2804 / Space

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON 25, D.C.

OFFICE OF THE ADMINISTRATOR

MAY 3 1962

SECRET

~~+ Bundy~~
~~Z. C. Johnson~~
Send to McB file

Mr. McGeorge Bundy
Special Assistant to the President
Washington 25, D. C.

Dear Mr. Bundy:

A copy of the latest revision of the Long Range Plan of the National Aeronautics and Space Administration is hereby transmitted for your information and use.

Obviously, a long range plan is sound only so long as its assumptions remain valid and no major changes take place in governmental policy or Congressional support. Therefore, this plan is revised annually in order to incorporate the results of technological progress, the discoveries in space science and such changes as may occur in governmental policies and national goals.

Sincerely,

James E. Webb

James E. Webb
Administrator

Enclosure

(When separated from enclosures, handle this document as unclassified)

SECRET

THE President

SECRET

copy 17 of 125

LRP-62

THE LONG RANGE PLAN

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

JANUARY 1962

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PREFACE

All Program Offices of the Headquarters of the National Aeronautics and Space Administration contributed to the Long Range Plan presented in this document. The contributions of the Field Centers were indirect, through the Program Offices. This document was prepared by the staff of the Office of Plans and Program Evaluation.

The general features of the Long Range Plan are approved in principle by the Administrator of the National Aeronautics and Space Administration. For specific programs, however, it serves as a guide only. Approval for initiation, pace and level of effort of any particular program must be obtained through established management channels.

Obviously, a long range plan is sound only so long as its assumptions remain valid and no major changes take place in governmental policy or Congressional support. Therefore, in order to incorporate the results of technological progress, the discoveries in the space sciences, and changes in governmental policies and national goals, this plan is revised annually.

Abraham Hyatt

Abraham Hyatt
Director
Plans and Program Evaluation

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DESIGNATION OF LAUNCH VEHICLES AS USED IN THIS DOCUMENT*

Launch Vehicle	Vehicle Designation	Stage Designations
Scout	Sc	
Delta	De	
Thor-Agena B	Tg	
Atlas	At	
Atlas-Agena B	Ag	
Titan II	Ti–II	
Centaur	Ce	Atlas Centaur
Saturn C–I	Sa–I	S–I S–IV
	Sa–II	S–I S–IVb(1J–2)
	Sa–III	S–I S–IVb 3rd stage
C–5	Sa–IV	S–Ib S–II(5J–2) S–IVb
Nova	No	N–I N–II (4M–I) S–IVb

* The names and symbols in this table have been adopted for internal consistency in this document only. An official designation list is in process of preparation.

This table is repeated as Table IV-4.

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INTRODUCTION

NATIONAL SPACE POLICY

A major realignment of the National Space Program has occurred since the last revision (January 12, 1961) of the Long Range Plan. The new National Space Policy was proposed by the President in his Special Message to Congress on May 25, 1961.* The President stated that "now is the time to take longer strides—time for a great new enterprise—time for this nation to take a clearly leading role in space achievements". As a consequence of Congressional Action on the President's proposals, the pace and level of the United States space program have been greatly increased.

The President more specifically defined four areas to be emphasized as a matter of National policy:

1. ***Manned Lunar Expedition:*** "I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth. No single space project in this period will be more exciting, or more impressive, or more important for the long range exploration of space."
2. ***Communications Satellites:*** "When we have put into space a system which will enable people in remote areas of the earth to exchange messages, hold conversations, and eventually see TV programs, we will have achieved a success as beneficial as it will be striking."
3. ***Meteorological Satellites:*** "A satellite system for world wide weather observation—will be of inestimable commercial and scientific value; and the information it provides will be made freely available to all nations of the world."
4. ***Development of Nuclear Rockets:*** ". . . the Rover nuclear rocket—is a technological enterprise—which gives promise of some day providing a means for even more exciting and ambitious exploration of space."

This was a clear strengthening of the National Space Policy as originally expressed in the National Aeronautics and Space Act of 1958**. The Congress of the United States indicated its endorsement of the President's policy through its authorization and appropriation acts for NASA for FY 1962. *This addition to the National Policy together with a broad program in science and technology provide the background for the pace and level of effort assumed in this Long Range Plan.*

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*A more complete quotation of the President's message relative to the space program is included in Appendix B.

**Revelant portions of the Space Act of 1958 are quoted in Appendix A.

OBJECTIVES OF THE SPACE PROGRAM

The national objectives in space exploration and the exploitation of space technology may be broadly stated as:

1. To provide insurance for the United States that its science and technology will not become obsolete in an age of explosive advances in scientific knowledge, engineering techniques and other technological innovations.
2. To provide insurance against the hazards of military surprise in space technology and the possible adverse psycho-political consequences.
3. To lead the world into the space age in such a manner as to derive benefits for all mankind.

Leaders of government and respected figures in education and industry have consistently stated that the United States must maintain scientific and technological eminence among the nations of the world. The National Space Program is believed to have a "spearhead" role in this effort.

PURPOSE OF THE LONG RANGE PLAN

The pace and promise of space exploration to the future of the United States requires the best available prognosis incorporating the wide range of scientific and engineering disciplines involved.

This Long Range Plan (LRP–62), the third such prepared, is based upon a substantial effort by every major program office of NASA over a period of months. It is a projection-in-time of the possible trends of existing programs of established feasibility, of known trends in space technology and the space sciences, and of estimated feasibility of more ambitious programs.

Long range planning is considered essential for the orderly and efficient management of allocated resources for the attainment of this Nation's vital objectives in space. The Long Range Plan serves the following primary functions:

1. It lays out the major activity of NASA over the next decade indicating the pace and the interrelationships of the various programs.
2. It helps management to assess the effect of current decisions on future events, thereby contributing to sound decision making.
3. It provides broad guidance for the succeeding annual budget cycle and programming, personnel and facility planning.
4. It enables units of the organization to do better short-term planning; their work can now be related to end programs, resulting in less random motion.
5. It provides broad guidance on the support that may be required of other governmental agencies, the scientific community, and the aerospace industry in fulfillment of the National Space Program.
6. It provides a broad basis for evaluation of the National Space Program by higher government authority.

PRINCIPAL ASSUMPTIONS

The principal assumptions underlying the Long Range Plan are:

1. A continued program of scientific investigations in space is necessary.
2. A strong program of applied research and advancement of technology in the aeronautical sciences will be continued for the foreseeable future.
3. A rigorous program of research and development will be carried out throughout the time period of this plan.
4. Unmanned probes to gain scientific and engineering information will precede manned flights.
5. Accomplishment of the manned lunar landing in five to seven years will be followed by the establishment of a manned lunar base and manned exploration of nearby planets.
6. National resources in appropriate manpower will be adequate for NASA's program as well as concurrently expanded R&D programs by other agencies.
7. The total annual budget will rise to a level of five to six billion dollars in a couple of years and remain fairly constant at that level over the next decade.

SYNOPSIS OF THE PLAN

SYNOPSIS OF THE PLAN

- Major Mission Target Dates
- Projected Annual Budget
- Projected Annual Launchings
- Projected Employment Levels
- Time Span of the Long Range Plan

MAJOR MISSION TARGET DATES

1962

- Orbital Flight of an Astronaut
- Orbiting Solar Observatory
- Flight Past Venus (Mariner R)
- Nimbus Meteorological Satellite
- Developmental Launching of Atlas-Centaur (Ce)
- Launching of a Lunar Impact Spacecraft (Ranger)
- Active Communications Satellites (Relay, Telstar)
- Ionospheric Topside Sounder

1963

- Active Communications Satellite (Syncom)
- Two-Man Earth Orbit Flight
- Orbiting Astronomical Observatory
- Eccentric Geophysical Observatory
- Initiation of Nimbus Meteorological Satellite System
- Developmental Flight of Two Stage Saturn C-1 (Sa-1)

1964

- Flights Past Venus and Mars (Mariner B)
- Lunar Orbiting and Soft Landing of Instruments (Surveyor)
- Initiation of Operational Low Orbit Communications Satellite System
- Flight Qualification of 1,500,000 Pound Thrust Rocket Engine (F-1)
- Rendezvous in Earth Orbit (Gemini)
- Three-Man Earth Orbit (Apollo)

1965

- Aeros Stationary Orbit Meteorological Satellite
- Developmental Flight of C-5 First Stage Launch Vehicle (S-1b)
- Developmental Flight of Three Stage Saturn C-1 (Sa III)
- Flight Qualification of 1 to 1.5 Million Pound Thrust Hydrogen-Oxygen Engine (M-1)
- Initiation of Stationary Orbit Meteorological Satellite System

MAJOR MISSION TARGET DATES

1966
- Radio Astronomy Satellite
- Artificial Comet
- Nuclear Turboelectric Power Generation Flight Test (Snap-8)
- Recoverable Geophysical Observatory
- Sun Orbiting Solar Observatory
- Launch of a Mars Orbiter and/or Lander
- Operational Stationary Orbit Communication Satellite System
- Manned Circumlunar Flight
- Three-Man Orbiting Laboratory
- Developmental Flight of Nova First Stage (N-I)
- Nuclear Rocket Flight Test (Rift) (1966-1967 Period)

1967–70
- Developmental Flight of 2 Stage Nova (N-I plus N-II)
- Initiation of Experiments in Weather Modification
- Manned Lunar Landing and Return
- High Power Stationary Orbit Communications Satellite
- Orbiting Astronomical Observatory with Recoverable Data Package
- Flight Test with 1500 Kilowatt Electric Rocket Engine

1970 TO 1975
- Cosmological Probe
- Twelve-Man Orbiting Laboratory
- Solar Scientific Probe
- Operational Lunar Scientific Base
- Probe out of the Ecliptic
- Developmental Flight of Nova with Nuclear Second Stage
- Manned Interplanetary Flight (Mars)

Beyond 1975
- First Manned Planetary Landing

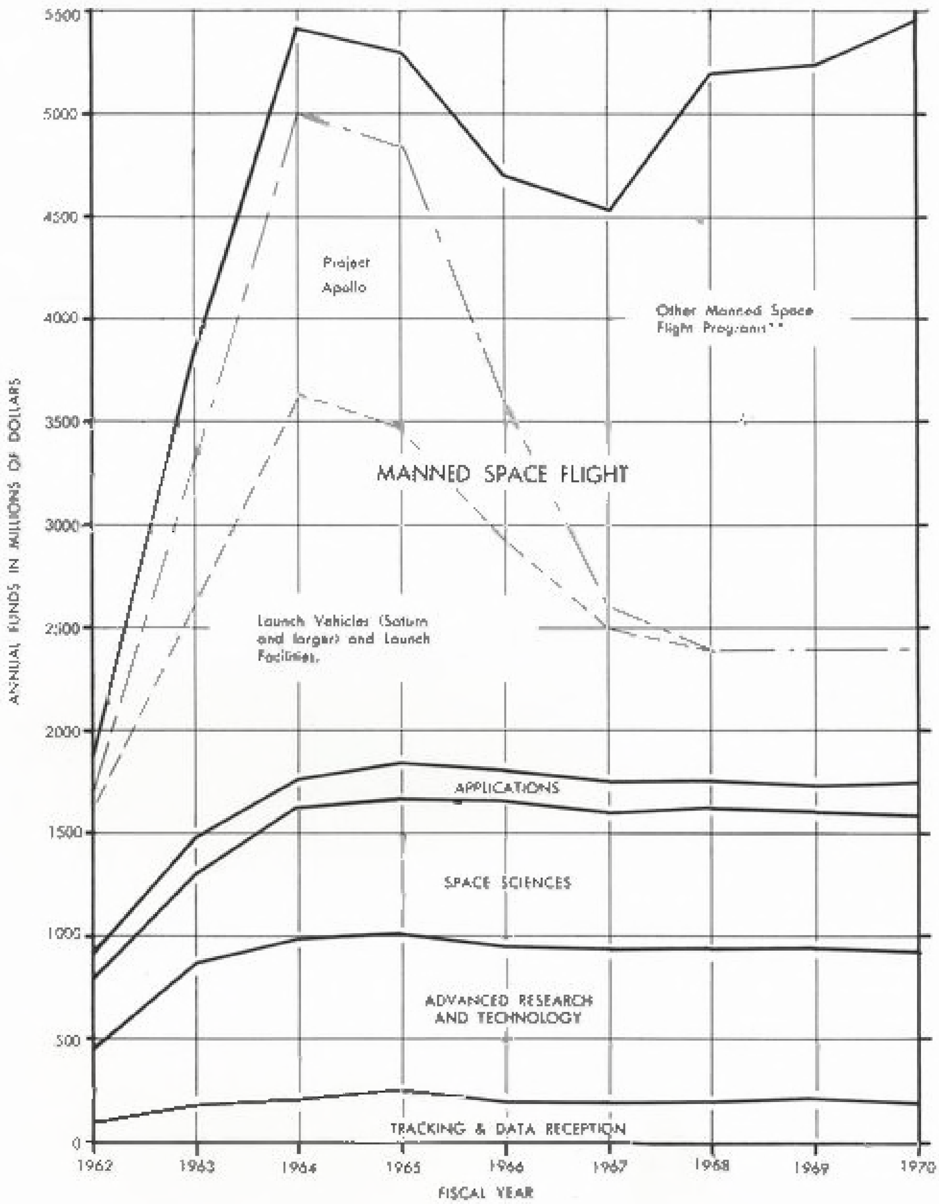
SYNOPSIS

PROJECTED ANNUAL BUDGETS

The manned lunar expedition program will likely surpass in complexity and difficulty any other single scientific and engineering program our nation has undertaken in its entire history. The multiplicity, variety and truly colossal size of many of the elements which will make up the program, demand a vast build-up of our national scientific, engineering, related industrial and management resources. If the target date of about 1967 is to be attained, the build-up must be very rapid. This is all reflected in the annual budget projection of Figure 1. A more detailed summary of estimated funding requirements is shown in Table 1.

FIGURE 1

NASA CURRENT AND PROJECTED ANNUAL BUDGET*



*Facilities Funding Included in Each Program
**Includes NASA Plant Operation for Manned Space Flight Programs

TABLE 1

NASA CURRENT AND PROJECTED ANNUAL BUDGET

in $1,000,000

Fiscal Year	1962	1963	1964	1965	1966	1967	1968	1969	1970
Manned Space Flight									
Research, Develop., & Operations	626	1806	3125	3115	2650	2545	3200	3255	3460
Facilities	180	706	487	328	235	220	250	250	250
Total	806	2512	3612	3443	2885	2765	3450	3505	3710
Applications									
Research, Develop., & Operations	103	137	118	185	140	145	115	130	150
Facilities	4	3	16	10	10	10	10	10	10
Total	107	140	134	195	150	155	125	140	160
Space Sciences									
Research, Develop., & Operations	379	553	663	651	682	657	682	637	642
Facilities	27	12	32	23	23	23	23	23	23
Total	406	565	695	674	705	680	705	660	665
Research and Technology									
Research, Develop., & Operations	208	399	671	700	700	700	700	700	700
Facilities	20	114	100	60	30	30	30	30	30
Total	228	513	771	760	730	730	730	730	730
Tracking & Data Reception									
Research, Develop., & Operations	95	158	174	179	190	185	185	185	180
Facilities	30	55	45	73	45	25	15	35	25
Total	125	213	219	252	235	210	200	220	205
Total Research, Develop., & Operations	1443	3053	4751	4830	4360	4230	4890	4905	5130
Total Facilities	229	890	680	496	345	310	330	350	340
TOTAL	1672*	3943**	5431	5326	4705	4540	5220	5255	5470

* The total for FY 1962 is the amount appropriated for FY 1962 by the Congress

** The total for FY 1963 is the amount submitted in the President's budget to the Congress for FY 1963 plus the 1962 supplemental

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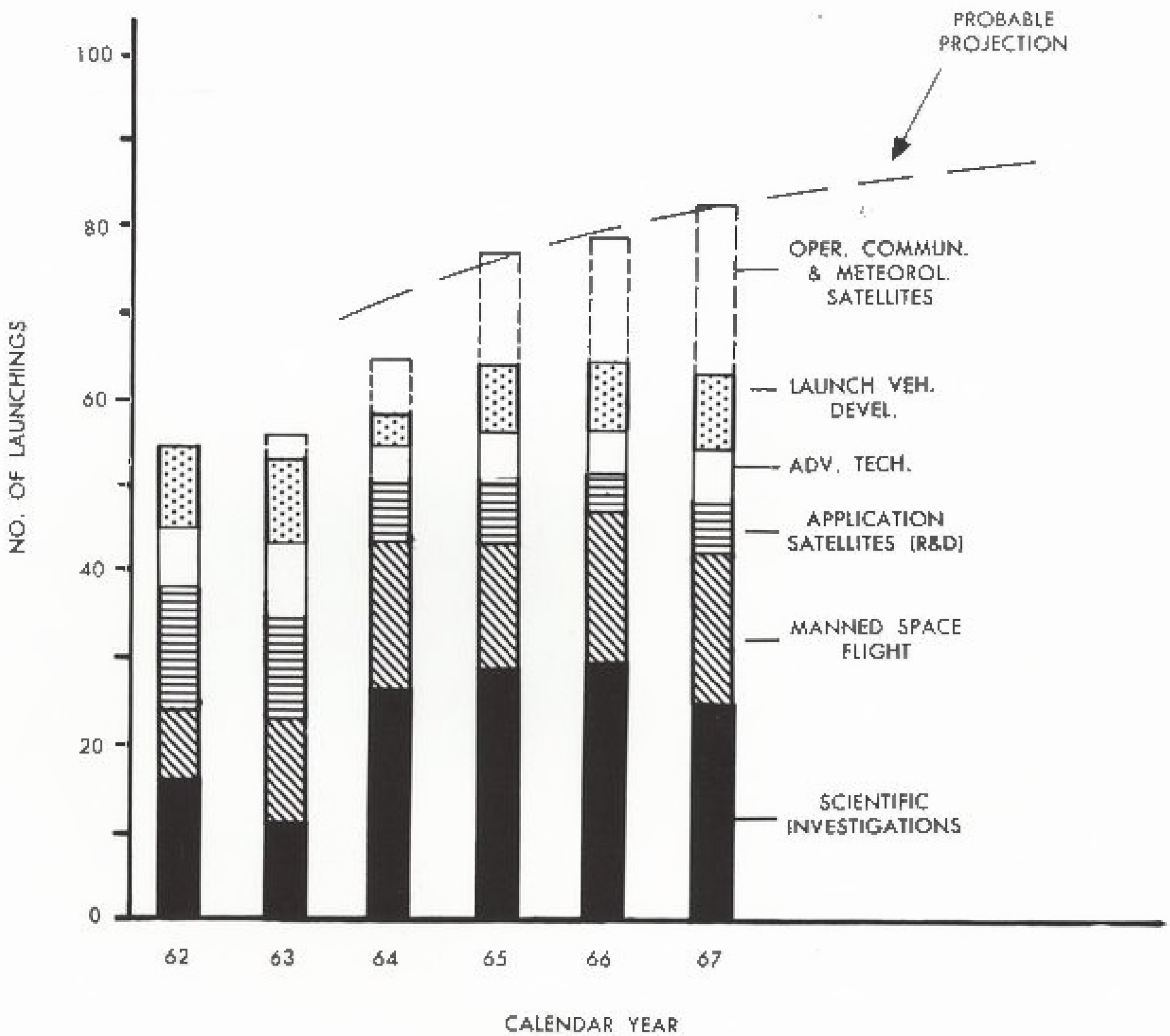
PROJECTED ANNUAL LAUNCHINGS

The planned operations of the National Aeronautics and Space Administration are reflected in the total number of launchings of major vehicles annually. Such a summation is shown in Figure 2. The rapid buildup in the total number of launchings is evident. Moreover, as we enter the period of high density operations related to the manned lunar expedition, the launch vehicles become larger by factors of 10 or more over current launch vehicles. Complexity of the launch vehicles and the launch operations will very likely increase. The result is that the rise in the magnitude of NASA operations will be greater than just the increase in numbers of major launchings.

A consolidated launch schedule by launch vehicle type is shown in Table IV-5 in Chapter IV.

FIGURE 2

NUMBER OF LAUNCHINGS PER YEAR



PROJECTED EMPLOYMENT LEVELS

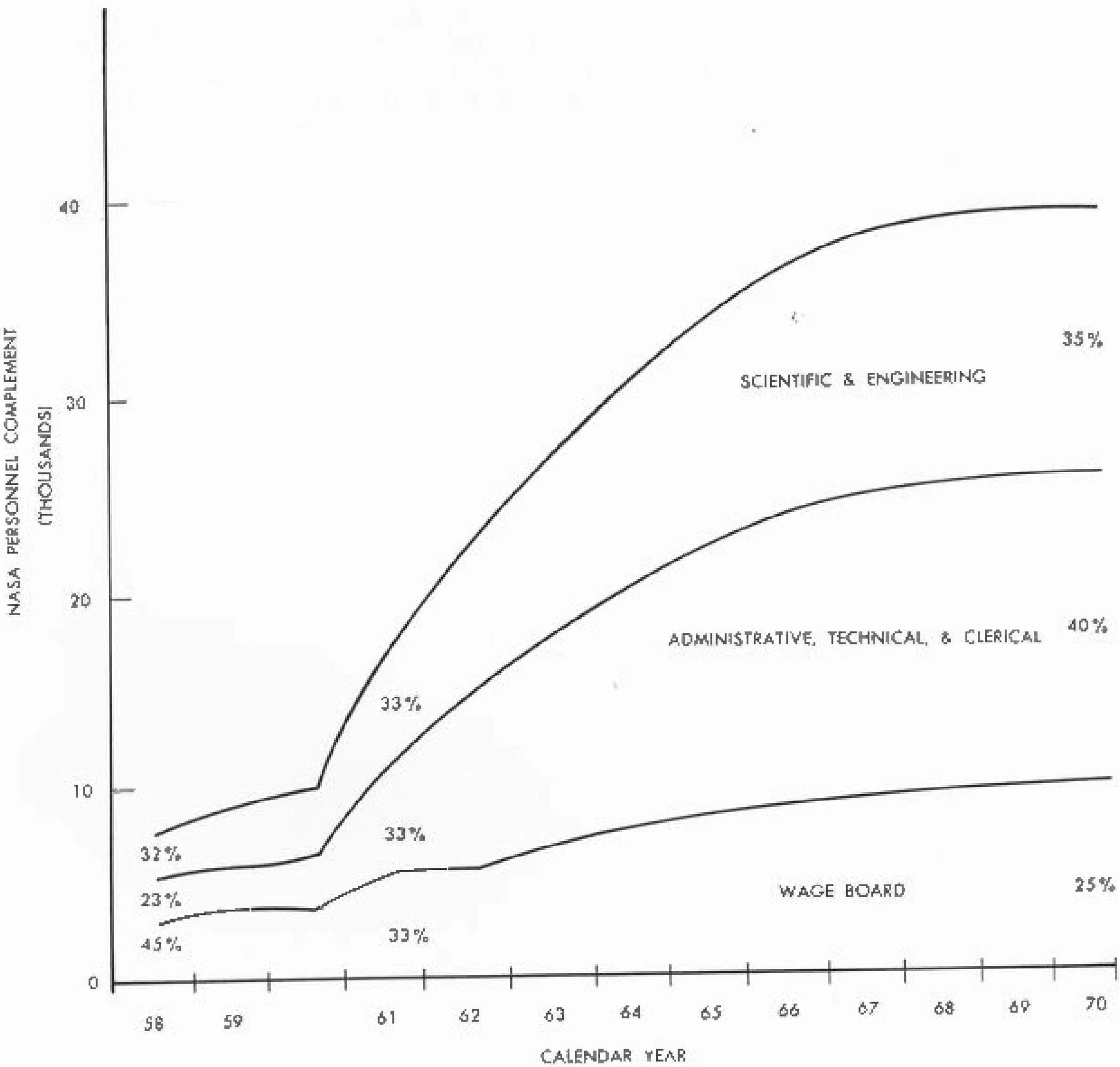
The volume of work as reflected by the rapid rise in the annual budget shown in Figure 1, and the very large increase in the tempo of operations will necessitate an increase in the number of NASA employees. A projection of this increase in personnel and change in composition is shown in Figure 3.

The present organization, made effective on 1 November 1961, was designed to carry out the NASA program. The evolution of the NASA organization to its present structure is reviewed in Appendix E, "NASA Organization." Further organizational changes may be made as the program gains momentum.

FIGURE 3

NASA STAFF
(Excluding JPL)

Actual & Projected



TIME SPAN OF THE LONG RANGE PLAN

Some of the programs of this agency appear to lend themselves to future projections for longer periods of time than others. Scientific explorations in space, for example, have been projected approximately to the mid-1970's. The manned space flight programs on the other hand can be visualized only to the first manned lunar expedition. For these reasons, some of the follow-on programs are not given in the same detail in terms of launchings as the other programs.

The peak effort for the manned lunar expedition is estimated to occur about 1965-1966. Initiation of direct substantial engineering effort for follow-on programs such as a lunar base, manned flight to the vicinity of Mars, etc., is shown subsequent to the period of peak effort for the manned lunar program. Certain long lead time elements of these programs, however, are shown to be carried on or initiated at an earlier time.

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CHAPTER I

SCIENTIFIC INVESTIGATIONS

CHAPTER I
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CHAPTER I

SCIENTIFIC INVESTIGATIONS IN SPACE

SCIENTIFIC INVESTIGATIONS IN SPACE

MISSION TARGET DATES

1962
- Orbiting Solar Observatory
- Flight Past Venus (Mariner R)
- Launch of Lunar Impact Spacecraft with Survival (Ranger)

1963
- Orbiting Astronomical Observatory
- Eccentric Orbiting Geophysical Observatory
- High Resolution T. V. pictures of Lunar Surface

1964
- Flights past Mars—possible capsule entry
- Flight past Venus
- Lunar Soft Landing (Surveyor)
- Lunar Orbitor

1965
- Orbiting Polar Atmosphere Satellite
- Orbiting Solar Observatory for Solar Monitoring

1966–68
- Sun Orbiting Solar Observatory for Activity Prediction
- Artificial Comet
- Radio Astronomy Satellite
- Launch of a Mars Orbiter and/or Lander
- Lunar Land and Sample Return
- Highly Eccentric Geophysical Observatory

1968–75
- Orbiting Astronomical Observatory with Recoverable Data Package
- Flight Past Jupiter
- Flight Past Mercury into Sun
- Land on Venus and Mars
- Probe out of the Plane of the Ecliptic
- Cosmological Probe
- Sun Orbiting Solar Observatories Used in Pairs to Observe Far Side of Sun
- Highly Eccentric Polar Geophysical Observatory

SCIENTIFIC INVESTIGATIONS IN SPACE

A. SYNOPSIS

Scientific investigations in space can encompass several fields of science, mathematical analysis, and areas of engineering technology. In carrying out the scientific exploration of space an amalgam of techniques is used, the ultimate purpose being the continued and expanded study of natural philosophy, made possible by a new ability to construct extra-terrestrial scientific stations.

The space program offers great potential in four major areas:

1. Sun-Earth, Sun-Planetary Relationships
2. Origin and History of the Solar System
3. Galactic and Extragalactic Physics
4. Origin of Life

Each of these four scientific areas has a long history and collectively have had a major influence in the philosophic and economic course of human society.

Spacecraft of all sizes can be utilized to obtain technical and scientific information. Smaller vehicles can be used to investigate near-Earth problems. Many of the significant scientific space experiments require voyages to the Moon, near the planets, or away from the orbit of the Earth. Such missions require spacecraft weighing several hundred pounds. Increasing the basic spacecraft weight to the order of a thousand pounds, exclusive of fuel, enhances the opportunities to reliably perform more difficult scientific investigations. Such spacecraft will require launch vehicles of the "Centaur" Class or larger.

As shown in Figure I–1 and Table I–1, the space science program is organized in several areas. The total program, including a share of NASA plant operations and construction of facilities, is estimated to rise to a plateau of about $700 million by 1964 and to continue at that general level.

The work in *Bioscience, Geophysics, Solar Physics* and *Astronomy* is conducted principally in earth satellite spacecraft.

The development schedule for these programs is shown in Figure I–2.

The *Astronomy* program has as its base a continuing series of launches of orbiting solar observatories using Atlas-Agena and, later, Saturn vehicles. Initially the observatories will be fitted out with small telescopes. In the later stages of the program much larger telescopes probably will be used and provisions will be made to return film to earth. The Astronomy program also includes: satellites designed to make observation in radio astronomy; a satellite, designed as an "artificial comet"; and then, when electric rockets are available, probes out of the plane of the ecliptic and beyond the solar system.

The part of the science program of the greatest immediate practical importance is that dealing with *Solar Physics.*

As in the Astronomy program, a series of orbiting Solar Observatories increasing in size and capabilities as the larger launching vehicles become available is planned. Included in this program is also a probe "into" the sun.

Geophysics has made giant strides in recent years with the advent of space vehicles providing a capability of measuring the nature of the earth's outer atmosphere and fields and of observing the nature of the particles and high energy radiations falling in the outer atmosphere. This program lends itself to a large university and international participation.

