design, and manage the development of complex boosters, spacecraft, aircraft, and ground facilities which represent the main thrust in the country's space and aeronautics effort. The trend toward narrow specialization and research oriented engineers in recent years must be balanced with creative professionals equipped to formulate and solve broadly defined design problems with complex technical and social considerations.

The Engineering Systems Design program brings together the relevant engineering and management specialists at the doctorate level to create a research team to undertake a major systems design problem, such as a satellite communications system. The design approach will use and promote the most recent advances in both the engineering and physical sciences. The projects incorporate the most advanced information and systems theories.

Professional personnel in computer-aided systems design are especially needed in industry and the academic community itself. A major secondary benefit of the Engineering Systems Design program is to acquaint a large number of engineering faculty and students with systems design concepts. Accommodations are made for students and faculty to participate in creative design efforts and to become involved in active design programs in government and industry.

This innovative program is being supported to produce professionals capable of understanding the full range of problems associated with complex systems. The program supports training and research for students working toward a doctoral degree in Engineering Systems Design. The first group of students began their tenure in September 1967. By September 1969 the five universities participating in this program will have students in all three years of graduate training as the initial group begins their final year of the design project.

In FY 1970 each of the five participating universities will have reached the planned level of operation. At this point the university will have the greatest flexibility in terms of numbers of students and stages of graduate training to permit team assignments in various disciplines and at all levels of responsibility.

## Special Training

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Special training..... | $1,500,000 | $1,500,000 | $1,500,000 |

As space-related manpower deficiencies are identified, the specialized training activities conducted under the Sustaining University program are reviewed and assessed to ensure harmony with the new conditions and tasks the Agency will encounter. The special training activities vary from intense, specialized four-week courses to two-year programs leading to an advanced degree, and involve faculty, graduate and undergraduate students.

In 1964, in cooperation with the American Society for Engineering Education, the Summer Faculty Fellowship Program, emphasizing individual research, was established. The program is designed to further the professional knowledge of faculty members, to stimulate an exchange of ideas between participants and NASA, and to enrich the research and teaching activities of the



332-276 O - 69 - 17

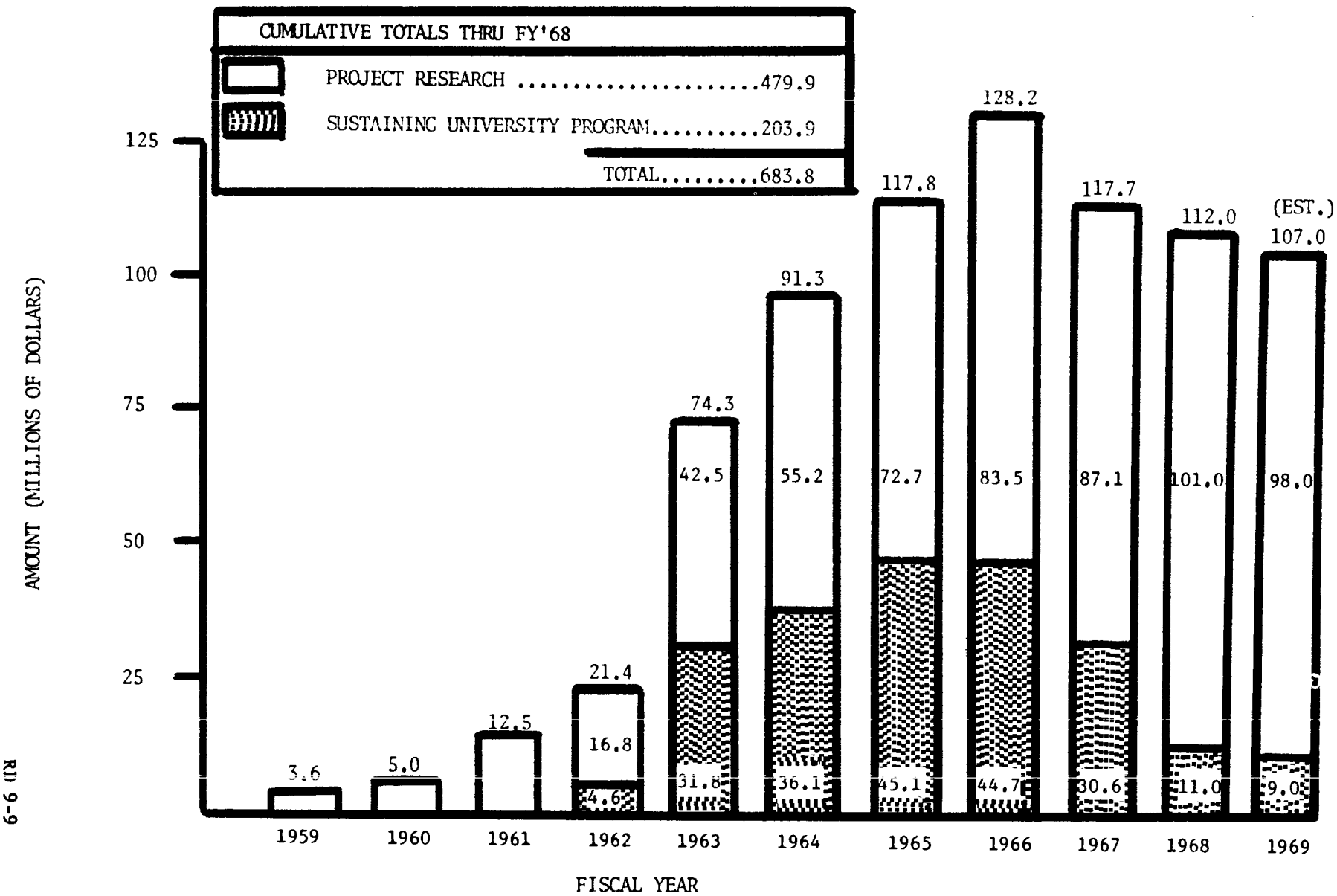
participant institutions. These 10-week summer sessions are cooperative endeavors undertaken in conjunction with universities located near NASA Field Centers. The participants usually spend about 80 percent of their time in the NASA Center working on research projects of mutual interest to themselves and the Center. The remaining 20 percent of their time is spent in seminars, workshops, or lectures usually on the campus of the sponsoring university. During the summer of 1969, it is estimated that about 250 young faculty members will participate in the program at one of eight NASA Centers and eleven universities. A program of similar magnitude is planned for the summer of 1970.

The Summer Faculty Fellowship Program in engineering systems design was started during the summer of 1966. Its main purpose is to allow young faculty members the opportunity to work together for eleven weeks on a broad space related problem to gain techniques and experience which will acquaint them with the mechanics of communication and collaboration, give them practice in applying engineering theory to actual engineering problems, and enable them to organize multidisciplinary engineering systems design courses at their home institutions. These activities are also carried on in cooperation with universities located near NASA Centers with Center personnel having special competence in engineering systems design lending strong support. During the summer of 1969, about 80 young faculty members will participate in the program involving four NASA Centers and six universities. Programs at the same locations are planned for the summer of 1970.

Another training activity of a specialized nature is the Summer Institute for upper-division undergraduates. The institutes are concerned with some of the problems of undergraduate education as affected by the new developments in space science and technology. A principal goal is to acquaint upper-division undergraduates with substantive problems of space science and engineering. Talented young men and women will be selected from a national competition to participate in these four- to six-week institutes. During the summer of 1969 and 1970, it is planned to conduct four of these institutes.

The post-M.D. training program is designed to help provide a few very select medical doctors with special advanced training for supporting roles in manned space flight efforts. In FY 1969 and FY 1970, the level of effort will be the same as in previous years.

NASA OBLIGATIONS TO UNIVERSITIES



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1970 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

ADVANCED RESEARCH AND TECHNOLOGY PROGRAMS

| Program | Fiscal Year 1968 | Fiscal Year 1969 | Fiscal Year 1970 |
|---|---|---|---|
| Basic research..... | $21,465,000 | $21,000,000 | $21,400,000 |
| Space vehicle systems..... | 34,100,000 | 31,700,000 | 30,000,000 |
| Electronics systems..... | 38,057,000 | 34,771,000 | 35,000,000 |
| Human factor systems..... | 19,828,000 | 19,700,000 | 23,600,000 |
| Space power and electric propulsion systems..... | 43,735,000 | 42,200,000 | 39,900,000 |
| Nuclear rockets..... | 54,000,000 | 32,000,000 | 36,500,000 |
| Chemical propulsion..... | 37,037,000 | 28,900,000 | 25,100,000 |
| Aeronautical vehicles..... | 66,800,000 | 74,900,000 | 78,900,000 |
| Total..... | $315,022,000 | $285,171,000 | $290,400,000 |

FISCAL YEAR 1970 ESTIMATES

The Advanced Research and Technology programs shown in the preceding table supports research in two major technological areas, Space Technology and Aircraft Technology. The division of effort between these two areas is shown below:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| SPACE TECHNOLOGY | | | |
| Program | | | |
| Basic Research | $17,165,000 | $15,100,000 | $14,900,000 |
| Space Vehicle Systems | 34,100,000 | 31,700,000 | 30,000,000 |
| Electronics Systems | 30,257,000 | 23,671,000 | 22,700,000 |
| Human Factor Systems | 17,328,000 | 16,700,000 | 20,600,000 |
| Space Power and Electric Propulsion Systems | 43,735,000 | 42,200,000 | 39,900,000 |
| Nuclear Rockets | 54,000,000 | 32,000,000 | 36,500,000 |
| Chemical Propulsion | 37,037,000 | 28,900,000 | 25,100,000 |
| Total 1/ | $233,622,000 | $190,271,000 | $189,700,000 |
| AIRCRAFT TECHNOLOGY | | | |
| Program | | | |
| Basic Research | 4,300,000 | 5,900,000 | 6,500,000 |
| Electronics Systems | 7,800,000 | 11,100,000 | 12,300,000 |
| Human Factor Systems | 2,500,000 | 3,000,000 | 3,000,000 |
| Aeronautical Vehicles | 66,800,000 | 74,900,000 | 78,900,000 |
| Total | $81,400,000 | $94,900,000 | $100,700,000 |
| TOTAL, ADVANCED RESEARCH AND TECHNOLOGY 1/ | $315,022,000 | $285,171,000 | $290,400,000 |

Aircraft technology includes supporting research and technology effort conducted under Basic Research, Electronics Systems and Human Factor Systems programs related to aeronautics, in addition to all projects itemized under the Aeronautical Vehicles program.

1/ Excludes Launch Vehicle Procurement as follows:

| | |
|---|---|
| 1968 | $4,066,000 |
| 1969 | 3,394,000 |
| 1970 | 650,000 |

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — BASIC RESEARCH PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Basic Research program supports fundamental research in the physical and mathematical sciences. It is aimed at providing an understanding of the physical phenomena pertinent to other NASA programs concerned with current and future aircraft and space activities. This basic research is carried out principally in NASA's Research and Space Flight Centers supplemented by investigations at universities, industrial research laboratories, and other Government research centers. Fundamental understanding of physical phenomena in many fields of science is required to develop the technology for NASA's programs. Basic research in NASA, therefore, must encompass a wide spectrum of disciplines. It ranges from very fundamental studies into the nature and properties of atoms and molecules to the more applied research areas such as determining the best materials for the supersonic transport airplane.

The Basic Research program is divided into four broad disciplines: Fluid Physics, Electrophysics, Materials, and Applied Mathematics.

The Fluid Physics subprogram promotes basic research on aerodynamic and gas dynamic problems relevant to NASA objectives in both aeronautics and space. During the past year the program has been reoriented to emphasize aeronautics problems. In aeronautics, for example, preliminary results show promise for understanding and reducing sonic boom and noise. A program of research on air pollution from aeronautics sources is beginning. Entry research continues with studies primarily concerned with experimental simulation and verification of theories regarding high speed entry.

The objective of the Electrophysics subprogram is to obtain a better understanding of fundamental electron-atom-molecule behavior in an environment of acoustic, nuclear, electric and magnetic forces. The research results will provide new information directly relevant toward advancing the technology of important elements of electronic communications such as signal sources, detectors, and computer elements and also toward ionized gaseous plasma type propulsion and power supply systems by learning how to increase the gaseous density and its ionization efficiency which is affected by undesirable instability and turbulent motion.

The Materials subprogram covers a broad spectrum of activities that seeks to explore the behavior of materials from the fundamental viewpoint. It is concerned with defining the relationship between the structure of solids and their characteristics. The definition of the structure involves the

geometric arrangements of the electrons and atoms and considerations of the forces between them. The characteristics of materials include both the conventional mechanical properties, strength, toughness, etc., and such physical properties as thermal and electrical conductivity. It also includes studies of the behavior of materials in their engineering environments. Increased emphasis is being placed on those programs which are pertinent to aeronautics. These include studies of ceramics and polymers for aircraft composite structures and the study of improved alloys for jet engine use. Long-range studies concerned with the processing of materials in space are a recent addition to the program.

The Applied Mathematics subprogram is aimed at producing new and improved mathematical techniques needed for, and adaptable to, problems of aeronautics and space technology. A mathematical approach is often the more economical and sometimes the only possible one for design of intricate hardware and for planning complicated experiments, especially when the ultimate working conditions will be in some extraterrestrial situation. For instance, optimal control of spacecraft, processes of orbit-change, rendezvous, or reentry requires extensive mathematical research in differential equations and the calculus of variations used as models for these complex operations, including adaptation of algorithms for use both by on-board and on-the-ground computers.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology..... | $21,465,000 | $21,000,000 | $21,400,000 |
| Total..... | $21,465,000 | $21,000,000 | $21,400,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| Marshall Space Flight Center | $824,000 | $900,000 | $930,000 |
| Goddard Space Flight Center. | 131,000 | 130,000 | 140,000 |
| Jet Propulsion Laboratory... | 4,175,000 | 3,720,000 | 3,830,000 |
| Ames Research Center..... | 2,336,000 | 2,450,000 | 2,520,000 |
| Electronics Research Center. | 1,999,000 | 2,380,000 | 2,450,000 |
| Langley Research Center..... | 2,818,000 | 2,830,000 | 2,920,000 |
| Lewis Research Center..... | 2,702,000 | 3,020,000 | 3,110,000 |
| NASA Headquarters..... | 6,465,000 | 5,570,000 | 5,500,000 |
| NASA Pasadena Office..... | 15,000 | --- | --- |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Fluid physics..... | $4,957,000 | $5,080,000 | $5,170,000 |
| Electrophysics..... | 7,245,000 | 6,530,000 | 6,660,000 |
| Materials..... | 7,819,000 | 8,080,000 | 8,230,000 |
| Applied mathematics..... | 1,444,000 | 1,310,000 | 1,340,000 |
| Total..... | $21,465,000 | $21,000,000 | $21,400,000 |

**Fluid Physics**

In the past year and a half, new programs were started to promote research in gas dynamic lasers, sonic boom and aerodynamic noise.

The new research program in gas dynamic lasers is studying a number of concepts for producing lasing action in flowing gases. Two concepts have been proven experimentally - both a molecular laser and an electric arc expansion laser. The kinetics of these and other concepts will continue to be studied in order to understand and improve on them. High power, high efficiency gas dynamic lasers show great promise for such aerospace applications as space communications, power transmission to satellites, and airport fog removal.

The sonic boom research has provided improved schemes for predicting the boom from aircraft maneuvering in a nonuniform atmosphere. Some theoretical results of aircraft configuration studies show promise for boom reduction with little apparent penalty in airplane performance. The concepts are being examined experimentally in wind tunnel tests. The origin and mechanisms of clear air turbulence, an important operational problem of current jet transports, is being studied as an aid to detection and avoidance.

Progress has been made in understanding the mechanisms of noise generation from supersonic engine exhaust jets. Theoretical studies for predicting noise are pursued and experiments for means of jet noise reductions have been carried out with encouraging results. The theoretical understanding of the mechanisms by which the reduction is achieved is still to be obtained.

It has been learned that the flow at the slender leading edge of engine intake ducts, control and lifting surfaces is more like the slip flow of rarefied gas dynamics than the continuum flow as had previously been supposed for flight Mach numbers above 5. Consequently, the heat transfer and pressure distribution are reduced by as much as a factor of 10, which is advantageous for high speed flight. Based on these results, the air flow distribution in the engine intake is different than assumed so far. The extent of the slip flow regime and its consequences are being investigated.

## Electrophysics

The Electrophysics program is conducted largely within the NASA laboratories with cooperative and coordinated assistance from industrial and university laboratories. The program includes a new research result which has application to medical diagnostics. It has been determined that a semiconductor, gallium antimonide (GaSb) is an outstanding transducer by which slight pressure variations are changed to electrical signals. In a cooperative investigation with the Harvard Medical School, a GaSb transducer was mounted on a catheter which was inserted in a dog. The transducer provided improved details of the variation of blood pressure during each heartbeat. Work is continuing to design a completely self-contained transducer so that no external power will be needed.

Investigation of superconducting junctions will be undertaken to determine their electrical characteristics as signal sources and as ultrasensitive detectors of radiation at the microwave and shorter wavelength regions. Also, data will be obtained on their sensitivity as indicators of very small magnetic fields as found in space and as ultrafast switching devices in memory storage subsystems of computers.

It is realized that for space propulsion and power systems, the density of the gaseous plasma must be increased to achieve higher overall efficiency. Research will be extended on high density plasma with emphasis on increasing the electrical conductivity, providing a better theoretical basis for the behavior of the plasma sheath and for the growth of instability and turbulence so these two undesirable effects can be overcome.

Research efforts to modulate lasers and increase the peak pulse power output will continue. Work will be undertaken on methods to vary the atomic and molecular energy levels themselves to obtain modulation. Techniques will be investigated to produce $10^{-12}$ second pulses to increase the peak power. The results should increase the usefulness of lasers for electronic communication.

## Materials

As in the past, the materials research program covers a broad spectrum that seeks to explore the behavior of materials from a variety of viewpoints. The principal thrust of the program is to define the relationships between the mechanical and physical properties and the geometric arrangements of the atoms and electrons and the forces that bind them together. It also seeks the understanding of the more macroscopic relationship between the microstructure and the properties of materials as they behave in the widely varying engineering environment. Within the past year, considerable progress was made in such basic areas as the diffusion of gases through solids and the interaction between solids and electromagnetic radiation. Both of these areas promise significant and early rewards and will be



332-276 O - 69 - 18

intensively pursued in the coming year. An example of such a reward is that a study of the interaction of microwaves with metals has already led to the construction of a crack detector that is simple to use and which promises to have greater sensitivity than existing inspection devices.

While high temperature materials continue to be an important topic for research, this past year has seen a change in emphasis which is expected to continue in the forthcoming year. The change in emphasis results from a greater concentration on those areas pertinent to aeronautics. Thus, our polymer research is now somewhat decreased in the area of ablation and increased in those areas related to structural laminates for aircraft. Similarly our studies of ceramics are concerned somewhat less with attaining materials which can withstand very high temperatures but are more directed toward the creation of fibers which are expected to reinforce the composites that are increasingly used in aircraft structures. Furthermore, our studies of alloys that are pertinent to jet engines are occupying a greater amount of research attention at the expense of refractory metals which were necessary for advanced versions of space power generators.

We are also placing greater emphasis in identifying and capitalizing on the nonaerospace uses for our science and technology. One particularly intriguing example of this category is the application of the chemistry that we learned in studying the ablation process to yield fire resistant paints and foams for a variety of safety applications.

Although the program has shifted somewhat towards near-term goals, several longer range projects have been initiated. For example, we have initiated studies which would lead us to new types of materials or materials applications which can be obtained by processing materials in space. It is envisioned that at some time in the future it may be possible to grow superior crystals for electronic circuits, and cast optical glasses with currently unavailable high indices of refraction in space -- and to do these operations at an economically attractive price.

## Applied Mathematics

The program in applied mathematics has as its objective the improvement of mathematical techniques needed for formulation of models of physical conditions and the production of economical and effective algorithms for computation. The mathematical fields of research related to these problems include differential equations, calculus of variations, and statistics.

Research in differential equations is necessary for gravitational and orbital mathematics, such as was applied, for example, to the design and operation of the Lunar Orbiters. Research in partial differential equations is required for solution of such problems as the heating and aerodynamic effects involved in planetary reentry.

Aeronautics also requires research in differential equations, as well as the calculus of variations involved in determining optimum aircraft trajectories. Shell theory, based on mathematical concepts, is required for design of both aircraft and spacecraft. Studies of nonlinear differential equations, including approximation methods for their solution, are necessary for the improvement of optimum control theory.

Analytical and celestial mechanics research is the core topic of geophysical and planetary mathematics. The varying physical structure of the planets have very important effects on planetary flybys, probes, and multiple planetary swing bys. The tracking of such probes yields much data, for which research in statistics and error analysis--the most active fields of the tracking and data analysis area--is necessary for reliable exploitation of such data.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1970 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — SPACE VEHICLE SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Space Vehicle Systems program is an applied research and technology program dealing with entry vehicle and launch vehicle aerothermodynamics, with launch vehicle and spacecraft structures and with spacecraft environmental protection and control. It also includes the space vehicle design criteria effort which formulates and documents authoritative guides to design. The objectives of the program are to conduct research and technology activities in laboratory facilities and by selected flight experiments to: Provide baseline technological information required for management and design decisions relative to new space vehicle mission undertakings; provide the advanced technology for the conception and design of future manned and unmanned spacecraft and for launch vehicles; and encourage and support technological innovations in the approach to space vehicle design to permit new and useful accomplishments.

Although the principal focus for the advanced research and technology efforts is NASA vehicles and missions, the program also recognizes and contributes to related DOD technology needs.

A new activity has been initiated, providing a data bank for the collection and dissemination of information on aerospace safety and providing for research programs in selected areas of aerospace safety.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Research and Technology: | | | |
| Space vehicle aerothermodynamics. | $11,815,000 | $ 9,605,000 | $ 8,545,000 |
| Space vehicle structures..... | 9,779,000 | 9,771,000 | 8,980,000 |
| Space environmental protection and control..... | 10,754,000 | 10,550,000 | 9,105,000 |
| Space vehicle design criteria.... | 1,752,000 | 1,774,000 | 1,570,000 |
| Aerospace safety research..... | --- | --- | 1,800,000 |
| Total..... | $34,100,000 | $31,700,000 | $30,000,000 |

Distribution of Program Amount by Installation:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Manned Spacecraft Center..... | $ 755,000 | $ 947,000 | $ 450,000 |
| Marshall Space Flight Center..... | 4,103,000 | 3,562,000 | 3,140,000 |
| Goddard Space Flight Center..... | 2,615,000 | 2,451,000 | 2,200,000 |
| Jet Propulsion Laboratory..... | 2,045,000 | 1,810,000 | 1,485,000 |
| Ames Research Center..... | 2,916,000 | 3,480,000 | 3,135,000 |
| Electronics Research Center..... | 410,000 | 390,000 | 340,000 |
| Flight Research Center..... | 1,350,000 | 1,320,000 | 1,220,000 |
| Langley Research Center..... | 15,716,000 | 14,123,000 | 13,085,000 |
| Lewis Research Center..... | 3,015,000 | 2,650,000 | 4,100,000 |
| NASA Headquarters..... | 1,175,000 | 967,000 | 845,000 |

BASIS OF FUND REQUIREMENTS:

Space Vehicle Aerothermodynamics

| | | | |
|---|---|---|---|
| Supporting research and technology..... | $ 7,073,000 | $ 6,505,000 | $ 5,695,000 |
| Head shield materials flight experiments..... | --- | --- | 100,000 |
| Parachute/decelerator flight experiments..... | 1,336,000 | 650,000 | 400,000 |
| Scout-launched reentry technology flight experiments..... | 2,206,000 | 1,250,000 | 1,150,000 |
| Lifting body flight research program..... | 1,200,000 | 1,200,000 | 1,200,000 |
| Subtotal..... | $11,815,000 | $ 9,605,000 | $ 8,545,000 |
| Scout (Launch Vehicle Procurement Program)..... | ($ 1,100,000) | ($ 1,200,000) | ($ 500,000) |
| Total (including Launch Vehicles)..... | ($12,915,000) | ($10,805,000) | ($ 9,045,000) |

The Aerothermodynamics subprogram is concerned principally with entry vehicles for near-earth and planetary missions. It also provides supporting technology for launch vehicles.

A primary objective is development of technology for manned orbital logistics vehicles with the goals of improved economy through land recovery and spacecraft reuse, and improved operational flexibility through greater maneuverability during reentry.

Research will continue on a number of techniques for terminal descent and landing of semiballistic types of spacecraft like Apollo. Of these, the gliding parawing offers promise for early application, and an ongoing large-scale flight technology program will continue during FY 1970. For advanced orbital logistics spacecraft larger and more maneuverable than Apollo, some

form of the horizontally landed concept may be required. Attention is being given to aerothermodynamic problems of such concepts throughout their flight spectrum from reentry to landing. This includes research on aerodynamic heating and improved heat protection systems, as well as vehicle performance, stability, control and flying characteristics. The research is being carried out in a wide variety of laboratory facilities and through related flight experiments.

Another major objective is to develop the critical technologies for planetary atmosphere probes and hard landers. Research will be continued to define the most promising configurations from the standpoint of entry heating and vehicle motions. Research will likewise continue on problems of descent to the surfaces of the planets with emphasis on decelerators that can be deployed at high supersonic speeds and on decelerators of advanced design. This research will be conducted both in ground based facilities and through related flight experiments.

### Heat Shield Materials Flight Experiments

These experiments, using small sounding rockets, provide anchor-point data to evaluate theoretical and ground based experimental estimates of ablation performance in the actual reentry flight environment. The next experiments will investigate a carbon phenolic material that is attractive for use in areas where heating rates and shear forces are high, and several lightweight, low cost materials that are promising for large areas on manned reentry vehicles where heating rates are low.

### Parachute/Decelerator Flight Experiments

These experiments verify deployment, performance and reliability of planetary decelerator systems in the earth's atmosphere under conditions representative of deployment in the atmosphere of Mars. The program will provide confirmation of supersonic deployment, drag, stability, and loads for trailing decelerators at Mach numbers up to about 3.5. Future experiments will investigate both trailing and attached decelerator concepts at Mach numbers up to 5.

### Scout-Launched Reentry Technology Flight Experiments

This continuing series of critical experiments deals with aerothermodynamic aspects of atmosphere entry flight. Three successful experiments have been accomplished since 1964: R-4 - Critical test of Apollo heat shield material; R-5 - Critical test of an improved ablator; and R-6 - Critical experiment on turbulent heat transfer on a non-ablating slender body.

Flight experiments planned are a planetary atmosphere experiment test and a heat transfer and boundary layer transition experiment. The planetary atmosphere experiment will perform a critical test in the earth's atmosphere of a technique based on special measurements of vehicle motions and heating to determine the properties and composition of an unknown planetary atmosphere. The heat transfer and boundary layer transition experiment will obtain further critical measurements of boundary layer heat transfer, map the transition region, and measure the acoustic environment.

## Lifting Body Flight Research Program

This cooperative NASA and USAF research program is investigating piloting problems and flying and handling qualities of configurations representing concepts of manned reentry vehicles during the terminal phases of space flight; i.e., from low supersonic speeds to landing. Thirty flights were accomplished by December 9, 1968. During FY 1970 the HL-10 test flights will move into the supersonic phase, to be followed by initial flights to study power-on landings. The X-24A will be flown early in calendar year 1969. The M-2 will be modified and used as a research tool for investigating advanced lateral control techniques and systems.

## Space Vehicle Structures

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology... | $9,779,000 | $9,771,000 | $8,980,000 |
| Total..... | $9,779,000 | $9,771,000 | $8,980,000 |

This subprogram provides advanced structures technology for manned and unmanned space vehicles. Major objectives relate to establishing the feasibility of new and improved structural concepts and materials, and developing advanced analysis and test techniques to permit future vehicles to achieve appropriate balance between efficiency and cost while maintaining high performance.

Progress is being made on advanced structural concepts for manned lunar exploration involving expandable structures for shelters and airlocks. Emphasis will be given to demonstrating concepts for near-term applications. Critical problems associated with orbital space station structures are being studied and results are being used in the design of the S-IVB Workshop. Future efforts will be directed to structural problems associated with larger, more complex vehicles required for missions of longer duration. Concepts are also being developed for advanced spacecraft structures to provide lightweight expandable configurations for larger areas, lengths, and volumes than have been feasible heretofore.

Development and qualification testing represent a large portion of the costs associated with launch vehicles. Emphasis is being given to improving the effectiveness of structural test programs to permit cost reductions without increasing the risk of failure.

Structures for orbiting radio telescopes to operate at frequencies lower than 10 megahertz (MHz) are being studied to develop feasible concepts. Since these telescopes involve dimensions greater than 1,000 meters in diameter, experimental investigations are conducted using scaled models. Models greater than 5 meters in diameter must be tested in space because it is not possible to simulate the combined vacuum and weightless environment of space in the laboratory for such large structural models. Flight tests are being defined

in conjunction with laboratory experiments and analytical studies to evaluate deployment, dynamics, and surface countours as well as other characteristics.

Space Environmental Protection and Control

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology..... | $10,754,000 | $ 9,653,000 | $8,605,000 |
| Radiation/meteoroid experiments (on orbiting frog otolith launch)..... | --- | 497,000 | 100,000 |
| Scout-launched near-earth meteoroid bumper experiment..... | --- | 400,000 | 400,000 |
| Total..... | $10,754,000 | $10,550,000 | $9,105,000 |

This subprogram seeks to define the space environment from the vehicle design viewpoint, to provide knowledge and understanding of its effects on space vehicle operation, to develop techniques for environmental protection and control, and to develop related technologies to insure efficient space vehicle design and operation. The principal areas of research include space radiation, meteoroid, and thermal/vacuum technologies.

Research will be continued on the effects of space radiation on vehicle materials and components and on radiation shielding. For missions where protons constitute the major hazard and for vehicles having thin shielding, shielding technology is reasonably well in hand. Emphasis during FY 1970 will be on research relative to those missions where electrons are the major contributor to the dose and where thick shields will be required.

The importance of meteoroid protection technology to vehicle design increases as space vehicles become larger and mission durations become longer. Most of the research in this area is conducted in the laboratory, with key flight experiments providing anchor-point data. Laboratory impact and penetration investigations will be continued to provide a better understanding of particle impact mechanics and to test promising meteoroid protection techniques. A space flight experiment to investigate the actual effectiveness of the meteoroid bumper protection technique will be undertaken to provide a correlation with laboratory investigations. Flight experiments to obtain additional data on both the near-earth and interplanetary meteoroid environments may be included on missions conducted for other purposes.

As more complex space missions are undertaken, the need for versatile and reliable active thermal control systems will increase. Emphasis will be placed on development of techniques for active temperature control. Also, research will continue on heat transfer technology for accurate prediction of spacecraft temperatures. The present state-of-the-art in thermal design requires preflight testing in space simulation facilities. Efforts will continue on improvement of simulation of solar and vacuum conditions in test facilities. The program to develop thermal scale modeling techniques will continue.

### Radiation/Meteoroid Experiments (On Orbiting Frog Otolith Launch)

Two "piggyback" experiments will be carried on the fourth stage of the Scout used to launch the Orbiting Frog Otolith Experiment. One experiment is to verify a new radiation dosimetry technique. The other experiment is to qualify in flight a thin-film meteoroid velocity sensor and obtain preliminary data on meteoroid velocity distribution. Fabrication of the experiment package was initiated in FY 1969. The FY 1970 funds will cover launch costs and data reduction.

### Scout-Launched Near-Earth Meteoroid Bumper Experiment

A flight designed to measure the effectiveness of a meteoroid bumper in the actual space environment was initiated in FY 1969 for an FY 1971 launch. Measurements of bumper effectiveness and secondary measurements of meteoroid velocity and impact flux will provide data for design of meteoroid protection systems and correlation with ground based experiments. The FY 1970 funds will provide for completion of fabrication and testing of the spacecraft.

## Space Vehicle Design Criteria

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology... | $1,752,000 | $1,774,000 | $1,570,000 |
| Total..... | $1,752,000 | $1,774,000 | $1,570,000 |

This subprogram develops, documents, and publishes criteria, including models of the environments, that are applicable to the design of space vehicle structures, propulsion systems, and guidance and control systems. Research results and experience gained from the design and operation of space vehicles are utilized to formulate and update design guidelines to insure the development of reliable and efficient space vehicles.

Documents in the general areas of launch phase heating and loads, entry heat protection, shock and vibration, solid rocket motor cases, guidance and control during entry, disturbance torques in spacecraft, and models of the Mars and Venus atmospheres are being developed and published.

The FY 1970 funds will be used to contract for the services of technical experts outside of the Federal Government who have knowledge and experience in fields of current interest.



332-276 O - 69 - 19

## Aerospace Safety Research

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Aerospace safety research..... | ---- | ---- | $1,800,000 |
| Total..... | ---- | ---- | $1,800,000 |

The objective of this new activity is to insure that NASA maintains and pursues an adequate research program to provide information needed for safety. An Aerospace Safety Research and Data Institute (ASRDI) has been established at the Lewis Research Center which functions as a central point within NASA for the gathering of technical data and coordination and stimulation of an active research program for increased safety of aerospace activities. Two basic services are supplied to NASA, other Government agencies, and the aerospace industry as follows:

1. Establish and maintain an Aerospace Safety Technical Data Bank for use in planning, design, fabrication, testing, and operation of aircraft and spacecraft systems and associated ground based facilities and personnel.

2. Maintain an overview of NASA safety related research programs and similar programs in other Government agencies and industry; seek practical solutions to major safety problems through existing NASA research programs; provide technical consultations as required; and initiate new research programs in areas of critical need.

The ASRDI is in its initial phases of implementation with staffing of ten professional and two administrative personnel. Preliminary activities relating to the establishment of the Technical Data Bank and the survey and analysis of ongoing safety related research and development activities are underway.

Funding will be utilized as follows:

1. For procurement of data storage and retrieval equipment at the Lewis Research Center to accommodate the extremely large quantities of technical information to be incorporated into the Data Bank.

2. For support of selected research programs in areas where major safety problems exist.

During FY 1970, emphasis will be placed on the development of the professional staff and activation of the Technical Data Bank.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1970 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — ELECTRONICS SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Maintaining a position of world leadership in aeronautics and space is dependent on having a strong national effort in the disciplines related to electronics and control. The objective of the Electronics Systems program is to identify and support endeavors fundamental to new and continued progress in electronic technology. Component and system progress in terms of performance, reliability, and cost provide the means for timely and efficient attainment of future national goals in aeronautics and space. Avionic components are an integral part of all automatic and semiautomatic systems used in aircraft and manned and unmanned space vehicles. Communications, flight control systems, navigation and guidance equipment, computation and data processing, a myriad of sensors, reference and controller systems, approach and landing, surveillance and identification, and collision avoidance are key features of the vast aerospace field which depends on electronic equipment. Individual research and development events are susceptible to influence; thus the time of their consummation can be modulated significantly by regulating the resources allocated to them.

NASA has a role of both performer and sponsor of advanced electronics research and technology since this program will be carried out in part by in-house research, supported by a major effort in industry and universities. In building a base of technology in electronics, NASA has struck a balance between system oriented efforts and efforts to develop new technology applicable to aeronautics and space operations. In addition to the accumulation of fundamental knowledge which can be drawn from over the years, this program provides for the generation of needed techniques and components, particularly those which will be pacing items in future aeronautical and space developments; exploration of more than one possible path to a desired goal; and configuration of some of these techniques and components into systems in order to demonstrate their technical feasibility, and collect data on their operational potential and cost effective application.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology..... | $37,557,000 | $34,271,000 | $35,000,000 |
| Flight projects..... | 500,000 | 500,000 | --- |
| Total..... | $38,057,000 | $34,771,000 | $35,000,000 |

Distribution of Program Amount by Installation:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Manned Spacecraft Center..... | $150,000 | --- | --- |
| Marshall Space Flight Center.... | 2,655,000 | $2,450,000 | $2,850,000 |
| Goddard Space Flight Center..... | 2,878,000 | 2,880,000 | 2,550,000 |
| Jet Propulsion Laboratory..... | 3,405,000 | 2,791,000 | 3,200,000 |
| Ames Research Center..... | 3,771,000 | 3,589,000 | 3,250,000 |
| Electronics Research Center..... | 16,679,000 | 15,675,000 | 16,500,000 |
| Flight Research Center..... | 890,000 | 830,000 | 800,000 |
| Langley Research Center..... | 5,357,000 | 4,931,000 | 4,220,000 |
| Lewis Research Center..... | 400,000 | --- | --- |
| NASA Headquarters..... | 1,872,000 | 1,625,000 | 1,630,000 |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

| | | | |
|---|---|---|---|
| Advanced concepts..... | $3,909,000 | $4,460,000 | $4,640,000 |
| Guidance systems..... | 8,026,000 | 5,067,000 | 6,100,000 |
| Control systems..... | 5,692,000 | 5,676,000 | 5,380,000 |
| Communications..... | 4,879,000 | 3,795,000 | 3,350,000 |
| Tracking and data acquisition..... | 3,429,000 | 3,838,000 | 4,120,000 |
| Data handling and processing..... | 3,960,000 | 3,870,000 | 3,930,000 |
| Instrumentation..... | 3,467,000 | 3,418,000 | 3,260,000 |
| Electronic techniques and components..... | 4,195,000 | 4,147,000 | 4,220,000 |
| Total..... | $37,557,000 | $34,271,000 | $35,000,000 |

Advanced Concepts

The objectives of research in the advanced concepts area are to define the environment in which future systems will be operating, understand the interaction of the system or subsystems with the environment and with other subsystems, development of advanced technology and new techniques indigenous to the system itself, and to complement and extend the capabilities of man in the system. This research involves the integration of technologies into the system from three distinct levels: (1) technologies that may significantly improve the performance, cost effectiveness and reliability of specific elements of the avionic system, (2) technologies that may provide important new functional capabilities for avionics in general, and (3) technologies aimed at solving interface problems between flight operations and the operating environment.

During the past year, a research program was initiated aimed at developing and demonstrating the key avionic systems technologies that will help V/STOL transportation realize the promise which V/STOL vehicles have in effecting more efficient air transportation systems. Since current V/STOL aircraft designs

place a very heavy workload on their pilots when operating under refined traffic control or deteriorated weather conditions, extensive research will be conducted in pilot displays, instrument approach techniques, and aircraft handling characteristics to make low speed, precision instrument approaches practical. The avionics program has a near-term purpose of providing V/STOL aircraft with economical and accurate navigation and control for terminal operations, including approach and landing, based on systems integration of radio and state-of-the-art inertial aids. Over a longer period, advanced inertial and radio navigation techniques will be applied to increase the navigation and control accuracy and reliability. By use of flight experiments and simulation, a data base will be established to provide the designer with the necessary information to design an optimum system configuration. A phase of the flight test program has been completed. This involved compilation of data from over fifty flights using a Gemini inertial navigation system in an H-19 helicopter to demonstrate radio update techniques.

Flight testing of several concepts for improving automatic landing system performance of conventional aircraft will start in 1970. These concepts include inertial stabilization of the aircraft control system, inertial filtering of the Instrument Landing System (ILS) reference beams, non-linear trajectory generation, command signal processing, and generalized trajectory control.

Because electronics is so intrinsic in both modern aircraft and air traffic control, NASA's advanced research and technology program in avionics offers substantial support to the various aspects of air traffic control such as communications, navigation, surveillance, and hazard avoidance. Conversely, the characteristics of the air traffic control system influence the allocation of NASA research resources towards critically needed techniques and components which may be feature items in improving, modernizing, or planning and developing future air traffic control systems. The increased number of aircraft operations at all terminals, the broad variety of vehicle flight characteristics, and the desire to eventually achieve truly all-weather operations have a profound impact on vehicle avionic systems and the role man plays in their operation and management. In view of this aspect, NASA is emphasizing vehicle avionic programs drawing on advanced electronic components employed as sensing, monitoring, data processing and communication systems. Specific efforts include: (1) display concepts involving new components, data formats, and pilot-computer interactions, (2) low visibility landing systems, (3) hazard avoidance and pilot warning systems, (4) aircraft guidance and control systems emphasizing accuracy, stability, economic operation and maintainability, (5) new design philosophies, system concepts, and control techniques for improving aircraft electrical power systems will be studied with the aim of effecting appreciable weight savings in system components, reducing the amount of wiring required, and developing components which can withstand the rigors of supersonic flight and offer cost effective operations.

Common to all the above efforts are improved electronic components and techniques capitalizing on and fostering advances in solid state electronics. Key aspects of these programs are directed to meeting technical requirements identified by the FAA. Examples of the areas of research in avionics are indicated in the illustration on page RD 12-11.

## Guidance Systems

Guidance system research has the objective of providing improved sensors and techniques for determining the position and flight path of aerospace vehicles. Principal efforts include the development of advanced inertial and electromagnetic sensors, high reliability guidance computers, and simplified techniques for navigation and guidance.

In FY 1970, evaluation of the first strapdown inertial aircraft navigation system using the electronstatic gyro (ESG) will be completed. Advanced precision gimballed gyros and accelerometers with increased performance and life will reach the prototype design stage. Advanced gyro bearing technology efforts will be continued to improve the producibility and reliability of conventional gyros. Research on laser gyros will continue towards the objective of providing a low cost, no-moving part, sensor for aircraft navigation, and guidance applications.

The development of electromagnetic detectors to provide greater resolution and operational simplicity for horizon sensors and star trackers will be continued. Results of a study to provide a highly sensitive infrared horizon measurement radiometer and associated calibration techniques will be extended to the development of experimental hardware by the Langley Research Center. On-board spacecraft guidance techniques for planetary approach will be evaluated in a laboratory simulation by the Jet Propulsion Laboratory using on-board data from the Mariner-Mars 1969 mission. The use of holographic star pattern recognition techniques for earth orbital attitude reference offers the potential for a single instrument with great operational flexibility to replace the multiple star trackers required on current unmanned orbiting observatories. Early feasibility efforts at the Electronics Research Center have been highly encouraging and effort will continue in FY 1970. Ames Research Center efforts to provide accurate manned space navigation using simple handheld instruments will continue with emphasis on determining spacecraft window effects. An Apollo Applications sighting experiment is planned to extend the limited star-to-star sextant measurements obtained on a Gemini flight. This experiment will add lunar landmark and limb sightings and compare handheld sextant measurement accuracy with that of the more complex Apollo navigation instruments.

An advanced landing radar for unmanned planetary missions, with potential application to VTOL aircraft, will be evaluated by flight test in a helicopter. The radar promises to provide equipment simplicity along with improved performance over current systems. An optical laser rendezvous radar developed for Marshall Space Flight Center has been tested and has demonstrated accurate automatic docking capability. Continued efforts on laser transmitters and laser beam steering will improve the long range performance and eliminate the need for electromechanical gimbals.

Evaluation of self test and repair computer techniques for long-term unmanned space missions will continue at the Jet Propulsion Laboratory. This technique, that automatically diagnoses failures and switches standby units into operation, offers the potential for providing a long lifetime on-board computing capability for unmanned deep space missions.

## Control Systems

Research in control systems for aircraft and space vehicles includes both automatic systems and systems in which man is an intimate, vital, and often irreplaceable system component. Emphasis will be placed on advanced component designs, exploitation of new fluidic and electronic technology for control use, and understanding the various ways in which the pilot can function as a controller and system manager.

The need for future aircraft with new and widely differing flight characteristics to operate in increasingly lowered visibilities and in dense air traffic environments may well require new concepts and technologies in cockpit displays and flight control systems. The transport of the future will be a large flexible vehicle to which rigid body dynamics do not apply. System studies will be made to identify and develop concepts, and to cite special control problems attendant to the flexure, size, and mass of the airframe and aircraft skin temperatures. The acceleration cues received by the pilot in advanced aircraft can be considerably different from those in the older, more rigid aircraft. Analysis of the effect of flexible body dynamics on pilot cues and the resultant effect on the ability of the pilot to fly the aircraft will be made.

There are general problems associated with manned flight displays. The manner in which information should be presented, both in content and format, will be studied on a systematic, continuing basis. Specific objectives of the study are to develop and validate a theory of aircraft flight displays based on control engineering concepts and measurement techniques. The use of control engineering methods to describe the pilot-aircraft system, combined with existing information on human perceptual models from the behavioral sciences field, will be used to predict several display design features such as preferred presentation and arrangement of displays, pilot's dynamic behavior in acting on displayed quantities, the quantities which must be displayed to enable mission accomplishment, pilot workload data, and fixation times and frequencies on each instrument. Simulation studies and actual flight investigations will be performed to verify the results of the analytical work.

Efforts initiated in the past on control moment gyro (CMG) systems and components have resulted in a system which is currently under development for use in the Apollo Applications project. Continuing technology efforts in FY 1970 for future manned orbiting spacecraft, requiring long lifetimes and increased pointing accuracy will include the integration of brushless, direct current motors into CMG designs. Studies of advanced CMG control systems for large, flexible, manned orbiting space laboratories will continue in order to meet the needs of future scientific experiments.

## Communications, Tracking and Data Acquisition

A continuing objective of the Communications, Tracking and Data Acquisition subprojects is the the improvement of our capability at higher frequencies. The advantages of operating at higher frequencies are: (1) higher information transfer rates, (2) smaller and lighter weight antennas, (3) simpler power generation equipment, and (4) less expensive overall equipment. Until the

invention of the laser, our capability for developing signal power dwindled rapidly at wavelengths in the one centimeter region and almost disappeared at one millimeter. The invention of the laser changed this situation and we have devoted considerable attention to exploiting this powerful new tool for many uses in both aeronautics and space. However, even the advent of the laser has not lessened our need for millimeter systems with their better all-weather capability and greater immunity to degradation by the atmosphere. A considerable effort will therefore continue to be expended on improved solid state and microelectronic devices for use at centimeter to submillimeter wavelengths.

One of the science community's long-term objectives is to place a large diffraction-limited telescope in space where it is free of the deleterious effects of the atmosphere and thus will permit astronomers to see deeper into space with greatly improved resolution. To do this we must develop the technology of large adaptive mirrors and the laser devices for measuring and correcting their shape, as well as superaccurate, long-term pointing and thermal control systems. Since much of the space environment which critically influences the overall optical and pointing systems in the space telescope cannot be adequately simulated on earth, our plans include definition of an orbiting telescope which, if flown, could simultaneously prove the technology and serve as a scientific instrument for astronomers. The definition effort for such a proof-of-concept satellite will be continued in FY 1970.

Although a system may be developed by the airlines to prevent mid-air collisions with a high degree of confidence, the cost of the equipment is projected to be so high that private and business aircraft cannot afford to use them. Two light weight inexpensive pilot warning devices are being studied by NASA that may have application to smaller aircraft. Flight tests of some concepts should be completed within the next year. After proof-of-concept has been achieved, technological data will be available to be used by industry as a basis for design of an operational system.

One of the limiting factors in aircraft traffic control over the North Atlantic and other ocean routes is lack of communication and navigation facilities. A cooperative development program between NASA and FAA is aimed at providing satellite communication and possible navigation services in the 1500 megahertz band (L-band) and at the same time providing FAA with the independent surveillance which they require to achieve traffic control on these remote routes. An aircraft terminal, including antennas and switching systems, will be developed to work with experimental repeaters on the ATS-E and ATS-F satellites. Extensive measurements will be made of propagation factors, aircraft antenna patterns, and the effect of multipath and different modulation techniques at these relatively untried communication frequencies.

## Data Handling and Processing

Continuing advancements in the technology of computing and data processing are required to keep pace with the growing complexity, variety and volume of data attendant to the experimental development and operation of advanced air and space vehicles. Such missions as earth resources survey, astronomy, lunar and planetary exploration, supersonic and hypersonic aircraft can be expected

to generate data of a complexity and volume far exceeding current capabilities for processing. Advances are needed to (1) ease the burden on communications channels and processing facilities, and (2) to facilitate the acquisition and extraction of useful information for human users.

Prior year efforts have shown the conceptual feasibility of computer techniques which reduce the processing burden by automatically recognizing significant patterns in meteorological and planetary imaging data and selecting for transmission only meaningful information. FY 1970 efforts will continue this work to expand the category of patterns and improve recognition confidence. Successful research on such techniques could reduce significantly the cost and amount of data processing over that now required to obtain meaningful new information.

Needs for on-board data storage capabilities 1000 times greater than current technology can provide are foreseen for such missions as Earth Resources Survey. Feasibility studies initiated in prior years have shown that holographic/optical methods are a potential solution. FY 1970 research will extend such studies and define the required system.

Research initiated primarily for support of space exploration has been expanded to provide solutions to problems inherent in aeronautics research. For example, development of means for voice control of computers will enable an aircraft pilot, as well as an astronaut, to literally talk with a computer and permit them to use the computer to calculate or adjust flight parameters while physically engaged in critical flight maneuvers. Prior research has shown the feasibility of such means of communication for a limited vocabulary and for elementary input of handwritten or printed text. FY 1970 efforts will be directed toward increasing the vocabulary and the variety of text which can be recognized.

Although the growth of computer usage in aerospace applications has led to significant advances in hardware, the ability to employ this technology effectively is dependent on the software (programs) required to control and operate computers and data processors. This is an area which has been recently identified as critical to the future operation and application of computers. An effort to clearly define specific software problem areas and to solve them was initiated in the Advanced Concepts subproject in FY 1969. This effort will be continued in FY 1970 in the Data Handling and Processing subproject.

## Instrumentation

Space instrumentation technology advancements have been made in a number of areas during the past year. For example, the capability to make radiation measurements in the ultraviolet and X-ray part of the spectrum, required for astronomy and interplanetary missions, was advanced as a result of the development of low cost filters and photo detectors with extended ultraviolet sensitivity and by the design of a broad band radiometer for use in the visible and infrared spectral regions. The latter will be used to measure accurately the solar constant (a standard for measuring solar radiation) in absolute units and may replace present reference standards. In FY 1970, research will be continued to further advance measurement capabilities for space missions, particularly in the field of detectors with selective band pass, and light sources with wideband spectral emission intensities in the far UV and soft X-ray region.

332-276 O - 69 - 20

There is a basic need to measure pressure down to $10^{-15}$ torr, and lower, in space environmental simulators in order to perform certain critical tests such as those required in the study of outgassing, fatigue and cold welding of materials which can occur under space vacuum conditions and are important for many experiments and operations related to future lunar, planetary and interplanetary missions. The development of new techniques, under prior funding, has advanced measurement capability down to $10^{-12}$ torr. However, calibration accuracy is still a problem. Work in FY 1970 will include extension of the measurement range of residual gas analyzers and improvement of vacuum gages to remove current limitations.

In FY 1969, research into the application of lasers to gas measurements led to the design of a highly sensitive system which can detect minute quantities of hazardous or combustible hydrocarbon gas compounds such as methane, butane, alcohol and gasoline. Work in FY 1970 will be directed to improve the sensitivity of this laser absorption detector so that concentration of 1 part per million can be detected.

One of the limitations common to studies of hypersonic aerodynamics, high pressure gas effects and entry heat transfer, is the lack of adequate gas parameter measurement techniques. Low density flow visualization and spatially resolved measurement of gas density, temperature, and velocity are essential to the accurate determination of flow characteristics in hypersonic test sections. An electron beam technique has been found feasible and is being developed to measure these important characteristics without the interference of instrument supports in the high velocity flow region. This has proved to be a very useful tool for low density measurements during the extremely short run times (1 millisecond) which prevail in certain hypersonic test facilities. In FY 1970 it is planned to continue development of this technique for a broader range of applications and for a lower density (higher altitude) of simulated flight regimes.

Laser probing for determination of atmospheric density profiles, reported last year, offers a potential technique for detecting clear air turbulence. Investigations will be continued with an improved optical radar system to determine the physical mechanism of atmospheric turbulence including mountain wave turbulence. The feasibility of an airborne system and the possibility of an optical radar synoptic network for meteorological and pollution monitoring are also planned for study in FY 1970.

The limited capability of sensing devices to obtain certain critical flight parameters, such as relative wind velocity, forms a fundamental limiting feature of pilot displays and flight control systems in V/STOL aircraft. Since conventional techniques based on air pressure sensing are impractical at low velocities, fluid amplification techniques which will permit sensing of relative wind velocities of less than one-half knot are under development. Prototype design configurations of such instruments are being tested and their development will be continued in FY 1970.

## Electronic Techniques and Components

Electronic components and the techniques associated with their manufacturing, assembly, and test are key factors in the development of efficient, reliable electronic systems for aerospace applications. The application of solid state technology to electronic components, particularly integrated circuits in which many components are combined into one functional assembly of minute size and weight, represent the leading edge of this technology.