The work in *Bioscience* is directed at a study of the effects of the space environment on living cells and tissues and a search for extraterrestrial form of life. The environmental studies will be conducted in a series of payloads launched by Atlas vehicles while the search for extraterrestrial life will be carried out in the lunar and planetary programs.

The *Lunar* program, Figure I–3, will use Atlas Agena and, later, Centaur vehicles to launch the Ranger and Surveyor spacecraft to the Moon where they will, in succeeding stages of the program, impact, "soft land" and orbit the Moon.

The *Planetary* program will conduct a series of unmanned explorations of the planets building up in scope as larger vehicles come into the program, so that by the time man is ready to travel to a planet he will have a much better understanding of the nature of the environment in which he must operate. The times when the planets Mars and Venus are in the vicinity of the earth so that launchings are possible are shown in Figure I–4.

The number of sounding rockets listed in the various launch schedules will depend on the types of rockets used and their cost.

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FIGURE I-1

SPACE SCIENCE FUNDING

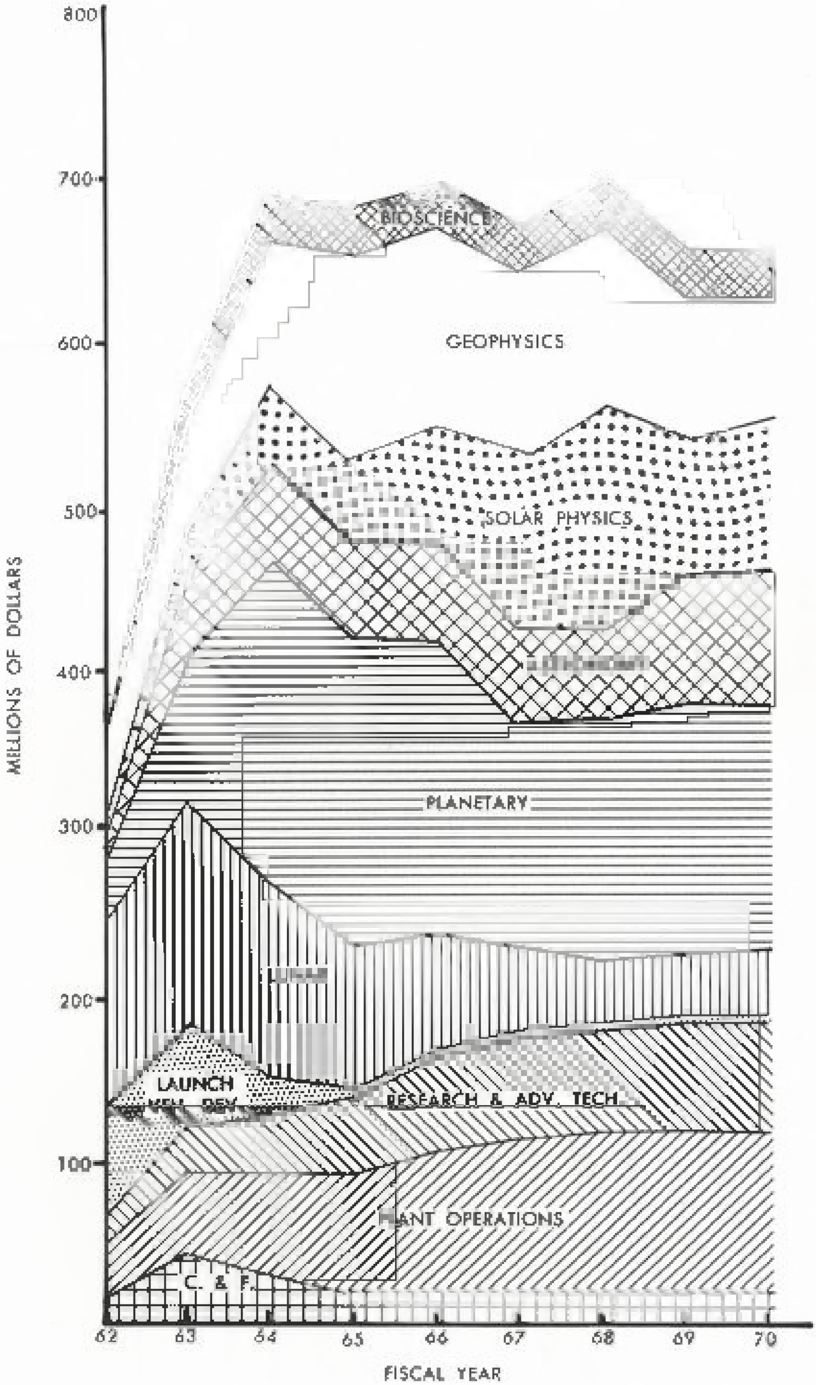

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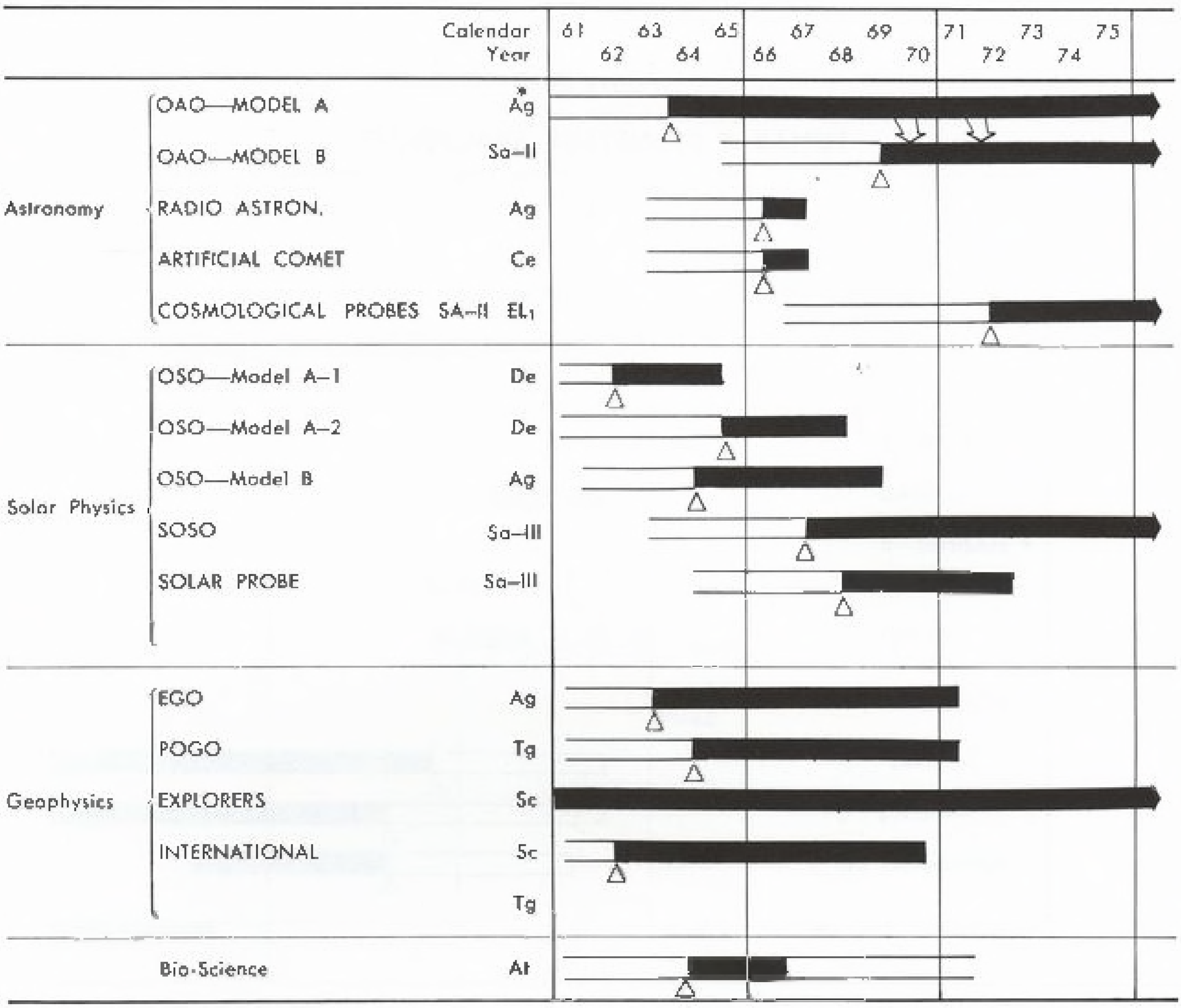
TABLE I-1

SCIENCE PROGRAM COSTS

PROGRAM FY	1962	1963	1964	1965	1966	1967	1968	1969	1970
Lunar, excluding "Prospector"	105	142.2	121	92	67	50	40	40	40
Planetary including Interplanetary	45.1	90	195	187	185	152	150	156	150
Astronomy	36.4	49	61	59	64	60	58	78	87
Solar Physics, including Solar Probe	7.7	20.2	46.0	54	69	103	145	84	99
Geophysics	47.7	80.5	87	117	126	109	101	84	70
Bioscience	4.6	7.5	32	31	31	31	31	31	31
Research & Advanced Technology	19.3	28	39	40	53	58	59	63	64
Plant Operations	36	50	60	70	87	93	97	100	100
Launch Vehicle Development	77	84.9	22	1	1	1	1	1	1
Construction & Facilities	27	12.2	32	23	23	23	23	23	23
TOTAL	406	565	695	674	705	680	705	660	665

FIGURE I–2

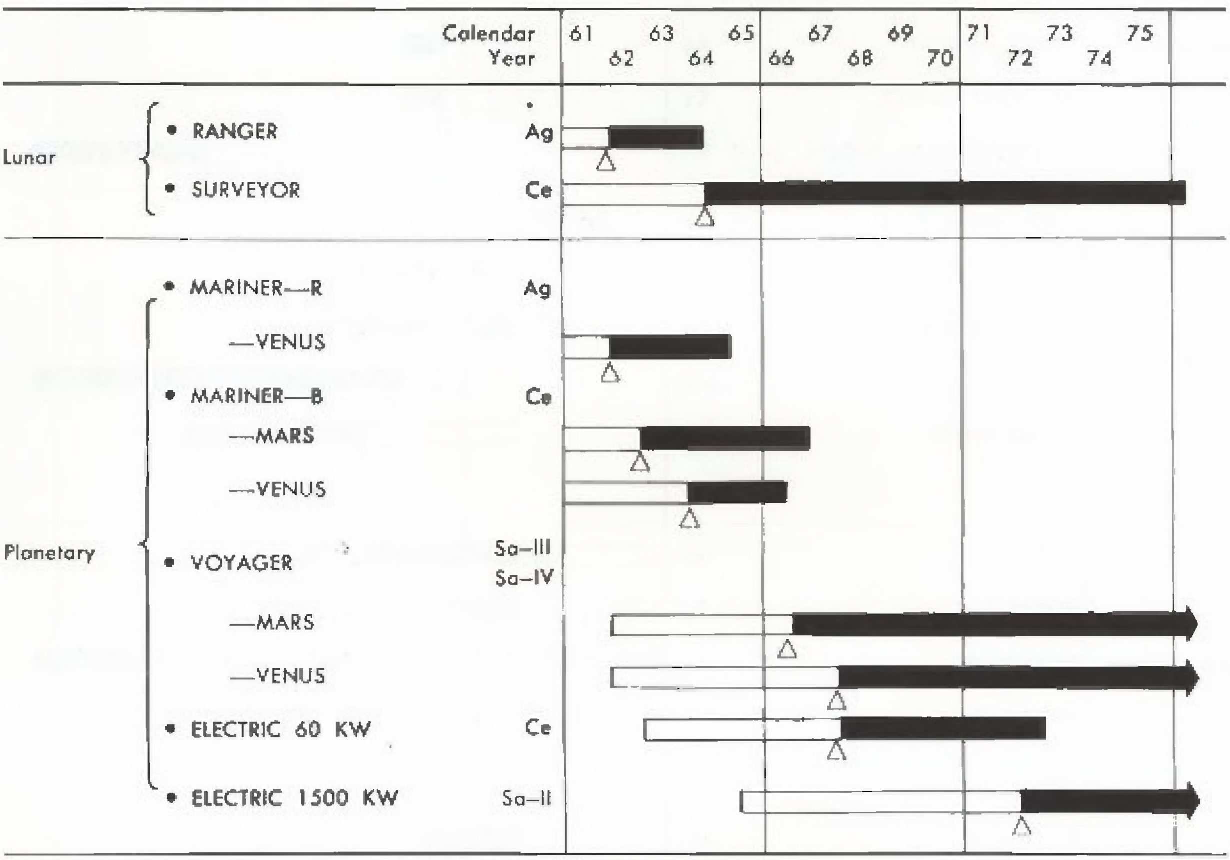
SCIENTIFIC SATELLITES & PROBES



Legend
△ First Flight in Program
*Launch vehicles planned for use

FIGURE I–3

LUNAR & PLANETARY SPACECRAFT



Legend
△ First Flight in Program
*Launch vehicles planned for use

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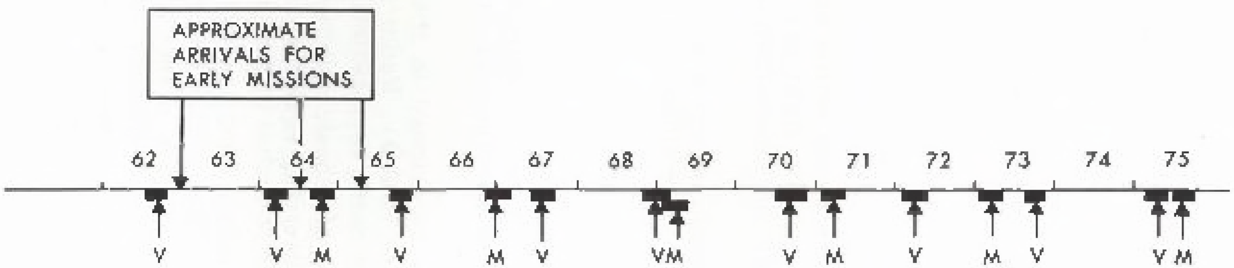
FIGURE 1-4

LAUNCH PERIODS (▬) FOR MARS AND VENUS MISSIONS



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B. ASTRONOMY

The earth's atmosphere, which displays so many interesting phenomena, is for that very reason a great nuisance to observational astronomy. It is opaque to most of the electromagnetic spectrum and it distorts the rays to which it is transparent. The upper atmospheric airglow also interferes with observations of distant stars and galaxies and extended cosmic sources such as the solar corona or the zodiacal light.

By placing astronomical observatories on satellite platforms the entire electromagnetic spectrum will become accessible to observation. This will tremendously broaden the observational basis of theories about the structure of the stars and the galaxies. For example, one of the most important problems is the detailed abundance of certain light elements and their isotopes in stars, the nebulae and interstellar medium. These data are closely related to the thermonuclear generation of energy in stellar interiors and its by-products.

It has been estimated that, by going outside the earth's atmosphere, it will be possible to observe farther into space by a factor of ten over what can be done now. This has far-reaching potential in cosmology. It would determine if the "apparent" velocity of recession of the galaxies continues to increase with distance to beyond the speed of light, or in more technical terms, help re-determine the distance scale and re-evaluate Hubble's universe expansion constant.

It is extremely important to obtain as much observational basis as possible for theories of stellar evolution. The approximate time of formation of certain stars has been calculated using certain formulae for nuclear processes. This is not consistent with the age of the universe when calculated from the Hubble constant.

Among the numerous other investigations to be made are the determination of the density of the universe and how it varies with distance from the sun, the nature and composition of interstellar gas, and methods for checking the general theory of relativity.

Several types of spacecraft are envisioned in the astronomy program: Orbiting Astronomical Observatories (OAO); Radio Astronomy Satellites; an Artificial "Comet"; and possibly some very esoteric cosmological probes.

The OAO Model A will consist of a basic stabilized platform to accommodate a variety of astronomical observing equipment. It is designed to take telescopes with primary mirrors up to 36 inches in diameter.

The complete observatory, including 1,000 pounds for experimental equipment, will weigh about 3,300 pounds. The satellite will have a maximum diameter in the launch condition of approximately 10 feet and will be about 10 feet in length. It is expected that the useful lifetime of each spacecraft will approach the design goal of one year with increasing reliability during the 10 to 15 year period of usefulness of this basic design.

The OAO platform will provide stabilized pointing to any direction in space with an accuracy of one minute of arc (0.1 second of arc with an auxiliary fine guidance system). It will contain a communications system with four radio links for tracking, command, and telemetry purposes. A data storage unit will be provided so that information derived when the OAO is out of sight of a ground station can be retained on-board until an appropriate time for transmission to the ground.

The OAO will be placed in an approximately circular orbit at an altitude of 500 miles and an orbital inclination of 32° by an Atlas-Agena B launch vehicle.

It is expected that at the beginning of the next decade there will be a requirement for larger and more versatile Orbiting Astronomical Observatories. It is too early to attempt a detailed design of such an observatory. However, in general it appears that there will be a need for very large optical systems (60 to 100 inch diameter primary mirrors) and antenna systems of 25 to 50 feet in diameter (for radio astronomy). Therefore, it appears quite likely that a Model B type OAO might weigh five or ten tons and be 15 to 20 feet in diameter in the launch condition (assuming some sort of folding antenna).

An Artificial "Comet" is conceptually the simplest of spacecraft since it has no electronics, stabilization, power supply, or other systems that must work in orbit. The spacecraft will in fact be a "block of ice" of known composition theoretically similar to that of natural comets. As the block evaporates it will hopefully form a tail and be observed from ground based optical observatories and the data compared with that obtained from observing real comets.

The spacecraft will weigh approximately 1,000 pounds. The optimum orbit is not yet determined.

The requirements for radio astronomy from satellites are not well enough defined to detail a spacecraft design at this time. However, this is a fast moving scientific discipline. It is anticipated that within the next year or two it will be desirable to initiate a Radio Astronomy Satellite to develop techniques in this field by studies of the sun (in the submillimeter wavelength). It appears that a stabilized spacecraft of the order of one ton weight with a five to ten foot diameter parabolic antenna might be useful and feasible. A particularly desirable configuration might utilize two such satellites as radio interferometers.

These satellites would be placed in low orbits with an Atlas-Agena B launch vehicle.

The detailed launch schedule and funding for the Astronomy program are given in Tables I–2 and I–3.

For the cosmological probes a Saturn II launch vehicle is assumed with a 1500KW electric propulsion system top stage.

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TABLE I–2

ASTRONOMY LAUNCH SCHEDULE

FLIGHT	CY	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
• Orbiting Astronomical Observatories															
—Model A			1 Ag	2 Ag	2 Ag	2 Ag	2 Ag	1 Ag	1 Ag	1 Ag	1 Ag	1 Ag	1 Ag	1 Ag	1 Ag
—Model B									1 Sa–II	1 Sa–II	1 Sa–II		1 Sa–II		1 Sa-II
• Radio Astronomy Satellite						2 Ag*									
• Artificial Comet						1 Ce*									
• Cosmological Probes											1 Sa–II		1 Sa–II		1 Sa-II
• Sounding Rockets		8	10	10	10	10	10	10	10	10	10	10	10	10	10

* As a result of these experiments and their precursors there could well be continuing programs in these two areas in following years

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TABLE I–3

ASTRONOMY FUNDING

COST (M$) FY	1962	1963	1964	1965	1966	1967	1968	1969	1970
OAO Model A	32.4	45.7	54.5	50.2	42.0	30.9	26.5	26.0	26.0
OAO Model B			1.	1.5	3.0	10.0	16.0	33.0	35.0
Radio Astronomy Sat.			1.	1.5	12.0	13.0			
Artificial Comet		.2	1.3	3.0	4.0	1.0			
Cosmological Probes						2.0	12.0	16.0	23.0
Sounding Rockets	4.0	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Total	36.4	49.0	60.8	59.2	64.0	59.9	57.5	78.0	87.0

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C. SOLAR PHYSICS

Aside from its great influence on the Earth, the Sun is of considerable astrophysical interest because it provides the only chance to study a star at comparatively close range. Fortunately for astrophysicists the Sun is an average kind of a star. It is typical member of the class of stars in which hydrogen is burned into helium in the core of the star but the burning has not progressed far enough to change its structure.

The Sun's spectrum is very nearly constant. In recent years a more detailed analysis of this spectrum has been made from observations on sounding rockets. But these observations were of very short duration. It is now appropriate to monitor the solar spectrum for small changes in local regions of the sun from satellite observatories. Small changes in the solar spectra will change the solar constant and in turn upset the energy balance of the earth's upper atmosphere. The unraveling of these causes and effects are obviously important.

The mechanism for the sudden onset of solar flares and the acceleration of high velocity particle streams requires an explanation. Another important question is "how are sun spots cooled?" Indeed the dynamics of the solar atmosphere involves problems of circulation, support, and heating of the chromosphere and corona, and phenomena arising from magnetohydrodynamical instabilities. All these questions require moderate and high dispersion spectrophotometry measurements of the entire sun's spectrum.

The solar program plans to have four kinds of spacecraft. Two are Earth Orbiting Solar Observatories (OSO) and two are Solar Orbiting Solar Observatories.

The OSO *Model A* (1962-67) will be put into a 300 mile circular orbit by a Delta vehicle. The total weight of the spacecraft will be about 440 pounds of which 100 pounds will be experiments. The satellite will consist of a spin portion for gyroscopically stabilizing the payload in space and the instrumentation will be servo-driven. Gas jets will keep the spin axis of the satellite nearly normal to the sun vector, and an additional electric servo will control the elevation. The instrument can then be pointed to within one minute of arc of the solar vector in both azimuth and elevation.

The instrumentation on the OSO Model A will be primarily spectrographs and various type of counters designed to make synoptic solar measurements in the ultraviolet, X-ray and gamma-ray regions of the spectrum. The optical instrumentation will be a few inches in diameter.

The Model B solar observatory is contemplated as similar to Model A but enlarged in scope and size. The three-axis pointing accuracy will be within 5 seconds of arc for any part of the sun. The optical equipment will be of the order of feet in diameter. The data storage capacity will be 2×10[illegible] bits and it will have a command capability of 100 or so operations. The orbit should be such as to maximize the viewing time of the sun, such as a low polar orbit. Weight of the spacecraft will be between 1,000 to 3,000 pounds and require an Atlas-Agena B vehicle for launch. Model B observatories would be flown in the 1964-74 period.

By 1972, nuclear electric stages suitable for use as an upper stage on a Saturn rocket should be available. This vehicle combination will provide sufficient excess velocity to make cosmological probes (see section on Astronomy), probes into the sun (this section and section on Planets), and probes out of the plane of the ecliptic available.

The probe into the sun (in 1968 using Sa-III or 1972 using Sa-II Electric) would go well inside the orbit of Mercury where, among other things, observations of the nature of the sun's magnetic field and the density, composition, and temperature of the solar corona could be made. Information on the true nature of the corona has great interest to solar physicists and will aid in a better understanding of the sun itself. There can be a similarity in the growth of knowledge here to the growth that has taken place in the last four years of our knowledge of the earth's outer atmosphere through our new found ability to make measurements in satellites travelling in the earth's outer atmosphere.

The detailed launch schedule and funding for the Solar Physics program are given in Tables I–4 and I–5.

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TABLE I-4

SOLAR PHYSICS LAUNCH SCHEDULE

FLIGHT	CY	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
• Solar Observatories															
Earth Orbiting															
Model A		3De	1De	2De											
Model A_2					2De	2De	2De								
Model B				1Ag	2Ag	2Ag	2Ag	2Ag	1Ag	1Ag	1Ag	1Ag	1Ag	1Ag	1Ag
Sun Orbiting							2Sa–III		2Sa–III		2Sa–III		2Sa–III		2Sa–III
• Solar Probe								2Sa–III				2Sa–III			
• Sounding Rockets		6	10	20	20	20	20	20	20	20	20	20	20	20	20

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TABLE I-5

SOLAR PHYSICS FUNDING

COST (M$) FY	1962	1963	1964	1965	1966	1967	1968	1969	1970
OSO Model A	4.2	3.8	8.0	9.5	9.4	5.7	1.1	0	0
Model B	.3	11.7	30.7	35.1	34.6	34.6	34.6	26.0	20.0
SOSO		1.5	2.0	3.0	16.0	31.0	59.0	30.0	51.0
Solar Probe			2.0	3.0	6.0	29.0	47.0	25.0	25.0
Sounding Rockets	3.2	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Total	7.7	20.2	45.7	53.6	69.0	103.3	144.7	84.0	99.0

D. GEOPHYSICS

One of the most curious and puzzling sets of physical phenomena in all science is the interactions of solar radiation with the earth's atmospheric blanket. These interactions generate the winds, create surface erosion and supply the energy for biological development. Nature, in all her perversity, still hides from us the "secrets of understanding" in a vast area of partially correlated and synthesized information. Viewing our planet from the outside on a satellite platform has uncovered new phenomena such as the radiation belt and has demonstrated that the organizational structure of the atmosphere cannot be fully pieced together from low altitude observations.

Just where the entity "earth" leaves off, either physically or conceptually (as an area of research), is difficult to define. For example, the major result of the International GeophysicalYear was that the Earth is immersed in the outer atmosphere of the Sun. One of the important problems of geophysics is the reason for the ice ages, the last being at its peak some 11,000 years ago. The answer to this question may be found in the field of solar astronomy by monitoring the energy output of the Sun.

But how unique are these geophysical phenomena? Are there similar manifestations on the other planets? The disciplines of geophysics such as aeronomy and seismology have found their way into the planetary programs as we begin to explore the nearer planets.

Sounding rockets to map the density, pressure and temperature of the earth's atmosphere, are programmed up through 1972. How these parameters depend upon solar heating, solar flares, geomagnetic storms, radiation belt activity and meteor streams will be investigated from sounding rockets and satellites. Sounding rockets will also be used to make measurements of the composition, wind, and airglow of the earth's atmosphere.

The major events of the Geophysics program are a series of Orbiting Geophysical Observatories (OGO) planned to start in 1963 and continue through the sixties. These vehicles, Class A, will weigh about 900 pounds with 150 pounds of scientific instruments. Later there may be a second, Class B type spacecraft, much larger and heavier and at least part of this spacecraft will be recoverable.

The Class A payloads are of two types: the Eccentric Orbiting Geophysical Observatories (EGO) which study geophysical parameters near the earth (170 miles) to within cislunar space (at least 69,000 miles); and the Polar Orbiting Geophysical Observatory (POGO) which will remain close to the earth (160-570 miles) in polar orbits. The POGO will use the Thor-Agena B vehicle for launch whereas EGO requires an Atlas-Agena B.

The Class B payloads will require Centaur and Saturn class vehicles because, in addition to increased size and weight, the spacecraft requires an eccentric polar orbit.

The geophysics program also calls for the lighter, special purpose spacecraft in the 100 to 500 pound class. These are the International Satellites and the Explorers. They will be launched with Scout and Delta launch vehicles.

The detailed launch schedule and funding for the Geophysics program are given in Tables I-6 and I-7.

TABLE I-6

GEOPHYSICS LAUNCH SCHEDULE

Flight	CY	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
• Orbiting Geo-physical Obs.															
EGO			2Ag	2Ag	2Ag	2Ag	1Ag	1Ag	1Ag	1Ag					
							2Ce	2Ce	2Ce	2Ce					
POGO				2Tg	2Tg	2Tg	2Tg	1Ag	1Ag						
• Explorers		2De	1De	2De	3De	3De	3De	3De	3De						
		4Sc		3Sc	3Sc	3Sc	3Sc	3Sc	3Sc	6Sc	6Sc	6Sc	6Sc	6Sc	6Sc
• International		2Ag													
		1De	2Sc		3Sc	1Sc	1Sc	1Sc	1Sc	1Sc					
• Sounding Rockets		70	100	100	100	100	100	100	100	100	100	100	100	100	100

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TABLE I–7

GEOPHYSICS FUNDING

COST (M$)	FY 1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
OGO	28.2	58.6	56.6	75.3	85.5	78.5	70.3	54.3	45.4					
Explorers	2.1	7.4	15.7	26.5	26.5	17.0	17.0	17.0	13.0					
International	12.0	4.2	4.5	5.0	3.5	3.5	3.5	2.5	1.5					
Sounding Rockets	5.4	10.3	10.0	10.0	10.0	10.0	10.0	10.0	10.0					
Total	47.7	80.5	86.8	116.8	125.5	109.0	100.8	83.8	69.9					

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E. BIOPHYSICS

A special topic in the later evolution of the solar system is the origin of life. Next to the synthesis of living matter in the laboratory, the discovery of life on another planet would be the most important event in basic biology. The "uniqueness" of organic systems based on nucleic acids and proteins as conveyors of life is one of the most important questions that the discovery of extraterrestrial life might solve. The importance of space research to basic biology is not limited to the discovery or study of extraterrestrial life (i.e. exobiology). Even if the planets are sterile, the possibility of sampling the organic compounds would provide invaluable evidence on the origin of life.

At the present time Mars appears to be the most promising body for research on exobiology, but the interest in Jupiter is quickening. Venus is probably too hot to support any life similar in molecular structure to our own, but forthcoming probes and research may alter our view on the surface temperature of that planet.