Research is needed to continue the evolution of this technology from the laboratory or development stage to useful economical applications in the aerospace environment. Principal program efforts center on: materials research to provide increased versatility and efficiency in the physical and electronic characteristics of these components; the application of computer-aided techniques to the design, construction and test of these devices; development of test criteria and tools for detecting failed components and the reasons for these failures; and development of new or improved techniques for the assembly and packaging of these components into operational systems or subsystems.

In FY 1970, these efforts will continue as the core of the program. Specific emphasis will be placed on techniques to reduce component costs such as improving fabrication processes to increase yields, reducing design and layout costs of the individual circuits, and standardizing manufacturing and test procedures to assure greater uniformity in the finished products. Integral to this program will be the search for material and techniques to provide longer useful lifetimes of the components and a consequent reduction in cost of both system and component testing.

### Flight Projects

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Radio Attenuation Measurements (RAM-C)..... | $500,000 | $500,000 | --- |
| Scout (Launch Vehicle Procurement Program)..... | (800,000) | (300,000) | (---) |
| Total (including Launch Vehicles) | ($1,300,000) | ($800,000) | (---) |

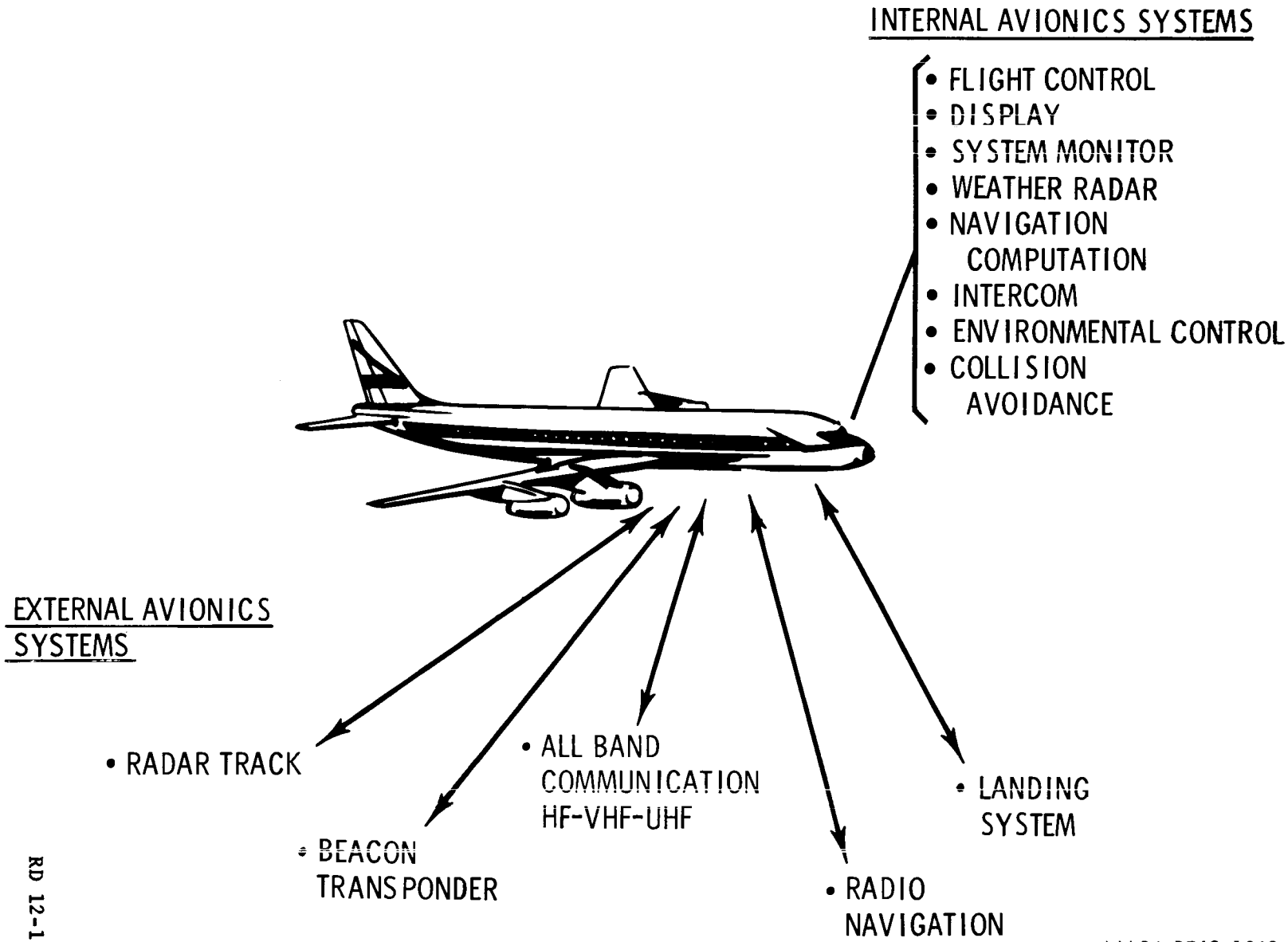
### Radio Attenuation Measurement (RAM)

The purpose of the Radio Attenuation Measurement (RAM) project is to develop the theory of the interaction of radio waves with a plasma, to verify this theory by laboratory and flight tests, and to apply this theory to the prediction and prevention of radio blackout in practical circumstances.

The RAM-C-II test vehicle was successfully fired back into the earth's atmosphere at a speed of 25,000 feet per second in August 1968. Valuable information was obtained for the theoreticians which will result in a better understanding of the blackout phenomenon.

The success of the RAM-C-I flight, which used water injection to ameliorate communication blackout, and of laboratory tests of electrophilic materials, which have a special affinity for the free electrons that cause blackout, indicate that a flight test using the available backup spacecraft should be made to explore the potential of these materials in a realistic re-entry environment. A project plan is now being formulated for such a flight in FY 1970.

# CRITICAL AVIONICS SYSTEMS




NASA RE68-1069
Rev 1-27-69

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY HUMAN FACTOR SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Human Factor Systems program is to provide the essential research data and the technology necessary to ensure safe and proper participation of man in advanced aeronautical and space missions and to further the development of the systems necessary to sustain him. As such missions require long durations and complex operations, it becomes necessary to obtain detailed information on man's capabilities and limitations and on vehicle design features that will permit man to perform his role most effectively. This information is obtained from comprehensive ground based research, development, and test efforts validated by pertinent flight experiments. Also required are baseline definition and control data against which future operational and experimental flight data may be interpreted.

The Human Factor Systems program aims to provide critical information with respect to: (1) man's physiological and psychological reactions to weightlessness and other flight stresses; (2) the requirement for and techniques of providing artificial gravity; (3) man's capabilities for performing useful tasks in air and space vehicles and in the extravehicular environment; (4) the environmental requirements, the design criteria for life support and protective systems, and the technology which will permit and assist man to do useful work in the aerospace environment for extended periods of time; and (5) design criteria for maintenance and reliability for extended missions. This research program must lead to understanding man's capabilities, limitations, and requirements in sufficient depth to provide data upon which future flight program decisions may be based and to allow subsequent development of appropriate manned flight and exploration systems. It must progress at a rate commensurate with the development of the other systems required to achieve the broad goals and the specific objectives of the national aerospace program.

The Human Factor Systems program includes: Human Research and Performance, Man-Systems Integration, Life Support and Protective Systems, Advanced Concepts and Biotechnology Flight Projects.

The Human Research and Performance sub-program includes research to determine: (1) the nature, time-course, and limits of human adaptation to flight environmental factors; (2) the specific mechanisms through which these adaptations are mediated; (3) the means of predicting the onset and severity of undesirable effects; (4) the means of preventing or ameliorating such effects; and (5) the effects of flight environment on human behavior. Man-Systems Integration research aims to determine, preserve, and extend man's performance capability through: (1) the identification of in-flight tasks which can best be performed by man; (2) the determination of optimal

measurement techniques required to assess performance; (3) the identification of crew skills and training needed to ensure optimal performance; (4) the development of equipment, design requirements, and techniques for critical operations such as command, control, rescue, maintenance, and repair; (5) the development of methods and design criteria to provide habitable living areas in space and on the lunar surface; and (6) the extension of extravehicular performance design information and the continued development of work aids. The Life Support and Protective Systems program element advances the technology required to provide controlled and physiologically acceptable environments for flightcrews during all phases of aerospace missions. Life support systems must supply food, water, and oxygen, provide for personal hygiene, and remove wastes and contaminants. As the name implies, the Advanced Concepts element of the program explores very advanced ideas evolved from the needs pointed out by the work in the above research areas. Biotechnology Flight Projects verify important ground based research in weightlessness.

The Human Factor Systems program, by necessity, is accomplished through a multidisciplinary approach which includes research in physiology, psychology, medicine, biology, engineering, physics, chemistry, and electronics. It is carried out at the various NASA Centers, Department of Defense aerospace medical laboratories, other Government facilities, universities; and in industry.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology..... | $18,228,000 | $17,910,000 | $21,600,000 |
| Biotechnology flight projects.. | 1,600,000 | 1,790,000 | 2,000,000 |
| Total..... | $19,828,000 | $19,700,000 | $23,600,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| Manned Spacecraft Center..... | $2,243,000 | $3,364,000 | $5,550,000 |
| Marshall Space Flight Center. | 300,000 | 410,000 | 700,000 |
| Jet Propulsion Laboratory.... | 50,000 | 50,000 | 100,000 |
| Wallops Station..... | 712,000 | 790,000 | 300,000 |
| Ames Research Center..... | 6,029,000 | 5,990,000 | 5,950,000 |
| Electronics Research Center.. | 910,000 | 995,000 | 1,250,000 |
| Flight Research Center..... | 1,000,000 | 900,000 | 900,000 |
| Langley Research Center..... | 5,682,000 | 5,310,000 | 6,900,000 |
| NASA Headquarters..... | 2,902,000 | 1,891,000 | 1,950,000 |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Human research and performance.. | $6,386,000 | $6,281,000 | $8,450,000 |
| Man-systems integration..... | 3,757,000 | 3,895,000 | 4,650,000 |
| Life support and protective systems..... | 7,585,000 | 7,234,000 | 8,000,000 |
| Advanced concepts..... | 500,000 | 500,000 | 500,000 |
| Total..... | $18,228,000 | $17,910,000 | $21,600,000 |

Human Research and Performance

The Human Research and Performance subprogram represents a continuing effort to qualify man for space missions of extended duration. The contents of the subprogram are in specific response to requirements spelled out in the President's Scientific Advisory Committee's Report entitled, "The Space Program in the Post-Apollo Period." In implementing the subprogram full consideration is given to the recommendations of the National Academy of Sciences' Space Science Board's summer study groups and committees.

In FY 1970, the ongoing systems analysis of cardiovascular adaptive mechanisms will emphasize neurohumoral control loops, particularly their responses to imposed stresses, extremes of responses before collapse, and methods of supporting or supplementing those responses. There is a strong probability that we will need to know how to control these mechanisms to aid man in the problem of reacclimatization to earth's gravity after prolonged weightless flight.

Additional physiological baseline information on man will be obtained by means of extended bedrest studies as well as measurement of stress in selected individuals by means of advanced bioinstruments.

In preparation for the changeover to two-gas atmospheres in space vehicles of the future, there will be an intensification of study of the so-called inert or diluent gases. Confirmation that they are truly inert or definition of their subtle functions is crucial to selection of optimum mixtures.

Prolonged flight will result in some exposure to varying doses of radiation and it is therefore important to understand the effects of this type of exposure. In FY 1970 we will be continuing to determine the extent to which the delicate lens of the eye is damaged by space radiation.

Increased emphasis will be given in FY 1970 to studies of potential microbiological problems in future space missions, particularly, virus infections.

## Man-Systems Integration

The Man-Systems Integration portion of our program will emphasize heavily in FY 1970 the very important area of man-machine relationships in aeronautical systems. Research will be conducted on the optimization of crew organization and duty performance in large subsonic and supersonic aircraft, V/STOL aircraft, and helicopters. Appraisal will be made of the effects of the stresses imposed on men who operate these vehicles. Human factors studies of men who carry out the air traffic control functions will receive attention through discussions and cooperative programs with FAA. Man-Systems Integration research will also emphasize the problem of man as a system component in space operations. High priority studies include space station habitability, problems of locomotion on the moon, and maintenance of equipment in space.

## Life Support and Protective Systems

Manned space flight missions require onboard life support and astronaut protective systems. For short duration missions, those of less than one month, storing expendables such as oxygen and water has been the most practical approach. For missions exceeding one month, the weight and volume penalties of carrying expendables are excessive and thus regenerative-type system techniques become desirable.

Extended manned system tests in simulated space cabins have been recently completed and have demonstrated for the first time that continuous water regeneration and oxygen reclamation techniques are feasible for an extended period of time (60 days).

In FY 1970 a 90 day manned test of a regenerative life support system will be conducted as part of the development of the technology required to support future extended manned space missions. In this test, emphasis will be placed on long-term system operation and long-term uninterrupted crew confinement.

Life support studies and hardware development and tests have shown certain areas of pacing technology. In FY 1970 we will initiate efforts to obtain performance data for new systems of oxygen and water regeneration. The most appealing oxygen regeneration system operates directly off humid cabin air by means of a water vapor electrolysis cell. It will be able to produce more than enough oxygen to fulfill a man's daily requirements and control space cabin humidity at the same time. The water reclamation technique that shows the most promise for space applications uses a principle called electrodialysis. The system eliminates the need for a phase change in the purification process and requires very little energy.

An advanced waste processing technique which NASA and the Federal Water Pollution Control Administration are jointly investigating can be applied either for disposal of wastes (including feces) or reclamation of water from these wastes. The technique employs a chemical process known as wet oxidation. The process is already in use in many cities and solutions are being sought



332-276 O - 69 - 21

for the few remaining problems associated with its use. In addition, the high temperature at which the reaction had to be carried out has been tremendously reduced by the development of a special catalyst (from 1500° to less than 200°F). This development, which will be especially important for space applications, was also a product of NASA FWPCA cooperation.

The thrust of the Advanced Astronaut Protective Systems facet of the Life Support and Protective Systems **subprogram** is aimed at producing improved space suits for both intra- and extravehicular operations and astronaut cooling devices to facilitate extravehicular operations. Suits will feature "stovepipe" and convoluted joints which will provide improved articulation and reduction of up to 50 percent in operating torques. A new extravehicular activity garment will cool the astronaut via internally contained evaporative cooling patches that absorb body heat. This garment eliminates the need for a backpack heat exchanger and water supply, resulting in a lighter operating weight.

## Advanced Concepts

The exploration of the feasibility of advanced concepts of technology applicable to future aeronautical and space operations is essential to continuing progress. One example of the type of effort which will be undertaken in FY 1970 is to apply the noninvasive ultrasonic method of measuring blood flowing through a particular vessel in a given period of time. Since the pulsatile flow of blood causes changes in the vessel diameter, both velocity and vessel size must be continuously monitored and these quantities integrated to obtain the volume.

### Biotechnology Flight Projects

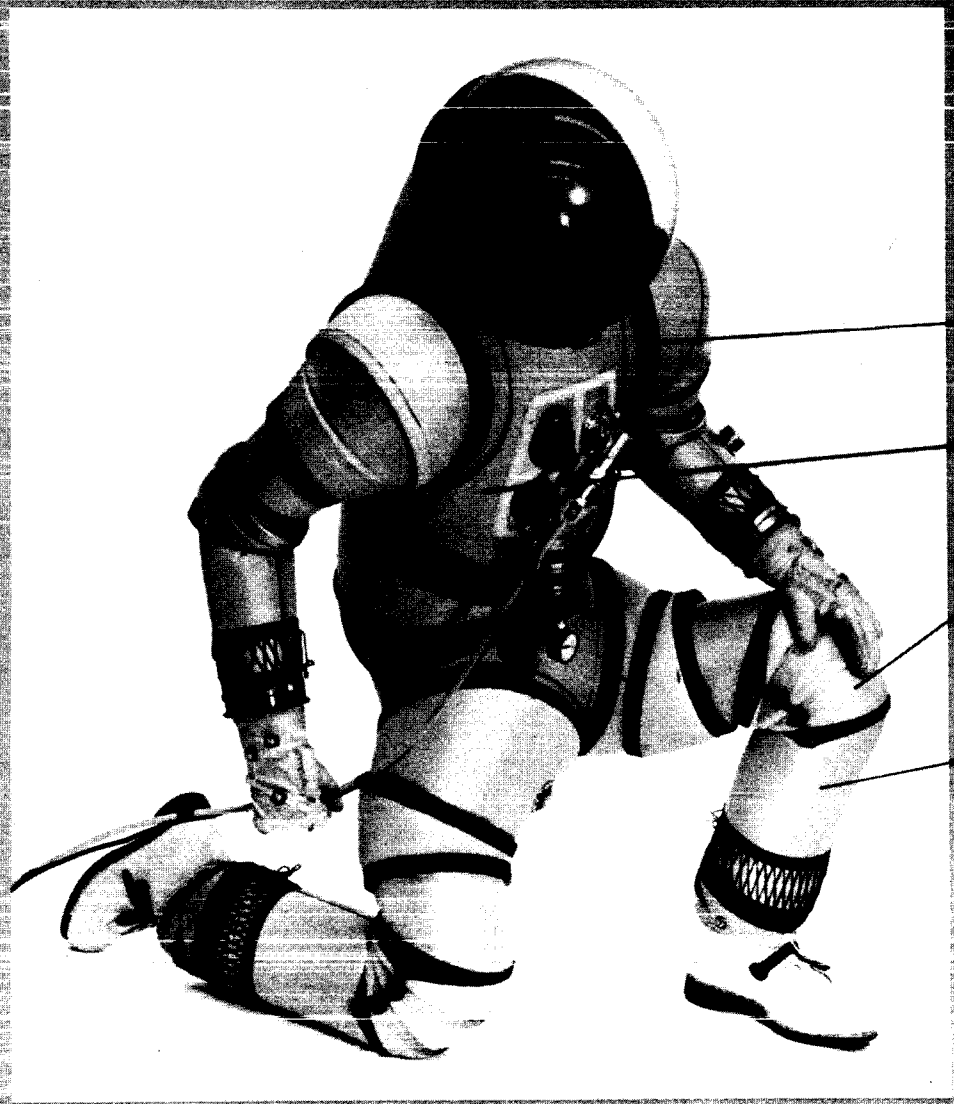
| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Biotechnology flight projects.... | $1,600,000 | $1,790,000 | $2,000,000 |
| Scout (Launch Vehicle Procurement Program)..... | (---) | ($1,100,000) | (---) |
| Total (including launch vehicles)..... | ($1,600,000) | ($2,890,000) | ($2,000,000) |

In FY 1970, a Scout launch of a vestibular experiment is planned to permit study of the action in weightlessness of the basic cells in the frog's balance mechanism, which is similar to the balance mechanism in man's inner ear (the otolith). These tiny otolith cells detect the presence of gravity and send coded messages to the brain control centers. A close study of the mechanism involved will help us to better understand the sensor which is so necessary to man's well being in space as well as on earth. Other physiological experiments are being defined by the Ames Research Center, as an outgrowth of their human and animal research.

The remaining Biotechnology Flight Projects activity in FY 70 is devoted

to experiment definition for needed future flight experiments as an outgrowth of the ground based research discussed in the previous **subprograms.** One important experiment under definition should bring us a step closer to the qualification of man for long duration weightless space flight. This study of the physiological baselines of the primates will continue at the Naval Aerospace Medical Institute, Pensacola, Florida, and at the Yerkes Regional Primate Center, Atlanta, Georgia. Other physiological experiments such as those concerned with the cardiovascular system, calcium metabolism, etc., are continuing at the Ames Research Center and collaborating universities.

Flight experiments on the life support systems are being defined by the Ames Research Center, the Electronics Research Center, the Manned Spacecraft Center, and the Langley Research Center. Langley is also defining other projects, including a manned research centrifuge, and determining the characteristics of an orbiting biotechnology research laboratory.



SOFT SUIT LEG

NASA RB69-835
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MANNED SPACE CRAFT CENTER

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1970 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — SPACE POWER AND ELECTRIC PROPULSION SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The primary objectives of the Space Power and Electric Propulsion program are to: (1) establish or advance the state-of-the-art of a limited number of systems and components having the greatest potential of satisfying estimated future mission requirements to the point where there is a high degree of confidence in their ultimate successful development, and (2) to effect a timely and orderly introduction of the new or advanced technology emanating from the program.

Current estimates of potential future mission power system requirements encompass a wide range of power, life and mission environments. No one power system can meet these varied requirements. The space power program is aimed at providing the research and technology necessary for the improvement and/or development of a limited number of solar, chemical and nuclear systems for anticipated auxiliary power and electric propulsion mission requirements ranging from watts to kilowatts in the 1970's to megawatts in the 1980's.

The early application of solar powered electric thrusters for spacecraft position control and for small, automated, interplanetary spacecraft continues to be a major goal of the electric propulsion program. The experience to date from the ATS (Applications Technology Satellite) flight program coupled with the design and ground evaluation of typical thruster systems confirms their potential advantages of spacecraft operational flexibility and simplicity, increased payload or decreased trip time or reduced spacecraft weight. The proposed SERT II (Space Electric Rocket Test) flight, the continuing ATS program and the ground technology program are essential steps toward the goal of early application.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology | $42,385,000 | $40,700,000 | $39,400,000 |
| SNAP-8 technology | (7,500,000)* | (5,000,000)* | (5,000,000)* |
| Space electric rocket test (SERT) | 1,350,000 | 1,500,000 | 500,000 |
| Total | $43,735,000 | $42,200,000 | $39,900,000 |

*Included in Supporting Research and Technology

Distribution of Program Amount by Installation:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Manned Spacecraft Center..... | $ 122,000 | $ 550,000 | $ 580,000 |
| Marshall Space Flight Center.... | 960,000 | 350,000 | 430,000 |
| Goddard Space Flight Center..... | 3,615,000 | 4,255,000 | 5,770,000 |
| Jet Propulsion Laboratory..... | 9,416,000 | 10,670,000 | 9,270,000 |
| Ames Research Center..... | 345,000 | 310,000 | 450,000 |
| Electronics Research Center..... | 1,350,000 | 1,410,000 | 1,610,000 |
| Langley Research Center..... | 665,000 | 815,000 | 1,480,000 |
| Lewis Research Center..... | 24,506,000 | 21,239,000 | 18,510,000 |
| NASA Headquarters..... | 2,596,000 | 2,601,000 | 1,800,000 |
| NASA Pasadena Office..... | 160,000 | --- | --- |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

| | | | |
|---|---|---|---|
| Nuclear flight safety..... | $ 278,000 | $ 100,000 | $ 300,000 |
| Electric propulsion..... | 7,840,000 | 7,480,000 | 6,800,000 |
| Nuclear power generation*..... | 21,150,000* | 18,910,000* | 18,100,000* |
| Solar power generation..... | 8,210,000 | 8,580,000 | 8,600,000 |
| Chemical power generation..... | 4,907,000 | 5,630,000 | 5,600,000 |
| Total..... | $42,385,000 | $40,700,000 | $39,400,000 |

*Includes SNAP-8 program

Nuclear Flight Safety

The objectives of the NASA Nuclear Flight Safety program include: (1) the coordination and direction of the NASA portion of the joint AEC/DOD/NASA reviews and analyses of proposed missions utilizing nuclear space power systems, (2) providing guidelines to the NASA Centers for future mission applications, (3) developing specific design information in such areas as reentry aerodynamics where NASA has special competence and facilities, and (4) the recovery of NASA launched spacecraft carrying significant quantities of nuclear materials in those cases where a determination is made that recovery is feasible and desirable.

Electric Propulsion

The Electric Propulsion program has the objective of providing the technology required for the application of such systems to future missions.

The principal motivation for this work stems from the high specific impulse possible with electric thrusters which can result in a lower propellant

expenditure rate to achieve a given thrust level. The net result of this fuel economy would be to increase payload of a given launch vehicle or reduce launch vehicle requirements and therefore costs for a given mission. In addition, missions totally impractical for chemical propulsion, such as an orbiter of Mercury, can be carried out with electric propulsion. Satellite station keeping and maneuvering at reduced system weight are also possible. Additional benefits, some of which are peculiar to a given mission, stem from other characteristics of electric thruster systems such as continuous low thrust, nonmechanical thrust vectoring and the availability of relatively large amounts of electric power during nonpropulsion periods.

The electrostatic thruster which accelerates charged particles by means of electrostatic fields will continue to receive the major emphasis in FY 1970.

The contact ion engine appears most suitable for very low thrust ($10^{-4}$ to $10^{-5}$ lbs thrust) auxiliary propulsion applications. Experimental cesium engines of this type were successfully operated aboard the ATS-IV spacecraft in the fall of 1968 and are also included as experiments on the ATS-E spacecraft to be launched in CY 1969. These engines can vary thrust level over a factor of four and electrically, rather than mechanically, align the thrust vector through the changing center of mass of the spacecraft. Work on a higher thrust version of the contact ion engine for north-south station keeping planned for FY 1969 was delayed in favor of an evaluation of the capabilities of the rapidly advancing electron bombardment ion engine for this role. This latter engine using either cesium or mercury propellant appears to offer the advantage of placing a smaller power demand upon the spacecraft. However, demonstration of a satisfactory thrust vectoring scheme has yet to be accomplished and work in this area, as well as on the more advanced colloidal thruster, will continue in FY 1970.

Electron bombardment thrusters appear to offer superior capability for spacecraft prime propulsion applications ($10^{-1}$ to $10^{-2}$ lbs thrust). Such thrusters at the one kilowatt power level have demonstrated operating lifetimes of about a year, which appear adequate for early solar powered missions. Work will continue in FY 1970 toward both improved efficiency in the low specific impulse range of most interest (2000-3000 sec) and larger single module size (2 - 2.5 KW). These engine modules are also being clustered as part of a program to simulate the operations required of an entire solar electric thruster system on a typical mission. Virtually all hardware has been procured and testing is scheduled to start in the last half of FY 1969 and will continue during FY 1970.

Resistojet thrusters which produce thrust via expansion of an electrically heated gas have also received attention in this program. ATS-IV carried low temperature (1600°F) ammonia resistojets for the operational east-west station keeping function and even though the spacecraft did not achieve the planned orbit, the resistojet systems were operated successfully. Such low temperature systems are now considered operational and future research efforts are expected to be limited to comparative evaluation and relatively minor research efforts.

Higher temperature (3600-4000°F) resistojets using hydrogen or ammonia and those capable of using biowaste products such as $CO_2$ for propellants have been shown to be of substantial interest for manned space station drag cancellation and attitude control. Conclusion of an 8000 hour life test of ammonia and hydrogen units and continuation of work initiated in FY 1969 on biowaste units are planned for FY 1970.

Research on electromagnetic thrusters which take advantage of forces generated by electric current-magnetic field interactions will also continue in FY 1970. Advances have been made in basic understanding which remains the fundamental research problem. The ultimate objective of the research is the eventual evolution of a system simpler and more compact than possible with electrostatic engines.

## Nuclear Power Generation

The primary objective of the Nuclear Electric Power Technology program is to obtain the experimental and analytical data needed to permit the ultimate development of the energy conversion equipment to be used in the advanced nuclear electric power generating systems required for future space missions. The conversion systems will utilize isotope or nuclear reactor heat sources furnished by AEC.

The conversion system program must cover the broad spectrum of potential space power requirements from tens of watts of power for unmanned science spacecraft to as much as megawatts for manned electric propulsion systems and for periods of one to five years. Very lightweight systems are required to make the electric propulsion system competitive with other rocket systems. The concepts under investigation range from some with as yet unproven feasibility to some that are established, but with a remaining need for improved performance, reliability and operating life.

The program is primarily concerned with the technology associated with: (1) the Brayton gas turbogenerator cycle, (2) the Rankine liquid metal turbogenerator, (3) thermionic direct conversion systems, (4) isotope thermoelectric generators, (5) a more general research effort on fuels, containment materials, etc., for a high temperature, liquid-metal-cooled reactor and (6) exploratory programs concerning advanced concepts such as liquid metal MHD (magnetohydrodynamics).

The Brayton turbogenerator effort is continuing as a combined in-house and contractual program whose objective is to demonstrate the high component, subsystem, and system performances needed to be useful with an isotopic heat source. The Brayton power conversion system uses the gas working fluid as the bearing lubricant which simplifies the turbogenerator design permitting a hermetically sealed system. Long time operation of a gas bearing mounted turbogenerator package at design temperature is yet to be achieved.

During FY 1969 the low temperature research rotating units such as the compressor, turbine and alternator units were tested and their predicted

performances were verified. Hot closed-loop testing of the single-shaft turbine-compressor-alternator package with and without the prototype recuperator will begin during FY 1969. Electrical heated; i.e., nonnuclear, testing of a complete Brayton power system is planned for early in FY 1970 at the Plum Brook Space Power Facility. Coordination of the Brayton program with the Atomic Energy Commission is continuing, and an isotope heated, Brayton power system test is being jointly planned by the two agencies.

The Rankine turbogenerator program in FY 1969 made progress in development testing of key components and in exploration of total system characteristics. Endurance testing of a three-stage potassium vapor turbine showed inconclusive evidence of erosion requiring further investigation of turbine performance and erosion in FY 1970. An alternator statorette built of advanced electrical, magnetic and insulating materials and a potassium filled ceramic bore seal completed a 10,000 hour test at 1300°F without degradation of materials or electrical performance. During FY 1970 further experimental and analytical work is needed to establish the prototype turboalternator design. Design of a turbine alternator simulator will be initiated to study the dynamic behavior of the full scale machine.

During FY 1970 fabrication of a three-loop high temperature boiler test rig will be completed and tests will be initiated on a prototype boiler tube with working fluids, temperatures, and materials typical of space operation. Development of potassium condenser designs will be continued in FY 1970.

Successful electrical and mechanical tests at 1100°F were completed on a full-scale model of the electromagnetic potassium boiler feed pump stator. This pump will be tested for performance and endurance in FY 1970.

Test on a small-scale, two-loop lithium-to-potassium Rankine cycle system coupled to a reactor simulator showed excellent system stability under severe changes in operating conditions and during 100 hours of hands-off operation. During FY 1970 investigations of system operational characteristics will be continued.

The reactor thermionic conversion program continued to make progress in a number of areas during FY 1969. Reference reactor designs were established (at the 300 KW power level) for each of the three principal in-core thermionic concepts by a joint contractor-AEC-NASA effort. Significant fuels and insulator irradiation data were obtained as well as important structural properties and electrical performance data on key construction materials such as tungsten and rhenium and alumina.

The NASA technology programs concerning thermionic reactor systems are planned to continue in FY 1970 at approximately the same level as in FY 1969. The main efforts will involve: (1) experimental and analytical reactor and system design studies; (2) continuation of four thermionic fuels irradiation tests at the NASA Plum Brook reactor to determine fission gas release rates, dimensional changes, etc.; (3) in-house and contractor thermionic converter performance and life tests; and (4) a number of smaller programs aimed at specific system problems or experimental program needs, such as insulator



332-276 O - 69 - 22

electrical breakdown studies, fission gas "venting" studies, development of high temperature thermocouples, studies of cesium reservoir materials, long term compatibility studies of fuels, emitters, insulators, brazes, etc.

The first NASA mission using a nuclear power supply, the Nimbus B weather satellite, was launched on May 18, 1968; unfortunately, a booster guidance malfunction necessitated mission abort. An identical spacecraft, the Nimbus B2, will be launched in early CY 1969, again utilizing two SNAP-19 radioisotope thermoelectric generators (RTG's).

During FY 1970, NASA will continue programs aimed at defining and minimizing spacecraft RTG integration and operational problems and will continue life testing of RTG's and their components. AEC and NASA will also conduct investigations of high temperature capsules and intact reentry vehicle designs which will lead to definition of the experimental heat source and necessary reentry protection intended for the ground test of an isotope-Brayton turbogenerator system.

The objective of the SNAP-8 program is to provide, by ground development, the technology for a 30-50KWe, 10,000 hour or longer reactor mercury turbogenerator space power system. SNAP-8 is a joint NASA-AEC technology effort with AEC responsible for the reactor and shield and NASA responsible for the power conversion system and, eventually, for full system integration and operation. SNAP-8 utilizes a mercury Rankine conversion loop to convert the thermal power developed by a compact reactor into electrical power.

During FY 1968 and FY 1969, primary attention was placed on developing the necessary performance and life of the major components of the power conversion system and on obtaining basic system technology data using the breadboarded system approach. This phase of SNAP-8 development has been substantially completed, thus permitting the technology to proceed to combined reactor plus power conversion system testing.

All major components of the power conversion system have now demonstrated more than 2500 hours of life in individual tests without failure with all system pumps having exceeded 10,000 hours in test. Demonstration of the full 10,000 hour life milestone of the boiler and turboalternator condenser has not yet been accomplished; however, the main problems previously encountered of turbine stage cracking and boiler corrosion and unreliable thermal performance at startup appear to be solved.

Testing of the two breadboarded SNAP-8 power conversion systems to develop system dynamics data and endurance has continued. A major milestone was reached on October 2, 1968, with the first demonstration of an automatic bootstrap startup, representative of space operation.

The budget request for FY 1970 provides for initiation of the next and final step of SNAP-8 technology development, the combined test of the power conversion system with the SNAP-8 reactor in NASA's Space Power Facility at the Lewis Research Center. This test is the logical extension of the

nonnuclear system development now being completed. It is needed to help achieve the future availability of SNAP-8 as a space power system and to provide knowledge and technology of complete reactor dynamic space power systems including the factors influencing combined system performance and life under realistic space simulated operating conditions.

The current breadboarded power conversion systems were not intended and are not suitable for combined system testing because of their experimental and configurational features. Therefore, the FY 1970 request provides funds, principally, for work toward a compact power conversion system which can be combined with the reactor and which includes the basic flight representative features which must be verified in actual reactor operation. In addition, endurance life testing of the major components will be continued beyond 10,000 hours.

## Solar Power Generation

Goals of the solar power system program are: (1) investigation of methods for compact stowage and reliable, automatic deployment of large area, lightweight solar cell arrays; (2) understanding the structural and flight dynamic interactions of large, flexible solar cell arrays with guidance, control, and propulsion subsystems; (3) development of reliable, long life electro-mechanical drive mechanisms for solar cell power systems for application to spacecraft flights on Venus-Mercury flybys, solar probes, Mars landers and Jupiter flybys and orbiters; (4) substantial improvement in the resistance of solar cells to degradation in the space radiation environment; (5) better metal-to-silicon contacts needed to withstand new extremes of temperature and thermal cycling; and (6) new solar cells having greatly improved efficiency and reduced cost.

There is also an urgent need to advance the technology of the power distribution, regulation and control systems. These circuits and components must handle all of the electric power generated and provide conversion and regulation as required by the individual spacecraft loads. The power conversion electronics account for the major complexity and cost of many solar power systems. Spacecraft failures in flight have been traced to deficiencies and failures in these circuits and components. Emphasis is needed to obtain a better understanding of the power conversion electronics under off-design conditions and to provide a major technological advance toward improved reliability and increased efficiency.

Research will continue toward a multipurpose control circuit for pulse modulated, voltage regulator circuits, such as are needed for most spacecraft power conversion electronic systems. Work in FY 1970 will continue toward more temperature resistant and thermally stable capacitors capable of storing large amounts of electrical energy per pound of capacitor weight. Research on converter/regulator units capable of operating reliably with several hundred volts input and capable of handling kilowatts of power in single modules will need to continue in FY 1970. A comprehensive test effort to identify basic failure modes in the complex power conversion electronics

will be undertaken in FY 1970 in a continuing program to improve reliability, life and efficiency and to reduce weight and eliminate spacecraft failures.

The second phase of a major effort to achieve technology readiness of an advanced 20 watt per pound (20 w/lb), 50KW folding solar cell array interplanetary flight was completed during FY 1969. Work was initiated to improve the ability of these new lightweight arrays to withstand repeated, deep thermal cycling such as would be encountered on earth orbiting spacecraft. The ability of the new beryllium frame-fiber glass tape substrate structure to withstand relatively high stress and acceleration while deployed will also be investigated during FY 1970.

A significant effort toward a goal of a 250 $ft^2$, 30 w/lb deployable array concept utilizing a thin plastic substrate and deployable structural booms was initiated in FY 1969 and will continue in FY 1970. In addition, the long term stability of a lithium doped, radiant resistant solar cell developed in previous years' work must be determined. Laboratory and space tests at realistic irradiation rates are needed to determine the self-healing rates of damage annealing.

## Chemical Power Generation

Work in FY 1969 has emphasized the search for more reliable sealing methods and materials, for better methods of constructing battery plates, and for a procedure that permits selection of reliable batteries. Auxiliary electrodes developed in previous years' programs that avoid overcharge and thus overheating and excessive pressure cycling, are beginning to be used in spacecraft. New materials for battery plates are being studied with a view to (a) increasing the energy density, (b) minimizing migration of active battery materials in long term use, and (c) eliminating drying over the years. A three-pronged approach to battery testing is being formulated, making use of chemical, statistical and crypto-analytical models. Its goal is to give the space power engineer a tool for nondestructively testing a battery over a period of less than 1% of its expected life, and to use the data for projecting its long term reliability.

The first requirement for a battery in a planetary lander was to make the power package sterilizeable and capable of surviving a hard impact. A small (5 amp-hour), primary (one-shot, nonrechargeable) sterilizeable cell with applicable impact resistance has been demonstrated.

Investigations in FY 1970 will be toward larger cells for higher power requirements having increased impact resistance that can be remotely activated to avoid any deterioration during prolonged storage.

A new set of problems appeared with the use of weather balloons at high altitudes. The power systems carried onboard will have to operate over wide temperature ranges and their batteries must be light in weight, fragile enough to be ingested in an airplane engine without causing any hazard, and inexpensive enough for mass use. Thus, a program has been started to find

(a) a battery electrolyte that does not freeze at the low end of the temperature excursion; (b) a structure that preserves the battery's integrity while in use, yet permits its quick disintegration in a jet engine; (c) a means for storing some heat and, in effect, narrowing the temperature cycle.

The Gemini spacecraft used the first functional fuel cell system. Apollo has another type of fuel cell. Though both systems are well suited to their purposes, neither is very appropriate for future space missions. A more rugged, flexible and longer lived power plant was urgently required. During several previous years of technological effort, the matrix type system was perfected for this purpose under a joint OART/OMSF program. It is now being qualified for manned spacecraft, according to both NASA and Air Force specifications and has been selected for MOL.

In FY 1970 research will be aimed at finding a more efficient and longer lived catalyst for the oxygen cathode, optimizing the electrode structure for better power density, replacing the asbestos matrix by a more inert structure, and searching for novel engineering approaches to improve power density by a factor of ten or so.

Basic research will continue in FY 1970 on such topics as heat and mass transfer in electrochemical power sources; stability of anode-electrolyte couples; effects of variables on shelf life; effects of electromagnetic radiation on electrochemical cells; application of holography to electrochemistry; mechanism of dendrite growth on zinc plates; and properties of novel electrochemical couples and cells.

Space Electric Rocket Test (SERT)

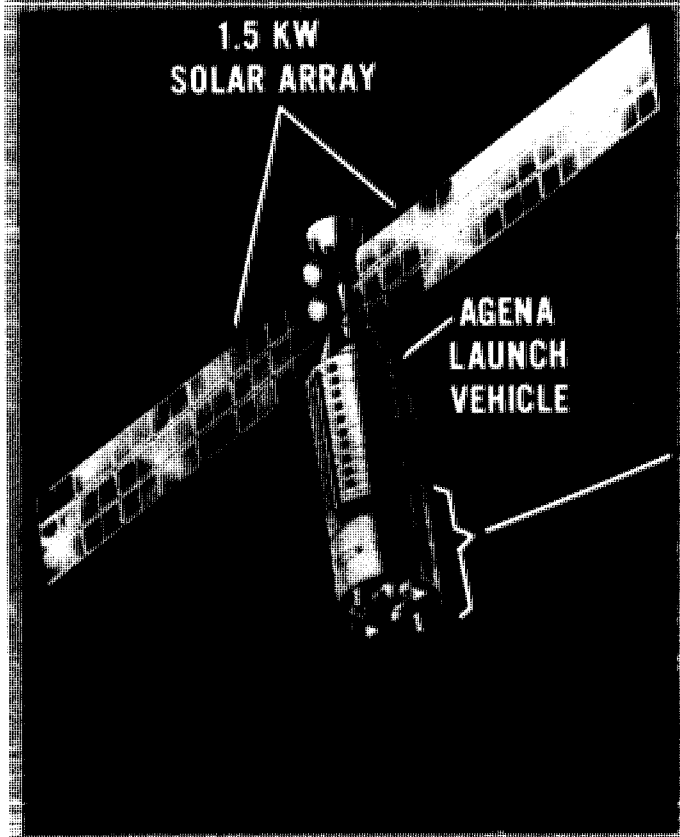
| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Spacecraft and experiment development..... | $1,350,000 | $1,500,000 | $500,000 |
| Agena (Launch Vehicle Procurement Program)..... | ($2,166,000) | ($794,000) | ($150,000) |
| Total (including launch vehicle)..... | ($3,516,000) | ($2,294,000) | ($650,000) |

After the successful demonstration on the suborbital SERT I in July, 1964 that ion beams could be neutralized in space and, hence, ion engines were feasible, work was initiated on a second spacecraft, SERT II. The primary objective of this second flight in the SERT program is the verification of long term, electron bombardment ion engine performance in space. The spacecraft will also carry experiments aimed at assessing possible electric propulsion spacecraft interactions. SERT II, as the next major step in prime electric propulsion, is expected to provide both valuable design information and confidence in adopting electric propulsion for prime mission use.

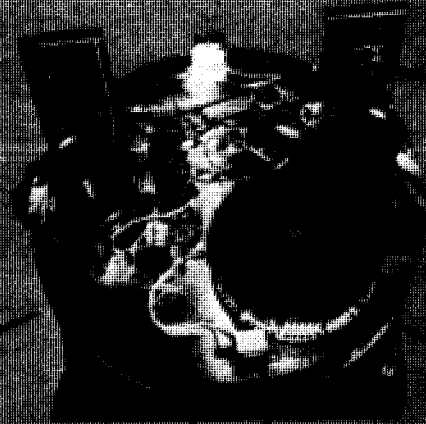
SERT II is scheduled for launch during CY 1969. The spacecraft will be injected into a near polar sunlit orbit by a Thorad Agena from the Western Test Range. A 1.5 KW solar array attached to the Agena vehicle will be used to sequentially power two 1 KW mercury electron bombardment thrusters with a goal of 6 months operation. The FY 1970 funds are required for launch support and data reduction.

# SPACE ELECTRIC ROCKET TEST (SERT-II)

## SCHEDULED LAUNCH - CY 1969




SPACECRAFT AND
SUPPORT UNIT



12 UNITS

MAJOR EXPERIMENTS

- THRUSTER SYSTEM ENDURANCE EVALUATION (6 MONTHS MINIMUM)
- RADIO FREQUENCY INTERFERENCE (RFI) MEASUREMENT
- PROPELLANT DEPOSITION MEASUREMENTS

NASA EN69-783
12-13-68

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — NUCLEAR ROCKETS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Nuclear Rockets program is to provide rocket propulsion systems for application to advanced orbital, lunar and planetary missions. In carrying out this objective, the AEC-NASA Space Nuclear Propulsion Office is conducting a detailed program of system analysis, design, development and testing to provide a 75,000 pound thrust NERVA engine capable of performing advanced space missions. Engine development is proceeding using the base of technology established through the Phoebus and NERVA technology programs.

Apart from NERVA development, the Nuclear Rockets program includes activities to advance the technology of nuclear rocketry, and in particular specific impulse, duration and reactor recycling capability. The Los Alamos Scientific Laboratory (LASL) PEWEE reactor program plays an important role in this work. Effort will continue to be directed toward the development of vehicle technology, radiation effects studies, and studies and experimentation to enhance the reliability of nuclear rocket components.

The prime output of the Nuclear Rockets program will be a nuclear engine, developed through Pre-Flight Rating Tests (PFRT), having a specific impulse of approximately 825 seconds and a thrust of approximately 75,000 pounds (equivalent to a reactor power of about 1500 megawatts). Other performance objectives include the capability for multiple cycles of operation, increased full power duration and high reliability. This engine will provide a major advance in propulsion capability. A nuclear stage would be capable of performing a wide variety of advanced space missions beyond the performance potential for chemical rockets.

The advantages of nuclear propulsion over chemical propulsion results from its high payload performance, propulsion efficiency and versatility. In the types of missions involving high energy and high payloads, specific impulse becomes an extremely important performance requirement. The nuclear rocket has a marked increase in specific impulse over the chemical rocket. Among the missions for which the nuclear rocket offers significant advantages are the movement of heavy scientific payloads into deep space, the movement of high payloads (both manned and unmanned) to the lunar surface, and the movement of heavy payloads on highly energetic transfers in earth orbit. Detailed studies of unmanned planetary missions using the nuclear rocket are continuing. As a third stage on the Saturn V launch vehicle, replacing the

chemical S-IV B stage, the nuclear rocket can increase the payload by a factor of two, the exact increase depending upon the mission. A payload increase of this amount would increase staytime for manned lunar exploration missions and would permit direct manned flights to any point on the lunar surface, as distinguished from the lunar orbit rendezvous used in Apollo. Operational advantages offered by the nuclear rocket include fewer launches to achieve a total program objective and lower sensitivity to trip time. Versatility appears in the variety of missions applications which can make use of a single basic engine.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology | $12,500,000 | $6,000,000 | $8,000,000 |
| NERVA | 37,500,000 | 22,200,000 | 27,500,000 |
| NRDS operations | 4,000,000 | 3,800,000 | 1,000,000 |
| Total | $54,000,000 | $32,000,000 | $36,500,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| Marshall Space Flight Center | $1,400,000 | $920,000 | $2,200,000 |
| Lewis Research Center | 2,200,000 | 1,000,000 | 1,500,000 |
| Space Nuclear Propulsion Office | 50,400,000 | 30,080,000 | 32,800,000 |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

| | | | |
|---|---|---|---|
| Rocket reactor research | $7,850,000 | $3,720,000 | $3,800,000 |
| Nuclear rocket engine systems | 3,100,000 | 1,180,000 | 1,800,000 |
| Safety | 150,000 | 100,000 | 200,000 |
| Vehicle technology | 1,400,000 | 1,000,000 | 2,200,000 |
| Total | $12,500,000 | $6,000,000 | $8,000,000 |

The supporting research and technology effort (SR&T) covers a broad spectrum of programs, most of which are of relatively small dollar value. The general aims are: (1) to provide support to the NERVA engine design and development program; (2) to extend the technology for solid-core, nuclear rocket systems beyond current performance levels; (3) to prepare the technology base for nuclear stage development; and (4) to investigate the feasibility of advanced propulsion concepts.



332-276 O - 69 - 23

## Rocket Reactor Research

The funding in this area supports: (1) nonreactor components for reactor testing (nozzles, turbopumps, controls, etc.) including the propellants necessary for experimental analyses; and (2) investigation of advanced concepts and design studies of reactors for future applications.

A significant portion of the funds applied in this area is used to provide propellant and nonnuclear support, such as propellant feed systems, to the Los Alamos PEWEE fuel element test bed reactor program. The second PEWEE reactor is scheduled for testing in the first quarter of CY 1970.

Research will continue in FY 1970 on advanced nuclear propulsion concepts. The primary emphasis of this effort is being directed toward closed-cycle gas core systems, namely, the nuclear light bulb concepts. Feasibility studies on this concept will continue to be conducted using a 1.2 megawatt radio frequency heater to provide high temperature plasmas which duplicate the heat fluxes of the nuclear light bulb. As the capability to cope with the high heat fluxes improves, simulated heat fluxes will be pushed to the point where thermal conditions are duplicated.

Research will also continue on advanced concepts such as the coaxial flow reactor. In-house capability and research is centered at the Lewis Research Center.

## Nuclear Rocket Engine Systems

The research conducted in this area provides information for specifying characteristics for improved nuclear rockets as well as establishing a general base of information on the design and operation of components and engines. The most significant need is for studies to aid systems engineering management in the NERVA development work and for research directed toward the enhancement of the basic design reliability of selected components of a nuclear rocket engine such as the nozzle, turbopump, valves, actuators and instrumentation. Proposed work on nozzle coatings and rotor dynamics are examples of the type of activity that the effort will be applied to.

Other important efforts are directed toward improved instrumentation, fluidic control system components and the analysis of engine transients. Effort is also conducted on the effects of radiation on nuclear engine components, materials and systems. The purpose of this work is to define the behavior of materials in a combined radiation and cryogenic environment. Such information supports all nuclear rocket program activities and is essential for the design effort.

## Safety

The effort in this area is directed toward completing the base of knowledge required to define and resolve the new and unique safety problems associated with nuclear rocket propulsion system development. Most of this information stems from the mainstream activities of the Nuclear Rockets program. Frequently, however, specially directed research and analyses must be conducted outside of these disciplines. Examples of work in progress or planned for FY 1970 include exploration of the relation between systems performance and safety requirements, and further analysis and conceptual design of measures to avoid or counter flight failures.

## Vehicle Technology

The effort in this activity is directed toward providing basic design information which will assist the development of nuclear rocket vehicles for flight mission applications.

At MSFC, effort will be continued in studies and experimentation of the effects of radiation on propellant heating. Understanding and controlling propellant heating phenomena is of fundamental importance since this effort determines propellant boil-off losses, tank pressure level, and the properties of fluid entering the pump.

Work will also continue to provide support in various system design concepts and studies. The studies will provide detailed analysis, conceptual design and development requirements of a nuclear flight propulsion system and its evolution from a flight test stage to an operational injection stage. The results of this study are vital to the conduct of the NERVA development program and will provide NASA management with a basis for future decisions for follow-on activity. No hardware is planned under these study contracts.

**NERVA**

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Engine system component and subsystem..... | $16,700,000 | $10,800,000 | $18,800,000 |
| Ground test and operations support..... | 18,500,000 | 9,800,000 | 7,700,000 |
| Propellants..... | 2,300,000 | 1,600,000 | 1,000,000 |
| Total.. ..... | $37,500,000 | $22,200,000 | $27,500,000 |

## Engine System Development

During FY 1970, full-scale NERVA development will be initiated. This will include: the establishment of the final engine design; the procurement, fabrication and testing of component development hardware; and procurement of nozzle forgings and other long lead time hardware for the first development reactor and engine. In addition, the design of ETS-1 modifications will be established and a contract will be initiated for the fabrication of a new test stand exhaust duct for NERVA engine testing.

## Component and Subsystem Development

The industrial contractor will be engaged in the design, procurement and testing of the following components to support NERVA:

1. Reactor subsystem: This effort is largely funded by the AEC and will be carried out by the Westinghouse Astronuclear Laboratory. The components of this subsystem which will receive attention during FY 1970 include reactor fuel elements, reactor support hardware, mechanical and electrical components, and ground support equipment.

2. Turbopump assembly: The detailed design, fabrication and testing of the development hardware for this assembly will be initiated during FY 1970 based on analysis of preliminary designs, configuration and requirements specified by SNPO and information from the NERVA technology phase.

3. Thrust chamber assembly: The basis for the design of the NERVA nozzle is the regeneratively-cooled, U-tube nozzle developed under the NERVA technology phase. Materials research conducted under the SR&T program also support this effort. During FY 1970, the design and fabrication of the nozzles for the NERVA R-1 reactor, the E-1 engine, and development testing will be initiated. In addition, design activities associated with the nozzle extensions and skirts will be continued.

4. Lines, valves and actuators: The design and fabrication of development hardware will be initiated during FY 1970 based on components fabricated and tested in the NERVA technology phase. Components required for the NERVA R-1 reactor and E-1 engine will stem from the effort.

5. Thrust structure and attitude control: During FY 1970, the long lead procurement and fabrication of development hardware for these components will be initiated.

6. Engine control system: The effort in this area will be based on information from the XE ground experimental test program, LASL Phoebus and PEWEE reactor test programs and laboratory analyses of subsystems and components evaluated under SR&T programs.

Studies will continue during FY 1970 on engine/vehicle interactions and interface requirements, e.g., radiation shielding; tank heating; propellants storage; and the effect of the space environment on engine-stage components and subsystems.