Experiments dealing with the search for extraterrestrial life will very likely be carried as separate experiments on many future planetary spacecraft. Two near earth programs in biophysics are planned. They are the Biological Investigations in space (BIOS) and the Earth Orbiting Recoverable Biological Satellites (EORBS).

The BIOS Program was initiated with the idea of utilizing probes or sounding rockets for a physical and biological assessment of the radiation belts. The program plans to use satellites in its later stages. The effects looked for in this program are the fundamental genetic and lethality changes in microbiological material.

The EORBS are designed as a broad spectrum life sciences experimental flight system. One major flight a year is planned using the Atlas-Mercury or Titan II-Gemini system. The effects of subjecting living matter, accustomed to a "one-g" environment, to "zero-g" for differing lengths of time will be observed to determine changes in fundamental biological processes.

As in other parts of the Science Program, it is planned that universities will participate extensively in these programs.

The detailed launch schedule and funding for the Biophysics program are given in Tables I–8 and I–9.

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TABLE I–8

BIOPHYSICS LAUNCH SCHEDULE

CY	1962	1963	1964	1965	1966	1967	1968	1969	1970
			2At	2At	2At	2At	2At	2At	2At

TABLE I–9

BIOPHYSICS FUNDING

COST (M$) FY	1962	1963	1964	1965	1966	1967	1968	1969	1970
BIOS PROGRAM	2.1	3.6	9.5	8.0	8.0	8.0	8.0	8.0	8.0
EORBS PROGRAM			15.0	15.0	15.0	15.0	15.0	15.0	15.0
GRANTS, FELLOWSHIPS OUTSIDE SUPPORT, ETC.	2.5	3.9	7.5	8.0	8.0	8.0	8.0	8.0	8.0
TOTAL	4.6	7.5	32.0	31.0	31.0	31.0	31.0	31.0	31.0

F. LUNAR SCIENCE

The origin of the solar system has received the serious attention of learned men for the last few thousand years. The proposed theories were at first metaphysical and gradually became scientific. As facts on the solar system have been accumulated, various theories such as the nebular hypothesis of the great philosopher Kant and the famous mathematician Laplace have been set aside. It was Kepler's early ideas on the formal structure of the solar system that in the course of twenty five years drove him empirically to his now famous laws and contributed to the philosophical foundation of modern experimental science.

It is current opinion that the Moon is one of the primary objects formed in the solar system and has undergone less modification in the course of history than have the planets. Thus, if the Moon is a prehistoric remnant, unchanged for four and a half billion years, it may be the "Rosetta Stone" for documentation of the early history of the solar system.

The techniques of geophysics and geochemistry will be employed to determine the moon's structure, chemical composition and energy release. These techniques include local geographic surveys of the moon's surface which should also provide assistance in executing a successful manned Lunar landing.

The Lunar Science Program and Manned Lunar Exploration are related. The extent and nature of the interaction of these two programs are not yet fully determined and, therefore, require additional study.

The lunar flight exploration program will be initiated by the Ranger series which rough land a capsule on the moon's surface. The capsule will carry a seismometer that will attempt to determine the amount of energy release in the form of quaking on the moon. On final descent the probe will telemeter a sequence of TV pictures of the lunar surface and will measure the amount of surface radio-activity with a gamma ray scintillation counter. A Ranger follow-on series (which also utilizes an Atlas-Agena B launch vehicle) will take higher resolution pictures prior to impact with more sophisticated vidicon systems.

The second generation lunar mission will be an oriented soft landed spacecraft called *Surveyor*. The launch vehicle will be the Centaur. The spacecraft is designed to accommodate a variety of instruments, not all on the same flight. These include television cameras for close-up observation of the lunar surface and the viewing of the handling of lunar samples, a drill and sample handler, an X-ray fluorescence spectrometer, a gas chromatograph for analysis and search of organic compounds, a magnetometer, a seismometer for studying the moon's inner structure, an ionization gage for measuring the tenuous Lunar atmosphere and a variety of particle detectors.

A *Surveyor* follow-on series is at present in the process of being defined. Missions involving a lunar sample return, a surface roving vehicle, and a lunar orbiting spacecraft are all under consideration. From the standpoint of pure science, that is, understanding the solar system, returning a sample from the moon is undoubtedly the most significant of the three. But other considerations such as schedule, vehicle performance, and the potential usefulness to the manned lunar landing will also determine the relative priorities of these missions.

The Surveyor spacecraft may land on the moon too late to have a significant influence on the system design of the first Apollo mission, but the findings of this program are judged to be of sufficient importance in themselves. They may also have important bearings on the post-Apollo missions.

Another approach is to land with the explorer spacecraft a scientific laboratory that is equipped to look into the far reaches of space, optically or otherwise. A radio telescope on the other side of the moon would be very useful, as would be a narrow beam gamma ray telescope with long integration time.

These programs or similar ones are planned for the period 1970-75.

The detailed launch schedule and funding for the Lunar Program are given in Tables I–10 and I–11.

"***Prospector—***" A third generation of unmanned lunar missions has been under discussion for some time and is usually called the "Prospector." It is thought of as an unmanned vehicle capable of roving on the lunar surface. A possible schedule, vehicle types and estimated costs for a program are shown in Table I–12 as a separate item but these vehicles and costs are not included in the summary totals of this plan. It is estimated that the Surveyor Follow-on series referred to previously will satisfy those requirements in aid of the manned program originally planned for Prospector and that all other scientific tasks planned for Prospector will be done in conjunction with the Manned Program. It is not clear whether such a mission belongs in the science program and this matter will have to be given more study.

TABLE I–10

LUNAR LAUNCH SCHEDULE

FLIGHT CY	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Ranger 3–5 (rough land)	3Ag													
6–9 (T.V.)		4Ag												
Surveyor—soft landers, etc.			4Ce	5Ce	5Ce*	3Ce	2Ce	2Ce	2Ce	2Ce	2Ce	2Ce	2Ce	2Ce

TABLE I–11

LUNAR FUNDING

COST (M$) FY	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Ranger 3–9	64.2	44.4	1.0											
Surveyor Lander	41.2	97.8	72	71	41.5	9.5								
Orbiter			47.7	21	25.5	40.0	40	40	40					
Total Lunar	105.4	142.2	120.7	92	67	49.5	40	40	40					

*The falloff in the Surveyor program after this date is subject to review contingent on the decision relative to the Prospector program.

TABLE I-12

PROSPECTOR PROGRAM

FLIGHT SCHEDULE

CY	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Prospector A				3 Sa-III	3 Sa-III	3 Sa-III	3 Sa-III	3 Sa-III	2 Sa-III	2 Sa-III	2 Sa-III			
Prospector B						2 Sa-IV	3 Sa-IV	2 Sa-IV	2 Sa-IV	2 Sa-IV	2 Sa-IV	2 Sa-IV	2 Sa-IV	2 Sa-IV

COST
(Millions)

FY	62	63	64	65	66	67	68	69	70
Prospector A	1.7	10	105	165	130	120	120	100	80
Prospector B			5	66	120	168	155	112	112
Total Prospector Program	1.7	10	110	231	250	288	275	212	192

(These vehicles and funds are not included in summary charts)

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G. PLANETARY AND INTERPLANETARY SCIENCE

Unmanned scientific exploration of the planets will tell much about the external configuration and state of the planets, the nature of the atmospheres and the condition of the surface. All of this will be of great interest to astronomy but will also be good preparation for the landing of man on the planets.

As in the case of the Moon, there is considerable uncertainty as to the origin of the planets. At the present time a more acurate determination of the density of Mars would provide as good a clue as any to the mechanism of solar system origin.

Mariner-R—The first planetary probe is planned to be launched in the third quarter of 1962 to fly by Venus. It is called Mariner-R, the spacecraft being a modification of the Ranger-3 lunar impact package. The spacecraft, to be launched by an Atlas-Agena B, weighs 460 pounds with 40 pounds being scientific instrumentation. This is in contrast to the much more sophisticated and reliable 900 pound Mariner-A spacecraft originally planned and which was to have been launched by Centaur vehicles. The Atlas-Agena-Mariner-R combination cannot always be employed as a backup for Centaur because the vehicle does not have sufficient performance to be useful for all earth-planetary conjunctions.

The experiments on Mariner-R attempt to obtain information on the temperature distribution of the surface and atmosphere of Venus. An attempt will also be made to measure the strength of the planet's magnetic field. The opportunities to launch occur approximately every two years for Mars and Venus. The planetary program with its fixed dates is, therefore, much more sensitive to changes in plans, design, or fiscal policy than are the lunar or satellite programs.

Mariner-B—In 1964 it is planned to have two Venus fly-bys of the Mariner-B. Later the same year a bus-capsule combination will be flown to Mars. The capsule would separate from the bus and go into the atmosphere of Mars and make direct measurements whereas the fly-by would do survey experiments of the surface and upper atmosphere. If it turns out that a capsule will be unable to accompany the fly-by in 1964 this may be delayed until 1966. By this date it may also be feasible to drop a capsule into the atmosphere of Venus.

The Centaur does not have sufficient performance to land an oriented spacecraft on the surface of Mars or Venus. Nor does it have sufficient performance to put a spacecraft in orbit around either of the planets. Therefore, a larger vehicle is required to advance beyond the split capsule class of payload.

With several thousand pounds delivered to the vicinity of either Mars or Venus it would be possible to both orbit a spacecraft around the planet and to land an automatic station as well. It would be especially desirable for these automatic scientific laboratories (Voyagers) to have lifetimes of the order of several months, because Mars is known to have surface features that change with the season.

Voyager—The Voyager, launched by Saturn, is the first spacecraft capable of orbiter-lander missions to Mars and Venus. The spacecraft will probably follow the module concept and will consist of a landing unit, basic "bus" unit to remain in orbit and serve as the communication center, and a propulsion unit to provide the necessary impulse to achieve an orbit about the planet.

Although one generally thinks of the interplanetary region as space between the major objects of the solar system, it is in fact a complicated media. It consists of gravitational and magnetic fields, low energy electrons and protons, high energy cosmic ray nuclei, solar and stellar radiation, high energy photons, neutral gas and cosmic debris. The observation of interactions between these components are extremely important and necessary for further understanding solar history and cosmological processes.

The case of cosmic rays is particularly important. Cosmic radiation, discovered in 1911, consists of high energy bare atomic nuclei. Most of the particles are protons, about 10 per cent are helium nuclei, and about one per cent are heavier nuclei. These particles seem to come from all directions. Where do they come from and how do they get accelerated to such high energies?

The rate at which cosmic rays strike the earth's surface is variable. There is a very small 24-hour variation and a moderate 27-day variation corresponding to the 27-day period of rotation of the sun. There are often sudden decreases in cosmic ray intensity which generally but not always are associated with magnetic storms. The most surprising fluctuation in cosmic radiation seems to be associated with the 11-year solar cycles. When the sun is most active, the average cosmic radiation is the least. Results from Pioneer V (the only interplanetary probe) indicate that this decrease is not due to something that happens on the earth but is caused by the shielding effect of solar magnetic fields trapped in traveling plasma clouds. The mechanism of the interaction of the sun and primary cosmic radiation will need further study.

It is also curious that the energy density of cosmic radiation in space is approximately equal to the energy density of starlight.

The interplanetary program is currently dependent on the planetary probes (Mariner R, Mariner B, and Voyagers), and the highly eccentric Orbiting Geophysical Observatories. Instrumentation such as magnetometers and particle counters, which are essential to geophysical studies, are just as significant in planetary and interplanetary research.

It is important to make interplanetary measurements at different distances from the sun, and if possible at the same time. For example, measurements from two identically instrumented probes, one en route to Venus and the other to Mars, would provide some extremely valuable data.

The Voyager spacecraft will be large enough to drop off light sub-satellite systems that could travel around the sun for extended periods.

Late in the decade when the techniques of spacecraft survival over long periods in variable temperature regimes have been developed, probes can be sent to the vicinities of Jupiter and Mercury.

The interplanetary region outside the earth's orbit is expected to be more interesting than the region inside. The reasons are two: namely that between the orbits of Mars and Jupiter is a great belt of cosmic debris, and between the orbit of the earth and Mars the interplanetary magnetic field is expected to become turbulent. There is an important exception to this reasoning and that is the region considerably inside the orbit of Mercury where the sun's outer atmosphere could be measured in situ.

Early in the next decade it is planned to send a probe out of the plane of the ecliptic (the plane of the planet's motions). This is potentially one of most interesting probes in the entire NASA program. Such a probe would be able to look further into the universe and back at the solar system. This would also require high performance boosters and electric propulsion.

Probes to investigate interplanetary space and probes to the vicinities of Jupiter and Mercury as well as probes out of the plane of the ecliptic may very well require electric propulsion stages. For this reason, both Centaur and Saturn launch vehicles with electric propulsion stages are scheduled as shown in Table I–13.

The detailed launch schedule and funding for the Planetary and Interplanetary Science program are given in Tables I–13 and I–14.

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TABLE I-13

PLANETARY—INTERPLANETARY LAUNCH SCHEDULE

FLIGHT SCHEDULE CY	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Mariner-R (Venus)	2 Ag		2 Ag											
Mariner B (Mars)		1 Ce*	2 Ce											
Mariner B (Venus)			2 Ce	3 Ce		3 Ce								
Voyager (Mars)					3 Sa-III			2 Sa-IV		2 Sa-IV	3 Sa-IV	4 Sa-IV	1 Sa-IV	1 Sa-IV
Voyager (Venus)						2 Sa-III			2 Sa-IV					
Electric 60 kw							1 Ce	1 Ce	1 Ce	1 Ce	1 Ce			
Electric 1,500 kw											2 Sa-II	2 Sa-II	2 Sa-II	2 Sa-II

*Interplanetary test of Mariner B spacecraft.

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TABLE I–14

PLANETARY-INTERPLANETARY FUNDING

COST (M$)	FY	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Mariner R		31.6	9.4	23	2										
Mariner B		13.1	73.6	91	78	62	24	3							
Voyager		0.4	7.0	80	97	103	94	94	94	100					
Electric 60 kw				1	10	20	24	33	33	21					
Electric 1,500 kw							10	20	29	29					
		45.1	90	195	187	185	152	150	156	150					

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CHAPTER II

SATELLITE APPLICATIONS

CHAPTER II

SATELLITE APPLICATIONS

SATELLITE APPLICATIONS

MISSION TARGET DATES

METEOROLOGY

1962 • Nimbus Meteorological Satellite

1963 • Inception of a System of Nimbus Meteorological Satellites

1965 • Aeros Stationary Orbit Meteorological Satellite
• Start of Flight Program of Advanced R & D Satellites in Polar Orbits
• Inception of a System of Stationary Orbit Meteorological Satellites

1967–70 • Initiation of Experiments in Weather Modification
• Start of Flight Program of Advanced R & D Satellites in Stationary Orbits

COMMUNICATIONS

1962 • Rigidized Balloon Communications Satellite
• Low Orbit Active Communications Satellites (Relay and Telstar)

1963 • Twenty-four Hour Orbit Active Communications Satellite (Syncom)
• Project Rebound Demonstration of Technique for Launching Several Satellites with One Launch Vehicle

1964 • Inception of Operational System of Low Orbit Communications Satellites

1966 • Inception of Operational System of Stationary Orbit Communications Satellites

1968–70 • High Power Stationary Orbit Communications Satellite

SATELLITE APPLICATIONS

A. SYNOPSIS

Satellite Applications involves the use of satellites to obtain tangible benefits for mankind. There are three fields of activity in which operational systems of satellites serving such purposes should be available in the near future. These are meteorology, communications, and navigation.

Meteorology and communications are major programs in NASA. Navigation is in a preliminary study phase.

Other applications of satellites may develop in the future. For example, the natural environment of extreme vacuum, weightlessness, and steadily available solar energy may be advantageous for some manufacturing processes. Also, by the latter 1960's our knowledge of the atmosphere and its response to varying energy inputs may be sufficient to permit the design of experiments leading to a degree of weather modification.

The responsibilities of NASA in the Applications areas are to conduct research and development programs and to design and perfect apparatus which will lead to operational systems or activities. Anticipated NASA activity in the Applications area is presented schematically in Figure II-1.

As more knowledge is gained about the characteristics and operation of meteorological, communications, and navigation satellites, it may become possible and beneficial to include all these functions in a multipurpose satellite.

The magnitudes of the meteorology and communications programs are shown by the total funding figures given in Table II–1. These funds are for research and development only. Funds for operational systems will be supplied by other agencies.

FIGURE II–1

SATELLITE APPLICATIONS

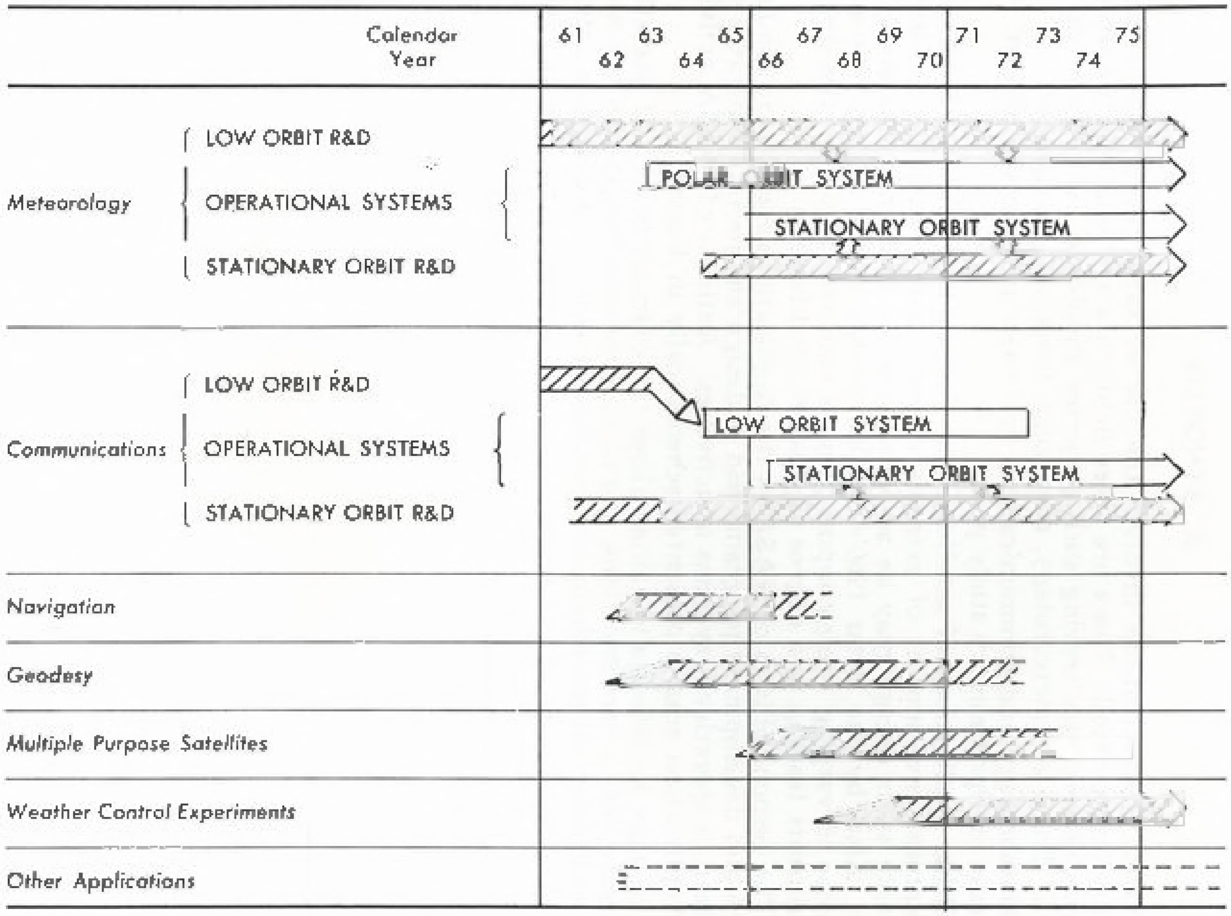

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TABLE II–1

PROGRAM FUNDING
METEOROLOGY AND COMMUNICATIONS

(Millions of Dollars)

FY	1962	1963	1964	1965	1966	1967	1968	1969	1970
Meteorology	47.8	47.0	67.2	84.2	83.9	79.8	62.7	50.2	50.2
Communications	46.0	76.7	38.1	82.6	37.1	43.8	30.8	60.7	78.9
NASA Plant Oper.	9.0	13.0	13.0	17.0	20.0	20.0	20.0	20.0	20.0
Construc. of Fac.	3.7	3.2	16.0	12.0	12.0	12.0	12.0	12.0	12.0
	106.5	139.9	134.3	195.8	153.0	155.6	125.5	142.9	161.1

B. METEOROLOGY

The meteorology program involves development of two complementary satellite systems. The first is a set of satellites in high inclination orbits, near polar, at altitudes of several hundred miles. These will provide relatively close-up looks at all points on the earth, including the polar regions, in a recurring manner. The second is an arrangement of satellites in stationary orbits above the equator at an altitude of about 22,300 miles. These will allow continuous viewing of very large areas, almost a complete hemisphere per satellite, but with poor coverage of the polar regions and with relatively low resolution.

The polar-orbiting satellite system will evolve from the present TIROS units and the Nimbus spacecraft. Three TIROS satellites have already been flown; Nimbus is under development and will supersede TIROS. The Nimbus satellites will have the advantages of continuous viewing of the earth (TIROS points away from the earth a large fraction of the time) and longer life.

The stationary equatorial orbit system will be based on the Aeros spacecraft, which will require the Centaur vehicle for launching.

Operational systems of meteorological satellites will be inaugurated as soon as spacecraft developments permit. It is expected that this will be about 1963 for the polar orbiting system and 1965 for the equatorial. The details of the arrangements under which these systems will be installed and operated are now under study.

Concurrently with the operation of these systems, NASA will conduct continuing research and development programs in advanced satellites, both polar and equatorial orbiting. It is planned to feed improvements from these programs into the operational systems on a continuing basis as appropriate.

Figure II-2 shows the anticipated phasing of the NASA meteorology programs and the operational systems. Tables II-2 and II-3 show the flight schedules and funding for the NASA research and development programs. A general discussion of the details of the meteorology program follows the funding table.

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FIGURE II-2

METEOROLOGY R&D PROGRAM & OPERATING SYSTEMS

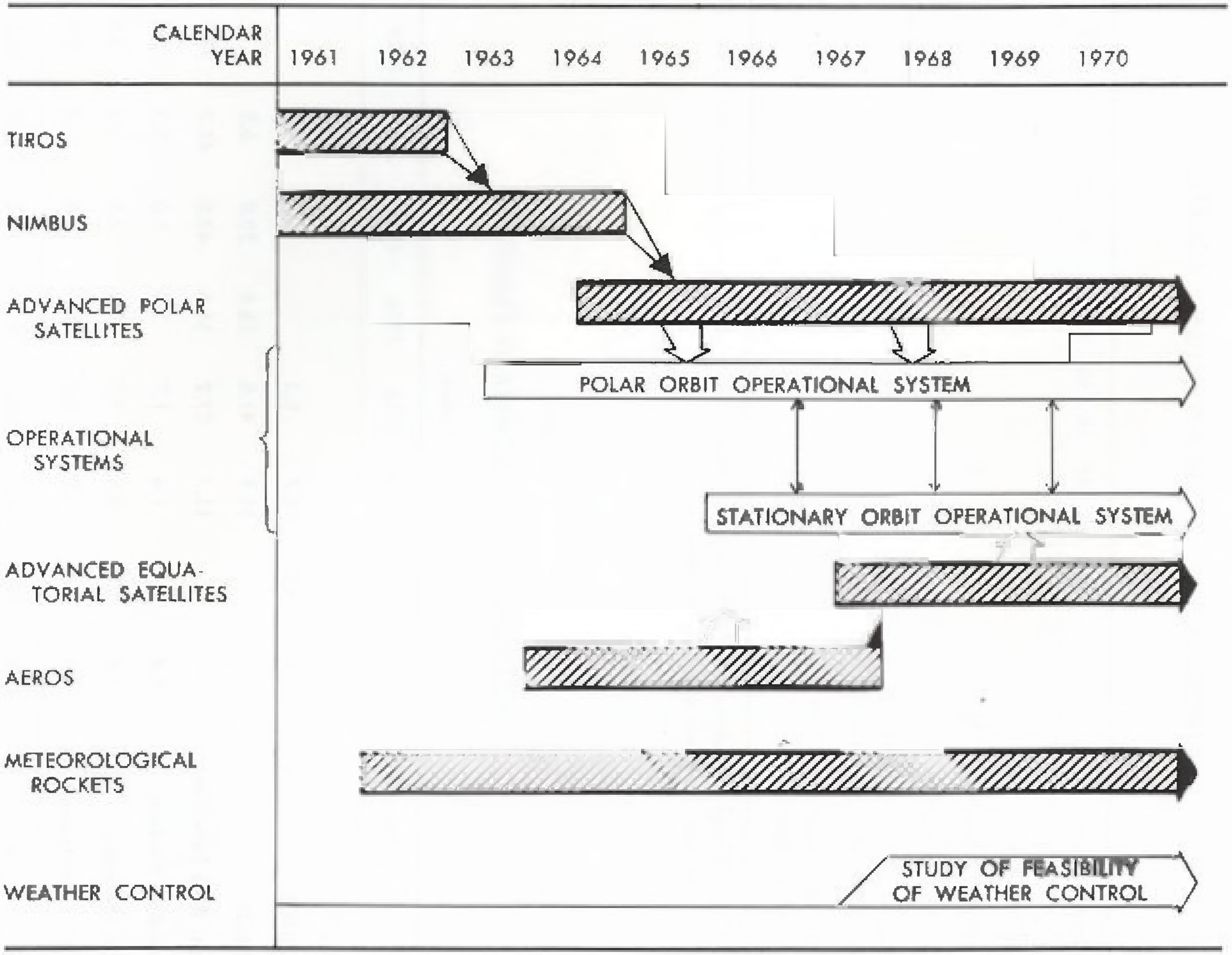

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TABLE II–2

METEOROLOGY PROGRAM FLIGHT SCHEDULE

Calendar Year	62	63	64	65	66	67	68	69	70	71	72	73	74	75
TIROS (Delta)	4	2												
NIMBUS* (Thor-Agena B)	1	2	2											
AEROS (Centaur)				1	2	2								
Advanced Polar Orbiting Satellites (Atlas-Agena B)				1	2	2	1	1	1	1	1	1	1	1
Advanced Equatorial Orbit Satellites (Centaur)							1	1	1	1	1	1	1	1

NOTE: *Official schedule as of 15 January 1962. Impending arrangements with the Weather Bureau may occasion some amendment.

TABLE II–3

METEOROLOGY PROGRAM FUNDING

(Millions of Dollars)

Fiscal Year	1962	1963	1964	1965	1966	1967	1968	1969	1970
TIROS	18.0	3.0							
NIMBUS	23.5	34.0	18.7	5.3					
AEROS			26.9	41.5	36.8	20.8	6.5		
Adv. R&D Satellites			11.7	27.2	36.6	48.5	45.7	39.7	39.7
Sounding Rockets	0.4	1.0	1.4	1.7	2.0	2.0	2.0	2.0	2.0
Adv. Research	1.4	1.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Tech. Development	4.5	7.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0
TOTAL	47.8	47.0	67.2	84.2	83.9	79.8	62.7	50.2	50.2

1. *Objectives*

The objectives of the NASA Meteorology Program are:

(a) to extend our knowledge and understanding of the atmosphere and its processes as related to the observation, forecasting, and, possibly, modification of weather;

(b) to extend our knowledge and understanding of meteorological phenomena, such as turbulence and wind shear, affecting the design and operation of flight vehicles;

(c) to develop and utilize satellite and rocket systems to make regular meteorological observations for use in weather analysis and forecasting;

(d) to investigate the feasibility of weather control.

2. *Achievements to Date*

The major achievements of the program to date are:

(a) successful launch and operation of three TIROS satellites;

(b) accumulation from the TIROS satellites of nearly 100,000 cloud cover and storm system pictures;

(c) utilization of the cloud picture data in operational weather analysis and forecasting by the Weather Bureau, Navy, and Air Force;

(d) discovery in 1961 of several major storms in their early stages before they were detected by conventional methods (e.g., Esther and Frances in the Atlantic, Madelaine in the eastern Pacific, and Marie and Tilda in the western Pacific);

(e) accumulation of several hundred reels of data on the radiation reflected and emitted by the atmosphere, and use of this and the cloud cover data in research to increase our understanding of the states and processes of the atmosphere. (Studies of these data have led to over 30 papers in scientific journals, plus 16 agency and contractor reports and many papers presented at technical meetings.)

3. *Basic Flight Program*

The basic flight program can be outlined as follows:

(a) There will be a continuing background program of sounding rockets with instrumentation for exploring the atmosphere up to an altitude of about 100 kilometers.