### Ground Test Operations and Support

During FY 1970, this effort will be directed toward completing XE post-mortem operations; preparation of ETS-1 for NERVA modifications, e.g., removal of the dry exhaust duct and associated lines, valves and instrumentation, the XE test stand adapter, etc.; design of ETS-1 engine development modifications; and design of GSE modifications for the E-MAD building and for the remote handling, checkout, test and maintenance of engine development hardware at NRDS.

In addition, the modifications of engine/reactor component development test facilities at Aerojet-General Sacramento and Westinghouse will be initiated.

### Propellants

Funding provided under this heading will be used for procurements of propellants, primarily liquid hydrogen, required in various parts of the NERVA program.

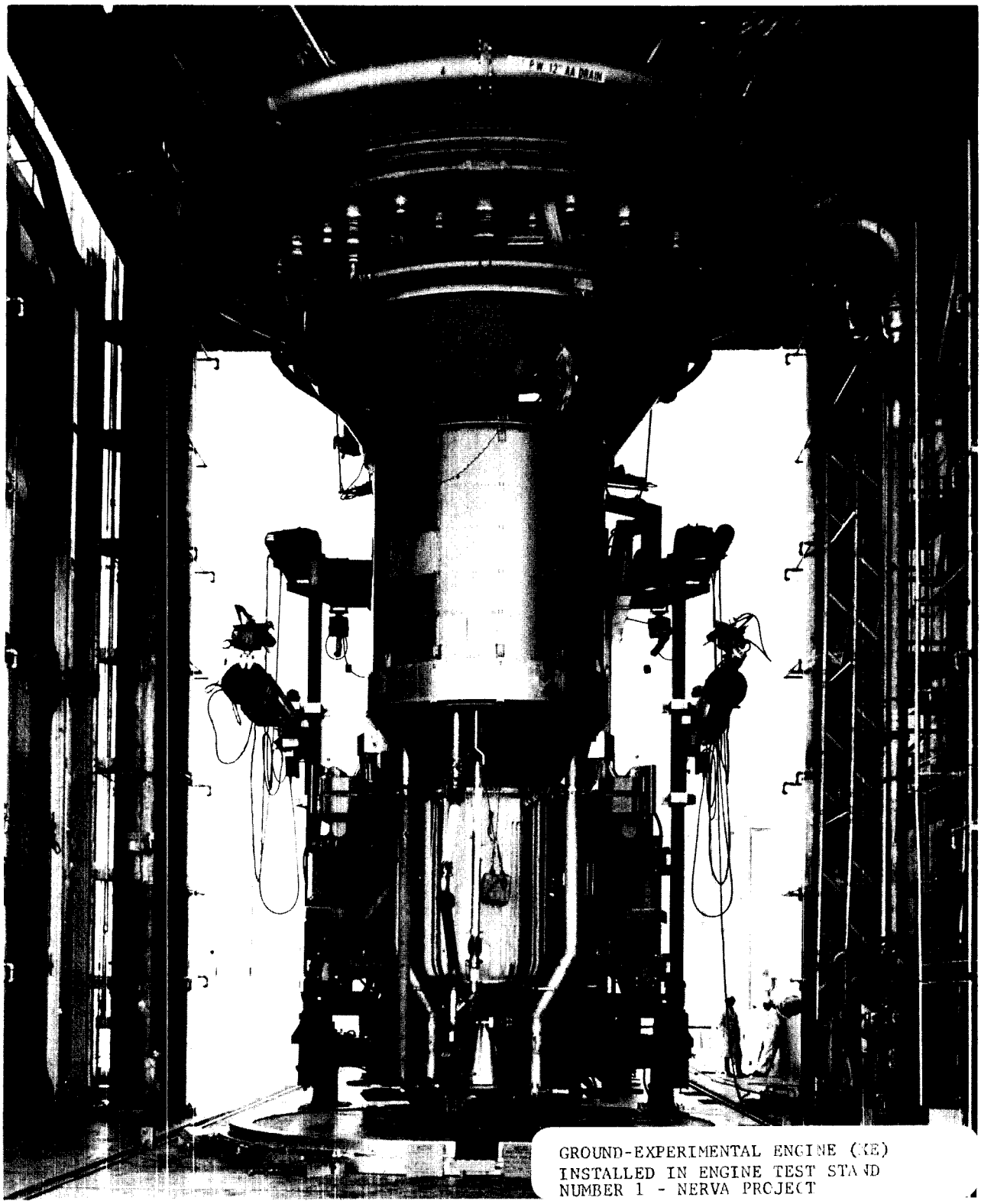
Nuclear Rocket Development Station Operations

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| General site support..... | $3,875,000 | $3,700,000 | $1,000,000 |
| Capital equipment..... | 125,000 | 100,000 | --- |
| Total..... | $4,000,000 | $3,800,000 | $1,000,000 |

The Nuclear Rocket Development Station is the national site for the ground, static-testing of nuclear rocket reactors and engines. Eventually, it will be used to test the propulsion modules or rocket stages associated with flight engine development. The major users of the Station are the Aerojet-General Corporation, the Westinghouse Electric Corporation, and the Los Alamos Scientific Laboratory. Overall management is provided by the AEC-NASA Space Nuclear Propulsion Office. The major activity to be conducted in FY 1970 is the PEWEE-2 reactor test program. The PEWEE-2 reactor will be used to qualify the fuel and critical core support hardware for NERVA reactor development. The reduced requirement for NASA funds in FY 1970 is the result of the completion of the XE testing program early in FY 1970 and the low level of activity for the balance of the year. NERVA testing will not be reinitiated at the site until FY 1972.

Maintenance, housekeeping and management functions must be provided at the site. These functions, taken together, constitute general site support. They include routine maintenance and operation of site facilities, e.g., custodial services; maintenance of roads, grounds and utility systems; the furnishing of utilities; fire protection; and cafeteria services. Also included are the services of a support contractor to maintain and operate electrical, plumbing, carpenter, welding and machine shops.

These funds provide for NASA's share of the general site operations.



GROUND-EXPERIMENTAL ENGINE (GE)
INSTALLED IN ENGINE TEST STAND
NUMBER 1 - NERVA PROJECT

RD 15-8

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — CHEMICAL PROPULSION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Chemical Propulsion Program has the objective of providing required technology to permit the straightforward development of advanced chemical rocket systems necessary for the nation's future space missions. Elements of this program are: (1) identification of future mission propulsion requirements; (2) research into fundamental propulsion concepts to meet these requirements; (3) study of principal design parameters; (4) investigation of sound technical solutions to key design problems; (5) development of experimental design, fabrication, and test techniques; (6) demonstration of experimental engines and motors, and (7) evaluation of concepts and verification of technical capability to meet the mission requirements.

The development of advanced propulsion systems to meet future space program needs for launch vehicles and spacecraft requires a carefully planned technology base which should precede the actual system development phase by many years.

Applied research and experimental work is directed toward two primary types of propulsion; systems using liquid propellants and motors which use solid propellants. Hybrid chemical propellant systems which use both liquid and solid propellants are also included. Thrust levels range from millipounds to several million pounds and applications range from small attitude stabilization thrusters for spacecraft to very large motors for first stages of future launch vehicles. In all of these applications of chemical propulsion the demands of future missions involve higher performance requirements and improved operating reliability to assure mission success. This program is directed at finding expeditious and economical solutions to these requirements.

Propulsion processes, performance improvements, combustion problems, engine design, engine materials, and fabrication techniques are major categories of active research. In addition, propellant physical properties, gas dynamics, heat transfer, fluid mechanics, solid mechanics, elastic properties, and chemical reaction phenomena, as they relate to advanced propulsion systems, are studied both experimentally and theoretically. The basic technological investigations are supported by complemintary system demonstration programs, which have the purpose of establishing the validity of the advanced propulsion systems concepts generated by the program.

The technical projects under the Chemical Propulsion program are managed by NASA field centers and the Jet Propulsion Laboratory (JPL), which use competent research and engineering personnel and unique equipment available

at these facilities. Work at the NASA centers is augmented by contracted effort in order to capitalize on the skills and specialized talent available in several industrial and university groups working in the field of chemical propulsion.

Problems experienced in the operation of existing space propulsion systems are also investigated as part of the overall effort in the Chemical Propulsion program.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Supporting research and technology | $33,537,000 | $28,900,000 | $25,100,000 |
| Large solid motor | 3,500,000 | --- | --- |
| Total | $37,037,000 | $28,900,000 | $25,100,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| John F. Kennedy Space Center, NASA | $75,000 | --- | --- |
| Manned Spacecraft Center | 950,000 | $550,000 | $500,000 |
| Marshall Space Flight Center | 6,175,000 | 2,800,000 | 2,750,000 |
| Goddard Space Flight Center | 540,000 | 150,000 | 250,000 |
| Jet Propulsion Laboratory | 5,319,000 | 4,497,000 | 5,200,000 |
| Langley Research Center | 2,673,000 | 2,630,000 | 2,200,000 |
| Lewis Research Center | 13,338,000 | 12,310,000 | 9,500,000 |
| NASA Headquarters | 2,743,000 | 2,364,000 | 1,150,000 |
| NASA Pasadena Office | 5,224,000 | 3,599,000 | 3,550,000 |

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

| | | | |
|---|---|---|---|
| Liquid rocket research and advanced technology | $12,504,000 | $12,575,000 | $10,000,000 |
| Liquid rocket experimental engineering | 12,210,000 | 6,075,000 | 8,200,000 |
| Solid propulsion research and advanced technology | 5,083,000 | 4,825,000 | 4,000,000 |
| Solid rocket experimental engineering | 3,740,000 | 5,425,000 | 2,900,000 |
| Total | $33,537,000 | $28,900,000 | $25,100,000 |



332-276 O - 69 - 24

## Liquid Rocket Research and Advanced Technology

The Liquid Rocket Research and Advanced Technology project consists of broadly based research applicable to advanced liquid rocket propulsion concepts. Effort is also directed to research that will lead to lower cost, improved reliability and better operational performance with existing concepts. The work is carried out through NASA centers and through the Jet Propulsion Laboratory, with roughly half the total work conducted under contract with industry and in universities.

The information generated is published as engineering reports and handbooks applicable to both the aerospace and non-aerospace industry. Coordination is maintained with the Department of the Air Force and other DOD programs, both informally and through formal information exchanges, administered by the Interagency Chemical Rocket Propulsion Group (ICRPG).

About one-half of the project can be classified as subsystem and component technology. This includes investigations of improved designs for pumps, turbines, injectors, thrust chambers, valves, and feed system components. About one-fourth of the project is devoted to generating scientific and engineering data on subjects such as stable and unstable combustion, ignition, heat transfer, and nozzle flow processes. The remaining one-fourth of the project includes propellant performance and chemistry, instrumentation and test techniques, and a small continuing analysis effort to identify that research and technology that will most effectively accomplish our goals.

Technology pertinent to launch vehicle engines includes improved methods of fabrication of components, better design parameters to prevent combustion instability, research in unconventional nozzles, and design criteria for low cost turbo-pumps.

The program includes basic technology for engines using high energy space storable propellants, and research in the factors related to long duration space missions, such as space ambient ignition, and gelled and partly frozen (slush) propellants.

Effort is being directed toward the tripropellant combination using liquid hydrogen, fluorine, and lithium to define a practical engine concept. An experimental system using this propellant has now demonstrated specific impulse performance in excess of 500 pound seconds per pound, the highest yet measured with chemical propellants.

## Liquid Rocket Experimental Engineering

The purpose of the Liquid Rocket Experimental Engineering project is to translate the improved component design and fabrication methodology evolved by the technology program into workable "breadboard" systems. These systems are then tested over a wide range of simulated operating conditions to define operating limits and to uncover system interactions and unanticipated problems. Frequently, additional research is required at the component level. This work

identifies and develops appropriate designs, fabrication methodology, test procedures, all with strong consideration of cost and performance advantages to future space programs. Probable cost, schedule, and facility requirements for a potential hardware development, can be estimated from the results of this experimental work.

Launch Vehicle Propulsion Systems - The main objective of the launch vehicle propulsion work is to reduce the present costs of launching space payloads. Near-term liquid propellant work is focused on "scrubbing down" hydrogen-oxygen upper stage costs and simplifying present hydrogen-oxygen engines. Several projects bear on this. These include work on engine turbo-pumps with the purpose of relaxing the temperature and pressure restrictions on starting cryogenic propellant engines.

Work is continuing on the further applicability of aerospike nozzle engines. The thrust chamber which was used last year to explore start and stop transients in an annular thrust chamber engine will be used to study nozzle base-pressure and thrust vector control. A modular thrust chamber element representing an arc-segment of a total thrust chamber will be built and tested to explore the applicability of low-cost fabrication procedures to meet the requirement of advanced, high thrust launch vehicles.

Space Propulsion Systems - The development of a technology base for use of high performance propellants in our future space systems will be continued. The performance advantage of such propellants for the high-acceleration requirements of lunar, planetary, and deep space missions will often permit realistically useful payloads to be carried on these missions with existing launch vehicles.

Hydrogen-oxygen engine technology is considered to be well understood and hydrogen-fluorine engine technology is well advanced. NASA's main effort in hydrogen-fueled systems is to develop methods of storing hydrogen for extended duration in space. This includes work on insulation, frozen hydrogen (slush), and self-refrigeration.

The high performance, high bulk density, and suitable physical properties of space storable propellants make them attractive for planetary orbiters, landers, ascent vehicles and earth return stages. The propellant combinations of interest are oxygen difluoride or mixture of oxygen and fluorine as oxidizer and either liquefied hydrocarbon gases or diborane as fuel. The oxygen-difluoride, diborane combination shows superior performance but limited capability for cooling; accordingly it is being pursued for small low-pressure propulsion systems. The oxygen-fluorine oxidizers are being investigated with methane fuel for pump-fed systems of larger size. Engine demonstrations of these propellant systems will be undertaken in FY 1970. Complete propulsion systems to be tested in facilities simulating the space environment should follow engine demonstration tests.

Auxiliary Propulsion - Current and future spacecraft require small thrust units to change orbit or trajectory, and to maintain attitude. Operational rendezvous will require precise auxiliary thrusters to operate reliably with

an exceedingly variable duty cycle. Thrust requirements for auxiliary propulsion units range from millipounds to several hundred pounds.

Research on monopropellant hydrazine will be continued in an attempt to improve the catalyst materials and to develop a better understanding of the transient operation of catalytic reactors started from low initial temperature. Prior work has led to the selection of this monopropellant in many applications such as Mariner, Mars 1969, Advanced Technology Satellite (ATS), Intelsat, and Titan.

Future large spacecraft will use high energy propellants for their main propulsion systems. Testing of auxiliary systems using these same high energy propellants is underway. Materials to allow zero-g positive expulsion of cryogenic liquid oxygen and liquid hydrogen have been tested and work is going ahead on small thrust chambers for these propellants.

## Solid Propulsion Research and Advanced Technology

The Solid Propulsion Research and Technology project provides the technical framework for developing and using solid and hybrid rocket systems. Solid/hybrid projects include analytical and experimental investigations in combustion, ignition, and extinguishment, acceleration effects, materials and fabrication techniques, high efficiency propellants, high performance rockets (solid, hybrid, tribrid), rocket defects and nondestructive testing, and pyrotechnics.

The project is broadly based by design. Generalized propulsion capability needs are modified by technical forecasts of specific future requirements. Research priorities are structured to provide an adequate technical base in the time frame of anticipated need.

Much of the research during the past several years bears on problems of large solid motors. Among these research tasks are burning rate control, rheological and mechanical properties of propellants, potential instability investigations and nondestructive testing techniques.

Planetary spacecraft propulsion systems must be sterilized. A significant effort is to develop solid propellant binders and oxidizers that can tolerate the sterilization (heat) processes.

## Solid Rocket Experimental Engineering

The Solid Rocket Experimental Engineering project advances the technology of all classes of solid motors to the point where selection and development for specific missions can begin. The work falls into the three categories of launch propulsion, space propulsion and auxiliary propulsion.

Solid Launch Vehicle Propulsion - The FY 1970 work continues with investigation and demonstration of a technology base for low-cost solid boost motors. One task is the design and verification of thrust vector control, which is unproven for large solid motors. Other tasks are developing new cost optimized

materials for large motor cases, nozzles and insulation. These tasks are aimed at defining a prototypical large solid motor for future development.

A steel alloy (HY 140) with exceptional combination of strength, toughness and formability will continue to be evaluated as a motor case material.

Laminates of cloth, paper, fiberglass, and castable carbon resin mixtures are being examined as low-cost substitutes for expensive components of solid motor nozzles. The bonding characteristics of cast propellant batches will be further studied as a function of casting methodology and propellant properties.

The motor test in calendar year 1967 showed unpredicted pressure peaks and propellant expulsion through the nozzle. Better understanding of the influence of process variables is essential. The equipment and methods for inspecting finished motors will be investigated to give means for verification of the quality of the internal propellant structure.

Space Propulsion - Work will continue on the high performance solid propellant motor with stop and restart capability, started in prior years. It will give the combination of low cost and reasonable performance in small size motors typical of the class widely used in NASA unmanned missions. The stop-restart capability, new for solid rockets, will give the motor flexibility especially attractive for transfer to high orbit and orbit insertion. The tasks for FY 1970 will continue the investigation of stop-start propellants, verification of motor case, insulation, and nozzle design, and proof of thrust termination and re-ignition.

Auxiliary Propulsion - The major work in this effort will involve evaluation of squibs and initiators used widely in vehicles and payloads. The emphasis of work with these components is enhancement of reliability through establishment of test methods and criteria, and investigations of improved designs.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY  AERONAUTICAL VEHICLES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The role of the Aeronautical Vehicles program is to provide continued improvements in the safety, efficiency and utility of all classes of military and commercial aircraft. Advanced data for the design of new aircraft, technological advances needed to develop safer and superior commercial aircraft, and leadership in the generation of advanced aircraft concepts are integral parts of the program. Effort in the advanced research and technology disciplinary areas of aerodynamics, loads and structures, propulsion, operating environment and flight dynamics; plus proof-of-concept effort in the general aviation, V/STOL, subsonic, supersonic and hypersonic aircraft areas; is conducted in furtherance of the above objectives. Proof-of-concept activity is system integration technology whereby full scale operating systems are used to extend laboratory technology in system elements. The programs in these areas encompass work in materials, noise and sonic boom, operational aspects, propulsion system and airframe integration and the relationships which exist between the pilot and the total aircraft system.

As has been noted in previous program justifications, the XV-5A fan-in-wing aircraft, the tilt-wing XC-142A V/STOL transport and the variable-sweep wing F-111 all appeared several years ago as promising NASA research concepts. Now, these aircraft, developed by the military, are part of the NASA's continuing flight research programs aimed at further exploration of the characteristics of such vehicles and for correlation with earlier NASA test results.

The NASA also conducts extensive wind tunnel tests, simulator studies, analyses and flight investigations to aid in the solutions of problems of a developmental nature in support of military and civil aircraft procurement. This work is performed in cooperation with the Department of Defense and other Government agencies and with Government-sponsored contractors at the request of cognizant Government agencies.

Technology in the Aeronautical Vehicles program in FY 1970 will include studies directed to improve safety of general aviation aircraft; studies of lightweight propulsion systems for both general aviation and V/STOL aircraft; studies of advanced rotor and STOL concepts to increase the utility of helicopter and short-field aircraft; prototype developmental research directed toward minimizing fan-jet noise radiation and for quieter engines; studies of air-breathing propulsion cycles and engine components for advanced supersonic and hypersonic aircraft; and studies directed toward the overall improvement of flight safety through increasing operational flexibility including adverse or all-weather conditions.

Experimental research and development aircraft and engineering test-pilot proficiency aircraft necessary to carry out and support the aeronautics effort are included under this program.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Advanced research..... | $12,800,000 | $16,891,000 | $21,785,000 |
| General aviation aircraft technology..... | 450,000 | 535,000 | 500,000 |
| V/STOL aircraft technology..... | 7,057,000 | 8,740,000 | 11,250,000 |
| Subsonic aircraft technology... | 7,905,000 | 17,046,000 | 16,190,000 |
| Supersonic aircraft technology. | 24,050,000 | 21,893,000 | 20,900,000 |
| Hypersonic aircraft technology. | 14,538,000 | 9,795,000 | 8,275,000 |
| Total..... | $66,800,000 | $74,900,000 | $78,900,000 |

**Distribution of Program Amount by Installation:**

| | | | |
|---|---|---|---|
| Marshall Space Flight Center. | $380,000 | $230,000 | $620,000 |
| Ames Research Center..... | 9,563,000 | 8,750,000 | 13,400,000 |
| Flight Research Center..... | 18,303,000 | 13,915,000 | 8,410,000 |
| Langley Research Center..... | 22,743,000 | 26,660,000 | 24,170,000 |
| Lewis Research Center..... | 13,989,000 | 20,645,000 | 31,500,000 |
| NASA Headquarters..... | 1,822,000 | 4,700,000 | 800,000 |

BASIS OF FUND REQUIREMENTS:

Advanced Research

| | | | |
|---|---|---|---|
| Aircraft aerodynamics..... | $1,910,000 | $2,150,000 | $3,730,000 |
| Aircraft loads and structures.. | 1,530,000 | 2,472,000 | 4,230,000 |
| Air breathing propulsion..... | 600,000 | 2,918,000 | 4,800,000 |
| Aircraft operating environment. | 3,100,000 | 2,803,000 | 3,215,000 |
| Aircraft flight dynamics..... | 1,400,000 | 783,000 | 1,910,000 |
| Aircraft support..... | 4,260,000 | 5,765,000 | 3,900,000 |
| Total..... | $12,800,000 | $16,891,000 | $21,785,000 |

Aircraft Aerodynamics

Advanced research in aircraft aerodynamics is a continuing investigation of airflows around airplane shapes and their effects on performance, stability, and control in flight. The research information obtained is the connecting link between basic fluid physics and aerodynamic design optimization of advanced aeronautical vehicles.

In the subsonic and transonic flow regimes, research will be conducted on applications of supercritical wing sections to minimize shock-induced boundary-layer separation near the speed of sound. An important extension will be to study supercritical wing characteristics at higher as well as lower speeds and with various high-lift systems for the takeoff/landing condition. With improved wing characteristics at transonic cruise or combat speeds, increased attention will be given to reducing low-speed boundary-layer separation, high-speed fuselage boundary-layer losses, and unfavorable wing-body interferences.

In the supersonic and hypersonic flow regimes, research will be continued on theoretical and experimental techniques for predicting the aerodynamics of configurations for operation at these speeds. Definition of optimum wing planforms and shapes (camber and twist) for high flight efficiency, shaping to minimize sonic boom, and techniques for predicting aerodynamic effects of the flexibility of large aircraft are major objectives in projected supersonic studies. Definition of flow fields and boundary-layer phenomena including turbulent heat transfer is the objective of research in aerodynamics in the high supersonic and hypersonic speed regime.

In addition to the advanced research, specific wind tunnel investigations will be conducted for other agencies of the Government as requested and indicated to be required. Technical support and assistance will be provided in aircraft aerodynamics to the Department of Defense in the development of new military aircraft and missiles systems. Similar support will be furnished to the Department of Transportation where the employment of NASA's existing facilities and capabilities are required.

The funds in aircraft aerodynamics are for support of in-house research by procurement of computer services, wind tunnel models, and special test equipment; updating of major wind tunnel facilities; and university/industry contracts for supplemental studies in low-speed, transonic, supersonic and hypersonic aerodynamics.

## Aircraft Loads and Structures

The response of very large aircraft to flight through atmospheric turbulence may be characterized by undesirable dynamic flexibility effects which produce pilot and passenger discomfort and increased structural stresses. Wind tunnel tests using flexible dynamically scaled models will be conducted to study this problem and to evaluate the use of an active control system to reduce stresses and accelerations. Complementary analytical studies to improve prediction techniques will be undertaken.

High strength boron or graphite filaments bonded to conventional aluminum or titanium structures represent a structural concept showing promise for significant weight saving. Analytical and experimental studies will be undertaken to evaluate and exploit this concept for a variety of structural applications.

A continuing effort will be expended on the development and acquisition of computer programs for structural analysis of aircraft components

with an ultimate goal of integrating these programs into an automated system applicable to a complete aircraft. Such a system would permit accurate structural weight estimates on a rational and timely basis.

The possibility of structural failures due to metal fatigue is of important concern in modern aircraft. The primary emphasis, in the continuing research effort on fatigue, is on engineering aspects of crack propagation and on the residual strength of structures containing a fatigue crack. Included will be studies of the effects of structural configuration, realistic thermal and corrosive environments and of more realistic random loadings.

## Air Breathing Propulsion

The primary goals of the advanced research air breathing propulsion effort are to provide advanced technology through analytical and experimental investigations of engine components and propulsion system concepts which either are not readily identified with a specific flight spectrum or else are identified over a broad flight spectrum. The major research effort will be in jet noise generation suppression and prediction, and advanced bearings, fuels, and lubrication. The noise research will include small scale and moderate scale research conducted with a 4,000 pound thrust, 6 to 1 by-pass ratio fan engine, and a 7,500 pound thrust turbojet engine. The effect of by-pass ratio, fan tip speed, inlet guide vanes, and sonic choke concepts will be examined. The work on advanced bearing and lubrication systems will be aimed for the higher temperature bearing speeds and loading associated with current and expected high performance engines. Analytical studies, supported by limited experimental research, will be conducted in a technology assessment program. Research will be conducted and aimed at eliminating or alleviating the tendency of jet engines to smoke. Other research will be conducted on inlets and afterbodies typical of high bypass ratio propulsion systems anticipated for very large subsonic aircraft.

## Aircraft Operating Environment

The research in this program area is aimed at solving general problems associated with runway and flight environment, flight safety, noise, flight instrumentation and sonic boom. It involves theoretical analyses and laboratory and flight test experiments to validate current engineering procedures and to explore solutions to aircraft operational problems. The results provide the technology for safer and quieter aircraft operations and the basic environmental data for application to specific classes of aircraft (e.g., V/STOL, subsonic, etc.).

Flight environmental research includes laboratory studies and field tests of warm air fog modification concepts, investigations of means for detecting clear air turbulence, the analysis and correlation of turbulence data collected on test aircraft with atmospheric parameters, and support



332-276 O - 69 - 25

of the National Severe Storms Laboratory programs related to electromagnetic characteristics of severe storms. Runway tire traction experiments are planned to assess the ability of various surfaces, tire treads and braking devices to improve braking and control.