(b) Spin stabilized satellites of the TIROS family will be flown through 1962. These will be in 48-60° orbits, and will be equipped with vidicon cameras to televise cloud pictures and radiometers to measure radiations, particularly in the infra-red, emitted by and reflected from the earth. They will provide continuity of meteorological observations for research studies and operational analysis until they are superseded by a later design designated NIMBUS. (The value of the TIROS type satellite is limited by a stabilization system which allows it to point toward the earth only part of the time; also the useful lifetime is only about four months.)

(c) Flight tests of the NIMBUS family of satellites will occur in 1962-64. These will be so stabilized that they will always point toward the earth, and they will be equipped with improved cameras and radiation sensors. They will be placed in near-polar orbits, and should have a useful lifetime of about one year, viewing each point on the earth once every twelve hours. The basic NIMBUS configuration should be useful for many years.

(d) For the period 1965-7, earth stabilized satellites in stationary 24-hour equatorial orbits are being considered to provide continuous viewing over the visible portion of the earth with controllable picture resolution for specific areas. These are designated as AEROS satellites.

(e) In the period from 1965 on, advanced research and development satellites of the basic NIMBUS configuration will be flown in polar orbits for full earth coverage. These will involve continuing improvements in techniques and incorporate advanced cameras, sensors, control systems, power sources, and data handling equipment.

(f) In the period from 1968 on, advanced research and development satellites of the basic AEROS configuration will be placed in stationary equatorial orbits.

4. Related Research and Development

The basic meteorology program will support continuing programs in mission oriented research and technical development. These will include the following:

(a) *Supporting Research*

1. Study of the sun-earth system as a meteorological entity to gain a better understanding of the relationships between radiant energy and weather;
2. Feasibility and application of various techniques and methods for optimum observation and analysis of weather and its development;
3. Operational analysis for system optimization;
4. The economics of meteorological activities;
5. Reduction and analysis of data from satellites and rockets;
6. Radiation characteristics of atmospheric gases;
7. Design studies related to data reduction, processing, transmission, and presentation;
8. Satellite-borne systems for reducing the amount of data transmitted without reducing its content of significant information.

(b) *Advanced Technical Development*

1. Detectors and sensors (e.g., radiometers, weather radar, sferics, electrostatic tape cameras, image orthicons);
2. Feasibility and design studies in components, instrumentation, subsystems, and spacecraft configurations (e.g., satellite weather radar, control systems, the AEROS spacecraft);
3. Stabilization, control, and station keeping systems for specific mission applications;
4. Techniques and equipment for data reduction, processing, transmission, and presentation.

5. *Relationship to Other Programs*

The meteorology program will draw on the Scientific Investigations in Space area for supporting effort and contributions. Information of meteorological significance can be expected from the following programs and spacecraft:

(a) Aeronomy;

(b) Energetic Particles and Fields;

(c) Ionospheric Physics;

(d) Orbiting Geophysical Observatories;

(e) Orbiting Solar Observatories.

The Ground Support Operations Program will provide the effort and facilities in Tracking, Spacecraft Control, and Data Handling needed to operate the spacecraft and spacecraft systems in flight, receive the data, and transmit the data to a central station sufficiently early for it to be processed into an integrated analysis.

6. *Operational Systems*

Present thinking is that an operational system will be funded and managed by the U.S. Weather Bureau. Under this arrangement, NASA will have responsibilities related to the spacecraft, payload, launch vehicle, and spacecraft operation. Concurrently, NASA will pursue its fundamental research and development objectives with the continuing aim of systems improvement.

Table II–4 shows NASA estimates of the time scale, flights, and funding for operational systems. It is presented for *information only*, inasmuch as it is not planned that NASA will fund these systems. The funds listed are *not* included in any other tabulation in this document.

It should be noted that the NASA development flights shown in Table II–3 are conceived to phase smoothly into the operational systems in Table II–4 in the sense that the development flights will be useful for operational data. This is the reason for the operational systems schedules starting with back-up flights. These back-up flights are essentially for the operational aspects of the development flights.

TABLE II–4

METEOROLOGY OPERATIONAL SYSTEMS

FLIGHT SCHEDULE

CALENDAR YEAR		62	63	64	65	66	67	68	69	70	71	72	73	74	75
NIMBUS SYSTEM	(Thor-Agena B)		(2)	4	(1)										
	(Atlas-Agena B)				3	3(1)	3(1)	3(1)	3(1)	3(1)	3(1)	3(1)	3(1)	3(1)	3(1)
STATIONARY ORBIT SYSTEM	(Centaur)				(1)	(1)	2	2(1)	2(1)	2(1)	2(1)	2(1)	2(1)	2(1)	2(1)

Notes: (a) Numbers in parentheses refer to back-up launches.

(b) The Nimbus and Aeros R&D programs phase directly into the above systems in the sense that successful R&D flights have operational utility. The back-up launches starting each of the above programs can be looked on as back-ups for the operational aspects of the R&D flights.

SYSTEMS FUNDING

(Millions of Dollars)

FISCAL YEAR	62	63	64	65	66	67	68	69	70	71	72	73	74	75
NIMBUS SYSTEM	16.3	45.8	52.7	73.6	65.2	69.2	65.2	65.2	65.2	65.2	65.2	63.2	63.2	63.2
STATIONARY ORBIT SYSTEM			0.5	31.6	32.5	43.2	50.2	52.7	52.7	52.7	52.7	52.7	52.7	52.7
GROUND STATIONS														
CONSTRUCTION	12.1	5.5	5.8	2.8		5.0								
OPERATION			2.9	2.9	2.9	2.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
COMMUNICATIONS		1.2	2.3	2.3	2.3	2.3	3.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5
CONTROL CENTER			3.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
TOTAL	28.4	52.5	67.2	113.5	103.2	122.9	122.7	125.7	125.7	125.7	125.7	123.7	123.7	123.7

C. COMMUNICATIONS SATELLITES

The Communications Satellite Program involves investigation of the three basic techniques which show promise of leading to efficient operational systems. These techniques are:

(a) Passive reflectors in low orbits;

(b) Active satellites in low orbits;

(c) Active satellites in 24 hour synchronous orbits.

Each of the above techniques has advantages and disadvantages, and data are not yet available for final comparative evaluation. NASA is therefore conducting several programs to obtain the required data. These are:

(a) *Project Echo A–12*, a balloon with a rigidizing construction;

(b) *Project Relay*, active satellites in low orbits;

(c) *Project Syncom*, active satellites in 24 hour synchronous orbits at 22,300 mile altitude;

(d) *Project Rebound*, a technique for launching several satellites with one launch vehicle;

(e) *Project S–64*, to determine the radiation environment which may degrade the performance of communications satellites.

In addition to the above, there is a *Project Telstar*, involving low orbiting relays, financed by the American Telephone and Telegraph Company.

Findings from the above projects will be evaluated and may lead to establishment of an operational system in about 1964.

Following up on the presently approved projects, NASA will conduct a continuing program of investigation in advanced systems. It is expected that this will lead to an operational system of satellites in synchronous stationary orbits in about 1966. Such a system probably would ultimately supplant the low orbit system, which may be expected to phase out by about 1973.

In about 1968, nuclear SNAP–8 units should become available and open up a new domain for communications satellites by providing kilowatts of power. The NASA research and development program will reflect this by including investigations in high powered systems.

Figure II–3 shows the anticipated phasing of the NASA Communications Satellite programs and the operational systems. Tables II–5 and II–6 show the flight schedules and funding for the NASA programs. A discussion of the details of the communications satellite program follows the funding table.

2

FIGURE II–3

COMMUNICATIONS: R&D PROGRAM & OPERATIONAL SYSTEMS

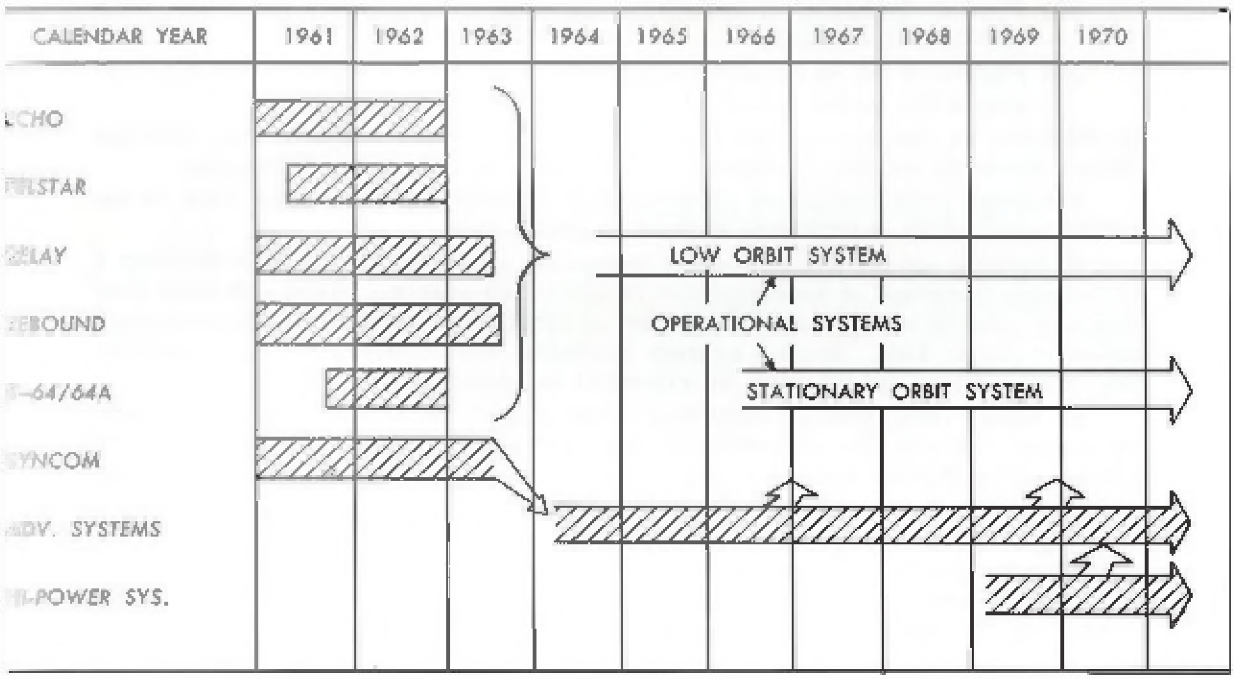

TABLE II–5

COMMUNICATIONS SATELLITES PROGRAM
FLIGHT SCHEDULE

		CY 62	63	64	65	66	67	68	69	70	71	72	73	74	75
Echo A–12 (Ballistic)	(Thor)	2													
(Satellite)	(Thor-Agena B)	1													
Telstar (Funded by AT & T)	(Delta)	4													
Relay	(Delta)	2	4												
Syncom	(Delta)		3												
Rebound	(Atlas-Agena B)		2												
S–64/64A	(Centaur)	2													
Advanced Systems	(Atlas-Agena B)			4	3										
	(Centaur)				1	1	2	1	1	1	1	1	1	1	1
Hi-Power Systems	(Centaur)								1	1	1				
	(Saturn C–1)										1	1	1		

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TABLE II–6

COMMUNICATIONS SATELLITE PROGRAM FUNDING

(Millions of Dollars)

FISCAL YEAR	62	63	64	65	66	67	68	69	70
Echo	4.5	0.1							
Telstar	(Funded by AT&T)								
Relay	7.7	17.8							
Syncom	13.9	3.8							
Rebound	11.4	15.5							
S–64/64A	1.2								
Advanced Systems	4.2	36.5	33.1	77.6	32.1	37.8	18.9	22.9	22.9
Hi-Power Systems						1.0	6.9	32.3	50.5
Supporting Research	1.1	1.0	2.0	2.0	2.0	2.0	2.0	2.2	2.2
Tech. Devel.	2.0	2.0	3.0	3.0	3.0	3.0	3.0	3.3	3.3
TOTALS	46.0	76.7	38.1	82.6	37.1	43.8	30.8	60.7	78.9

2

1. Objectives

The objective of the NASA Communications Satellite Program is to insure the development of communications satellite systems which meet the national objectives expressed by the President: ". . . a system that will enable people in remote areas of the earth to exchange messages, hold conversations, and eventually see television programs, . . .". This objective is being pursued through research, development, flight testing, and systems planning involving many of the basic techniques which show promise. These include reflectors in low orbits and active repeaters in both low and high (24 hour stationary) orbits.

2. Achievements to Date

The major achievements of the program to date are the launching of the ECHO balloon and the knowledge obtained from experiments and observations made with it. The work with ECHO I has demonstrated the feasibility of inflating large structures in space and of using such structures as communications reflectors over transcontinental and transoceanic distances. It also has revealed information on environmental factors, such as the effects of solar radiation pressure, and atmospheric density variations induced by solar flares, on structures with large area-to-mass ratio.

The Department of Defense has launched two communications satellites, *Score* and *Courier*. These were delayed repeaters in which a received message could be recorded for future re-transmission. Score, launched in December 1958, had a useful life of 33 days. *Courier*, launched in October 1960, operated for 17 days. These projects demonstrated the basic feasibility of active repeater satellites as communication instruments.

3. Basic Program

The basic program can be outlined as follows:

(a) In 1962 there will be flight tests of an improved passive structure, an inflatable balloon 135 feet in diameter with a laminated construction to give it greater rigidity than ECHO I. This balloon is designated ECHO A–12.

(b) In 1962-63 there will be flight tests of the first active low orbit relays, Projects *Relay* and *Telstar*.

(c) In 1963 there will be flight tests of an experimental relay satellite in a synchronous orbit, Project *Syncom*.

(d) In 1963 there will be flight tests of Project *Rebound;* this is a technique for placing several satellites in orbit with one launch vehicle. The need for this follows from economic considerations associated with the cost of launch vehicles and the fact that low orbit systems, active or passive, require many satellites.

(e) The foregoing tests will be followed by evaluation of the results and further tests leading to the establishment in 1964 of the earliest operational system. Present assessment is that this will be made up of *active repeaters* placed in low orbits by multiple launch techniques.

(f) In the 1964 to 1967 period there should be experiments leading to establishment, possibly in 1966, of a *stationary orbit operational system*. As this system becomes operational, the low orbit system will probably start to phase out, with completion of phase-out anticipated for about 1973.

(g) In 1969-70 there may be flight tests of stationary orbit satellites with kilowatts of primary power supplied by SNAP–8, which is scheduled to be available in 1968. Operational use of a system of such satellites should be in about 1972.

(h) In the early 1970's there may be flight tests of *advanced communications satellites* with megawatts of power available from nuclear plants.

4. *Related Research and Development*

The Communications Satellites Program will include investigations of the feasibility, operational characteristics, and reliable life of various advanced systems. Examples are: techniques to add gain to passive structures, multiple launch of relay packages with Rebound techniques, and active satellites with attitude control. It will also support a continuing program in mission oriented research and technical development which in the period up to about 1965 will include the following:

(a) Passive structures with improved scatter characteristics;
(b) Quasi-passive structures providing some on-board power;
(c) Omni-directional antennas;
(d) Antenna technology;
(e) Antenna direction command systems;
(f) Transmitter and receiver technology;
(g) Modulation methods;
(h) Passive techniques for stabilization;
(i) System optimization studies;
(j) System comparison studies;
(k) Switching studies;
(l) Ground complex studies.

The research and development effort beyond 1965 will be emphasized in the direction indicated by the trend of overall communications and satellite developments up to that time.

5. *Relationship to Other Programs*

The Communication Satellites Program will draw on the Scientific Investigations in Space area for appropriate effort such as study of the radiation environment which may degrade the performance of satellites.

The Ground Support Operations Program will provide some of the facilities for tracking and working with the experimental research and development satellites. Additional facilities will be available under contract support and, in some cases, from the Department of Defense stations.

The Department of Defense is also involved in communications satellite work, with *Advent* as one of its major programs. A Technical Committee on Communications Satellites, made up of program and project level representatives from NASA and DOD agencies, exists for the exchange of technical information.

6. *Operational Systems*

The NASA program should lead to the establishment and operation of public service communications systems. The sponsorship for such systems is now being studied. It is anticipated that NASA will continue its fundamental research and development work to provide the basis for continuing systems improvement.

Table II–7 shows NASA estimates of the time scale, flights, and funding for operational systems. The funding does not include the ground stations and ground equipment which would be needed. Table II–7 is presented for qualitative information only, inasmuch as it is not now planned that NASA will fund these systems. The funds shown are not included in any other table in this document.

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TABLE II–7

COMMUNICATIONS SATELLITES OPERATIONAL SYSTEMS

FLIGHT SCHEDULE

CALENDAR YEAR	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Low Orbit System (Atlas-Agena B)			3	8	5	5	3	3	2	2	2	1		
Synchronous Orbit System (Atlas-Agena B)					3	8	2	2	2	1		1		
Hi-Power Synchronous Orbit System (Centaur)											6		2	

SYSTEMS FUNDING

(Millions of Dollars)

FISCAL YEAR	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Low Orbit System		5.6	55.6	95.2	67.3	54.1	29.9	30.6	24.0	18.2	22.2	12.2	0.8	
Synchronous Orbit System				5.1	61.8	85.8	23.2	24.0	19.0	9.8	10.6	6.3	10.6	6.1
Hi-Power Synchronous Orbit System										66.6	88.8	20.2	27.6	

NOTE: Cost of ground stations is *not* included in this funding.

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D. NAVIGATION

The Department of Defense (Navy) is developing the *Transit* satellite system for navigation applications. NASA has no active program in this area, but is making a study to determine what effort, if any, it should pursue.

The Navy schedule calls for an operational Transit system in late 1962. This system is being designed to permit operation with three degrees of accuracy, which nominally will allow position determination to within 0.1, 0.5, and 1.0 miles respectively. The most accurate technique (0.1 mile) will be classified and restricted to military use; the less accurate techniques will be made available by the Navy for non-military use when ready.

The NASA study is designed to investigate the technical and economic factors involved in navigation satellite systems for non-military ships and aircraft, including analysis of user requirements, system capabilities, system expense, and the economic implications of the fact that the Transit system satellites will be available in any case. It may develop that without an existing military system a non-military system would not be justifiable, but that with a military system in being the non-military application becomes expedient. The study will take this factor into account.

Closely related to Navigation is Geodesy. The Department of Defense is developing a Geodesy System, Project ANNA, in a tri-service program. NASA has no active Geodesy program as such, but analysis of the motions of NASA satellites will undoubtedly continue to contribute to geodetic knowledge.

E. OTHER APPLICATIONS

Other applications of satellites may develop in the future. For example, the natural environment of extreme vacuum, weightlessness, and steadily available solar energy may be advantageous for some manufacturing processes.

By the latter 1960's our knowledge of the atmosphere and its response to varying energy inputs may be sufficient to permit the design of experiments leading to a degree of weather modification.

As more knowledge is gained about the characteristics and operation of meteorological, communications, and navigation satellites, it may become possible and beneficial to include all these functions in a multiple purpose satellite. Progress in large orbiting laboratories and high powered sources of auxiliary power will have a strong influence on this type of development. This area will be investigated, as will the management and economic complications of organizing, funding, and operating such multiple purpose systems.

2

CHAPTER III

MANNED SPACE FLIGHT

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MANNED SPACE FLIGHT

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MANNED SPACE FLIGHT

Mission Target Dates

A. Synposis

B. Introduction

C. Project Mercury—Development of Manned Earth Orbital Spacecraft

D. Project Gemini —Development of a two Manned Spacecraft

E. Project Apollo —Development and Operation of Manned Lunar Landing Space Flight System

1. Earth Orbital Flights
2. Aerospace Medicine and Crew Selection
3. Possible Effects of Solar Flares
4. Possible Meteoroid Damage
5. Flights to Vicinity of the Moon
6. Rendezvous vs. Direct Ascent
7. Manned Lunar Landing
8. Results from Project Apollo

F. Development and Use of Manned Earth Orbiting Laboratory

G. Development and Use of Manned Lunar Scientific Station

H. Development of Manned Planetary Expedition System

MANNED SPACE FLIGHT

MISSION TARGET DATES

1962	• Manned Earth Orbit Flight
	• Manned One Day Flight
1963	• 2-Man Earth Orbit Flight
1964–65	• Rendezvous in Earth Orbit
	• 3-Man Earth Orbit Flight (Apollo)
1966–67	• Manned Circumlunar Flight
	• 3-Man Earth Orbiting Laboratory
1967–70	• Lunar Landing and Return Flight
1970–1975	• Multimanned Earth Orbiting Laboratory • Lunar Scientific Station
About 1975	• Manned Interplanetary (Mars) Flight
Beyond 1975	• Manned Planetary Landing

2

MANNED SPACE FLIGHT

A. SYNOPSIS

The NASA Manned Space Flight Program is currently planned in six phases:

1. **Project Mercury & One Day Manned Flight**
2. **Project Gemini**
3. **Project Apollo**
4. **Manned Earth Orbiting Laboratory**
5. **Manned Lunar Scientific Station**
6. **Manned Planetary Exploration**

1. *Project Mercury and 1 Day Manned Flight*—Development of and flights of a one-manned spacecraft in low earth orbit (100 n.mi.) for durations of 3 orbits (4½ hours) to one day. The purpose of these flights is to determine man's ability to function in the space environment of zero gravity for periods up to twenty-four hours and to develop manned spacecraft technology.
2. *Project Gemini*—Development of and flights of a two-manned spacecraft in low earth orbit (100-300 n.mi.) for periods up to one week or more. The purpose of these flights is twofold:
   (a) To develop man-piloted spacecraft orbital rendezvous and docking techniques. For this development the Gemini spacecraft will rendezvous and dock with a second spacecraft which will be unmanned.
   (b) To determine man's ability to function in the space environment of zero gravity for periods of one week to two weeks.
3. *Project Apollo*—Development and operation of a manned lunar landing spacecraft system. Project Apollo calls for two approaches:
   (a) *Rendezvous*—In this case the spacecraft will be launched in two or more sections which will be joined in earth orbit. The complete spacecraft will then be launched from earth orbit into a moon approach trajectory.
   (b) *Direct Ascent*—In this case a launch vehicle of sufficient size will be developed to launch the complete spacecraft from the earth into a moon approach trajectory.

   The rendezvous technique is favored over direct ascent because of the belief that the pacing item in achieving the manned lunar landing is the development of the required launch systems (launch vehicles and launch facilities) and that the smaller system required with rendezvous can be developed in less time than the larger system required with the direct ascent.

The Apollo Program is scheduled chronologically as follows:

(a) Further refinement of rendezvous in earth orbit and extended manned earth orbital flights.

(b) Manned flights to the vicinity of the moon.

(c) Manned lunar landing and return.

4. *Manned Earth Orbiting Laboratories*—The Apollo Program will provide information directly applicable to the development and use of manned earth orbiting laboratories. Such laboratories, it is expected, will be of immediate use in the Applications and Space Sciences Programs and in the general engineering development of spacecraft components and payloads. The earliest manned orbiting laboratory may consist of an adaptation of the Apollo spacecraft.

5. *Lunar Scientific Station*—Successful completion of the Apollo Program will provide the United States with information on which to base the development and operation of a space flight system suitable for transporting to the moon and supplying on the moon a manned lunar scientific station. Development and operation of such a system is planned for the latter part of the period covered in this Long Range Plan.

6. *Manned Planetary Expedition*—During the latter part of the decade, development of a space flight system suitable for manned exploration of Mars may be started. Flights from the earth to Mars and return will require 12 months to 3 years. For this reason emphasis will be placed on development of life support and protection systems and on spacecraft nuclear propulsion and power generation systems.

The Manned Space Flight Program is presented graphically in Figure III-1, and by objectives and launch vehicles in Table III-1. The estimated funding requirements (including supporting programs) are shown in Figure III-2 and Table III-2.

FIGURE III–1

MANNED SPACE FLIGHT PROGRAM

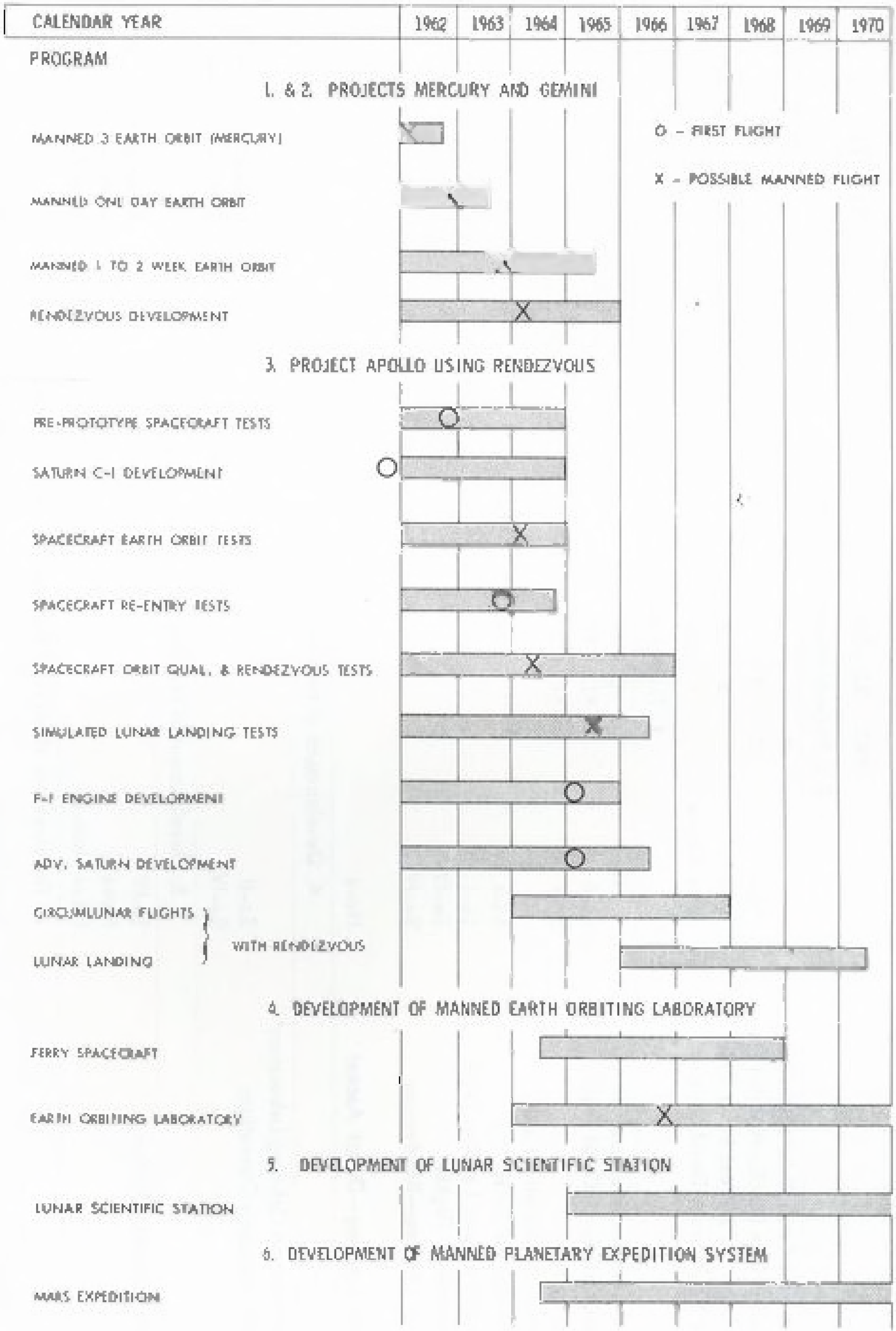

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TABLE III–1

MANNED SPACE FLIGHT PROGRAM

Program Objectives	Launch Vehicles	1962	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76
1. & 2. Projects Mercury and Gemini																
• Manned 3 Earth Orbit Flight (Mercury)	Atlas	4														
• Manned One Day Earth Orbit Flight	Atlas	2	2													
• Manned 1 to 2 Week Earth Orbit Flight	Titan II		5	6	1											
and Rendezvous Development	Atlas-Agena		1	6	1											
3. Project Apollo																
• Pre-Prototype Spacecraft Tests	Joe		8	6	3											
• Spacecraft Earth Orbit Tests	Sa–I		*2	*1												
• Reentry Tests	Sa–I		*2	*1												
• Orbital Qualifications and Rendezvous Tests	Sa–I			4	8	4										
• Simulated Lunar Landing Tests	Sa–I				4	4										
• Circumlunar Flights	Sa–IV					6	4									
• Lunar Landing—Rendezvous	Sa–IV						6	6								
• Lunar Landing—Direct Ascent	Nova							4								
4. Development of Manned Earth Orbiting Stations																
• Multimanned Orbiting Laboratory with Resupply Operations	Sa–II					3	4	4	4	4	Operation of Multimanned Earth Orbiting Stations					
	Sa–IV					3	4	4	4	4						
5. Development of Manned Lunar Scientific Station																
• Lunar Scientific Station	Sa-IV Nova Nova-Nuclear										Development and Operation of Multi-Manned Lunar Scientific Stations					
6. Development of Manned Planetary Expedition Systems																
• Mars Flight	Nova-Nuclear					Development of Manned Mars Expedition System										

* Launched by development launch vehicles

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FIGURE III-2

FUNDING FOR MANNED SPACE FLIGHT

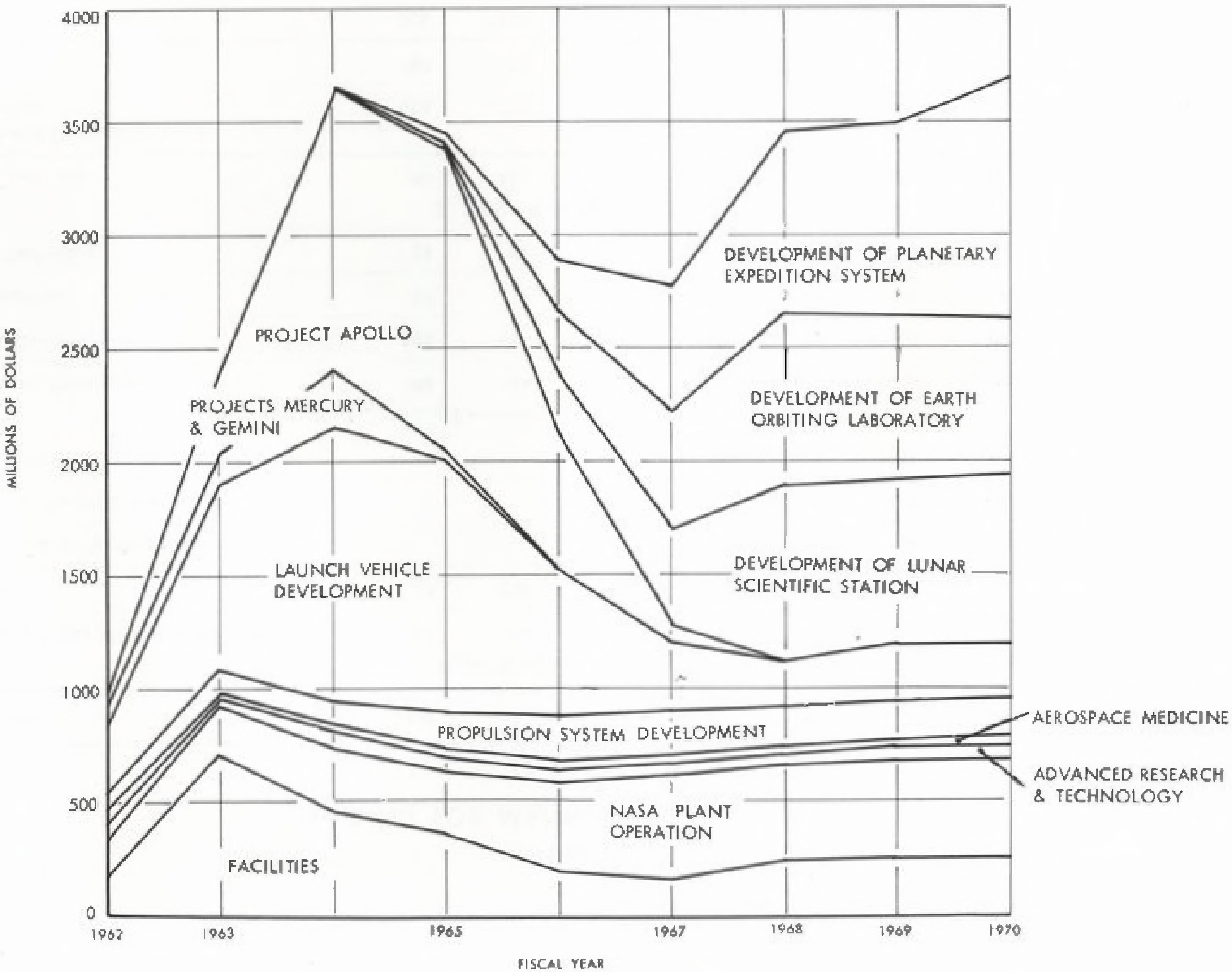

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TABLE III-2

FUNDING FOR MANNED SPACE FLIGHT

in $1,000,000

Fiscal Year	1962	1963 (1)	1964	1965	1966	1967	1968	1969	1970
1. Flight Development Programs									
Projects Mercury, 1-Day Mission, and Gemini	65	176	226	65					
Project Apollo	75	558	1268	1315	600	60			
Development of Earth Orbiting Laboratory				10	310	520	830	780	750
Develop. of Lunar Scientific Station					205	430	680	680	700
Development of Planetary Expedition System				40	240	530	770	850	1050
2. Supporting Research and Development Programs									
Propulsion System Development	90	134	128	120	135	140	145	155	155
Launch Vehicle Development	280	693	1163	1145	690	360	250	250	250
Aerospace Medicine	13	19	25	35	40	40	40	40	40
Research and Technology	23	41	55	62	60	60	60	60	60
3. NASA Plant Operation									
NASA Plant Operation	80	185	260	325	370	405	425	440	440
Total Research and Development and Plant Operation	626	1806	3125	3117	2640	2545	3200	3255	3460
Facilities	180	706	487	328	235	220	250	250	250
Grand Total	806	2512	3612	3445	2885	2765	3450	3505	3710

(1) Includes 1962 supplemental

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B. INTRODUCTION

The most significant change in the manned space flight program in relation to the previous Plan is the goal of accomplishing a manned lunar landing expedition within this decade. In the first version of the Plan (December, 1959) specific schedules did not go beyond that of orbiting a manned spacecraft three times around the earth and returning the craft to earth (Project Mercury). There were also the corollary joint NASA-Department of Defense projects, the *X-15* and *Dynasoar*. The *X-15* is essentially a Mach 6 rocket research airplane capable of placing a man in space environment for a period of minutes. The *X-15* is discussed in detail in Chapter VI. The *Dynasoar* was originally planned as a pilot controlled hypersonic Mach 16 glider. The project has recently been changed to the development of a pilot controlled earth orbital spacecraft suitable for winged reentry through the earth's atmosphere to an aerodynamically controlled earth landing.

In the first revision of the Plan (January 1961) the manned space flight program was expanded greatly by introducing project Apollo. Project Apollo called for a manned spacecraft capable of prolonged flight in space and capable of an earth orbit of sufficient ellipticity to include the moon within the orbit. This latter goal, termed a circumlunar flight, required that the spacecraft provide:

1. Extended manned life support and protection.
2. Guidance and control capability to accurately navigate to and from the moon and to enter and leave a lunar orbit.
3. Structural design to withstand the earth atmospheric reentry heating and aerodynamic forces.
4. The ability to land on the earth's surface at a predetermined landing area.

The manned lunar landing expedition was projected for the post 1970 period.

In the President's Special Message to the Congress (May 25, 1961) the date for the manned lunar landing expedition was advanced to "within this decade," that is, prior to 1970. This change has required major reorganization of the Apollo program and the introduction of supporting phases that were not previously included. The manned space flight program through the lunar landing project is divided into three phases:

1. Project Mercury and the 1-Day Manned Flight
2. Project Gemini
3. Project Apollo

With the successful completion of these programs, the United States will have developed manned space vehicle systems capable of operating within the earth-moon environs, and specifically will have developed:

1. Manned spacecraft capable of operating for prolonged periods (weeks) in near-earth space (i.e. below the Van Allen belt)
2. Spacecraft rendezvous equipment and procedures for joining (docking) of major spacecraft units or for transfer of men and material from one spacecraft to a second spacecraft
3. Man-piloted spacecraft capable of landing men or material on the moon, and returning the men and materiel to the earth.

The NASA Long Range Plan incorporates the exploitation of manned space flight capabilities in the earth-moon environs and incorporates the extension of these capabilities towards manned exploration of the planets.

In the following pages these different phases of the NASA Manned Space Flight Program are discussed in more detail.

The spacecraft considered for the approved and the planned NASA Manned Space Flight Programs are described briefly in Table III-3 (pages 97-101).

2

C. PROJECT MERCURY AND 1-DAY MANNED FLIGHTS

These Programs have as objectives:

1. The determination of the extent to which man can function normally in a zero gravity space environment for periods up to slightly more than 24 hours.
2. The development of manned spacecraft techology.

The Mercury program is proceeding satisfactorily from a technical standpoint although the original schedule has not been maintained. Astronauts Shepard and Grissom have both piloted the Mercury spacecraft through a ballistic trajectory reaching altitudes of 110-120 miles, and velocities of 5,000 miles per hour with 5 minutes of zero gravity. The Mercury spacecraft has made two earth orbital flights, the first unmanned and the second with a chimpanzee as passenger. Based on the results from these flights, a manned orbital flight is currently scheduled for early 1962. Several additional manned flights will complete the Mercury program.

For the 1-Day Manned Flight the Mercury spacecraft will be altered to make it suitable for flights of 18 orbits, enabling the pilot to remain in space for up to 27 hours. Consequently, information will be obtained on the ability of the pilot to function normally in regard to mental and bodily actions for this period.

D. PROJECT GEMINI

The spacecraft for Project Gemini will be suitable for two man occupancy for a period of one week or more. It will be similar in configuration to the Mercury spacecraft, but will weigh about 6,000 pounds as compared to 2,700 pounds for Mercury. It will require a launch vehicle of greater capacity than the Atlas used in the Mercury program. The Department of Defense Titan II has been selected for this purpose.

The Gemini spacecraft will be used to develop man piloted spacecraft rendezvous techniques. In this phase of the program two spacecraft will be launched separately, the manned craft by means of Titan II. The unmanned "target" craft will be the Agena stage of an Atlas-Agena. The two spacecraft, following launch, will be maneuvered, with some phases under pilot control from the manned craft, until they contact each other and can be joined into a single spacecraft. The actual joining of the spacecraft is termed "docking." Rendezvous including docking of spacecraft will have many uses in space transportation systems beyond the use to be made of it in Apollo.

The Gemini permissible flight period of one to two weeks will extend manned operation well beyond the time involved in the earth lunar manned landing flights—about 5 days. These two-week flights are critical in the program in that they will show whether or not man can function adequately in a zero gravity field for the extended period. If ill effects do result, artificial gravity can be produced in a spacecraft. Provisions have not been made in the Plan for this alternative.

2

E. PROJECT APOLLO

The Apollo Program (see Figures III-3 and III-4) to achieve a manned lunar landing includes:

1. Development of necessary launch vehicles including new propulsion systems as required.
2. Development of three-manned spacecraft (including necessary propulsion systems) suitable for the lunar trip.
3. Development of necessary lunar landing and launch systems.
4. Refinement of spacecraft orbital rendezvous and docking procedures.
5. Conduct of necessary aerospace medicine programs and crew selection and training.

Preliminary unmanned investigations of lunar landings and investigations of the effects of the space environment, notably the effects of solar flares, will be conducted under the Space Sciences Program, discussed in Chapter I. Research on effects of meteoroid damage and research on earth atmosphere reentry problems will be conducted under the Research and Technology Program, discussed in Chapter IV.

1. *Earth Orbital Flights*

The development of the launch vehicles and the required launch vehicle propulsion systems are discussed in detail in Chapter IV.

The first flights involving the Apollo spacecraft (see Table III-1) will be those of the pre-prototype test models. A total of eight flights are scheduled. The purpose of these tests is to produce engineering data having to do for the most part with:

(a) The development of the earth launch abort and escape system.

(b) The parachute deceleration system used during the latter phases of the earth atmosphere re-entry.

(c) The launching system and landing procedures.

Included in the tests will be experiments to qualify components to be used in these phases of the operation of the Apollo spacecraft. The spacecraft earth orbital tests (Table III-1) will continue the development testing and engineering data determination for the complete spacecraft.

In the Manned Space Flight Program shown in Table III-1, development flights of the launch vehicles are shown only if the flight was used in the spacecraft development program. The launch vehicle development program is covered in Chapter IV. Back-up flights* are not listed as such in Table III-1 because of the nature of the program. Propulsion systems that are part of the spacecraft as distinct from the launch vehicle are included as part of the spacecraft development (including costs).

* See ch. IV

The reentry tests (Table III–1) are to obtain engineering information and to complete the development (following extensive tests in hypersonic wind tunnels) of the reentry heat absorption and dissipation section of the Apollo spacecraft. In the Mercury flights a solution was developed for reentry from earth orbit velocities, 17,000 miles per hour. The Apollo spacecraft returning from the moon reenters the earth's atmosphere at a velocity of about 25,000 miles per hour. Twice the energy per pound of spacecraft has to be dissipated as was the case with the Mercury spacecraft reentering at 17,000 miles per hour. Much ground based research has been done and will be done on the solution of this problem. The flight program is required to obtain full scale results and to test the specific design solutions being considered for Apollo. Following these tests and the incorporation of the results in the Apollo spacecraft, the craft will be flown for qualification tests including both orbit and rendezvous in orbit. The next series of flight tests will attempt to simulate a lunar landing operation by going through the various propulsion and control sequences in a manner similar to that required for a lunar landing.

2. *Aerospace Medicine and Crew Selection*

The term Aerospace Medicine refers to the physiological, psychological, and health requirements imposed by the space program.

The current aerospace medical effort in the Manned Space Flight Program has the immediate objectives of insuring the safety and effective performance of the flight crews and ground operations personnel during the conduct of the Apollo flight missions. In order to accomplish these objectives, the aerospace medical effort must provide the engineering data to insure that the spacecraft provides the environment, life support, and life protection required to meet the physiological and psychological requirements of the crew. And further it must provide trained medical monitoring personnel throughout the operation.

As currently approved, the aerospace medicine and crew selection phases of the manned space flight program have been divided into five technical areas:

(a) Acceleration and weightlessness.

(b) Radiation protection.

(c) Life Support Systems Requirements.

(d) Crew selection and training.

(e) Crew monitoring.

The program of crew selection and training will utilize ground facilities to condition the crews to those aspects of the flight environment (isolation, close quarters, etc.) that can be reproduced on the ground. In this program the appropriate existing and planned Department of Defense facilities will be used extensively. The size of the Apollo program requires the training of several crews. Also crews must subsequently be selected and trained for the manned laboratory and lunar scientific station operations and for the manned planetary expeditions planned in the 1970's.

3. *Possible Effects of Solar Flares*

The dependency of the lunar flight time scale on the assumption that zero gravity would not adversely affect man's physiological or mental functioning has been discussed. In the flights to the vicinity of the moon the Apollo spacecraft must pass through the Van Allen radiation belt. The radiation in the belt will be passed through too quickly to adversely affect the men in the spacecraft. However, having passed through the belt the spacecraft will no longer have the shield against solar flares provided by the earth's atmosphere and magnetic field.

During the period prior to the first flight to the vicinity of the moon extensive investigations of the possibility of predicting solar flares will have been conducted as part of the Space Science Program. Also, during the engineering phase of the Apollo spacecraft design, studies will continue on the shielding required by the Apollo pilots in case a flare is encountered. The program is scheduled on the assumption that these actions will provide a solution to possible solar flare radiation hazards.

4. *Possible Meteoroid Damage*

The flights to the vicinity of the moon may also subject the spacecraft to meteoroid collisions. Research on this problem and on means to combat it is being conducted in the program on Spacecraft Technology (Chapter VI). The purpose of these tests is to provide information on the probability of such collisions and to give design information to provide suitable structural protection.

5. *Flights to the Vicinity of the Moon*

The first flights to the vicinity of the moon will be in an earth orbit of sufficient ellipticity to include the moon (termed a circumlunar flight). These circumlunar and lunar orbit flights will provide the pilots with experience in navigating to the moon and returning to earth including the atmospheric reentry and deceleration encountered under these conditions. On these circumlunar flights the spacecraft will have adequate propulsion and guidance and control to go into and come out of the lunar orbit, and on one or more of these flights a lunar orbit may be flown. In addition to crew training, circumlunar and lunar orbit flights will provide observational information concerning landing sites on the moon. These landing areas, including measurements of the moon surface at the landing area, will have been investigated previously as part of the Ranger and Surveyor flights in the Space Sciences Program (Chapter I).

6. *Manned Lunar Landing*

On completion of the Apollo circumlunar flights and lunar orbit flights the first manned lunar landing flight will be attempted.

7. Rendezvous Versus Direct Ascent

Up to this point the flight programs for the Apollo spacecraft, whether for the rendezvous procedure or the direct ascent, have been essentially the same. There is however a major difference in the vehicle requirements for the spacecraft for the two procedures. In rendezvous the spacecraft is launched from earth orbit and must therefore incorporate a rocket stage to accelerate the craft to the additional 7,000 or more miles per hour required to leave earth orbit and approach the moon. In direct ascent, the Nova launch vehicle (see Chapter IV) accelerates the spacecraft directly to the earth escape velocity (although a parking orbit technique will probably be used).

Present scheduling calls for the conduct of both the rendezvous* and Nova programs since both are desirable for future work regardless of which provides the first manned lunar landing. However if budgeting limitations require a slow down in the program, present scheduling calls for the slow down to be applied to the Nova development unless lack of progress in the rendezvous and docking tests dictate otherwise.

* In addition to the work on rendezvous in earth orbit, studies are being made on the possible advantages of rendezvous in lunar orbit.

F. MANNED EARTH ORBITING LABORATORIES

Development of earth orbiting laboratories is shown in Figure III–1 and Tables III–1 and III–2 as starting in 1964 with first flight, based on a modification of an Apollo spacecraft, shown in 1966. Both Saturn C–1's and C–5's are shown as the launch vehicles to be used. The ferry spacecraft listed in Table III–3 is to assist in logistic support for the earth orbiting laboratory and will be developed as part of this program. In developing the ferry or resupply spacecraft an objective will be to permit landing, on return to earth, at a preselected landing site similar to landing of conventional airplanes. Information gained from the Dynasoar program may prove of value in the landing system development. First use of manned orbiting laboratories may be for conducting scientific or engineering experiments or in support of the satellite meteorological and communications programs. .

Specific programs for utilizing these manned earth orbiting laboratories will be evolved during the Apollo Manned Space Flight Program and the Applications and Space Science Programs conducted prior to the extended flights with the Apollo spacecraft. It is not advisable to set up specific programs until the advantages and limitations of man's use in space are more definitely known. First use of manned orbiting laboratories may be for conducting scientific or engineering experiments or in support of the satellite meteorological and communications programs.

G. LUNAR SCIENTIFIC STATION

The initiation of the development of a manned lunar scientific station is planned for 1965. Based on preliminary studies the weight that must be transported to the moon for a 6 to 12 man station is given in Table III-3 as 150 tons. Any one of several launch vehicle systems could be used to transport 150 tons to the moon. They could consist of advanced Saturn vehicles using rendezvous, Nova launch vehicles, or nuclear rockets, as they become available.

H. MANNED PLANETARY EXPEDITIONS

Development of long lead-time elements for manned space flight systems for planetary exploration is scheduled to start in fiscal year 1965 (Table III-2) with the first attempts for manned flights to the vicinity of Mars scheduled to take place about the mid 1970's. Many facts must be learned before the manned flight is attempted, notably those facts connected with the factors referred to in the lunar program—zero gravity (weightlessness), solar flare radiation, and meteoroid impact. The minimum duration for a Mars expedition will be about 12 months with a period of a few days in a Mars orbit. An important factor to be considered is the interrelation between the trip time and the spacecraft propulsion requirements as measured by the total velocity change required. For a minimum energy trip the velocity change is about 25,000 miles per hour from earth orbit to earth orbit return. This trip requires a total time of somewhat more than 2½ years with a fifteen month wait at Mars. A 12 month trip requires a significantly greater velocity change and possibly several times the energy required in the minimum energy trip.

The development of adequate life support and life protection systems will require extensive technological developments as well as some fairly basic research. According to current concepts the first attempt will be a Mars rather than a Venus flight because of the more favorable climatic conditions on Mars and the more extensive knowledge of these conditions. The actual planetary flight will be preceded by extensive unmanned exploration flights to the planets and manned earth orbit flights of long duration and simulating as many conditions of a Mars flight as possible.

TABLE III–3

SPACECRAFT FOR MANNED SPACE FLIGHT PROGRAMS

Mercury

Weight	2700 lbs
Maximum Diameter	74.5 inches
Mission Flight Path	Near-earth orbit
Mission Lifetime	3 orbits

Special Features
- 1 man crew
- De-orbit and recovery capability
- Emergency crew escape system
- Attitude stabilization and control
- Capable of modification for use in one day manned flight

Launch Vehicles
- Redstone for ballistic flights
- Atlas for orbital flights

One Day Manned Flight

Weight	2800 lbs
Maximum Diameter	74.5 inches
Mission Flight Path	Near-earth orbit
Mission Lifetime	18-orbits (27 hrs.)

Special Features
- 1 man crew
- De-orbit and recovery capability
- Emergency crew escape system
- Attitude stabilization and control
- Basic design applicable to Gemini spacecraft

Launch Vehicle
- Atlas

Gemini

Weight	6500 lbs
Maximum Diameter	84.5 inches
Mission Flight Path	Near-earth orbit
Mission Lifetime	up to two weeks

Special Features
- 2 man crew
- De-orbit and recovery capability
- Emergency crew escape system
- Attitude stabilization and control
- Rendezvous propulsion system
- Rendezvous docking equipment

Launch Vehicle

Titan II modified to aircraft design reliability standards

Rendezvous Target (Unmanned)

Weight	4,000 lbs
Mission Flight Path	Near-earth orbit
Mission Lifetime	To be specified

Special Features
- Unmanned
- Command thrust-vector control system
- Rendezvous docking equipment

Launch Vehicle

Atlas-Agena B

Apollo

Weights	
Command Center	8,500-10,000 lbs
Service Section	2,500-40,000 lbs
Lunar Landing Propulsion Section	80,000-100,000 lbs
Maximum Diameter	150-160 inches
Mission Flight Paths	(a) 300 mile earth orbit (b) Circumlunar geocentric orbit (c) Lunar Landing and Return
Mission Lifetime	one to two weeks

Special Features
- 3 man crew
- "Shirt-sleeve" crew compartment
- Emergency crew escape system

2

Emergency mission abort system
Navigation and Flight Path Control Capability
Lunar Orbit Capability
Radiation Protection
Lunar Landing and Take-off Capability
Spacecraft Air-lock Exit Capability

Expected Useful Life .... To be utilized through 1970 decade.

Launch Vehicles
Saturn C-1
Advanced Saturn
Nova

*3-Man Laboratory**

Weight	10,000 lbs
Maximum Diameter	154-200 inches
Mission Flight Path	Low inclination 300 nautical mile earth orbit
Fully Operational Lifetime Without Resupply	2 months
Emergency Lifetime	3 months
Expected Useful Life	Until larger laboratories become operational

Special Features
Suitable for engineering and scientific activities
Emergency Earth Return Capability

Launch Vehicle
Saturn C-1

Multimanned Laboratory

Weight	150,000 lbs
Maximum Diameter	18 feet
Mission Flight Path	Polar 300 n.mi. earth orbit Low inclination 300 n.mi. earth orbit

* This and following spacecraft are preliminary estimates only and are subject to considerable change.

Lifetime Without Resupply .... 1 year
Additional Emergency Lifetime .... 3 months

Special Features
- Suitable for engineering and scientific activities
- Emergency Earth Return Capability

Expected Useful Life .... Indefinite

Launch Vehicle
- Advanced Saturn

Ferry Spacecraft

Weight .... 15,000 lbs
Maximum Diameter .... 18 feet

Special Features
- Command Center Concept
- Advanced Reentry Guidance and Control Capability

Lunar Scientific Station

Total Operational Weight .... 300,000 lbs
Envelope Diameter .... 18 feet
Fully Operational Lifetime without Resupply .... 3 months
Emergency Lifetime .... 6 months

Special Features
- 6-12 man crew
- Quarters suitable for continuous occupation
- Suitable for Scientific and Exploration Activities

Expected Useful Life .... Indefinite

Launch Vehicles
- Nova-Nuclear
- Advanced Saturn/Nova

Planetary Spacecraft

Weights:
- Command Center .... 12,500 lbs
- Planetary Service Section .... 50,000 lbs
- Shielding .... 37,500 lbs
- Guidance and Propulsion Section .... 100,000-200,000 lbs
- Earth Escape and Planetary Orbit Propulsion Section (from earth orbit) .... 700,000-1,200,000 lbs

Maximum Diameter	24 feet
Mission Lifetime	1½-3 years
Expected Useful Life	Indefinite

Special Features
- Continuous Life Environment
- Mission Abort Capability with Emergency Life Support
- Adaptable to Planetary Landing Mission

Launch Vehicle
- Nova-Nuclear (with rendezvous)

FIGURE VII-3

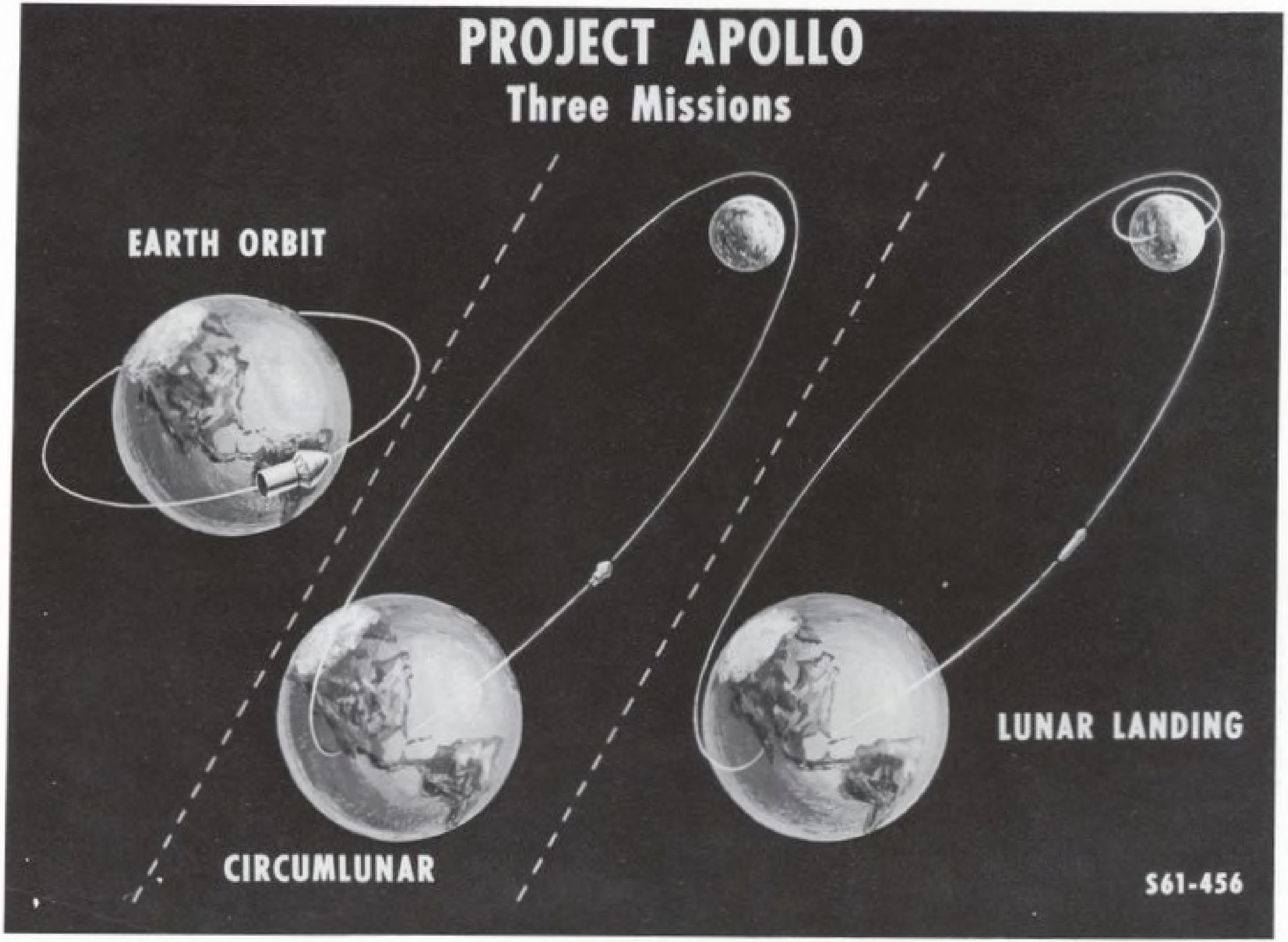

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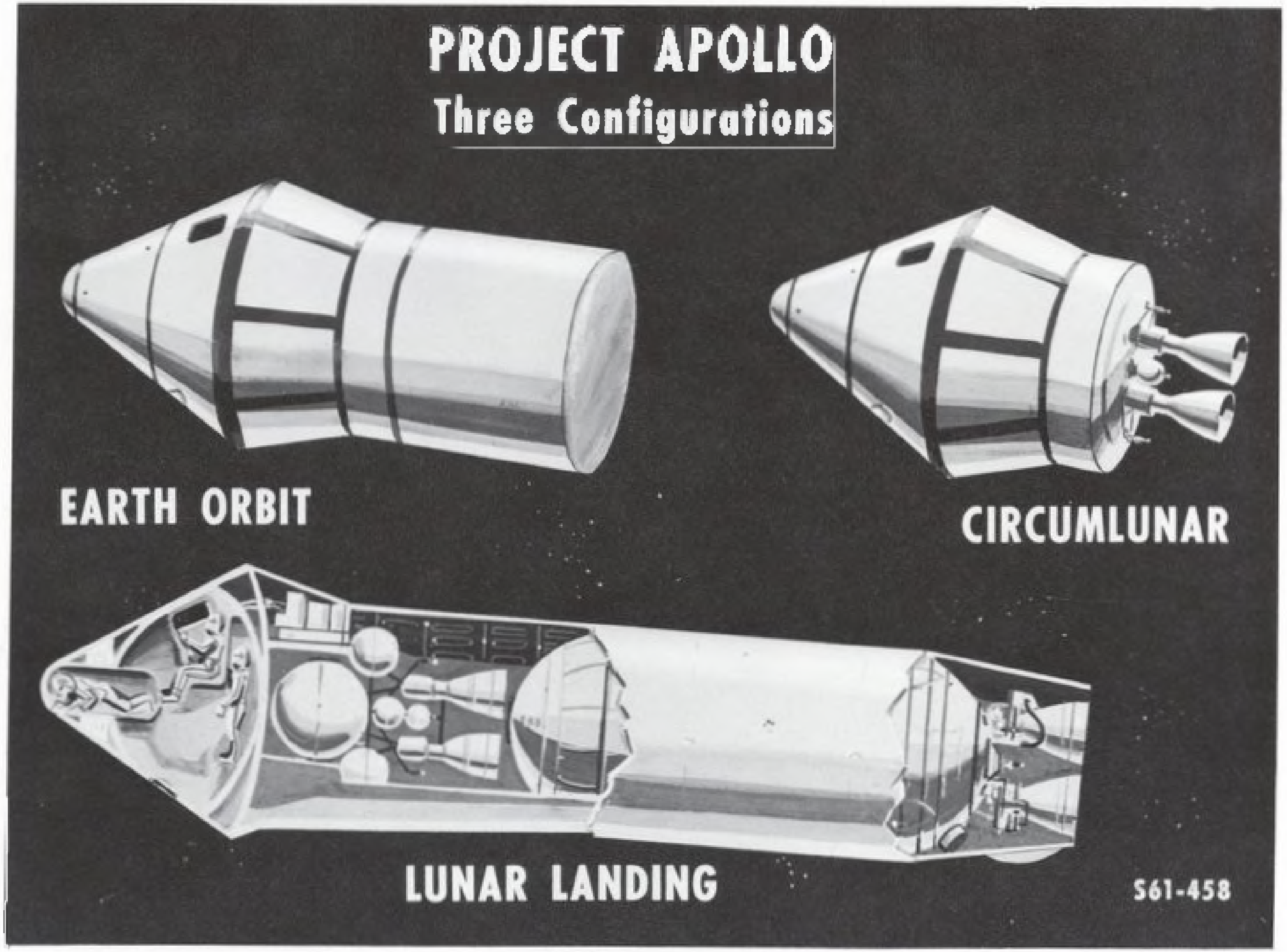
FIGURE III-4