In the flight safety area research is planned to determine the feasibility of protection schemes to avoid critical airplane structural damage resulting from rotor disk failures in jet engines. Various composite materials are being evaluated for containment and deflection functions. The lightning hazards studies have been extended from materials tests to an investigation of effects of lightning on aircraft electrical systems.

NASA aircraft noise alleviation research is a continuing effort directed primarily at means of minimizing engine noise at its source. A better understanding of the fundamentals of compressor and fan noise generation is sought. Fundamental information on the generation and propagation of noise from the exhaust jets of turbofan engines having high ratios of bypass to primary mass flows will be obtained. Particular emphasis will be placed on the low exhaust velocity range where the turbulence level of exhaust jets may be a dominant factor in noise generation. The experimental studies will be conducted under carefully controlled laboratory conditions with jet velocity and jet turbulence level as the main variables.

## Aircraft Flight Dynamics

Research in this area is aimed at the determination of the dynamic interaction and the fundamental relationships between the pilot and the vehicle he controls. This involves theoretical analyses, ground based simulator studies and measurements in the real flight environment to investigate basic handling qualities factors. The research program also includes studies of improved methods for aircraft control and of improved test techniques, and investigations to achieve more realistic piloted flight simulators.

Among the studies planned are investigations to determine the effects of atmospheric turbulence on piloting problems during the landing approach flight phase, to determine the aircraft handling qualities factors of primary importance in establishing optimum high speed turbulence penetration speeds, to establish the influence of multi-dimensional vibrations on piloting, and to improve methods and techniques for measuring aircraft stability and control parameters in flight. Planned simulator related research includes investigations of optimum motion-generator washout characteristics to achieve improved fidelity with limited motion travels. Existing and new simulator improvement and upgrading efforts will include work with the basic computer systems, the visual, audio and motion-generator devices and the cockpit displays and controls.

## Aircraft Support

The NASA Research Centers use various aircraft in direct support of advanced research and technology programs. The maintenance, spare parts

and ground support equipment for these R&D aircraft and chase and proficiency aircraft which are used for various missions are included in this funding category.

General Aviation Aircraft Technology

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Disciplinary technology..... | $450,000 | $535,000 | $500,000 |
| Total..... | $450,000 | $535,000 | $500,000 |

The small aircraft has assumed an increasingly important role in the economy of our nation and is being used as an extension of our major airline networks through the so-called third level airlines. Individual businessmen are also piloting their own or company airplanes on trips where schedules to be met sometimes result in flight environmental conditions beyond the combined capabilities of the aircraft and pilot. Thus, the elements of the effort are aimed at improving the utility and safety of the small airplane and includes the aerodynamics, structures, and flight dynamics disciplines. Environmental research performed under the Advanced Research program applies equally well to the small airplane as to the large transport or military aircraft.

The general aviation aircraft technology effort is a balanced technology, addressing each of the disciplines as it applies to the small airplane: aerodynamics, flight dynamics, structures, and operating environment. The major thrust of the current effort continues to be devoted to handling qualities studies and flight dynamics investigations. Following full-scale wind tunnel tests of a typical light piston twin engine airplane, similar tests were conducted on a typical jet twin engine airplane (#A-40939 in 19th Semiannual Report to Congress). Additional full-scale tunnel tests are planned involving other twin engine aircraft and typical single engine small airplanes. The purpose of these tests is to obtain aerodynamic derivative data for this class of airplanes which is necessary to any thorough engineering understanding of a class of aircraft. A NASA Technical Note is being published summarizing the results of the first full-scale tunnel test in this series. Results of the successive tests will be reported in forthcoming NASA Technical Notes.

Flight tests of the light piston twin engine aircraft have been completed and the data has correlated well with the full scale wind tunnel data. Similar flight testing of the twin jet engine aircraft is currently underway for correlation with the tunnel data.

An analytical technique used by the Air Force to predict flying characteristics of large aircraft from basic specification information has been simplified and applied to the light twin piston engine aircraft program. It shows good correlation, and it is hopeful that this technique can be reliably developed and provided to the general aviation industry as an effective design evaluation tool for their use.

The light twin piston engine aircraft is being modified for use as a test bed for the investigation of advanced control systems concepts. As an initial step in the control systems investigation, a simple yaw damper has been installed in this airplane and flights to date indicate great promise for this device as an effective cockpit workload reliever. In the NASA study of general aviation handling characteristics made several years ago, it was found that one of the main contributors to a low pilot opinion rating during an instrument approach made in turbulence was low dutch roll damping. The yaw damper consists of a parallel-connected magnetic powder clutch, servo actuator, power amplifier assembly, and a rate gyro. Yaw rate, sensed by the rate gyro, commands a proportional torque output from the servo actuator which is connected directly to the rudder control cables through a friction slip-clutch. Thus any yawing, induced by internal or external inputs is cancelled by the damper. It is so configured that it does not interfere with normal safe operation of the airplane. Significant improvements in aircraft dutch roll characteristics are achieved with this yaw damper. The damping is most effective in turbulent air where ride quality is improved in both cruise and approach modes, allowing for better control of the airplane during a critical tracking task such as flying an ILS path. Additionally, the yaw damper system effects a considerable improvement in the basic autopilot performance, specifically in the lateral-directional response mode. With this improvement in performance, the normal autopilot usage could be extended to include satisfactory heading and bank angle control in turbulence, and also as a valuable pilot aid in smooth or turbulent air landings made either under VFR or IFR conditions. Preliminary results also indicate that the yaw damper provides a significant stabilization of aircraft attitude during the stall or simulated sudden engine failure. The normal sudden onset of yaw during engine failure is significantly reduced in severity, providing the pilot with additional time to properly assess the situation and follow the correct procedure for such an emergency. This foregoing discussion was provided as a typical example of the type of contribution NASA can make to General Aviation Technology.

Scale models of small aircraft are being employed in dynamic wind tunnel tests to determine rotary stability derivatives, steady state spin modes, and spin recovery techniques. A model is also being used to determine what effects various configurations of large, flat, overhung engine nacelles have upon wing lift distribution and aerodynamic behavior of the aircraft.

The survey of post-1940 NACA/NASA reports of interest to General Aviation Technology has been completed by North Carolina State University, and a summary report is due to be issued in the near future. Over 10,000 reports were examined, and abstracts written on some 5,000 that had applicability to general aviation. Based upon this work, an additional contract effort will prepare summaries of disciplinary research information and identify gaps in research needed for this class of aircraft.

Flight tests of light, high performance STOL aircraft are planned to explore the operational margins appropriate for operation under such adverse environmental factors as low visibility, turbulence, wind shear, and gusting winds.

Crashworthiness of general aviation is being looked at both analytically and experimentally. The U.S. Army's full modification program test involves crash testing of various aircraft, and NASA plans to additionally instrument a flight single engine aircraft which the Army is crashing for other purposes. NASA's objective here is to update crash data obtained 15 years ago with a light tubular-longeron-stringer fabric-covered airplane. The presently planned test will involve a monocoque structure monoplane at an impact speed representative of today's small aircraft landing or takeoff speeds.

Examination of the practical feasibility of tee tails for light aircraft is planned from the structural analysis and aerodynamics point of view.

V/STOL Aircraft Technology

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Disciplinary technology..... | $6,607,000 | $7,280,000 | $7,550,000 |
| Proof-of-concept: | | | |
| Rotating cylinder flap..... | 450,000 | 450,000 | 1,000,000 |
| Jet-augmentor wing..... | --- | 210,000 | 1,200,000 |
| Jet-flap rotor..... | --- | --- | 500,000 |
| Tilt rotor research aircraft..... | --- | 100,000 | 400,000 |
| XV-5B advanced lift-fan aircraft..... | --- | 700,000 | 600,000 |
| Total..... | $7,057,000 | $8,740,000 | $11,250,000 |

Technology will be increased primarily in the proof-of-concept area. In the general area of aerodynamics, studies will continue to gain a better understanding of induced interference effects which can have an important influence on the control and handling characteristics of V/STOL aircraft in the low-speed takeoff and landing condition. Increased attention will be given to the study of the aerodynamics characteristics of lift-fan configurations and of advanced higher-performance rotorcraft, leading to configurations optimized for low and high-speed flight. Basic studies will be expanded to determine the factors affecting the loading and vibration characteristics of advanced rotors, particularly at high speeds.

In the area of V/STOL propulsion, continued emphasis will be given to providing information leading to improved lift-fan designs. Studies will include fundamental studies at relatively small scale and more comprehensive studies of near full-scale fans, to determine the effect of cross flow on the operation of high pressure ratio fans. The study

of the means of alleviating problems associated with direct-lift engine hot exhaust gas reingestion will continue. Consideration will be given to means of reducing the noise of various V/STOL concepts, particularly the lift fan.

Flight and simulator studies will continue to establish more reliable criteria for handling qualities requirements for V/STOL aircraft. Particularly valuable information is expected to be acquired from the recently obtained XC-142 tilt-wing and XV-5B lift-fan aircraft as well as from the X-14 direct-lift jet aircraft now equipped with an advanced variable stability system, and the Dornier DO-31 jet VTOL transport with which a joint NASA-West German program is planned. Particular attention will be given to an understanding of problems encountered in VTOL landing operation, especially under poor visibility weather conditions.

Five specific "proof-of-concept" areas are included in the overall V/STOL problem.

Based on results of feasibility studies completed in FY 1969, design studies will be undertaken aimed at modifying an OV-10 airplane, now loaned to the NASA by the Department of the Navy, to incorporate a rotating cylinder flap, which previous wind tunnel model studies indicated is a very promising means of providing good STOL capability for propeller driven aircraft. Flight research studies will be carried out later to verify the wind tunnel studies and to uncover possible operational problems.

Other wind tunnel tests have shown the jet-augmentor wing to be very effective in producing improved STOL characteristics for a jet-propelled aircraft. Based on the results of a design study initiated in FY 1969, modifications of the NASA C-8 transport to incorporate an augmentor wing will be initiated to enable flight verification of the STOL potential of the concept.

The jet-flap rotor has been shown from wind tunnel tests to be a promising means of reducing rotor vibration, increasing rotor lift capability, and cruise speed. Based on results of such tests, an aircraft design feasibility study will be undertaken aimed at modifying a rotorcraft to incorporate the jet-flap rotor for flight evaluation.

Another promising means of increasing the cruise speed of rotorcraft is the tilt rotor, which operates as a propeller in conventional flight. Following wind tunnel tests of a full-scale tilt-rotor designed for a high performance rotorcraft, design will begin of a research rotorcraft to verify the characteristics in flight.

Recent studies have evolved lift-fans showing substantially improved performance over those included in the XV-5B fan-in-wing aircraft presently undergoing NASA flight research. Based on studies conducted in FY 1969 and continued in 1970 on the application of such advanced fans to the XV-5B, design studies will be initiated in FY 1970 of modifications to

the XV-5B aircraft to provide a research lift-fan aircraft having substantially improved lift and control characteristics, enabling tests over a broader envelope of take off and descent conditions.

Subsonic Aircraft Technology

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Disciplinary technology..... | $1,989,000 | $2,596,000 | $2,390,000 |
| Proof-of-concept: | | | |
| Aircraft noise..... | 4,200,000 | 6,950,000 | 3,800,000 |
| Quiet research engine..... | 1,716,000 | 7,500,000 | 10,000,000 |
| Total..... | $7,905,000 | $17,046,000 | $16,190,000 |

Technology on subsonic aircraft is oriented toward safety of flight, improvement of flight efficiency and the reduction of noise. This class of aircraft includes all of the commercial subsonic jet transports and many military types.

Aerodynamic technology will relate to the airbus and other advanced subsonic jets, with particular emphasis on seeking favorable flow interactions between the airframe and high bypass ratio turbofan engines. Configuration studies will be directed toward use of the propulsion system flows to improve landing characteristics at low speeds, as well as to increase transonic cruise flight efficiency. For fighter aircraft, the aerodynamic emphasis will be on improvement of combat maneuverability at transonic speeds.

Structures technology applicable to commercial aircraft will include studies of structural loads and environment, fatigue and the development of improved crack detection techniques.

The primary effort of the subsonic aircraft air breathing propulsion program is aimed at providing supporting research for the Quiet Engine project with the major portion of the effort focused on in-house research on large-scale, high-pressure ratio, low-noise fans. The planned experimental work will provide more insight as to the effect of scaling, fan pressure ratio, fan blade loading and fan tip speed on fan noise generation and prediction. High work load turbines and low smoke generating combustors required for the low noise fans will also be examined. Studies of problems related to integration of the Quiet Engine in various aircraft will also be conducted.

Flight dynamics technology effort will be concentrated on investigations of handling qualities and operational techniques of subsonic jet transports to provide a more rational foundation for certification criteria, studies of pilot managed automatic flight control in terminal area operations, and tests of improved vertical situation displays for noise abatement steep approaches. This investigation was recommended by the Federal Aviation Administration and began in FY 1969 with studies of the applicability of an improved minimum speed certification criteria, the determination of quantitative standards for low-speed control capability, and validation tests of simulator derived optimum landing-flare-initiation altitude

criteria. Although the concept of pilot managed automatic flight control offers considerable promise to help alleviate the air traffic control delays in terminal area operations, extensive simulator and flight research is required to establish optimum realistic system mechanization characteristics, to isolate and solve problems associated with the possible various techniques for implementing the concept, and to define system dynamic response and performance criteria. Planned technology effort related to steep approaches for noise abatement will include ground based simulator and flight tests of improved pilot displays currently under study.

In FY 1969 a systems technology program was initiated to carry ground based research on promising new transonic wing sections (supercritical airfoils) into flight. An F-8 aircraft on loan from the Department of the Navy is being modified for this purpose to incorporate a high-aspect-ratio swept supercritical research wing, but with a minimum of other changes. The experimental airplane will be instrumented and operated in FY 1970 to obtain basic data for future applications. In particular, stability and performance margins will be defined under adverse and off-design flight conditions and sensitivity to practical surface deformations under flight loads will be assessed. Most of the work involved, except for detailed structural design and construction of the modifications, will be carried out in-house at the Flight Research Center to minimize costs.

The NASA's role in the Interagency Aircraft Noise Abatement Program involves a primary responsibility for the research and development leading to a major reduction of aircraft noise at its source. It is for this reason that the NASA is heavily involved in the aircraft noise and quiet research engine proof-of-concept activities.

The aircraft noise proof-of-concept work is directed at providing a means for minimizing the noise radiated from the primary landing approach configuration noise sources, the inlet and the fan discharge ducts, of turbofan engines such as are now installed in presently operating four-engine commercial jet transports. This fan compressor noise minimization program, which was initiated in FY 1967 and FY 1968 included wind tunnel testing, analysis design and testing of boilerplate nacelle modifications, will reach the flight test stage in FY 1969 with completion of some phases in FY 1970. In FY 1969 and FY 1970 the final and now selected nacelle configurations will be flight proof tested on a 707 type aircraft and on a DC-8 aircraft. Analysis of the flight test results and detailed analyses of the impact of such potential noise minimization modifications on operating costs and efficiency will serve as a basis for FAA regulation of noise levels of present and future transport aircraft. Additionally, in FY 1970 a phase of the program which promises several orders of magnitude reduction in inlet noise radiation, the sonic choke inlet, will be carried from ground to flight test. This should complete the total nacelle modification program.

The Quiet Research Engine project has as its objective the development and test of a research engine designed with low noise production as the

primary configuration constraint. Some important features of this research engine are that it will have a bypass ratio between 5 and 6, a maximum fan tip speed of 1,030 ft/sec and a sea level thrust of at least 22,000 lbs. Work accomplished in FY 1968 under a Quiet Engine Definition Program has indicated the feasibility of such an approach. In FY 1969 a contractor or contractors will be selected to perform the detailed design and to begin the fabrication of the long-lead time hardware items. FY 1970 funding is required for the developmental and fabrication work necessary in this time period to produce and test components of the engine as designed in the FY 1969 phase. In future fiscal years the work will be completed with the testing, including detailed noise and performance measurements, of engines at the Lewis Research Center's propulsion test facilities.

Supersonic Aircraft Technology

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Disciplinary technology..... | $14,050,000 | $15,843,000 | $18,700,000 |
| Proof-of-concept: | | | |
| XB-70..... | 10,000,000 | 5,000,000 | --- |
| F-111A..... | --- | 1,050,000 | 1,200,000 |
| YF-12..... | --- | --- | 1,000,000 |
| Total..... | $24,050,000 | $21,893,000 | $20,900,000 |

The objective of the continuing NASA technology program for supersonic aircraft is to provide advanced technology in the various disciplines for improved military and civil supersonic aircraft.

The aerodynamic technology that has evolved has been programmed on highspeed electronic computers which can now be used as design tools to optimize a configuration for high speed flight and to establish new, higher levels of aerodynamic efficiency. Technology effort on improving and extending this prediction program will continue. Configurations so evolving for military fighter aircraft and military and civil transport aircraft will be analyzed and tested to determine their potential for high aerodynamic efficiency with adequate solutions for stability and control problems. In the case of advanced aircraft, studies will be made to approximate optimum aircraft concepts that would satisfy specific or proposed mission requirements, recognizing the emphasis to be placed on aerodynamics, engine selection and integration, and stability and control.

Wind tunnel and flight tests will be conducted to determine means to minimize buffeting and increase maneuver capabilities of fighter type aircraft at transonic speeds.

Studies will continue to evaluate experimentally materials and structural concepts, such as composites, which offer promise of more efficient structures for supersonic aircraft.



332-276 O - 69 - 26

Each major component of the supersonic aircraft engine is considered a critical problem area marked for improvement, with the hot section area most critical.

In the compressor, boundary layer control devices, such as part span slots, fences, and vortex generators will continue to be investigated as means for attainment of increased pressure ratio per stage, increased range of operation, and increased tolerance to inlet air distortions. High rotor tip Mach Numbers (multiple circular arc blades) and high pressure ratio rotor stages are under investigation to minimize shock losses. Low rotor tip speeds, blade arrangements and boundary layer controls are included in order to obtain lowered noise outputs.

Aerodynamic tests of the turbine are continuing to improve stage loadings of multistage axial flow designs, so that fewer stages will be required to do the same work. Tandem blades, boundary layer control, and jet flap blades are to be examined. Methods of cooling turbine blades and vanes in cascades subjected to gas temperatures up to 2,500°F using cooling air up to 1,200°F are being tested. The effect of cooling air discharge into the main engine hot gas stream is being studied experimentally and analytically.

Full scale annular extra short length primary burners and full scale duct burners, using methane and JP4 fuel, are being tested to provide radial and circumferential temperature profiles, blow-out limits, and durability. Special high temperature (3,000°F) burners, capable of giving high performance by use of cooling techniques, are to be tested. Studies of fuel-air (JP, Methane) heat exchangers will be studied for high temperature turbine (2,500°F) applications.

In FY 1970, the large Propulsion Systems Laboratory facility for testing full scale engines under simulated altitude conditions is expected to be operational. Full scale engine components incorporating advanced concepts in compressors, combustors, turbines, and exit nozzles are scheduled for evaluation in this facility to determine their interaction effects in the engine system.

In addition to the continuing program on high temperature turbine materials investigation, titanium alloys for compressor blades, vanes, and discs will be investigated for the effects of operation in a salt air environment. Composite materials for compressor disks and cases show great promise for weight reduction and expanded effort in this area is planned. Tests of compressor blade composites which reduce blade bending are planned so that narrow chord blades for shorter compressors may be used. Materials for cooled turbine airfoils which resist oxidation at metal temperatures up to 2,200°F will be tested.

Flight dynamics technology will be concentrated on supersonic transport flight characteristics to assist the Federal Aviation Administration, handling qualities investigations of critical control situations of large

supersonic aircraft, and studies of advanced military aircraft piloting problems. Ground based and in-flight simulators will be used to explore the validity of proposed supersonic transport certification standards and to investigate unique response characteristics of supersonic transports currently under development. The capabilities of existing motion simulators and variable stability aircraft will be expanded to achieve improved simulation fidelity. Advanced military aircraft technology activity will include investigations of improved methods for control, simulator and flight tests to determine rational handling qualities criteria for high maneuverability, and studies of post-stall and spin behavior.

The joint NASA-FAA-USAF program to measure the cosmic radiation environment at SST altitudes is continuing. Measurements are being made with NASA instruments carried aloft in balloons, and in U-2 and RB-57F aircraft supplied by the USAF. The objective of the program is to map the radiation levels of biological significance during the ascending portion of the 11-year solar cycle. Measurements are to be obtained at SST altitudes and at a high latitude (above 50°) during a large solar event when radiation levels are expected to be most intense.

Special gust measuring and recording equipment has been assembled for installation on a research aircraft to obtain a definition of atmospheric turbulence intensity. The turbulence measurements will provide information on the intensity of discreet gusts and power spectral density of the gust environments encountered, as in mountain waves, gravity waves and jet streams.

An F-111A was loaned to the NASA in January 1967 for flight research purposes. Initial tests included a structural temperature survey requested by the Air Force and a brief program to determine the handling qualities of this advanced variable sweep airplane. Following these tests, special instrumentation was installed to measure the effect of high-frequency inlet airflow oscillations on a supersonic turbofan-powered airplane. This work is continuing. A second F-111A will be loaned to NASA for flight testing boron composite structures for the Air Force and for use in an aerodynamic buffet improvement program. Both aircraft will be used in FY 1970 by the Flight Research Center.

The Flight Research Center in cooperation with the USAF will evaluate data obtained during flights of the YF-12 aircraft. The data acquired will be combined with data obtained from ground based facilities, in order to assess the validity of current analytical and experimental test procedures. Special emphasis will be placed on problems which have been observed during flights of modern high-speed high-altitude aircraft. The results will be useful in the design of future, more advanced civil and military aircraft.

Hypersonic Aircraft Technology

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Disciplinary technology..... | $4,090,000 | $4,295,000 | $6,275,000 |
| Proof-of-concept: | | | |
| X-15..... | 3,448,000 | --- | --- |
| Hypersonic research engine.. | 7,000,000 | 5,500,000 | 2,000,000 |
| Total..... | $14,538,000 | $9,795,000 | $8,275,000 |

Disciplinary technology activity is directed at providing the technology for the design of efficient hypersonic airbreathing aircraft.

Aerodynamic studies are continuing to determine the characteristics of vehicles with large fuel volume requirements and vehicles proportioned for new propulsion systems. Problems of stability and control, boundary layer, propulsion system integration and heating are included. Analytical studies will be made in conjunction with wind tunnel tests to generate configurations which will be evaluated experimentally.

Hypersonic airbreathing propulsion systems and their exhaust flow can have a significant aerodynamic influence on hypersonic aircraft. Thus, methods are being devised of designing hypersonic vehicles which derive maximum benefits from the mutually interacting airframe and propulsion system flow fields. Studies are required to evaluate these effects and provide a basis from which optimum arrangements can be defined. Accordingly, the power-off and power-on effects of airbreathing propulsion installations on the aerodynamic characteristics of hypersonic aircraft will be determined.

A critical requirement for a successful hypersonic cruise airplane is that the airframe weight compare favorably with current successful aircraft. The general aim of loads and structures research is to establish a basis for the design of a hypersonic airplane structure which will withstand the high temperature environment with a minimum weight penalty, and with no loss in reliability. Analytical studies and structural tests will be conducted to evaluate promising structural concepts for cooled and uncooled structures applicable for wing leading edges, wing surfaces, cryogenic tankage, and inlets and engine components.

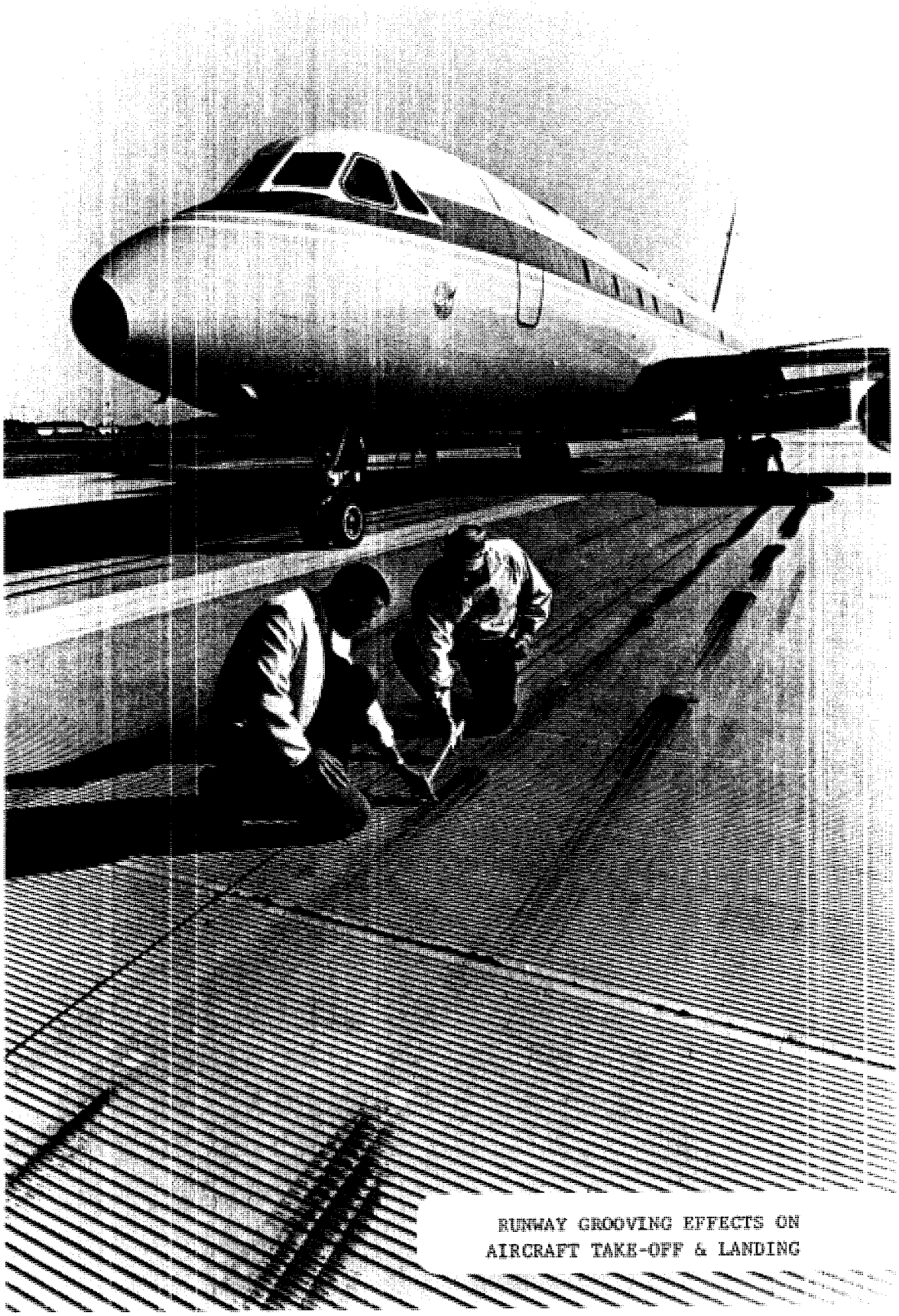
The hypersonic inlet project is oriented to develop the basic understanding required to design hypersonic inlets. Methods for assessing the complex interactions between shock wave and boundary layer flow, inviscid flow field, and shear flow are being developed. The knowledge gained by analytical and experimental research will then be applied to the design of an inlet and investigated throughout its Mach number range to ascertain its predicted performance. Future analytical and experimental studies are being considered which will involve inlet-combustor systems directly applicable to hypersonic scramjet cruise and boost vehicles.

Basic studies are continuing on supersonic combustion and supersonic mixing of hydrogen-air systems. These studies are exploring the lower Mach number limits for hydrogen-air ignition, methods for obtaining satisfactory ignition at reduced flight speeds, heat transfer in a scramjet combustor, its design parameters, and its operation. Tests will also be conducted on 18-inch diameter supersonic combustion chambers and nozzles using combined wall and strut fuel injection, with the concentration of effort being placed on fuel injection and mixing.

The Hypersonic Research Engine proof-of-concept program continues to furnish design information for hypersonic propulsion systems. Inlet performance and operating characteristics have been substantiated through tests of one-third and two-thirds scale inlet models with simulated wall cooling. Nozzle testing and analysis of results have been completed, and final nozzle contours for use in a boilerplate engine have been selected.

Combustor development is presently being conducted on a 2-inch by 6-inch combustor model to determine fuel injection, mixing, and ignition characteristics with both subsonic and supersonic combustion. The investigation will also include tests to determine the effect of a simulated inlet boundary-layer on combustion.

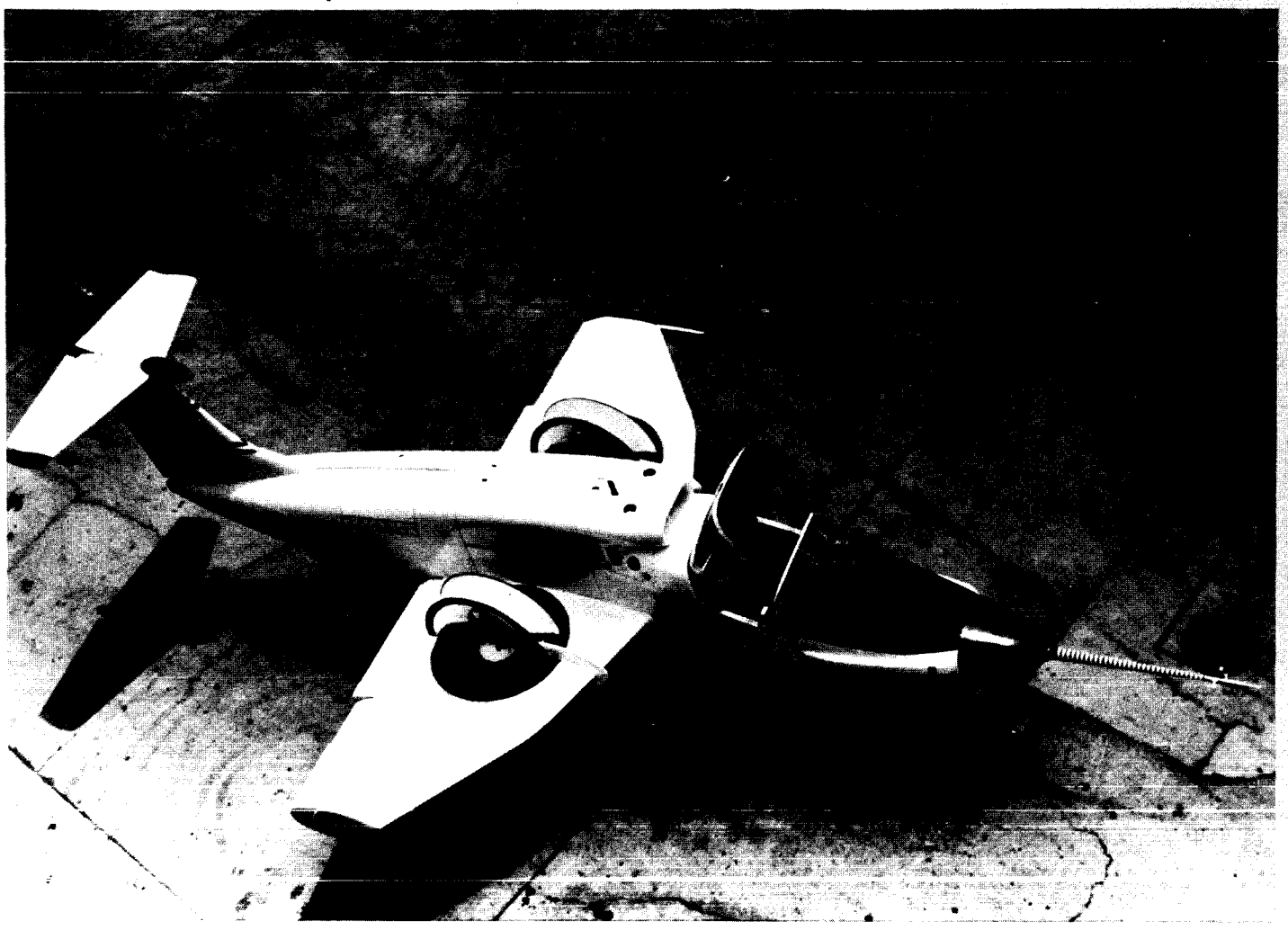
The boilerplate engine will be built based on the results of the individual component studies, and will be assembled and tested in discrete units to determine component interactions. This engine will incorporate the most advanced aerothermodynamic technology developed during the program. Complete boilerplate engine tests, including the inlet, will ultimately be conducted at the Lewis Research Center's Plum Brook Facility to demonstrate overall operating performance and stability.



RUNWAY GROOVING EFFECTS ON
AIRCRAFT TAKE-OFF & LANDING

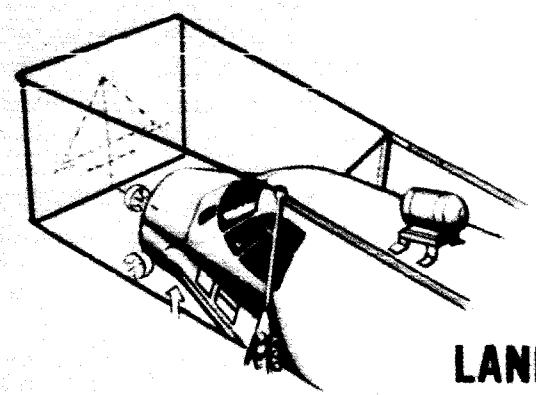
RD 17-17

# XV–5B FAN-IN-WING V/STOL RESEARCH AIRCRAFT

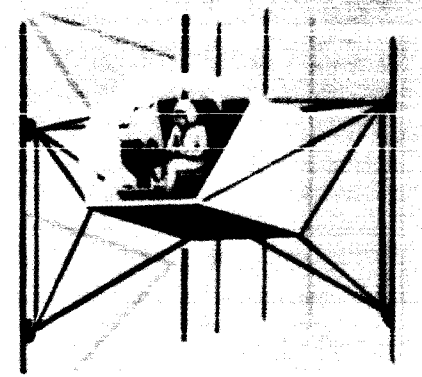


NASA HQ RA68–16829 6-24-68

TRANSPORT SIMULATOR COCKPIT



MOTION DEVICE



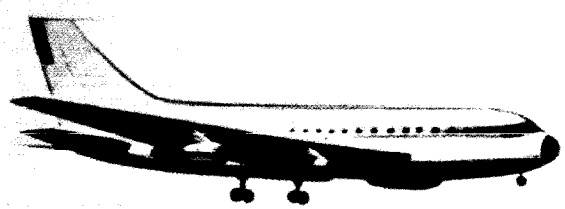
# SIMULATION

## LANDING APPROACH STUDIES

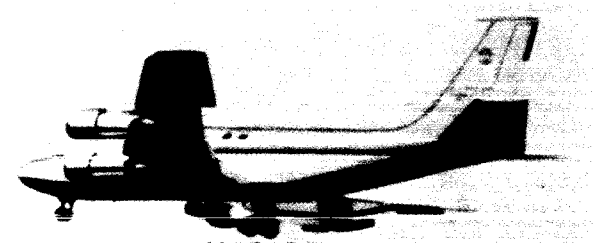
FOR NOISE ABATEMENT

- FLIGHT PATH CONTROL
- GUIDANCE AND DISPLAYS
- PILOT WORKLOAD

# FLIGHT TEST

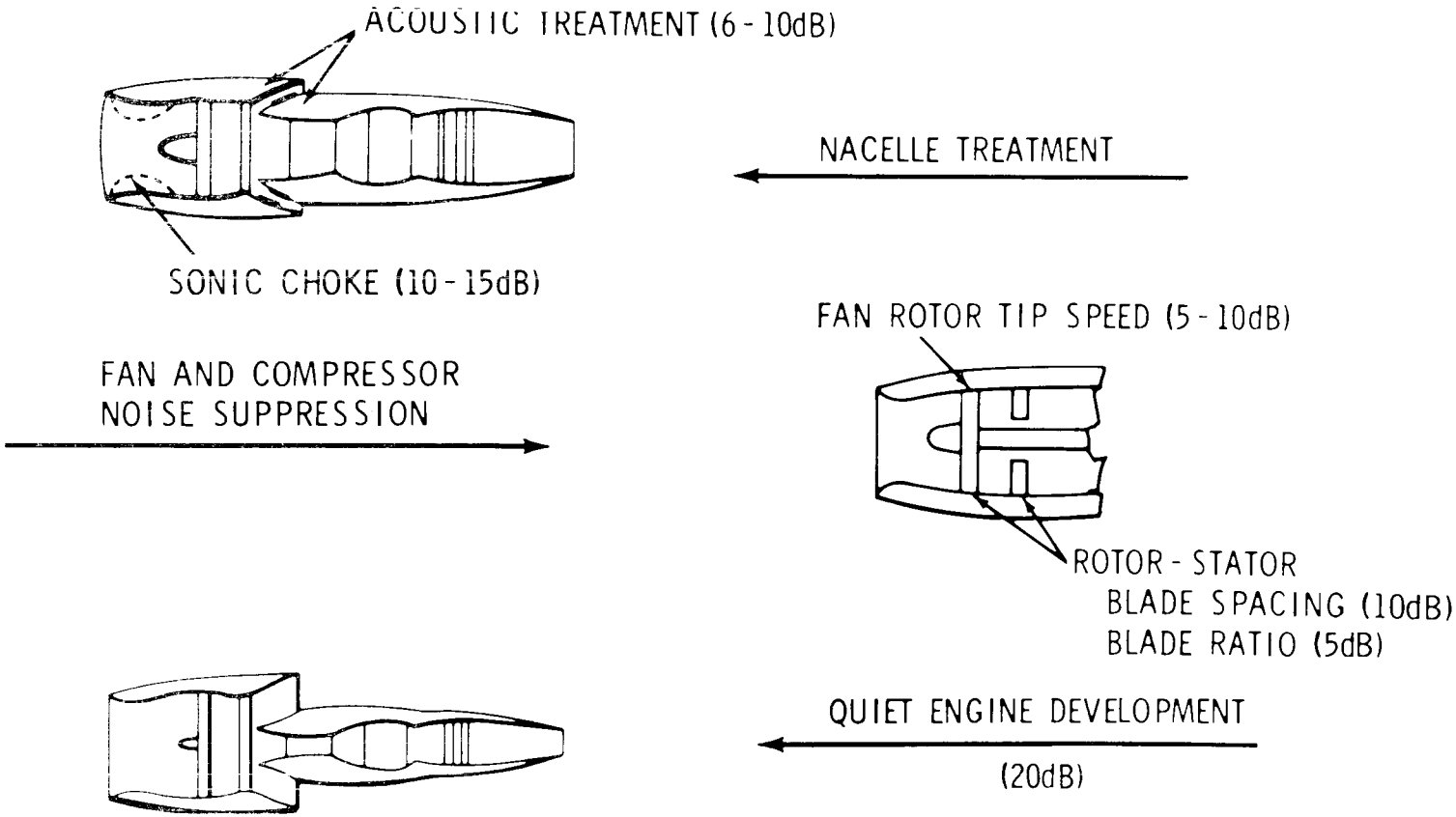


JET TRANSPORT



VARIABLE STABILITY AIRPLANE

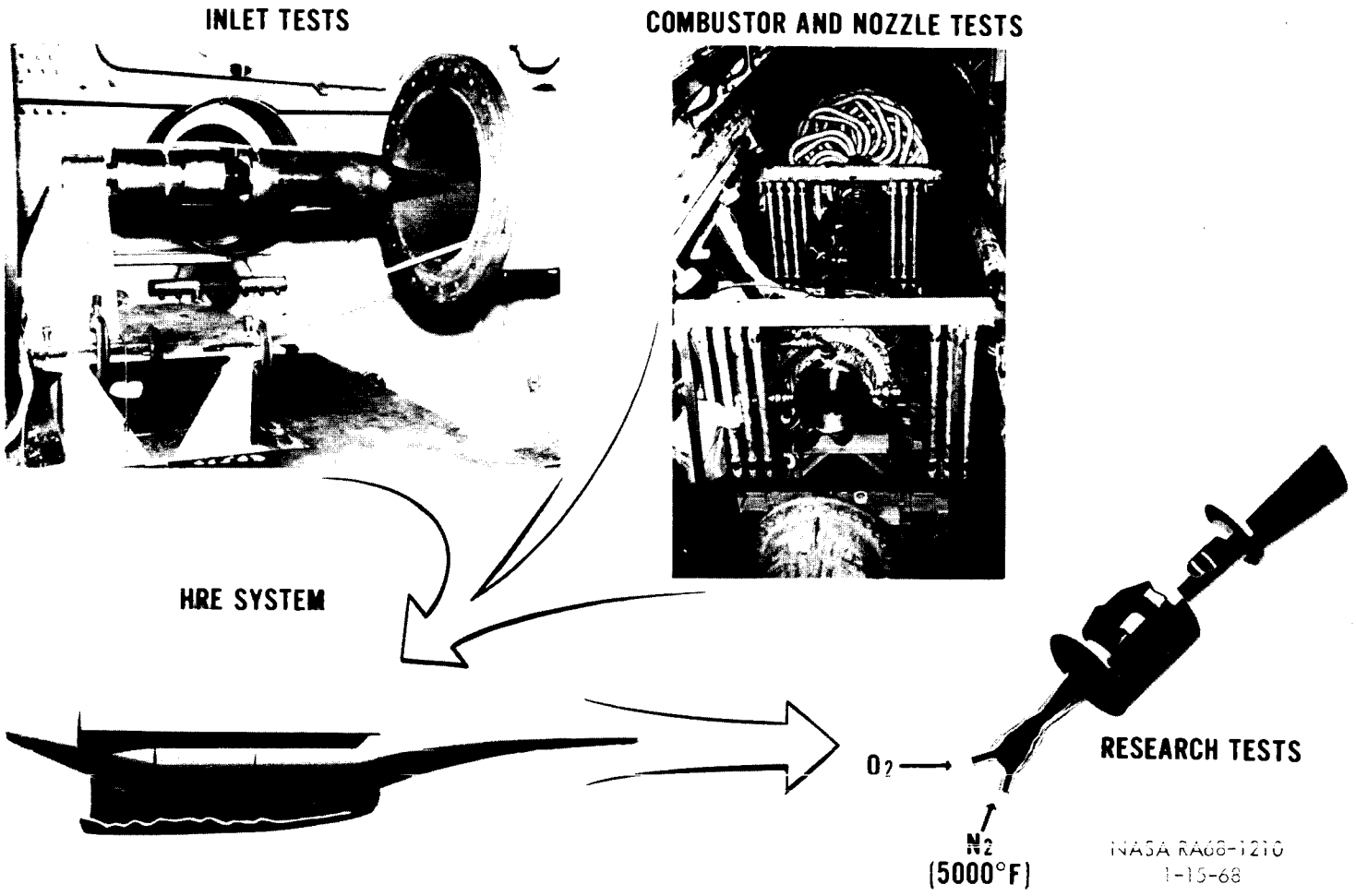
# QUIET ENGINE R&D PROGRAM




NASA RA68-1194
1-15-68

RD 17-80

# HYPERSONIC RESEARCH ENGINE PROGRAM




NASA RA68-1210
1-15-68

RD 17-21

OFFICE OF TRACKING AND DATA ACQUISITION

TRACKING AND DATA ACQUISITION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of this program is to provide responsive and efficient tracking and data acquisition support to meet the requirements of all NASA flight projects. In addition, support is provided, as mutually agreed, for projects of the Department of Defense, other Government agencies, and other countries and international organizations engaged in space research endeavors.

Support is provided for manned and unmanned flights; for spacecraft, sounding rockets, and research aircraft; for earth-orbital and suborbital missions; for lunar and planetary missions; and for space probes.

Types of support provided include: (a) tracking to determine the position and trajectory of vehicles in space, (b) acquisition of scientific data from onboard experiments, (c) acquisition of engineering data on the performance of spacecraft and launch vehicle systems, (d) transmission of commands from ground stations to spacecraft, (e) communication with astronauts and acquisition of medical data on their physical condition, (f) communication of information between various ground facilities and mission control centers, and (g) processing of data acquired from the space vehicles. Such support is essential for achieving the scientific objectives of all flight missions, for executing the critical decisions which must be made to assure the success of these flight missions, and, in the case of manned missions, to insure the safety of the astronauts.

Tracking and data acquisition support is provided by a worldwide network of NASA ground stations supplemented by appropriate instrumentation ships, aircraft, and ground stations of the Department of Defense. These facilities are interconnected by a network of ground communications lines, undersea cables, high frequency radio links, and communication satellite circuits, which provide the capability for instantaneous transmission of data and critical commands between spacecraft and the control centers in the United States from which the flights are directed. Facilities also are provided to process into meaningful form the large amounts of data which are collected from flight projects. In addition, instrumentation facilities are provided for support of sounding rocket launchings and flight testing of research aircraft.

The Research and Development appropriation provides funds: (a) for the operation and maintenance of the worldwide facilities; (b) for the procurement of equipment and for modifications to facilities to support continuing,

new, and changing flight project requirements; and (c) for the investigation and development of advanced tracking and data acquisition equipment and techniques. The subsequent sections describe plans and related funding requirements to continue the Tracking and Data Acquisition Program in each of these areas during FY 1970.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Operations..... | $211,483,000 | $226,950,000 | $239,400,000 |
| Equipment..... | 51,567,000 | 41,222,000 | 46,100,000 |
| Supporting research and technology..... | 12,800,000 | 11,500,000 | 12,500,000 |
| Total..... | $275,850,000 | $279,672,000 | $298,000,000 |

Distribution of Program Amount by Installation:

| | | | |
|---|---|---|---|
| Marshall Space Flight Center..... | $400,000 | $300,000 | $400,000 |
| Goddard Space Flight Center..... | 201,302,000 | 209,522,000 | 220,100,000 |
| Jet Propulsion Laboratory. | 52,368,000 | 50,400,000 | 54,200,000 |
| Wallops Station..... | 5,000,000 | 6,000,000 | 6,000,000 |
| Electronics Research Center..... | --- | --- | 200,000 |
| Flight Research Center.... | 2,000,000 | 2,000,000 | 2,000,000 |
| Langley Research Center... | 1,625,000 | 1,350,000 | 1,300,000 |
| NASA Headquarters..... | 13,155,000 | 10,100,000 | 13,800,000 |

BASIS OF FUND REQUIREMENTS:

Operations

| | | | |
|---|---|---|---|
| Manned space flight network. | $71,079,000 | $82,000,000 | $89,200,000 |
| Satellite network..... | 41,488,000 | 43,000,000 | 44,500,000 |
| Deep space network..... | 37,290,000 | 34,600,000 | 36,900,000 |
| Other instrumentation..... | 5,900,000 | 6,150,000 | 6,300,000 |
| Communications..... | 42,118,000 | 45,500,000 | 46,500,000 |
| Data processing..... | 13,608,000 | 15,700,000 | 16,000,000 |
| Total..... | $211,483,000 | $226,950,000 | $239,400,000 |

Manned Space Flight Network Operations

The primary function of the Manned Space Flight Network is to provide tracking, data acquisition, communications, and command support for NASA's manned space flight programs. The Network: (a) provides spacecraft tracking data which are used for orbit and trajectory determination and to

initiate and verify orbital maneuvers, (b) receives telemetered information concerning the condition of the astronauts and the performance of the spacecraft, (c) provides for voice communication with the astronauts, (d) receives television data from the spacecraft, (e) communicates information to control centers in real time for critical decisions, (f) transmits commands to the spacecraft, and (g) records engineering data from the spacecraft.

In addition to the support provided for manned missions, selected stations of the Network provide support to unmanned deep space and earth orbital projects of NASA and the Department of Defense. Based upon requirements for each mission, manned or unmanned, the Manned Space Flight Network (MSFN) and other resources of the Office of Tracking and Data Acquisition, such as the Space Tracking and Data Acquisition Network (STADAN), the NASA Communications Network (NASCOM), and the Deep Space Network (DSN), are called upon to provide support. The DOD also provides tracking support as required.

The Manned Space Flight Network is a worldwide tracking and ground instrumentation system which originated with the Mercury Program, was modified and expanded for the Gemini Program, and has been further modified and expanded for the Apollo Program. Completed and fully checked out during FY 1968, the MSFN by the end of December 1968, has successfully supported three unmanned and two manned Apollo missions. Testing and training is continuing to assure readiness for future manned orbital and lunar flights.

The Network consists of: (a) ten 30-foot diameter antenna stations located at Cape Kennedy; Bermuda; Antigua; Ascension Island; Grand Canary Island; Carnarvon, Australia; Guam; Kauai, Hawaii; Guaymas, Mexico; and Corpus Christi, Texas; (b) three 85-foot diameter antenna stations located at Madrid, Spain; Canberra, Australia; and Goldstone, California; and (c) one transportable 30-foot diameter antenna station presently located at Grand Bahama Island. In addition, four instrumentation ships and eight aircraft, operated by the Department of Defense, and three 85-foot diameter antenna stations of the NASA Deep Space Network will provide support for Apollo. Secondary support will be provided by the NASA station at Tananarive, Madagascar; and by the Department of Defense stations at Point Arguello, California; Eastern Test Range facilities; and White Sands, New Mexico, using existing equipment.

The currently planned mission workload requires a limited second shift of personnel at the stations for Apollo support in FY 1970. Leadtimes associated with programming, simulations, and checkout result in overlap between actual mission support and the preparation necessary for subsequent missions. This is beyond the capacity of a single shift of personnel and required the buildup for a limited second shift which was initiated during FY 1968 and is being completed in FY 1969. The FY 1970 budget includes funds to cover a full year's effort for this additional manpower and is reflected in the increased request over FY 1969 for Manned Space Flight Network operations.

The second area of increase over FY 1969 is for reimbursement to DOD for operational support and for technical and administrative assistance. Estimates for DOD operation of the Apollo ships and the Apollo/Range Instrumentation Aircraft in FY 1970 are included and reflect a full year's cost for the operation of these ships and aircraft.

Other areas in the MSFN operations budget, including logistics, network support, and programming, reflect an increase over FY 1969 costs and are associated with pay escalation and cost-of-living additions. The procurement of magnetic tape is also expected to increase in FY 1970 due to the number, duration, and complexity of the missions to be supported.

## Satellite Network Operations

The primary function of the Satellite Network is to support NASA's unmanned scientific and applications satellite programs. The Network includes the electronic stations of the Space Tracking and Data Acquisition Network (STADAN) operated by the Goddard Space Flight Center, supplemented by the optical tracking stations operated by the Smithsonian Astrophysical Observatory. The STADAN stations provide a ground system which: (a) tracks each satellite, (b) determines the status of onboard systems, (c) commands the satellite functions, and (d) acquires stored or real-time data from the satellite. The optical stations provide specialized services in precision orbital tracking as well as backup support to STADAN during launch and early orbit tracking of satellites.

STADAN stations are located at Fort Myers, Florida; Mojave, California; Quito, Ecuador; Lima, Peru; Santiago, Chile; Johannesburg, South Africa; Tananarive, Madagascar; Canberra, Australia; Fairbanks, Alaska; St. John's, Newfoundland; Winkfield, England; Rosman, North Carolina; and Toowoomba, Australia.

During FY 1969, continuing budget constraints and personnel limitations at overseas locations, due to the balance of payments problem, have required a curtailed level of operational support. A number of telemetry links, the operation of which was curtailed in FY 1967, continue to be maintained only in a caretaker status. Operations at stations in the optical network are being reduced even further in FY 1969, support of older satellites continues to be terminated, and other satellites currently being supported are being reviewed periodically for either termination or reduced levels of support.

Funds requested in the FY 1970 budget will cover a continuation of the present level of operations requiring the caretaker status of certain facilities and resulting in permanent loss of data from selected satellites and experiments. The requested increase in funds over FY 1969 will provide only for cost-of-living increases and for additional costs to operate the existing control centers for the Orbiting Astronomical Observatory (OAO), Nimbus, the Applications Technology Satellite (ATS), and the smaller scientific satellite launches scheduled during FY 1970.

Currently the network, with around-the-clock operation, is supporting an average of over 35 satellites most of which will constitute an on-going workload in FY 1970. The additional satellites to be launched in the remainder of FY 1969 will, in most instances, require extended support in FY 1970. Added to this workload will be 19 satellites scheduled for launch during FY 1970. Despite this anticipated total workload, existing limitations on facilities and manpower will be continued in FY 1970.