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CHAPTER IV

LAUNCH VEHICLE AND LAUNCH FACILITY DEVELOPMENT

CHAPTER IV
LAUNCH VEHICLE AND FACILITY

CHAPTER IV

LAUNCH VEHICLE AND LAUNCH FACILITY DEVELOPMENT

Mission Target Dates

A. Synopsis

B. Launch Vehicle Development

1. Earth-Launch Vehicles
   a. Class A—Scout, Delta, Thor-Agena B, and Atlas-Agena B
   b. Class B—Centaur
   c. Class C—Saturn C-1
   d. Class D—C-5
   e. Class E—Nova
2. Orbital-Launch Vehicles
   a. Earth-Lunar Transportation Systems
      Earth Orbit Escape Vehicle
      Ferry: Earth Orbit to Lunar Orbit and Return
   b. Earth-Planet-Sun Transportation Systems
3. Rescue Vehicles

C. Chemical Propulsion Systems Development

D. Launch Facilities Development

LAUNCH VEHICLE DEVELOPMENT

MISSION TARGET DATES

1962 • Launching of Centaur

1963 • Flight of 2-Stage Saturn C-1

1964 • Qualification of 1.5 Million Pound Thrust Rocket Engine (F-1) for Flight
• Qualification of 200,000 Pound Thrust Hydrogen-Oxygen Rocket Engine (J-2) for Flight

1965 • Flight of Complete 3-Stage Saturn C-1
• Flight of C-5 Launch Vehicle
• Qualification of 1.0-1.5 Million Pound Thrust Hydrogen-Oxygen Rocket Engine (M-1) for Flight

1966 • Flight of 60 KW Planetary Orbital-Launch Vehicle
• Flight of Nova

1967-70 • Flight of Nuclear Thermal Rocket (RIFT-NERVA modified)
• Flight of Earth-Orbit to Moon Nuclear Orbital-Launch Vehicle
• Flight of 1500 KW Planetary Orbital-Launch Vehicle

A. SYNOPSIS

Over the next several years, a large portion of NASA effort and funds will be expended in developing large launch vehicles and their launch complexes. The purpose of this chapter is to discuss the launch vehicle development programs including the engines and the launch complexes needed for the NASA flight programs.

The largest launch vehicle now available is Atlas-Agena B. It will launch a 5000 pound payload (spacecraft)[1] into a 300 nautical mile orbit and 750 pounds into escape from earth. This falls far short of the large payload requirements for future missions. Furthermore, no orbital operations capability (e.g. launch from orbit or orbital rendezvous) has yet been developed to give the maneuvering flexibility or the payload capacity required for future missions.

The plan presented herein covers the development of those new launch vehicle systems required to accomplish the planned NASA missions that cannot be accomplished with existing operational vehicles. The proposed vehicle family is divided into two parts:

1. *Earth-Launch Vehicles*—A group of launch vehicles of varying size capable of placing up to 400,000 pounds into a 300 nautical mile orbit from the surface of the earth.
2. *Orbital-Launch Vehicles*—A group of launch vehicles capable of launching payloads from earth orbit. These vehicles will utilize chemical, nuclear and electric propulsion of varying energy and payload capacity to satisfy advanced interplanetary mission requirements.

Figure IV-1 shows a picture of the Earth-Launch Vehicles and indicates their relative size. Centaur, Saturn C–1, the C–5 and Nova are the vehicles still to be developed by NASA. The Air Force is developing Titan II which will be modified for use in the NASA rendezvous development program described in Chapter III.

Table IV–1 shows the launch vehicle development anticipated funding through Fiscal Year 1970.

The engines for the four earth-launch vehicles being developed are either underway or planned. Their thrust levels, propellants and the anticipated funding for their development are shown in Table IV–2. Engines for the orbital-launch vehicles are in the research phase and are included under Chapter VI (Research and Technology).

[1] The spacecraft placed in a space flight trajectory by the launch vehicle can be termed the payload of the launch vehicle.

The Launch Complex Development Plan provides for the construction, modification and operation of the launch complexes and facilities needed for the scheduled vehicle launchings. All facilities for launching vehicles for NASA missions from AMR, PMR, and Wallops Island are included except those for tracking and data acquisition. The latter are treated in Chapter V (Tracking and Data Acquisition). Table IV-3 shows the anticipated funding for development and operation of the launch complexes and associated facilities. These costs are broken down into Research and Development and Construction of Facilities. The latter is further divided into funding required specifically for the launch complex and for the necessary support facilities such as Assembly Buildings, Office and Laboratory Buildings, Storage Buildings, Control and Telemeter Buildings, etc. Except for the one Atlas-Agena B pad at PMR, all facilities are at AMR.

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FIGURE IV-1 *Launch Vehicles*

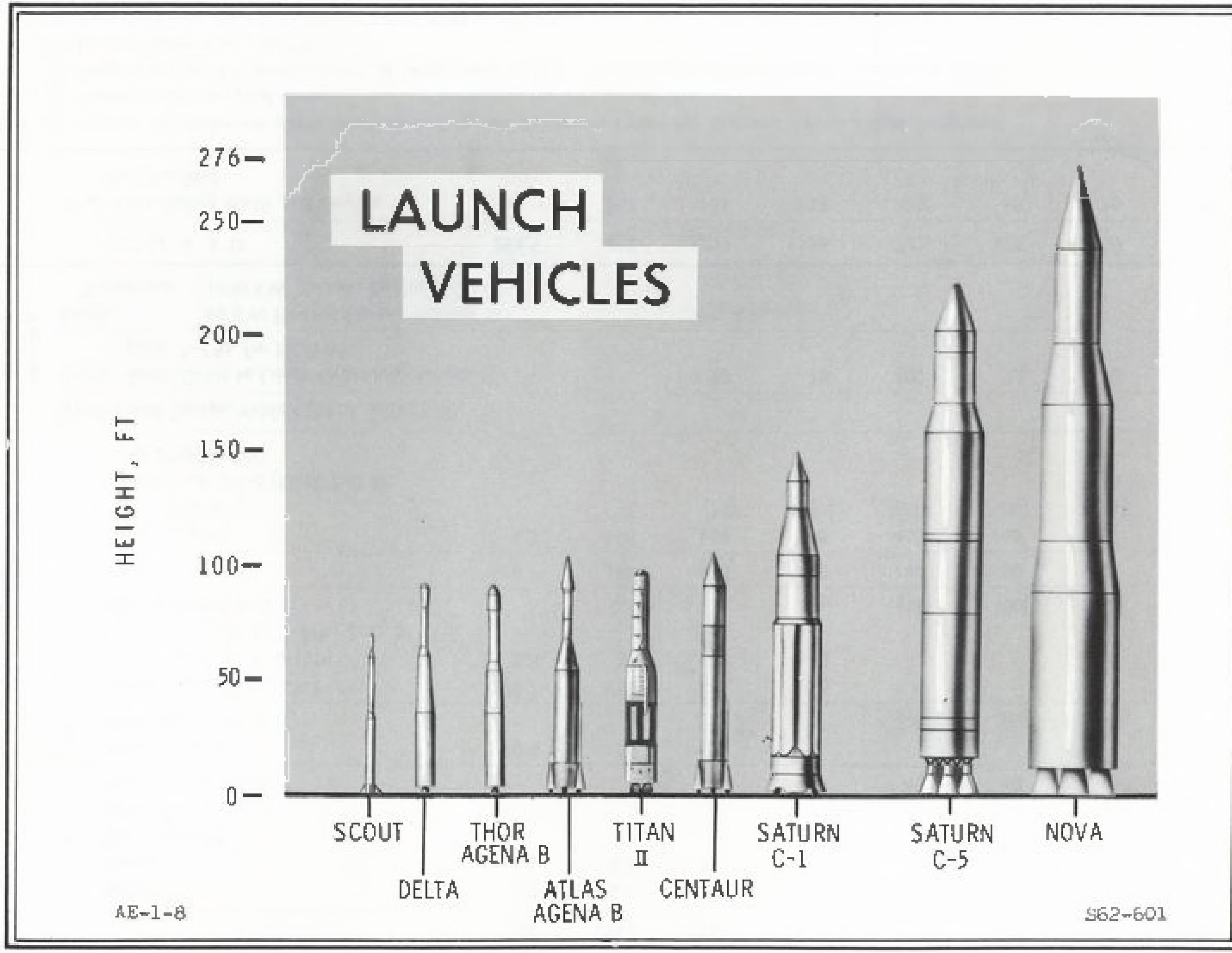

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TABLE IV–1

VEHICLE DEVELOPMENT ANTICIPATED FUNDING (S)

(In Millions of Dollars)

		FY	1962	1963	1964	1965	1966	1967	1968	1969	1970
Earth-Launch Vehicles	A	Scout	4.0	8.9	2	1	1				
		Delta	2.6	0.3							
		Thor-Agena B (1)									
		Atlas-Agena B (1)									
		New Vehicle LV–A				10	40	40	10		
	B	Atlas Centaur	70.4	76	20						
		New Vehicle LV–B (7)					(10)	(60)	(40)	(40)	(10)
	C	Saturn C–1 (S–I, S–IV)	279.7	218	65	10					
		C–1 (S–I, S–IVb)	2.5	31	30	5					
		C–1 (S–I, S–IVb, 3rd. St.) (2)									
		New Vehicle LV–C (7)					(10)	(80)	(120)	(40)	
	D	C–5	28	385	400	300	140	50			
	E	Nova (Liquid)	6.3	158	660	760	440	160	50		
		(Solid) (3)		5	(25)	(150)	(250)	(100)	(25)		
		New Vehicle LV–E (Nucl. 2nd St., 10-20,000 MW)							30	70	100
Orbital-Launch Vehicles		Earth Orbit Escape Vehicle (Mod. S–IVb) (4)									
		Ferry: Earth-Orbit to Lunar Orbit and Return (5) (nucl. 3rd St. for NOVA)			30	70	100	70	10		
		Earth-Planet-Sun 60 KW Electric Engine Vehicle (6)									
		Earth-Planet-Sun 1500 KW Electric Engine Veh. (6)									
		TOTAL R & D	393.5	882	1207	1156	721	320	100	70	100
		C of F (Excluding AMR and Engine Test Facility)	80	207	139	132	80	60	70	90	30

NOTES:
(1) Vehicle development costs are included in vehicle procurement for Manned Space Flight Programs.
(2) Funded under original C–1.
(3) Dependent on AF development of large solid motors. Funds in parentheses are not included in totals.
(4) Funded under C–1 and NOVA.
(5) Launched into orbit by 2-stage C–5 or 2-stage NOVA.
(6) Funded under spacecraft and electric propulsion technology.
(7) Go-ahead decision date in 1966. Funds in parentheses not included in totals.
(8) Classes A & B funded under Space Science Program. All others in Manned Space Flight Program. Plant operation not listed separately

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TABLE IV–2

LIQUID ROCKET ENGINE ANTICIPATED FUNDING*

(In Millions of Dollars)

Fiscal Year	62	63	64	65	66	67	68	69	70
Launch Vehicle Engines									
H–1 188K (O_2–RP)	8.2	6	5	3	3	2	2	2	2
A–1, A–3 15K (O_2–H_2)	28.0	28	15	10	8	6	6	4	4
J–2 200K (O_2–H_2)	38	39	26	17	10	8	6	6	6
M–1 1,000K (O_2–H_2)		55	62	45	40	20	20	20	10
F–1 1,500K (O_2–RP)	57	55	40	38	37	20	10	10	10
New Large O_2–H_2 Engine Larger than M–1	—	—	—	20	40	60	70	70	60
*Spacecraft Engines***									
Advanced Lunar Take-Off & Abort Propulsion	—	15	30	25	20	10	5	5	5
TOTAL ENGINE R&D	131	183	178	158	158	126	119	117	97
CoF	15	31	15	8	10	24	10	6	4

* H–1 funded under Saturn C–1 development; A–1, A–3 under Centaur developments; all others funded under Manned Space Flight Program (Propusion System Development).

** Other spacecraft engines funded in Manned Space Flight Program.

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TABLE IV–3

LAUNCH FACILITIES DEVELOPMENT ANTICIPATED FUNDING*

(In Millions of Dollars)

	FY	62	63	64	65	66	67	68	69	70
ATLAS–AGENA B AMR	(Mod. to Pad)		—	0.1		0.2				
	(Assoc. Facil.)		—	5.8		—				
	PMR Pad		30	—		—				
CENTAUR	AMR Pad 36B	18.8		—	0.1	—				
	Assoc. Facil.	—		2.5	0.5	—				
	Mod. for Elec. Stage (60 kw)	—		—	3.0	1.0				
TITAN II	Mod. of AF Pads 18 & 19	—	12	—						
SATURN C–I	Pad 37A & B	27.6	2	—	—	1.0	—	—	0.5	
	Assoc. Facil.			30.9	0.1	—	1.3	0.7	—	
C–5	3 Pads, 4 Booths	3.7	173	25	5	1.5	—	—	1.0	—
	Assoc. Facil.		4.8	1.5	0.1	—	0.8	0.2	—	—
	Mod. for Elec. Stage (1500 kw)						2.5	10	10	1
NOVA	Pads A, B, & C	1.0	80	200	120	60	—	—	2.0	—
	Assoc. Facil.				0.6	0.4	—	17	0.6	—
	Mod. for Nucl. 3rd St.					3	10	20	10	3
INDUSTRIAL AREA (AMR)		3.6	31.6	0.2	0.7	0.7	1.2			
NEW INDUST. AREA (Assoc.		33.8	77.6	5.0	1.0	—	3.0			
with Man. Sp. Fl.)		6.7	15	20	26.4	35.2	35.2	35.2	35.2	35.2
WALLOPS STATION C&E		8.0	4.3	6	14.3	15.3	9.5	7.3	8.5	6
TOTAL FACILITIES		103.2	428.3	299	171.8	118.3	63.5	90.4	67.8	45.2
R&D (Including Wallops)		1.5	8.5	7	5.5	6	6.5	6.5	6.5	7.5
TOTAL		104.7	436.8	306	177.3	124.3	70	96.9	74.3	52.7

* Atlas-Agena B, Centaur and Wallops facilities funded under Space Science Program. All others under Manned Space Flight Program.

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B. LAUNCH VEHICLE DEVELOPMENT

Space transportation systems are required on a timely basis for the satellite, lunar, planetary, solar, out-of-ecliptic and manned flight programs.

All launch vehicles used to date have launched the spacecraft from the earth and placed the craft either in an earth orbit or in an earth escape trajectory. For future missions larger and more complex transportation systems will be required. These systems must be able to perform a multitude of new missions such as the following:

1. Place large payloads into earth orbit.
2. Rendezvous with other space vehicles in earth orbit in order to assemble large payloads or to build up larger vehicles as orbiting stations or to resupply them.
3. Launch payloads from earth orbit to the moon and planets.
4. Land and take off from the moon.
5. Maneuver into lunar, planetary or earth orbit.

1. *Earth-Launch Vehicles*

The NASA earth-launch vehicles, defined as rocket systems which launch spacecraft from the earth surface, are listed in Table IV–4 and a summary of their development programs are shown in Figure IV–2. Their capabilities and primary usage are shown in Figure IV–3. The scope of the total vehicle development effort is pictured by Figure IV–4 which shows the development period of the stages planned for NASA vehicles. It shows that eleven stages will be under development in 1963, the peak period.

A further indication of the scope of NASA activity is given by the Master Launch Schedule of Table IV–5. It should be emphasized that the schedule from 1968 on is incomplete since requirements for the manned missions beyond that time are too uncertain at this time. The schedule does reflect, however, a reasonable projection of the unmanned flights for scientific investigations and application satellites. As indicated by the dashed line in the bar chart of Figure 2 of the Synopsis of the Plan, the likelihood will be for an increasing number of total launches rather than a tapering off after 1967.

During the past year, significant decisions, actions and accomplishments were made which are important in the development of NASA vehicles. Some of these were the following:

(a) Contract for Saturn C–1 first stage (S–I) manufacture.
(b) Contract for Saturn C–1 second stage (S–IV).
(c) Successful firings of the F–1, 1.5M pound, thrust engines to be used in the larger than Saturn boosters.
(d) Successful launch of the Saturn C–1 first stage.
(e) Contract for C–5 first stage (S–Ib) development.
(f) Purchase of real estate at Cape Canaveral for C–5 and Nova launch sites.
(g) Acquisition of the Michaud, Louisiana plant for the manufacture of the large first stage of C–5 and Nova.
(h) Initial steps in acquisition of the Mississippi Test Site for development and tests of large engines for C–5 and Nova.

(i) Contract for NERVA development and design studies for RIFT.

(j) Contract for 200,000 lb. thrust H_2–O_2 engine (J–2).

(k) Large solid engine firing (4–500,000 lb. thrust).

(l) Decision to develop 1.0-1.5 million lb. thrust H_2–O_2 engine (M–1).

(m) Contract for S–IVb stage for use in Nova, C–5 and Saturn C–1.

Since the previous NASA Long Range Plan was issued in January 1961, the pace of the entire NASA program has been accelerated and this has necessitated a major realignment of the launch vehicle requirements.

With regard to *rendezvous* and *orbital operations*, the NASA plan is to develop the necessary techniques as quickly as possible. The plan calls for the development of a launch vehicle (designated C–5) large enough so that, with a single rendezvous in earth orbit, two spacecraft sections of sufficient size can be joined to provide the complete spacecraft for the flight to the moon to accomplish the first manned lunar landing and return. Concurrently but at somewhat lesser emphasis, a parrallel program for accomplishment of the first manned lunar landing by direct flight with Nova will be carried out. It is also envisaged that the Nova will be needed for more difficult missions such as manned expeditions to near planets, Mars for example.

With regard to *solid fueled rocket* engines, the NASA plan is to place first reliance on the large liquid engines and to monitor the development of solid rocket engines by the Air Force for possible use in NASA launch vehicles.

An inspection of Figure IV–2 and IV–3 will indicate that the spectrum of mission requirements can be divided into five classes of payload weights as follows:

Class	*Vehicles*	*300 n. mi. Earth Orbit*	*Escape (lbs.)*
A	Atlas-Agena B and smaller	<5,000	<750
B	Centaur	8.5–15,000	2.5–4,000
C	Saturn C–1	20–30,000	4–10,000
D	C–5	200–225,000	30–90,000
E	Nova	350–400,000	155,000

Each class is discussed in more detail below.

a. *Class A Launch Vehicles.* Vehicles currently authorized in this class are Scout, Delta, Thor-Agena B and Atlas-Agena B.

Scout is a four stage, all solid propellant vehicle capable of placing small scientific satellites of up to 200 pounds in a 300 mile orbit. Operational use of Scout, with some technological improvements, will continue at a rate of about eight a year.

Delta is a three stage vehicle for medium payload satellites (up to 500 pounds) and space probes (up to 60 pounds). Its primary use will be in sending application satellites and scientific satellites into earth orbit.

Thor-Agena B is a two stage operational vehicle capable of injecting medium sized payloads (1600 pounds) into orbit. Its missions require launches both from the Atlantic and Pacific Missile Ranges. Payload requirements for the Thor-Agena diminish rapidly by 1967. For this reason it is phased out in 1967.

Atlas-Agena B is a vehicle capable of application in earth-lunar exploration (Ranger) and large earth satellite experiments. The number of missions requiring the Atlas-Agena size launch vehicle increases appreciably in the 1964-69 period and then stabilizes at a lower rate probably through 1975.

b. *Class B Launch Vehicles.* The only vehicle currently authorized in this class is the Centaur. The Centaur has a capability of placing payloads up to 8500 pounds in low earth orbit and will be used in a variety of earth satellite and lunar and planetary missions. The Centaur stage will be the first vehicle utilizing hydrogen-oxygen propellants. Its initial objective is to place a communications satellite (under development by the Department of Defense) in a 24-hour equatorial orbit. Centaur usage builds up rapidly through 1967 and then decreases to about six per year thereafter.

c. *Class C Launch Vehicles* (Saturn C-1). The only authorized vehicle in this class is the Saturn C-1 which, as presently constituted, is a 2-stage vehicle. It has a LOX-RP first stage (S-I) with 8 H-1 engines (1,500,000 pounds of thrust) and a H_2–O_2 second stage, S–IV, with six A–3 engines (total of 90,000 pounds thrust). Because of its configuration, it has no escape capability. Over 50 Saturn C–1's are scheduled in the 1964-68 time period for the manned space flight program.

The requirements for Saturn C-1 continue past the end of this decade. The replacement of the six A–3 engine second stage (S–IV) with a single J–2 powered stage (S–IVb) should improve stage reliability and double the payload capability since the vehicle would be better matched as regards thrust to weight ratio of second to first stage. Also, the vehicle will then be adequately staged for the addition of a possible third stage for earth escape trajectory launches. The S–IVb stage is an essential "building block" of the orbital operations lunar program, and will be the third stage of the next larger vehicle, the C–5, as well as Nova. With this new second stage, the earlier Saturn C–1, described in the previous paragraph, can be phased out in 1967.

The unmanned lunar and planetary program has need for a vehicle with escape payload capacity greater than 2500 pounds (Centaur) but much less than the 90,000 pounds of the C–5 to be described later. The needs starting in 1965 are in the 4,000-10,000 pound class with a maximum spacecraft diameter of the order of 15 feet. The most direct way to meet this requirement is to add a third stage to the Saturn C–1. By adapting an S–IV as the third stage an operational 3-stage escape requirement could be met in late 1965. It provides the large diameter as well as a stage that will have experienced many flights on the original Saturn C–1. Another approach could be to modify the Centaur stage as a third stage. These possibilities require further analysis before a decision can be made. Studies are presently under way to determine the better configuration.

d. *Class D Launch Vehicles* (C–5). The D class vehicle (herein denoted as C–5) will have 5 F–1 engines in the first stage, 5 J–2's in the second, and 1 J–2 in the third and be capable of use as a 2-stage vehicle. It will have the following performance capabilities:

	2-stage	*3-stage*
300 n. mi. orbit	200-225,000 lbs.	200-225,000 lbs.
Escape	30- 45,000 lbs.	85- 90,000 lbs.

A number of considerations entered into the design of this vehicle. They are:

(1) To obtain the earliest accomplishment of the first manned lunar landing by a single rendezvous, a D class vehicle is required.

(2) It is the largest vehicle which can be built with facilities now available or under construction.

(3) It can be designed with engine out capability in both first and second stages thereby having an increased mission reliability with a payload significantly larger than that required for manned circumlunar and lunar orbit missions.

(4) The 2-stage configuration of this vehicle offers an escape capability in excess of that required for manned circumlunar and lunar orbit missions and sufficient for unmanned lunar and planetary missions.

e. *Class E Launch Vehicles (Nova).* To provide a direct ascent mode for an earliest manned lunar expedition program, a vehicle in this class is required. For effective manned planetary exploration after the lunar landing, rendezvous of Novas and even Nova-nuclear vehicles will be necessary.

The Nova vehicle is designed to accelerate 150-160,000 pounds to escape velocity in order to satisfy the direct ascent approach to the manned lunar landing and return problem. It is possible, however, that its reliability growth may be slower than anticipated or the spacecraft weight may increase beyond that now established. The manned capsule can then be launched with a Saturn C–1 or C–5 to rendezvous with a Nova launched unmanned spacecraft which will then accelerate the lunar landing payload to escape velocity.

Many Nova configurations have been examined with particular emphasis on (1) the achievement of early high reliability, (2) earliest vehicle availability, and (3) growth potential for missions beyond the manned lunar landing. The proposed vehicle configuration is as follows:

First Stage	— 8	F–1 engines
Second Stage	— 4	M–1(1.0-1.5 million lb. thrust H_2O_2) engines.
Third Stage	— 1	J–2 engine

The Nova first stage (N–1) uses the liquid F–1 engines. The choice of the F–1 engine is predicated on the fact that: (1) the F–1 engine has already been under development for three years, and (2) the F–1 engine will be developed to a high degree of reliability for the intermediate C–5 vehicle.

As solid rocket technology progresses under Department of Defense sponsorship, its use in future versions of Nova will be considered. In fact, the above Nova configuration has been selected so that it could utilize a cluster of 20 foot diameter solid motors in the first stage as a growth version. It can also utilize a nuclear third stage.

The Nova second stage *(N–II)* uses the high thrust (1.0-1.5 million lbs.) liquid hydrogen-oxygen M–1 engines. The choice of these engines is predicated on the fact that: (1) the earliest launch of a 2-stage Nova is paced by facilities and will not occur until the end of 1966 thus permitting 5-years for the M–1 development, and (2) an alternative use of a cluster of eight or more J–2's results in having to ignite a large number of engines in space, a lower payload capacity and a lack of growth capability in comparison to that which exists with the M–1 powered second stage.

The third stage of Nova is a prime building block in the NASA launch vehicle program. It is basically the third stage (S–IVb) of the C–5 vehicle, the second stage of the later version of the Saturn C–1, and the earth-orbital-launch stage for the Apollo lunar landing spacecraft.

As time goes on, the plan calls for reappraisals of the NASA family of earth-launch vehicles based on two primary considerations:

(a) The development of the minimum number of launch vehicles necessary to encompass the projected payload requirements, the assumption being that a high utilization rate resulting in high reliability will offset non-optimization of launch vehicle to payload.

(b) Replacement of vehicles only when it can be demonstrated that technological advances permit the development of a more reliable and less expensive system, taking into account the development costs. This approach is based on the thesis that after an operational period of 5–8 years, advances in technology may permit overall improvements which would result in substantially lower cost.

A reappraisal of all launch vehicles periodically is planned. As our knowledge of the operational characteristics increases and technological advances in rocket design are made, it may become advantageous to replace some of the vehicles with more up-to-date designs. Examples of the present thinking are the possibility of replacing the eight H–1 engines in the S–I stage by one F–1 engine or the replacement of some or all of the class A vehicles by a single solid rocket launch vehicle. In Figure IV–2, decision points are indicated when it appears it might be appropriate to initiate new designs.

2. *Orbital-Launch Vehicles*

For future missions, launching spacecraft from earth orbit will be necessary. The spacecraft may perform flights, for example, to the moon and planets and return to earth orbit.

The propulsion system used to launch the spacecraft from earth orbit may be staged in the same way that launch vehicles are staged from the earth's surface. For instance, the Apollo spacecraft could have three propulsion stages—one to launch the craft from earth orbit towards the moon, a second to decelerate the craft from the lunar approach velocity to a lunar landing and a third to launch the craft from the moon's surface into a moon escape trajectory and an earth approach. Such stages are designated as orbital-launch vehicles in this report.

The propulsion system for an orbital-launch vehicle may include the following types:

(a) Chemical rockets with a velocity change capability in the range of 10,000-25,000 ft/sec.

(b) Nuclear thermal rockets (Project ROVER) with a velocity change capability of up to 45,000 ft/sec.

(c) Electrical propulsion systems with a velocity change capability of 30,000-90,000 ft/sec or more.

Utilizing the three kinds of propulsion systems presently being developed or planned for development, four orbital-launch vehicles are planned for future NASA missions. They fall into two main categories of two vehicles each: earth-lunar-transportation systems and earth-planet-sun transportation systems. The former utilizes the chemical and nuclear rockets and the latter the electric rockets. Each is described below and their development program shown in Figure IV–5.

a. *Earth-Lunar Transportation Systems*—This class encompasses an Earth Orbit Escape Vehicle utilizing chemical propulsion and an Earth-Orbit to Moon-Orbit-and-Return Ferry utilizing nuclear rockets.

The earth orbit escape vehicle is a modified S–IVb stage now being developed as the third stage of C–5 and Nova and described earlier in the chapter. It will also be used as the second stage of Saturn C–1. Whether manned lunar landing and return is performed by earth orbit rendezvous with C–5 vehicles or by direct ascent with Nova, the Earth-Orbit Escape stage will be used. It will be able to accelerate as much as 150,000 lbs. to escape velocity from earth orbit (10,000 ft/sec).

Ferry: Earth-Lunar Flights—For the lunar resupply and scientific station missions it is likely that an operational nuclear stage based on the RIFT stage with the NERVA (nuclear) engine will be developed to shuttle payloads between earth and lunar orbits. Both the RIFT and NERVA are in development status. The schedule shows such a ferry vehicle being developed by mid-1969. It will be able to propel almost 100,000 lbs. from earth orbit to moon orbit and return to earth orbit, requiring a total velocity change of about 28,000 ft/sec. This ferry vehicle will be placed into earth orbit by a two stage NOVA or C–5.

b. *Earth-Planet-Sun Transportation Systems*—High and very high energy missions such as orbit-and-return from the far planets, Venus or Mars landing and return, Mercury, Jupiter, solar and out-of-ecliptic probes will demand the use of nuclear rocket engines and electric propulsion. The precise roles of each cannot be determined until more experimental results become available. From these, their relative performance will be established more firmly than is now possible. In Table IV–6 are shown present estimates of payloads available with a Centaur launch vehicle using a 60KW electric top stage and with a C–5 launch vehicle using a 1500KW electric top stage. Figure IV–6 shows some present estimates of performance of several launch vehicles with chemical, nuclear and electric third stages.

3. Rescue Vehicles

A requirement for an emergency rescue function will exist when manned flights—orbital, lunar and planetary—become more frequent. The definition, design and development of such a rescue vehicle must await results of further studies and experience in the manned flight program.

2

C. CHEMICAL PROPULSION SYSTEM DEVELOPMENT

Chemical propulsion systems will be used in launch vehicles and spacecraft for the major NASA missions for at least the next decade. Therefore, a continuing program of advanced technology will be undertaken in chemical propulsion.

The engine designations, propellant combination, thrust size and development programs of the major chemical, nuclear and electric engines which are underway or planned in the immediate future are given in Figure IV-7.

In the more distant future a high energy propellant engine in the 2 to 20 million lb. class may be required. Prior to development, concepts such as segmented combustion chambers using a single nozzle and pump will be investigated under the propulsion technology program.

1. *Spacecraft Propulsion*

The requirements for spacecraft propulsion fall in the following categories:

(a) Abort
(b) Lunar Landing
(c) Lunar Take-Off/Abort
(d) Rendezvous
(e) Course Correction
(f) Attitude Stabilization

The abort propulsion requirement for orbital and lunar missions could be liquid, solid or a combination of liquid and solid rockets. The requirement for the abort system of the Apollo orbital capsule at present calls for a system using liquid rocket units.

The lunar landing system may require a high energy hydrogen-oxygen rocket with variable thrust. The lunar take-off propulsion program will pursue at least two alternatives. One approach will be based on low energy propellants and utilize the present state-of-the-art. At least one other approach will be started using hydrogen and oxygen as the propellants.

D. LAUNCH FACILITIES DEVELOPMENT

The primary objective of the Launch Facilities Development Plan is to provide for the construction, modification and operation of the Launch Complexes and Facilities needed for the scheduled vehicle launchings, and for the support of the associated missions.

In forming this plan, consideration has been given to using existing launch complexes and facilities for new programs as far as possible. Economy is achieved through modifications to adapt existing facilities to the new programs as the older programs phase out, or through the sharing of facilities with other Government agencies. Figure IV–8 presents in simplified form the launch complex requirements and the scheduling of their completion.

The following paragraphs describe briefly the launch facilities plan for each launch vehicle:

1. *Launch Facilities*

a. *Scout*—Two launch facilities are in existence for this vehicle, one at Wallops Island, and the other at PMR. With the launch rate estimates not exceeding 10 per year, the existing facilities are adequate to fulfill this need. Adequate supporting facilities are also available. Only in the event of major changes in Scout launching rates would additional facilities be required.

b. *Delta*—A two-pad single blockhouse launch complex is in operation at AMR. It can accommodate 12 vehicle launchings per year. This rate can be easily increased to 18 per year if necessary. Since the forecast at this time shows 17 launchings in 1962 then drops to a rate of less than 10, no further launch facilities are planned.

c. *Thor-Agena B*—One launch pad will be modified at PMR during FY–62 for the NASA programs. This pad will be suitable for a launch rate of 12/year which is adequate for the planned program. No Thor-Agena B launchings are planned for AMR.

d. *Atlas-Agena B*—Launch facilities exist at the present time at AMR only. Here one pad is already operational with a capacity of 8 launches per year and a second pad will be modified upon the completion of the Mercury-Atlas program, giving a total Atlas-Agena B launching rate at AMR in 1963 of 16 vehicles per year. In addition, two pads are funded in the FY–62 U.S. Air Force Budget with operation expected by 1964. This total number of pads will be sufficient to handle the NASA requirements, including the anticipated operational meteorological and communications satellites.

At the present time, NASA can launch only two Atlas-Agena B vehicles per year from PMR by sharing USAF pads on a tight scheduling basis. The low rate of two per year will barely take care of the NASA requirements even if the operational meteorological satellite launchings were not taken into account. The latter will increase the NASA requirement to nearly full-time use of a single pad at PMR by 1966. Any additional shots would have to be phased again into Air Force pads. For this reason, construction of a new PMR pad is scheduled to begin early in 1963 as indicated in Figure IV–8.

e. *Centaur*—One complex is now in existence at AMR. A second one is planned for operational use in early 1965. These two will be adequate to meet the planned launch rate during the period considered.

f. *Saturn C–1*—For the Saturn C–1 vehicle, the program indicates that both three stage and two stage vehicles will be used. The existing launch facility, Complex 34, was originally planned for a three stage C–1 so no change will be required to accommodate either two or three stage configurations. Complex 37, which is now under construction, was designed for a three stage vehicle and will require only minor modifications to accommodate both versions. Completion of Complex 37 (Pads A and B) will provide, in 1964, the capacity for launching 10 vehicles per year from the two complexes (34 and 37). However, the proposed schedule indicates that the C–1 launch rate increases substantially in 1965 and a third complex of two pads may be required. Alternately, this high launch rate may be achieved as follows:

(1) Reduction of the present three-month turn around time in a single pad to two months, thus increasing the total launch rate of two complexes to 16 per year.

(2) Building a third complex.

A reduced turn around time can be achieved in time as the quality of the launch vehicles increases, the crews become more familiar with the vehicle and the handling and checkout procedures and additional supporting facilities are built. However, no backup capacity would be available. It is therefore desirable to build a third C–1 complex. The Plan takes account of this by providing for the third complex in early 1965.

g. *C–5*—A launch complex consisting of three pads and four assembly and checkout booths are planned and funded for the new area north of the present Cape Canaveral. The unique feature of this new complex is the assembly and test of the vehicle in a booth and transfer to the pads only for launch. This procedure will allow a turn-around time on the pads of about one week. The limiting item in the complex will be the assembly and checkout booth. Only one vehicle every two months can be assembled and checked per booth. With four booths, a rate of 26 per year can be accommodated. Even if this high launch rate may not be required on a yearly basis, rendezvous operations will require this rate on a short term basis. Both the 3-stage and 2-stage C–5 vehicles can be launched from the same pads. Since their combined launch rate does not exceed 25 per year, the three pads planned appear to be adequate for the planned missions and will in fact provide one backup.

h. *Nova*—A three pad complex for Nova is planned for construction in the new north area of Cape Canaveral. Vehicles will be assembled and checked out on the pad. Rate of launching per pad is estimated at 4 per year. Funds are now programmed in the FY–63 budget for start of major construction of this complex, and a small amount of design funds are planned in FY 1962. Estimates are that four years will be needed to construct the Nova launch complex. It will be necessary to start construction by mid 1962 in order to finish the facility by mid 1966.

i. *Nuclear Vehicles*—The plan indicates flight tests of nuclear engines will start in 1967. Present scheduling calls for launching of these engines only at AMR. Initial studies of the radiation and contamination hazards of nuclear engines, even under destructed conditions, shows that, with adequate safety zones, launch can be accommodated at AMR. Safety zone definitions are no more severe than those imposed by sound levels at time of launching. Therefore, no off-shore launch facilities for nuclear engine use were included.

j. *Titan II*—The follow-on to Mercury (Gemini) program will use Titan II. The schedule of desired mission launches indicates that during 1963 and 1964 a rate of six (6) launches per year will take place. To have the necessary launch pads available for the Titan II launchings, the program must be immediately approved and funds made available in FY–62 so that modifications to an Air Force pad can be made in time for the mid 1963 launchings.

2. *Launch Operations Development (R&D)*

Launch operations development includes launch facilities studies, advanced instrumentation development, ground support equipment development and investigation of hazards at the launch site. With the planned development of larger space vehicles and the utilization of nuclear propulsion and nuclear power in space vehicles, the matching facilities, instrumentation and ground support equipment will have to be developed. Launch site hazards that must be determined for both liquid and solid propellant vehicles include explosive hazards, toxicity, acoustic effects, radiation and fire. Incorporation of rendezvous techniques into the space flight operation requires a considerable increase in the launch rate and a high degree of reliability through improved checkout systems. Techniques and systems will have to be developed for checkout and count down while the vehicles are orbiting the earth, moon, or planets and when preparing to depart for the moon or planets.

TABLE IV–4

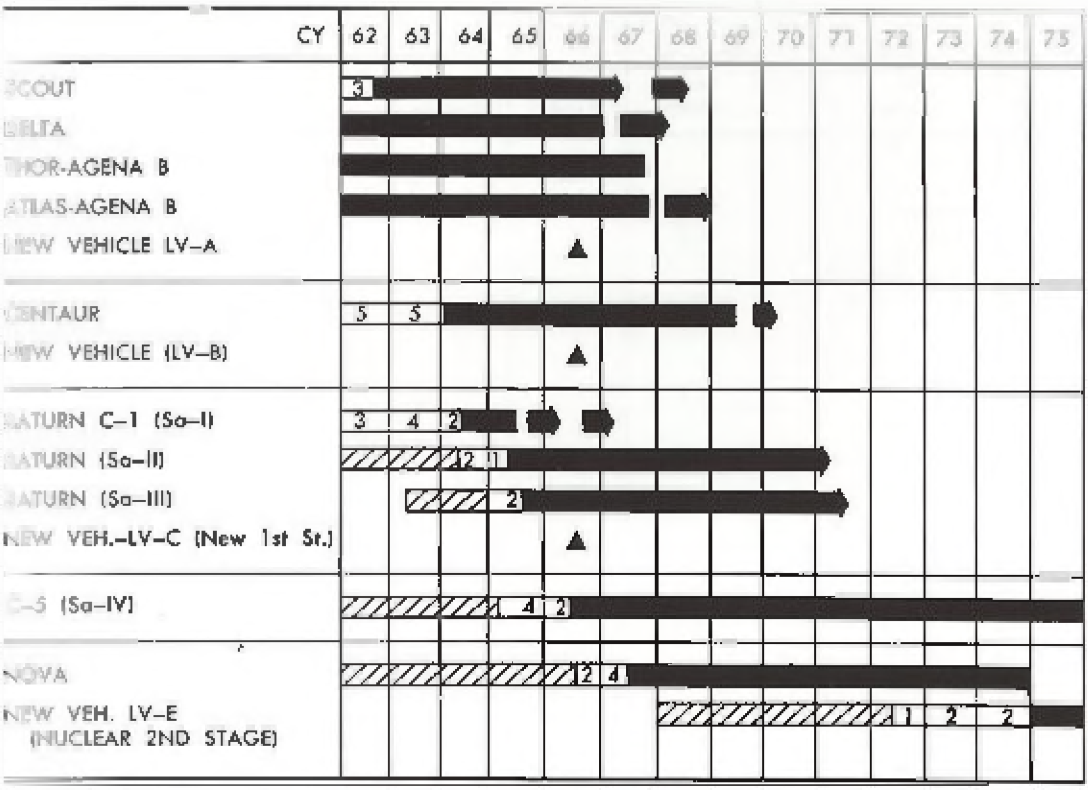
DESIGNATION OF LAUNCH VEHICLES AS USED IN THIS DOCUMENT*

Launch Vehicle	Vehicle Designation	Stage Designations
Scout	Sc	
Delta	De	
Thor-Agena B	Tg	
Atlas	At	
Atlas-Agena B	Ag	
Titan II	Ti–II	
Centaur	Ce	Atlas Centaur
Saturn C–I	Sa–I	S–I S–IV
	Sa–II	S–I S–IVb(1J–2)
	Sa–III	S–I S–IVb 3rd stage
C–5	Sa–IV	S–Ib S–II(5J–2) S–IVb
Nova	No	N–I N–II (4M–1) S–IVb

* For the purpose of consistency in the Long Range Plan, the names and symbols in this table have been adopted. The question of appropriate symbols for the launch vehicles is now being considered.

FIGURE IV–2

DEVELOPMENT PLAN
EARTH-LAUNCH VEHICLES



NOTES: 1. NUMBERS IN BOXES ARE NUMBER OF FLIGHT TESTS

2. DESIGN, R&D, GROUND TEST

FLIGHT TEST

OPERATIONAL

3. ▲ DECISION POINTS FOR GO-AHEAD

2

FIGURE IV–3

LAUNCH VEHICLE PERFORMANCE & MISSION SUMMARY

Vehicle	Stage or Engines	Payload (1000 Lbs) 300 n.mi. Earth Orbit	Escape	Planetary	Primary Missions
SCOUT B	Algol Castor Antares Altair	0.2			Small Scientific Satellites & Probes
DELTA	Thor (DM–18) AJ 10–118 Altair	0.5	0.06		Medium Payload Scientific and Application Satellites (Solar Geophysics, Communications, Meteorology)
THOR—AGENA B	Thor (DM–21) Agena B	1.6			Scientific Satellites MIMBUS (Meteorological Satellites)
ATLAS					18 ORBIT MANNED FLIGHT (Mercury) BIOSCIENCE SATELLITE
ATLAS—AGENA B	Atlas D Agena B	5.0	0.75		LARGE SATELLITES (Scientific, Communications, Meteorological) LUNAR IMPACT (Ranger) RENDEZVOUS DEVELOPMENT
TITAN II		6.2			RENDEZVOUS DEVELOPMENT (Gemini) 2-WK. MANNED ORBIT
CENTAUR	Atlas D Centaur (4A–2)	8.5	2.3	1.3	MOON SOFT LANDING (Unmanned-Surveyor) PLANET PROBES MARINER B (Mars, Venus)
SATURN C–1	S–I (8H–1) S–IV→S–IVb [3rd Stage]	20–30 —	— 4–10	— 2–5	APOLLO R&D MANNED ORBITAL STATION DEVEL. NUCLEAR PROPULSION DEVEL. VOYAGER (Mars, Venus)
C–5	S–Ib (SF–1) S–II (5J–2) S–IVb (1J–2)	200 200	30–40 85	— 60	APOLLO (Manned Circumlunar, Manned Lunar Landing) PROBES TO OUTER SPACE MULTIMANNED ORBITING STATION
NOVA	8 F–1 (4–1) M–1 S–IVb [1J–2]	350 350	— 150	— 100	APOLLO (Manned Lunar Landing & Return by Direct Ascent) FUTURE PLANETARY MISSIONS

FIGURE IV–4

STAGES FOR NASA VEHICLES

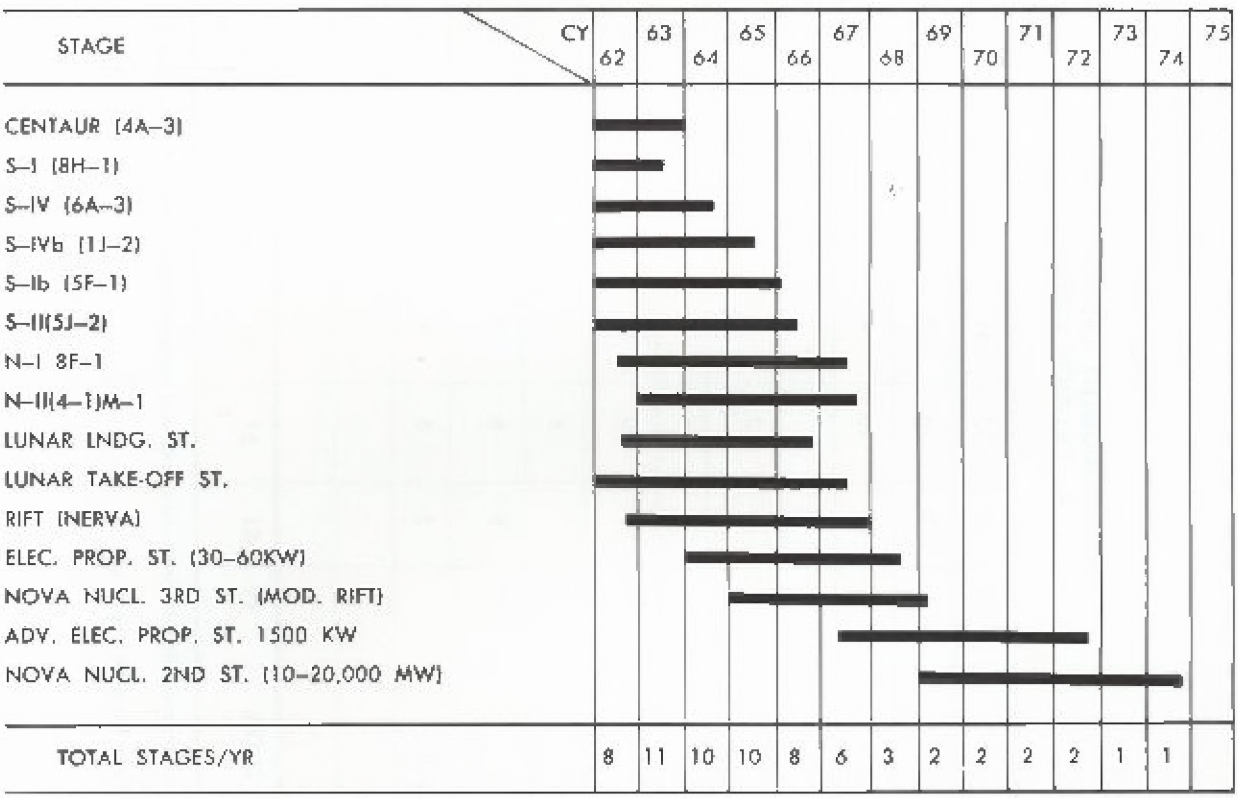


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TABLE IV-5

CONSOLIDATED LAUNCH SCHEDULE by LAUNCH VEHICLE TYPE

CY		62	63	64	65	66	67	68	69	70	TOTAL
SCOUT		12	10	7	10	6	6	6	6	9	72
DELTA		17	10	4	5	5	5	3	3		52
THOR		2									2
THOR-AGENA B	**	2	2 2	4 4	2 1	2	2				14 7
ATLAS		6	4	2	4	2	2	2	2	2	26
ATLAS-AGENA B	**	6	10	18 3	14 11	12 12	9 17	8 9	5 9	6 8	88 69
TITAN II			5	6	1						12
CENTAUR	**	5	6	8	9 1	11 1	9 2	5 3	6 3	6 3	65 13
SATURN C-1 (Sa-I, Sa-II, Sa-III)		3	4	8	15	15	9	9	7	5	75
C-5 (Sa-IV)					4	11	12	12	*9	7	55
NOVA						3	6	*6	1		16
TOTAL	**	53	51 2	57 7	64 13	67 13	60 19	*51 12	39 12	35 11	477 89

NOTES: ** Lower figures are for operational communications and meteorological satellites launched by NASA for other agencies or industry, including "back-ups".
* Estimates incomplete from this year on.

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FIGURE IV–5

DEVELOPMENT PLAN
ORBITAL-LAUNCH VEHICLES

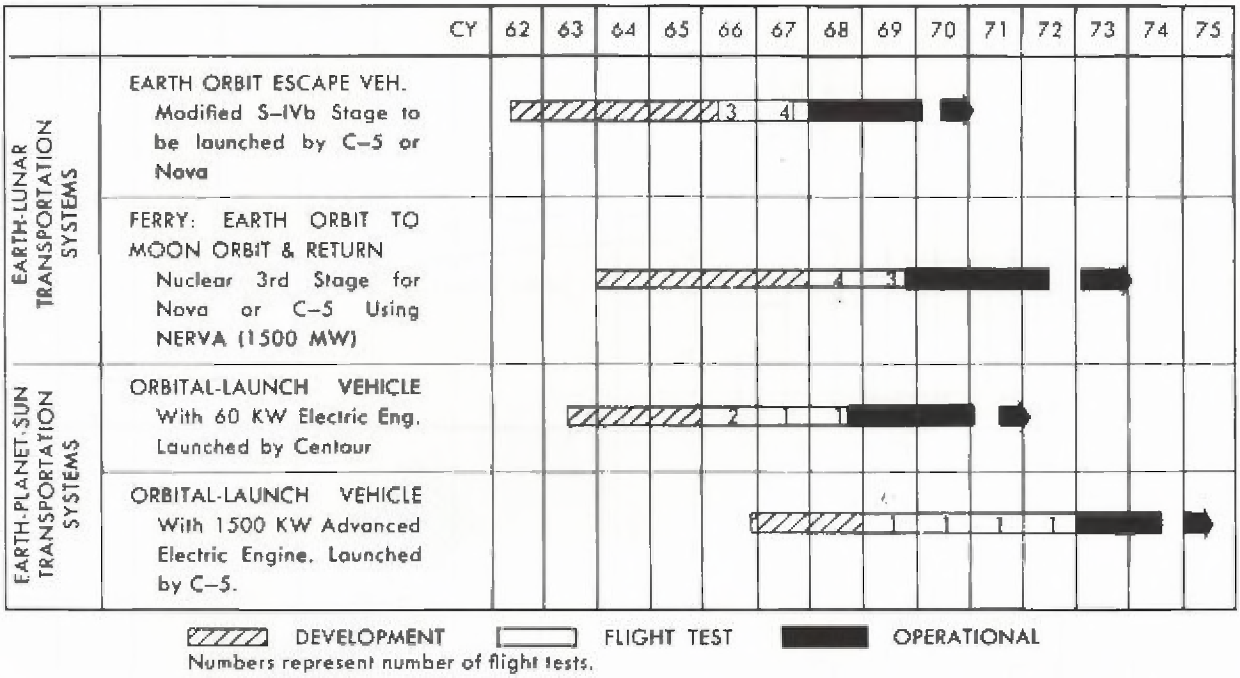


TABLE IV–6

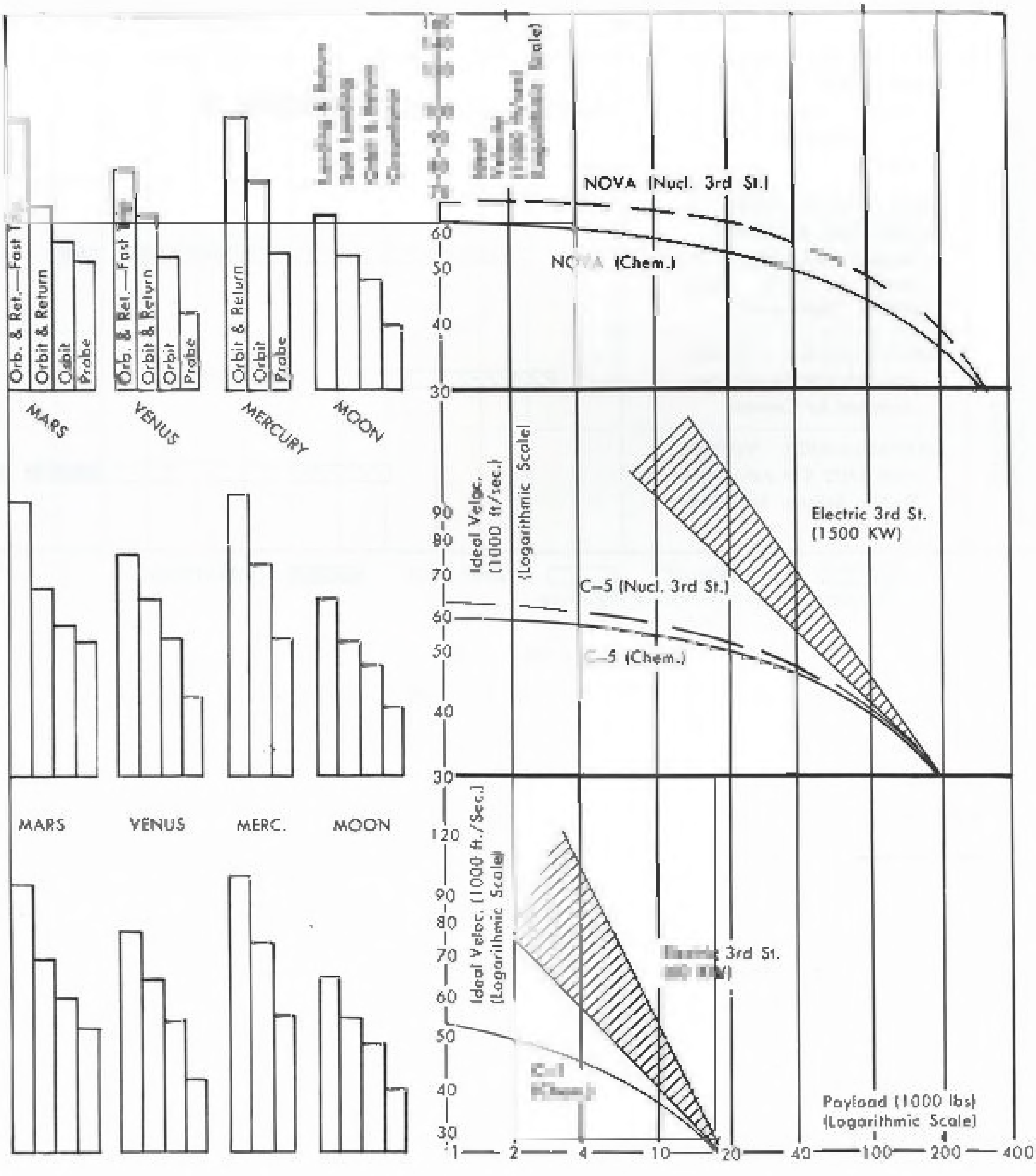
ELECTRIC PROPULSION ORBITAL-LAUNCH VEHICLE PAYLOAD CAPABILITIES

For Planetary Missions

	Total Vehicle Weight in Low Earth Orbit Prior to Orbital Launch (Orbital-Launch Vehicles Plus Planetary Payload)	General Payload Range (lbs.) for Various Planetary Missions	Required Electric Power Level	Operational Date
Small Orbital-Launch Vehicle	8,500	1000-5000	60 KW	1968
Large Orbital-Launch Vehicle	85,000	10,000-60,000	1,500 KW	1972

FIGURE IV–6

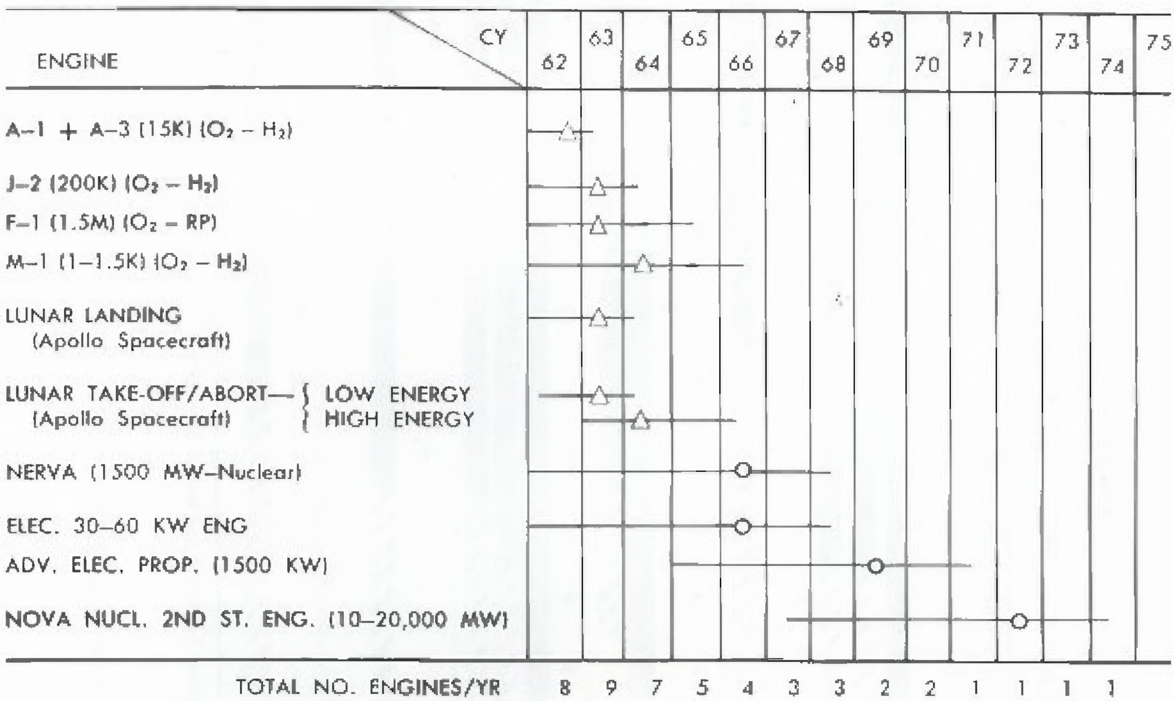
PAYLOAD CAPABILITIES OF ORBITAL-LAUNCH VEHICLES



NOTES: 1. Nuclear and electric 3rd stages used only for orbital launch.
2. Payload plus 3rd stage weight constant for each vehicle.