## Deep Space Network Operations

The primary function of the Deep Space Network is to support unmanned lunar and planetary space flight missions. The network: (a) provides tracking data which are used to determine and make mid-course corrections and terminal maneuvers to spacecraft trajectories, (b) acquires engineering telemetry data concerning performance of the spacecraft, (c) transmits commands to the spacecraft, and (d) receives and records the scientific data which are acquired from the spacecraft. The network consists of stations located at Goldstone, California; Woomera and Canberra, Australia; Madrid, Spain; Johannesburg, South Africa; and Cape Kennedy, Florida.

The control center for the Deep Space Network is the Space Flight Operations Facility (SFOF) located at the Jet Propulsion Laboratory in Pasadena, California. The SFOF: (a) receives information transmitted via ground communications from stations of the Deep Space Network, (b) processes the data, (c) displays the resulting information so that mission directors and associated project personnel can analyze mission performance and make critical decisions in near real time concerning functions to be executed by the spacecraft, and (d) transmits instructions to the stations for commands that must be sent to the spacecraft.

The Deep Space Network achieved a high workload level in FY 1968, principally as a result of the numerous missions involved in unmanned lunar exploration. Completion of the Lunar Orbiter, Surveyor, and Mariner IV programs in FY 1968 and the Mariner V program in the early part of FY 1969 allowed reductions in personnel at the control center and stations which were reflected in the FY 1969 budget. However, increased engineering effort starting in late FY 1969 and continuing through FY 1970 is required for the Mariner '71 and the Pioneer F and G missions. This is reflected in the FY 1970 budget request.

The flight missions of the Pioneer program will continue through FY 1970. The Mariner-Mars flyby missions are scheduled for launch in late FY 1969 and ground support is required well into FY 1970 for these missions. In addition, four stations in the Network, one each in Australia and Spain, and two in California, will provide joint support for the Apollo manned lunar missions. In summary, the Deep Space Network and the Space Flight Operations Facility (SFOF) must be staffed and equipped to support five Pioneers, the Mariner F and G missions, and Apollo during the FY 1970 time period, plus engineering and programming effort required for the Mariner '71 and follow-on Pioneer missions.

## Other Instrumentation Operations

Instrumentation systems are operated and maintained in support of sounding rockets and reentry vehicles launched from Wallops Station, Virginia, and the Churchill Research Range, Canada; and for flight research programs of the Flight Research Center, California. General purpose tracking, telemetry, data handling, recording, timing, plotting, and communications systems are provided as well as special purpose fixed and mobile optical and sound ranging (acoustical) equipment.

The instrumentation at Wallops Station is operated by NASA contractors and by other Government agencies such as the Environmental Science Services Administration (ESSA), the National Bureau of Standards, the U.S. Navy, the U.S. Air Force, and the Military Sea Transportation Service. Funds requested in FY 1970 will maintain a required level of effort which closely approximates that of prior years.

Mobile telemetry and optical equipment are maintained and operated at selected sites along the eastern seaboard to support rocket flights from Wallops Station. This down-Range support is funded by Langley Research Center.

Instrumentation at the Churchill Research Range consists of general purpose tracking, telemetry, command and control, and associated systems required to conduct sounding rocket experiments in the high latitudes. The Range is operated under the management of the National Research Council of Canada which shares the costs with NASA as a cooperative effort.

The Flight Research Center operates the Aerodynamic Test Range consisting of facilities at the Edwards Air Force Base and the up-Range site at Ely, Nevada. The increased tracking capability at the Ely site, obtained by the addition of a precision radar, resulted in the closure during FY 1969 of the tracking and telemetry facility at Beatty, Nevada. Programs supported by the Aerodynamic Test Range include various research aircraft and lifting body projects.

## Communications Operations

The Goddard Space Flight Center operates NASA's global communications system and serves as its major switching point. The system interconnects all NASA tracking stations in operational support of all NASA projects and projects of other agencies that are supported by the NASA networks. It interconnects such facilities as telemetry and command control sites, launch areas, test sites, and mission control centers. In the interest of economy, reliability and full utilization of circuitry, subswitching centers have been established at London, Honolulu, Canberra, Madrid, Guam, and Cape Kennedy. During this fiscal year, another subswitching center will be established at the Jet Propulsion Laboratory in Pasadena, California.

Communications satellites will continue to provide service to the Apollo ground stations and ships. As new communications satellite ground stations are established, such as one recently completed in Chile, and another to be completed in 1969 in Ecuador, existing high frequency radio circuits to NASA tracking and data acquisition stations in these areas will be changed to the more reliable communications satellite service. In a further effort to improve the reliability of the communications network, high frequency radio circuits to South Africa are being replaced with circuits leased in a new submarine cable installed between South Africa and Ascension Island which will link up with communications satellite circuits.

The FY 1970 communications budget reflects only a slight increase over the FY 1969 budget. This increase is due in part to a heavier Apollo mission support schedule in FY 1970 than in FY 1969 which will require that the full communications network be kept up during the year rather than calling up and taking down circuits between missions. Also included in the FY 1970 budget are funds for television coverage from Australia and a full year's funding for an increase in domestic long-line tariff rates which became effective in September 1968.

There will also be increases in the costs of operating personnel due to the requirement for four-shift operation at all locations, salary increases, and the introduction of technical controllers at key switching locations. These controllers, through circuit patching and switching, will select the best route of cable and satellite services for the transmission of data.

## Data Processing Operations

Information received in the form of tracking and telemetry data from satellites and space probes must be processed into a form that is useful to both those performing the real-time control of the space vehicle and those responsible for analyzing the scientific data acquired by the spacecraft.

Tracking data are processed to provide orbital elements which are used to supply stations with predictions on future passes of the spacecraft, and to provide position information that can be used by the scientific experimenters to determine where in the trajectory the scientific measurements were made.

Telemetry data must be processed to: (a) separate the information obtained from the various scientific experiments aboard the spacecraft, (b) consolidate information from each experiment, (c) apply the necessary scaling factors and calibrations on the measuring instruments, (d) determine spacecraft attitude, and (e) correlate these measurements with the position data mentioned above. Processed data are the primary product of the spacecraft missions, and it is through reduction and analyses of these data by the experimenters that a better understanding of space is achieved.

Several projects, particularly those in the Observatory and Geodetic classes, require extensive pre-mission orbit studies, including spacecraft position predictions and mutual visibility analyses. Studies are also



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required to work out operational methods and procedures to be used during the actual mission operations.

Support must be given to a wide variety of programs which vary from the small University Explorer satellites to the large and complex Solar, Geophysical, and Astronomical Observatories, and Applications Technology Satellites.

The FY 1970 budget request is based upon the workload which will result from previously launched satellites that will require continued support, plus additional satellites that are scheduled to be launched during the period. This workload includes an increase in the number of high data rate satellites, such as the Nimbus D, OAO-C, OSO-H, and IMP-I, which will result in additional telemetry data processing and mission related computer support. There will also be an increase in orbit and attitude computations due to greater spacecraft complexity. The telemetry data processing workload in FY 1970 is projected to be about 10 percent above the FY 1969 workload.

Equipment

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Manned space flight network.... | $24,181,000 | $14,200,000 | $13,300,000 |
| Satellite network..... | 9,478,000 | 9,000,000 | 13,000,000 |
| Deep space network..... | 9,354,000 | 10,200,000 | 12,500,000 |
| Other instrumentation..... | 3,300,000 | 3,800,000 | 3,600,000 |
| Communications..... | 3,090,000 | 2,300,000 | 2,200,000 |
| Data processing..... | 2,164,000 | 1,722,000 | 1,500,000 |
| Total..... | $51,567,000 | $41,222,000 | $46,100,000 |

Manned Space Flight Network Equipment

The Manned Space Flight Network equipment program encompasses the procurement of equipment and services necessary for incorporation of new capabilities in the network to meet new manned space flight program support requirements, for modification of existing equipment to increase the network's operational effectiveness and efficiency, and for sustaining the network's continuing capability for reliable mission support.

Implementation of the Manned Space Flight Network's basic capability for Apollo Program support was completed during FY 1968. During FY 1969, activity has been primarily devoted to maintaining the network in a continuing state of readiness for support of the changing mission requirements of the manned space flight program. This effort will be continued in FY 1970.

During FY 1970, the network will be heavily engaged in Apollo mission support. In such an environment, a continuing effort will be necessary to maintain the support capability throughout the flight program. Accordingly, funds are requested for facility modifications and for equipment to be used

in off-line monitoring of station and system performance, for correction of operational deficiencies, and for replacement of failure prone systems with more reliable units. Funds are also requested for the engineering effort required for system checkout, provision and modification of test equipment, continuation of the test and training satellite capability, and for the procurement of module spares needed to preclude long periods of station downtime.

Tracking and data acquisition requirements for missions in the Apollo Program vary from mission to mission depending on specific mission objectives, flight plans, and the requirement to investigate special problem areas discovered in the spacecraft on previous flights. In general, it is necessary to modify or augment network equipment to enable support of these varying requirements. Such changes are anticipated in most systems areas and funds are requested in FY 1970 for procurement of equipment at the system and module levels to provide for these mission-to-mission changes.

The complex orbital flight operations planned for Apollo Applications will require Manned Space Flight Network support of multimodule rendezvous maneuvers with an orbiting spacecraft cluster equipped with a broad spectrum of scientific and technological experiments. To fulfill both mission control and experiment support requirements, it is necessary to augment the data handling capabilities of the network stations. Currently, most of the stations are equipped with three PCM systems for decommutation of the three telemetry data links used for Apollo mission control. An additional decommutator is required at each station to handle AAP experiment data. These systems were originally programmed for procurement in FY 1969; however, the delay in the Apollo Applications mission schedule has permitted postponement of the procurement to FY 1970.

The rendezvous phases of Apollo Applications missions will require network support of the orbiting spacecraft cluster simultaneously with support of manned or unmanned rendezvous spacecraft. Since the data systems aboard the rendezvous spacecraft differ functionally from those aboard the orbiting cluster and since individual network stations will be required to support the two vehicles in rapid sequence, station capabilities for rapid reprogramming and quick configuration turnaround are required.

Currently, these capabilities are limited by the time requirements for configuration verification and checkout. Accordingly, funds are requested to initiate provision of automatic configuration monitoring and automatic checkout capabilities in the network stations. Provision of these capabilities will significantly reduce the time required for the reliable configuration turnaround necessary for support of these complex missions.

## Satellite Network Equipment

In fiscal year 1970, the equipment program for the Satellite Network consists of three major categories with the following objectives: (1) sustaining the basic capability of the network; (2) improving the utilization

of existing equipments; and (3) implementing required new capability. As in previous years, funding constraints in fiscal year 1969 have required equipment deferrals into fiscal year 1970.

Under the sustaining effort for fiscal year 1970, the objective will be to maintain the minimum level of performance necessary to meet the requirements of the numerous and varied on-going programs which are supported by the network. In meeting this objective, the fiscal year 1970 effort will include the replacement of command encoders and command antennas, essentially completing a three-year program to update the command systems in a general purpose configuration.

On a continuing basis, equipments are needed at both the stations and the control centers to meet requirements of mission-to-mission changes within a program. As part of the sustaining effort, these changes include modifications to display boards, computer interface equipment, and mission directors' consoles.

In addition, funds are included in the fiscal year 1970 budget request for the more routine functions associated with maintaining a global network. These include the procurement of test and calibration equipment necessary to insure a high performance level of the electronic systems and subsystems, provision for facility repairs and alterations, procurement of specialized non-expendable spare components and modules, and procurement of station maintenance vehicles.

The major effort planned in fiscal year 1970 to improve the utilization of existing equipment is the implementation of Station Technical Operations Control (STOC) consoles. These consoles, by centralizing a number of routine operations at the stations and affording a rapid checkout of a station's configuration to support a particular satellite pass, will reduce the turnaround time between passes. With a reduced turnaround time, more satellite passes can be supported with existing equipment, and without the addition of new telemetry and command links. Due to budget constraints in fiscal year 1969, this item was deferred into fiscal year 1970.

The new capability category includes those equipments which are needed to meet new requirements brought about by new program starts in the fiscal year. For fiscal year 1970, the high data rate of the Earth Resources Technology Satellite will require antenna modifications and recording equipment at two sites; and command, display, computational, and video data handling equipment at the control center. For the new OSO missions, equipment is needed to update the control center to support these higher data rate spacecraft.

## Deep Space Network Equipment

As the emphasis in the unmanned lunar and planetary program in the early 1970's changes from lunar to planetary exploration, the Deep Space Network is being augmented to provide a general purpose capability to support the

more demanding and complex mission requirements associated with this change. These requirements include precise ground control of orbiting spacecraft at planetary distances, data processing systems to handle large quantities of both visual imaging (TV) and scientific data, and sensitive and reliable ground systems to handle multiple spacecraft, particularly during critical mission modes, at extreme distances.

To provide a general purpose configuration in the network to meet these newly evolving requirements, the development and testing of several systems are underway in FY 1969. The FY 1970 budget request includes funds to continue with this development which is required to implement or modify selected proven systems for support of Mariner 1971. Funds are also included in this request for sustaining the network capability to support the on-going Mariner 1969 and Pioneer missions.

For the Mariner 1971 mission, modifications will be made to the general purpose telemetry system at the 85-foot antenna sites. These modifications will allow a more rapid transfer of data to earth from spacecraft at planetary distances. Also, to provide for the handling of visual imaging data from two spacecraft orbiting Mars in 1971, and to allow for the simultaneous processing of such data, certain modules of the 210-foot Goldstone antenna data processing and receiver systems will be dualized.

General purpose command generation equipment will also be implemented at those sites supporting Mariner 1971. This equipment, a prototype of which has been developed, provides a direct, automatic command capability from the control center. This centralized command capability allows prompt and reliable initiation of commands for those spacecraft requiring close operational surveillance and real-time control as typified by the two orbiting Mariner '71 spacecraft.

The two Mariner 1971 spacecraft orbiting Mars every 12 hours will also relay an extremely large volume of occultation data. This type of data, derived from the perturbed radio transmissions through the Martian atmosphere, will be acquired two times during each 12-hour orbit of the planet. Since previous planetary missions allowed only one occultation opportunity they were conducted on an experimental basis using a slow data processing technique at only one ground station. To enable the network to handle this greatly increased data workload, it will be necessary to implement or modify selected systems, including new digital recorders and receiver modifications, at four DSN stations.

Funds are included in the FY 1970 request for sustaining the network at the required levels of reliability to support the on-going program. Updating and replacement of obsolete or high maintenance components, modules, and subsystems are necessary on a continuing basis to maintain network integrity and reliability. This requires the procurement of such items as test and calibration equipment, major cabling assemblies, antenna and servo components, and power distribution modules. It also provides for module spares provisioning, minor mission-to-mission changes, and simulation interface modules for system training and testing.

## Other Instrumentation Equipment

A wide variety of fixed and mobile equipment is used to provide instrumentation support for sounding rockets and reentry vehicles launched from Wallops Station and other locations, and for flight research projects conducted at the Flight Research Center.

At Wallops Station, these funds in FY 1970 are required to sustain existing capability by the provision of maintenance and spare parts, the procurement of non-recoverable flight hardware (antennas, transponders, command/destruct receivers, and small test rockets for calibrating ground support instrumentation) and the accomplishment of the third phase of the S-band telemetry conversion scheduled for completion in FY 1971. In addition, a C-band radar, surplus to the Canary Island tracking station, will be refurbished to meet current requirements.

The Aerodynamic Test Range radar systems have been converted from S-band to C-band. Fiscal year 1970 funds are required for integration of the new system into existing instrumentation, for associated ground support test and calibration equipment, and for the procurement of maintenance and repair parts. This effort was essentially deferred from FY 1969 due to budget constraints.

## Communications Equipment

Procurement of communications equipment will maintain the present level of capability and provide a few necessary improvements. One of the improvements will be the addition of technical control facilities at Ascension Island and Canary Island to permit maximum cross-use, by switching and patching, of communications satellite circuits and new submarine cable circuits. This equipment will permit the controllers to monitor and evaluate each type of circuit and pick the best one for transmission of data.

Another improvement is the standardization of the teletype network at 100 wpm worldwide. Presently, the network consists of teletype equipment capable of handling various data rates which require special conversion equipment. In addition, equipment items such as direct wideband computer-to-computer interface units, core modules, tape units, and replacement parts and spares will be purchased to meet normal requirements to sustain the network.

## Data Processing Equipment

The operational data processing equipment requires a continuing program of minor redesign, modification, and improvement, as well as normal maintenance and repair. While the data processing lines are designed to be as flexible as possible, changes and updating are necessary to meet the requirements of new programs and to accommodate mission-to-mission changes within existing programs. The objective of these changes is to accelerate the processing of data and thus minimize the acquisition of new processing

equipment. An example of such a change is the addition to an existing data processing line of a command decoder and PCM equipment to support IMP's H, I, and J. The FY 1970 budget includes funds to provide the components necessary for these modifications and improvements to existing processing equipment.

Supporting Research and Technology

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| New systems..... | $685,000 | $801,000 | $1,370,000 |
| Integrated systems analysis, development and test..... | 2,916,000 | 2,382,000 | 2,540,000 |
| Antenna subsystems..... | 1,505,000 | 836,000 | 1,340,000 |
| Receiving and transmitting subsystems..... | 2,481,000 | 2,798,000 | 2,510,000 |
| Data handling and control..... | 1,920,000 | 1,923,000 | 1,970,000 |
| Data processing and reduction. | 1,660,000 | 871,000 | 1,150,000 |
| Spacecraft subsystems..... | 1,633,000 | 1,161,000 | 990,000 |
| Network performance and operations technology..... | --- | 728,000 | 630,000 |
| Total..... | $12,800,000 | $11,500,000 | $12,500,000 |

The Supporting Research and Technology (SRT) program for tracking and data acquisition is undertaken to develop the telecommunications technology needed to support future flight missions. The program is planned to provide the studies and developments needed for the orderly evolution of network support capabilities and for the cost effective augmentation of tracking and data acquisition support systems.

The effort in FY 1970 will remain focused on the Deep Space Network role in the telecommunications link and the Satellite Network capabilities to provide cost effective support to future scientific and applications satellite missions. The objective for deep space is to receive spacecraft telemetry at higher rates than now obtainable and at greater distances, to receive planetary lander telemetry directly from the spacecraft on the surface, to allow simultaneous operation of several spacecraft, and to provide the more accurate tracking needed for advanced planetary missions.

The prime objective of SRT support of earth satellites is the application of cost effective techniques for implementing required augmentations and for operating the total network of ground stations, control centers, and special facilities which support NASA flight projects, both manned and unmanned. Work will continue on data relay satellite studies, techniques to automate station operations and reduce station turnaround time between missions, methods for onboard data handling and processing, and development of network subsystems to meet specific mission needs.

The program for SRT comprises effort in eight task areas as follows:

## New Systems

The effort in this category consists primarily of studies to define the configuration and operation of a Data Relay Satellite System (DRSS). These studies are also intended to identify any potential problems in the technology of such a system. This system would use relay satellites in synchronous orbit to gather data from lower altitude orbiting spacecraft to augment the capability and improve the efficiency of the NASA tracking and data acquisition networks. Studies will be conducted to define the system which can most economically and reliably satisfy support requirements of NASA flight programs projected for the mid-to-late-1970's.

These studies will make use of appropriate technical and cost trade-off analyses to define the DRSS; that is, the number, location, and performance specifications of supporting ground stations, and the characteristics of the telecommunications subsystems of mission spacecraft for which the DRSS is to provide support.

## Integrated Systems Analysis, Development and Test

The main purpose of this effort is to prove the acceptability of software concepts and hardware models in a real or simulated network operating environment before they are committed to implementation into the network stations, control centers and other facilities. Also to be continued in this task area in FY 1970 is the development of techniques for network frequency and time synchronization, the development of techniques and computer programming for more precise orbit determination, and planetary radar and telecommunications experiments to obtain data which are used for both scientific and network engineering purposes. As part of the interface planning between the networks and the flight missions, work will continue on the analysis of on-going and future mission trajectories and profile alternatives to ensure ground system compatibility with these new flight requirements.

## Antenna Subsystems

The objective of this task area is to provide technology for improving overall performance of ground antenna systems and subsystems in terms of efficiency, reliability, and maintainability. Improvements are needed to achieve operational flexibility for transmitting various frequency bands using fixed and rapidly changeable antenna feed configurations. Digital antenna control and other automation techniques are needed to provide more effective utilization of large antenna facilities and decrease the time required to change the antenna mode from one mission to another. This work will continue and includes the measurement and calibration of antenna performance, studies to lower noise interference, and the evaluation of design techniques for large antennas.

## Receiving and Transmitting Subsystems

The objectives of this category are to devise, construct, test, and demonstrate prototype versions of transmitters and receivers needed to meet the requirements of approved flight missions. For deep space missions, a major objective is to allow two-way radio communications simultaneously with orbiting spacecraft and lander vehicles at several frequencies and at extreme distances. Developments for multi-mission telemetry through use of hybrid computers to perform digital decommutation will continue. For earth satellites, the primary effort in FY 1970 will focus on the automated multi-function receiver and low noise masers for future ATS and other flight missions.

## Data Handling and Control

The objective of this effort is to provide efficient and error-free data transmission, handling, and control required by the networks in their support functions of telemetry, command, tracking, ranging, and timing. Effort will continue on the development of hardware and software to prove out techniques that are cost-effective in providing a moderate degree of station automation. This work will include more efficient handling of data for commanding satellites, monitoring station status, fault detection and isolation, and for operational flexibility to respond quickly to changes in mission support requirements. Work will also continue on techniques for receiving high-rate coded telemetry and methods of obtaining useful data from very weak signals that are below present signal thresholds.

## Data Processing and Reduction

The objectives of this task are the efficient and reliable operation of the control centers and the preparation of flight experiment data which is acceptable for use by scientific and engineering personnel participating in the NASA space programs. Computer programming theories and languages will be applied and techniques will be developed to fulfill control center needs for multiple spacecraft mission support. Development will continue on more efficient methods of displaying, reducing, and processing large volumes of data. Investigations will be made of techniques using optical data processing equipment and other methods of providing capabilities needed to fulfill future requirements.

## Spacecraft Subsystems

The main objective of this effort is the development of common-usage spacecraft telecommunications subsystems that are compatible with the ground stations and are optimized for spacecraft-network trade-offs. Development of general-purpose spacecraft subsystems will continue in FY 1970 primarily in the area of on-board information processing and control, and a unified radio frequency subsystem. Techniques will be examined to reduce the amount of redundant and unnecessary data transmitted to the stations.



332-276 O - 69 - 29

## Network Performance and Operations Technology

The objectives of this new task area are to determine the performance and limitations of the networks as a whole and to exploit ways of reducing recurring operations costs. Specifically, in FY 1970, effort will concentrate on cost analyses of station automation, automating range scheduling, improving the quality of tracking data, and obtaining greater efficiencies in operations by reducing radio frequency interference in the spacecraft-to-earth telecommunications link.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1970 ESTIMATES

OFFICE OF TECHNOLOGY UTILIZATION — TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

This program provides a necessary follow-on to all Government supported programs in line with the principle that techniques and methods discovered and/or developed with public support should be made available to the public expeditiously for their benefit. Those techniques and methods which are of direct benefit to the aeronautical and space communities almost automatically are put to use throughout that community. However, there are inevitably discoveries and developments in any line of research which are of potential benefit to users outside of the developing community. It is the purpose of the program to uncover such useful discoveries and provide a mechanism for making them known and available to the general public. In addition, this program provides a similar service in connection with management techniques for large, complex research and development activities by giving wide dissemination to new systems and concepts in this area.

The primary objectives of the Technology Utilization program are: (1) to increase the return on the national investment in aerospace research and development by encouraging additional uses of the knowledge gained in those programs; (2) to shorten the time gap between the discovery of new knowledge and its effective use in the marketplace; (3) to aid the movement of new knowledge across industry, disciplinary, and regional boundaries; (4) to contribute to the knowledge of better means of transferring technology from its points of origin to its points of potential use.

SUMMARY OF RESOURCES REQUIREMENTS:

| | 1968 | 1969 | 1970 |
|---|---|---|---|
| Identification and publication... | $1,500,000 | $1,600,000 | $1,700,000 |
| Evaluation..... | 700,000 | 800,000 | 950,000 |
| Dissemination..... | 1,600,000 | 1,400,000 | 2,350,000 |
| Analysis..... | 200,000 | --- | --- |
| Total..... | $4,000,000 | $3,800,000 | $5,000,000 |

**Distribution of Program Amount by Installation:**

| | | | |
|---|---|---|---|
| **NASA Headquarters.....** | **4,000,000** | **3,800,000** | **5,000,000** |

BASIS OF FUND REQUIREMENTS:

## Identification and Publication

Technology Utilization Officers at NASA field installations and specialists from universities, research institutes and private industry search through selected areas of scientific and technical endeavor, and identify and document those inventions, innovations, improvements, and discoveries that have potential utility to the nonaerospace sector of the economy. Increased emphasis is placed on the identification and reporting of new technology, particularly in the areas of computer programs and biomedical instrumentation with high potential for secondary application. Also, efforts will be undertaken to evaluate prospectively the potential for generating new technology at the initiation stage of R&D programs.

## Evaluation

Personnel at NASA installations and research institutes evaluate the new technology so identified, determine its novelty, significance and potential nonaerospace industrial application and utility and prepare reports which are published and made available to the scientific, industrial and academic communities. In addition, NASA personnel and research institute personnel are continually evaluating technology transfer mechanisms and feeding the new knowledge back into the Technology Utilization program.

## Dissemination

This program element is accomplished by the employment of regional dissemination centers that store, retrieve and interpret, the new technology developed by NASA for local industry. Biomedical applications teams are also employed to assist researchers in defining and solving medical problems by adaptation of NASA technology. In addition, Government developed computer software is evaluated and disseminated to industry. Cooperative programs are underway with several other agencies such as the Bureau of Reclamation, Law Enforcement Assistance Administration, Social Rehabilitation Service of HEW, Small Business Administration, Atomic Energy Commission and others to disseminate applicable new technology developed by NASA. Such dissemination programs are to be expanded and strengthened. Increased emphasis is to be placed on cooperative interagency programs, particularly those now reaching the full implementation stage such as the agreement under which Department of Defense computer programs are to be made available to the Computer Software Management Information Center for evaluation and distribution to secondary users. Increased participation with trade associations, the arrangement of Technology Utilization conferences and seminars, and continued high emphasis on the announcement and publication of available new technology through the trade press is planned.



U. S. GOVERNMENT PRINTING OFFICE 1969 O - 332-276