FIGURE IV–7

ENGINES FOR NASA VEHICLES

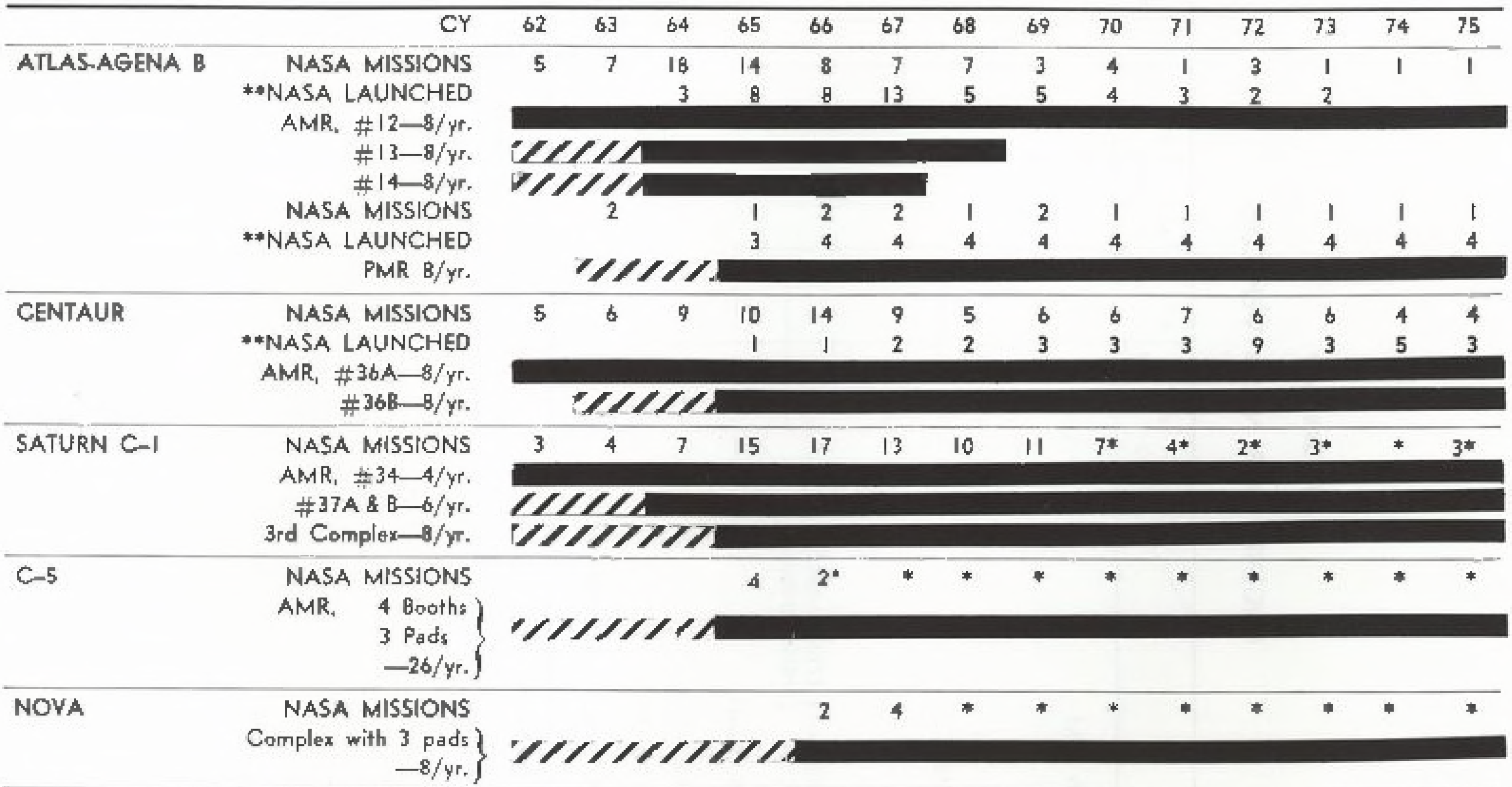


△ PREFLIGHT RATING TESTS

O FIRST DEVEL. FLT.

FIGURE IV-8

LAUNCH FACILITIES REQUIREMENTS



**Operational Meteorological & Communications Satellites Launched by NASA for other agencies and/or industry.

*Total No. of missions not defined.

NOTE: Figures above bars indicate number of scheduled launchings per year.

Development ////

Operational ▬

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CHAPTER V
TRACKING AND DATA ACQUISITION

CHAPTER V

TRACKING AND DATA ACQUISITION

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CHAPTER V

TRACKING AND DATA ACQUISITION

A. Synopsis

B. Objectives

C. Present Networks

D. Improvement Program
   1. Satellite Instrumentation Net
   2. Deep Space Instrumentation Facility
   3. Manned Space Flight Net

E. Related Research and Development

TRACKING AND DATA ACQUISITION

A. SYNOPSIS

The Tracking and Data Acquisition function is to provide the radio communication coverage needed to implement the NASA space flight programs. This coverage is furnished through networks of stations spread over the entire world.

The space flight programs fall into three categories: satellites near the earth, spacecraft traveling to great distances from the earth, and manned spacecraft. Each of these categories presents special tracking and data acquisition requirements.

Satellites near the earth pass rapidly across the field of view of ground antennas and so are in radio contact with any given ground station for only short time intervals. Therefore many ground stations are needed for routine coverage. For the more elaborate earth satellites, such as those transmitting television pictures of cloud cover, selected ground stations must have the special ability to handle large volumes of radio data and so need extra large antennas.

Stations for communication with spacecraft at lunar and planetary distances require powerful transmitters, large antennas, and sensitive receivers. The contact time problem is relaxed, however, because the range is great and the direction of travel is more along the line of sight than across it. Therefore fewer stations are needed. Contact time for each station will be limited by the rotation of the earth.

Manned flights can be in either the satellite or deep space class, and in addition present a greater need for continuity and reliability of communications.

The foregoing requirements are to be met by worldwide networks of stations. The larger stations will be equipped with big parabolic dish antennas, 85 feet in diameter for the earlier programs and for near earth satellites, and over 225 feet in diameter for the later programs in deep space. The time scale on which these antennas will be provided is keyed to the time scales of the flight programs and is shown in Figure V-I. Table V-I shows the detail funding for the Tracking and Data Acquisition program.

FIGURE V–1

TRACKING AND DATA ACQUISITION
85′ and 240′ Parabolic Antennas

	CY		60	61	62	63	64	65	66	67	68	69	
Satellite Net	East U.S.	#1		85	—	—							
	East U. S.	#2			85	—	—						
	Alaska	#1	85	—	—								
	Alaska	#2				85	—						
	Far East	#1			85	—	—						
	Near East	#1						85	—	—			
Deep Space Net	Goldstone	#1	—	85									
	Goldstone	#2	—	85									
	Goldstone	#3			240	—	—						
	Woomera	#1	—	85									
	Woomera	#2			85	—							
	Woomera	#3				240	—	—					
	Jo'burg	#1	—	85									
	Jo'burg	#2			85	—							
	Jo'burg	#3					240	—	—				
	Europe	#1			85*	- - -							
	Europe	#2				85*	- - -						
	Europe	#3					240	* - - -	- - -				
Manned Flight Net	U.S.	#1				85	—						
	U.S.	#2					85	—					
	U.S.	#3						△					
	Austral.	#1				85	—						
	Austral.	#2					85	—					
	Austral.	#3								△			
	0° Merid.	#1				85	—						
	0° Merid.	#2					85	—					
	0° Merid.	#3							△				

* The European site antennas will be installed only if the Johannesburg site is given up.

△ Time for final decision on the need for a 240 foot antenna at the site indicated.

TABLE V–1

TRACKING AND DATA ACQUISITION PROGRAM FUNDING

(In Millions of Dollars)

	FY	1962	1963	1964	1965	1966	1967	1968	1969	1970
Satellite Network	Technological Dev.	6.8	6.8	6.8	7.3	6.4	4.4	3.3	3.0	3.0
	Exp. and Equipment	23.2	38.0	43.5	44.5	44.5	37.0	42.0	40.0	40.0
	C & E	11.0	11.0	10.0	10.0	15.0	5.0	5.0	5.0	5.0
	Sub-total	31.8	47.7	60.3	61.8	65.9	46.4	50.3	48.0	48.0
Deep Space Net	Technological Dev.	4.6	4.8	4.7	4.4	4.7	5.9	6.5	6.7	6.7
	Exp. and Equipment	10.3	25.2	24.2	21.6	22.8	20.0	19.0	19.0	20.0
	C & E	15.5	28.6	5.0	15.0	15.0	5.0	5.0	2.0	—
	Sub-total	21.4	48.9	33.9	41.0	42.5	30.9	30.5	27.7	26.7
Manned Space Flight Net	Technological Dev.	—	—	3.5	3.3	3.9	4.7	5.2	5.3	5.3
	Exp. and Equipment	41.9	54.6	74.0	79.5	86.0	86.0	83.0	80.0	77.0
	C & E	3.0	15.1	30.0	48.0	15.0	15.0	5.0	30.0	20.0
	Sub-total	34.7	66.7	107.5	130.8	104.9	105.7	93.2	115.3	102.3
	Total	87.9	163.3	201.7	233.6	213.3	183.0	174.0	191.0	177.0
	NASA Plant Operation	8.0	19.1	17.0	18.0	23.0	27.0	28.0	30.0	30.0
	TOTAL	124.3	213.1	218.7	251.6	236.3	210.0	202.0	221.0	207.0

B. OBJECTIVES

The objectives of the Tracking and Data Acquisition Program are to provide the following services for all the spacecraft in NASA's flight programs:

(a) Tracking;

(b) Determination of orbits and trajectories;

(c) Transmission of commands;

(d) Reception of telemetry;

(e) Collection and processing of received data.

C. PRESENT NETWORKS

These objectives are being met by the following three tracking and data acquisition networks:

(a) The *Deep Space Instrumentation Facility*, composed of a master station in California and two companion stations in Australia and South Africa. This facility is operated by the Jet Propulsion Laboratory.

(b) The *Manned Space Flight Net*, made up of 17 ground-based and shipboard stations located to provide maximum coverage for manned satellites fired at 33 degree inclination from the Atlantic Missile Range.

(c) The *Satellite Instrumentation Net*, made up of the following three sub-networks:

1. A precision optical tracking network of 12 stations operated by the Smithsonian Astrophysical Observatory.
2. The Minitrack network of 14 narrow band telemetry and radio interferometer stations, with its control center at the Goddard Space Flight Center.
3. A wide band Satellite Data Acquisition Network to be made up of four stations controlled from the Goddard Space Flight Center.

D. IMPROVEMENT PROGRAM

In general, the foregoing networks will have to be maintained, modified and augmented and the individual station equipments will have to be continually improved to anticipate and keep pace with the needs of the entire space flight program. The flight program will involve, as is shown in other sections of this document, steadily increasing numbers of spacecraft of progressively greater intricacy, many of which will operate in elaborate systems. The Tracking and Data Acquisition task will correspondingly evolve from the present day manipulation of a few simple spacecraft to control and handling of a large number of intricate vehicles, most of which will have a high volume of communications traffic. (It should also be recognized that expeditious handling of large quantities of control and telemetry data poses problems in ground-to-ground as well as spacecraft-to-ground communications.)

The specific plans in the Tracking and Data Acquisition improvement program can be outlined as follows:

1. *For the Satellite Instrumentation Net:*

   (a) A number of medium gain antennas will be installed at selected Minitrack sites to provide for data acquisition from complex observatory-type satellites. These will also provide apogee coverage for satellites with orbits of high eccentricity, and back-up for the high gain wide band facilities.

   (b) High gain wide band facilities will be completed at four separate geographical locations. Each location will have 85 foot parabolic antennas and associated electronics to permit data acquisition from wide band complex satellites to the extent of about 80% of the theoretically possible coverage.

   (c) From 1963 through 1966, the Minitrack stations will be improved from the aspects of performance and automation.

   (d) From 1963 through 1968, the satellite interferometer tracking system at the Minitrack stations will be replaced by a more accurate and versatile system.

   (e) From 1965 through 1970, the high gain wide band data acquisition facilities will be improved to permit automatic acquisition, tracking, programming, and data processing.

   (f) From 1970 through 1975, extremely wide band systems using the most up-to-date techniques will be developed and used.

2. *For the Deep Space Instrumentation Facility:*

   (a) Transmitting capabilities will be added to the Australian and South African stations to allow continuous control of deep spacecraft. (At present, control is restricted to times when the spacecraft are in unobstructed line of sight from the transmitter in California.)

   (b) Additional 85 foot antennas will be installed at the South African and Australian stations to provide for the heavy load in the lunar and planetary programs and to serve as back-ups.

(c) Precision range measuring equipment (15 meters resolution at planetary ranges) will be installed at each of the three stations.

(d) Between 1963 and 1966, a 240 foot parabolic antenna will be installed at each station to permit television bandwidths to lunar distances and very wide band communications with interplanetary vehicles.

(e) From 1964 to 1967, data acquisition and command control will be automated. By 1972 this should be extended to the 240 foot receiving antennas.

(Should it develop, in connection with the Deep Space Instrumentation Facility, that it is not expedient to continue operation or augment equipment at the African site, plans call for establishment of a station at a European site at approximately the same longitude. This station would be a back-up for loss or threatened loss of the African station.)

3. *For the Manned Space Flight Net:*

(a) In 1962 and 1963, the net will be augmented to provide increased coverage, improved tracking, and more reliable communications and data transmission so as to give suitable support to 18 orbit Mercury missions and subsequent Apollo missions. (The net is now adequate for single orbit Mercury missions.)

(b) Instrumentation will be incorporated in the net to provide for development of the rendezvous techniques which may be used in manned circumlunar flights and lunar landings.

(c) From 1963 through 1965, there will be major instrumentation additions in the form of launch control, mission control, re-entry control, and landing facilities to support manned lunar orbiting and landing programs.

(d) In the 1963-64 period a study will be made to evaluate the specific requirements of manned lunar scientific stations and the extent to which these requirements can be met by the 240 foot dishes of the Deep Space Net.

(e) In 1964, three 85 foot antennas and associated equipment will be installed at suitable geographic locations to insure continuous communications and data transfer from and to manned lunar vehicles.

(f) In 1965, an additional 85 foot antenna and receiving and transmitting facilities will be provided at each of the above three sites.

(g) From 1967 to 1972, the facilities for the manned orbiting laboratories will be converted to an automated system.

E. RELATED RESEARCH AND DEVELOPMENT

The basic Tracking and Data Acquisition program will support continuing programs in function oriented technical development. These programs will be closely tied to the operating problems encountered in running the nets and handling the received data. They can be outlined roughly in the following five categories:

1. *Improvement in communications systems*
   - (a) Low noise amplifiers (parametric, MASER)
   - (b) Antennas and antenna systems
   - (c) Coding
   - (d) Modulation
   - (e) Automation
2. *Tracking Problems*
   - (a) Definition of geophysical constants
   - (b) Propagation effects
   - (c) Timing devices
   - (d) Computer programming
   - (e) Automation
3. *Data Processing*
   - (a) Error detection and reduction
   - (b) Reduction of redundancy
   - (c) Sampling techniques
   - (d) Increased speed in processing
   - (e) Automation of processes
4. *Hardware*
   - (a) Storage devices
   - (b) Electronic components
   - (c) Miniaturization
5. *Systems Integration*

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CHAPTER VI

RESEARCH AND TECHNOLOGY

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RESEARCH AND TECHNOLOGY

RESEARCH & TECHNOLOGY

MISSION TARGET DATES

1964 • First Nuclear Rocket Engine Test (NERVA)

1966 • First Nuclear Turboelectric Power Generation Flight Test (SNAP-8)

• First Nuclear Rocket Flight Test (RIFT) (1966-1967 Period)

RESEARCH AND TECHNOLOGY

A. SYNOPSIS

The NASA Research and Technology Program has two major functions. First, the research program is directed toward discovering and investigating the feasibility of new concepts and providing fundamental data and understanding of the physical processes. Second, the technology program is aimed at bringing the specific concepts and components to a useful state and providing design data required for specific and proposed missions. A large portion of the effort in the next few years will be devoted to technology in support of the manned lunar landing program. In the latter portion of the period a shift in emphasis will influence problems associated with more advanced missions. Concurrent with the research effort for the manned lunar landing mission, work in similar disciplines will be conducted in support of:

- Nuclear Rockets
- Power Generation
- Electric Propulsion
- Unmanned Scientific Probes
- Launch Vehicles and Missiles
- Aircraft

Conventional test facilities such as wind tunnels will continue to be used. However, new facilities to simulate the space environment, reentry conditions, etc., will have to be provided. These facilities will include improved "arc wind tunnels," shock tunnels, plasma accelerators, space environment simulators, special simulators, and engineering spacecraft for test where ground simulation is not feasible.

The Research and Technology program is divided into the following categories:

- Aeronautics
- General Research
- Nuclear Systems
  1. Nuclear Rocket Engines
  2. Nuclear Power Generation
  3. Electric Propulsion
- Advanced Spacecraft Technology
- Chemical Propulsion and Power Generation
- Electronics and Control

The research and technology funding for each of these categories is given in Table VI–1.

The planning and typical problems are given in the following sections and are in addition to the work performed under approved projects and described in other parts of the plan.

TABLE VI–1

RESEARCH AND TECHNOLOGY FUNDING

(in millions)

PROGRAM	FY 62	63	64	65	66	67	68	69	70
• Aeronautics	5	16	25	25	25	25	25	25	25
• Research	10	28	40	40	40	40	40	40	40
• Nuclear Systems	45	120	215	230	230	230	230	230	230
—Nuclear Rocket Engines	(26)	(80)	(146)	(165)	(146)	(130)	(120)	(115)	(115)
—Electric Propulsion	(10)	(20)	(36)	(38)	(42)	(50)	(50)	(55)	(55)
—Nuclear Power	(9)	(20)	(33)	(27)	(42)	(50)	(60)	(60)	(60)
• Advanced Spacecraft Tech.	22	37	75	75	75	75	75	75	75
• Chemical Prop. & Power Gen.	13	33	50	50	50	50	50	50	50
• Electronics & Control	13	21	56	80	80	80	80	80	80
• Research & Dev. Total	108	255	460	500	500	500	500	500	500
• Plant Operation	100	144	200	200	200	200	200	200	200
• Facilities	20	114	100	60	30	30	30	30	30
TOTAL	228	513	760	760	730	730	730	730	730

Numbers in parentheses included in Nuclear Systems total.

B. AERONAUTICS

The rapid advance in aeronautics since the birth of the American aviation industry sixty years ago is illustrated by the increase in speed of aircraft shown in Figure VI-1. While the entry of man into space has overshadowed this field to some extent, important goals and potential remain. The development of the B-70, the supersonic transport, the vertical and short-take-off and landing aircraft (V/STOL) and improvement in the helicopter best illustrate the near future goals. In the more distant future, advanced military aircraft such as the "aerospaceplane," the supersonic V/STOL applications and the flexiwing concept require continued investigations. These programs, which are described further in the following paragraphs, are required to fulfill NASA responsibilities in civil and military aircraft fields. In addition, programs such as the X-15 are providing information for supersonic and hypersonic aircraft as well as for manned space flight.

1. *V/STOL, Helicopters*

The present effort in V/STOL aircraft is conducted primarily through the use of large wind tunnels and flight studies. In the immediate future, emphasis will be placed on the investigation of specific configurations chosen by the military services for a subsonic VTOL assault transport, a fan-in-wing research VTOL vehicle and a light observation helicopter. For the future, studies are being made of concepts considered of most interest for supersonic V/STOL aircraft.

2. *X-15*

The X-15 research aircraft was conceived and built to explore the following research areas:

(a) Aerodynamic and structural heating.
(b) Hypersonic stability and control.
(c) Control at low dynamic pressure.
(d) Piloting problems.
(e) Landing.
(f) Aeromedical studies.
(g) Simulation.
(h) Flight control systems.

The flight testing of this vehicle to date has provided a considerable amount of flight data in each of the above areas. The altitude speed regime which has been explored and remains to be explored is shown in Figure VI-2. The initial exploratory program is expected to be completed in 1963. Significant results to date are the attainment of its design speed of Mach number 6.04, attainment of an altitude of over 200,000 feet, successful application of reaction control, demonstration of manned capability at supersonic and hypersonic speeds, integrity of the structure at temperatures ranging from 700 to 1200° F., confirmation of wind tunnel results, and development of long life throttlable rocket engine capability with fail-safe features and restart capability.

The future program of investigation planned for the X-15 after completion of the initial objectives will be geared to supersonic transport, lifting reentry spacecraft, aerospaceplane and space science problems.

3. *Supersonic Transport*

A substantial effort has already gone into the supersonic transport concept and NASA is cooperating actively with the Federal Aviation Agency and the Department of Defense in the supersonic transport development. A detailed research program involving the Ames, Langley, Lewis and Flight Research Centers of NASA has been established and will be undertaken in cooperation with the FAA and the Air Force. This program is aimed at providing research information to answer questions in critical problem areas by 1963. The timing should permit construction of the aircraft to start in 1964 with flight testing occurring three to four years later and culminating in type certification in this decade. When the final configuration is determined and construction starts, the NASA effort will concentrate on development studies and experimentation relating to the specific design.

The problems which are foreseen for the next decade which arise as a result of the supersonic transport effort are brought about by the operational speed and altitude and the customer requirements. The customer requirements are not firmly established but could include the following:

Must equal today's standard for reliability.

Minimum increases in fares over subsonic transports.

Must operate from 10,000 foot runways.

Must have an operating life in the order of 30,000 hours for major portion of airframe.

Must meet the same standards of comfort as slower aircraft.

Must have no serious limitation on operation such as limited flight over populous areas due to noise.

These requirements, when combined with the speed and altitude requirements of cruising at Mach 3 and 70,000 feet, give rise to problems of aerodynamic configuration, construction methods, materials, power plants, fuels, air conditioning system, supersonic noise, etc.

4. *Hypervelocity Lifting Vehicles and Advanced Concepts*

A major portion of the NASA effort in manned hypervelocity lifting vehicles is devoted to the Air Force Dyna-Soar project. This effort includes the complete flight spectrum of booster, launch abort, high altitude flight, reentry and landing. The magnitude of the problems is illustrated in part by a comparison of stagnation temperature between the X–15 research airplane and the Dyna-Soar. The stagnation temperature on the X–15 reaches 1200° F., while the Dyna-Soar may reach 2500° F. when reentering from orbital or near-orbital speeds. Furthermore, these reentry temperatures must be sustained for a relatively long period of time. The Dyna-Soar requirements dictate the use of high temperature radiation cooled structures. The basic research areas being investigated by the X–15 aircraft must therefore be extended over a much larger altitude speed regime. In addition to this large area of research, NASA has a prime responsibility for flight instrumentation in the Dyna-Soar and will have direct participation in the flight test program.

In the advanced aeronautical concept area, studies and experimental work are being conducted on the application of the flexi-wing to recovery of rocket boosters, to the Apollo space capsule, and to utility aircraft. For hypersonic flight within the atmosphere, analytical studies of air breathing propulsion systems and basic aerodynamic configuration are being studied to provide information applicable to such concepts as the aerospaceplane. The level of effort in these areas in the future is entirely dependent on showing practicability of these concepts.

C. GENERAL RESEARCH

The research effort is aimed at a continuing search to understand the fundamental behavior in such fields as physics of fluids, materials, structures, polymer chemistry, ceramics, metallurgy, solid state physics, ablation phenomena, fatigue and effects of space environment. A few typical examples are as follows:

1. *Physics of Fluids*

The properties and flow behavior of fluids in gaseous, liquid and plasma states must be extended over a much wider range. For example, the temperature range must be extended to cover from near absolute zero to temperatures approaching that of the sun. The pressure range must be extended from near absolute vacuum conditions, where a fluid must be considered as a collection of discrete particles, to several thousand atmospheres. Thermodynamic, transport, and radiation properties are almost completely lacking outside of the more conventional temperature and pressure ranges. The property of fluids over these wide ranges of conditions is important to such practical problems as reentry heating, magnetohydrodynamics for power generation and propulsion, nuclear turboelectric power generation, etc.

2. *Materials*

Work in the basic materials sciences of physics, chemistry, and metallurgy, forms the basis for developing new materials and increasing the operating temperature of materials. The objective in regard to increasing the operating temperatures is shown in Figure VI–3, which gives the estimated maximum operating temperatures of the best high temperature materials versus years and some of the known requirements.

3. *Plasma Accelerators*

The interest in plasma accelerators stems from their application to power generation, propulsion and communications systems. Typical applied research problems are:

- Wall cooling,
- Electrode surface phenomena,
- Flow stability,
- Pre-ionization methods,
- Plasma characteristics,
- Light weight magnets,
- Leakage current in the boundary layer,
- New measurement techniques.

The requirement for light weight magnets with low power requirements leads to the investigation of superconducting materials. This problem in applied materials research involves investigations at near absolute zero where materials exhibit superconductivity. This aspect of the materials problem is in contrast to the high temperature materials problem mentioned previously.

D. NUCLEAR SYSTEMS

Nuclear systems technology includes the work required for development of:

- Nuclear Rocket Engines,
- Electric Propulsion,
- Nuclear Power Generation Systems.

Electric propulsion is dealt with under nuclear systems because the large power requirements can only be provided by power generating systems using a nuclear heat source.

1. Nuclear Rocket Engines

The nuclear rocket development is jointly sponsored by NASA and the AEC. The program is directed through a Joint NASA-AEC Program Office. To support these developments a National Rocket Development Center is under construction in Nevada. The long range objectives of this Joint NASA-AEC development are to develop nuclear rocket engines of high specific impulse of reasonable weight, and to apply these engines to propulsion of launch vehicle stages and spacecraft. The requirement for stages and spacecraft powered by nuclear rockets arises out of the limitation of chemical launch vehicles. A nuclear rocket powered upper stage has a potential of delivering two to three times the payload to escape velocity of an equivalent chemical system. Launch vehicles with nuclear stages are applicable to:

- Lunar base supply,
- Manned lunar trips,
- Solar probes,
- Venus and Mars orbit missions,
- Probes to the outer planets.

The nuclear rocket propulsion program, designated Project ROVER, includes the following developments:

(a) KIWI reactor
(b) NERVA engine using KIWI reactor technology
(c) RIFT (Reactor in Flight Test) vehicle
(d) PHOEBUS reactor investigation
(e) High power reactor
(f) High power engine

The power level, thrust and application of these developments are:

Development Items	Power Level Mw.	Thrust Level lb.	Application
• KIWI Reactor	1100	50,000	Test
• NERVA Engine	1000-2000	50,000-100,000	3rd Stage of Saturn C–5 and NOVA
• RIFT	1000-2000	50,000-100,000	Ballistic Flight Test Stage
• PHOEBUS Reactor	Investigation of high reactor power densities		
• High Power Reactor • High Power Engine	10,000-20,000	500,000-1,000,000	Second Stage C–5

The schedules for the above developments are given in Figure VI–4.

The technology effort will be a continuing one during the engine development programs. Investigations already under way include:

- Determination of liquid hydrogen properties,
- Radiation effects,
- High temperature hydrogen nozzle flow phenomena,
- Shielding design.

The NASA-AEC funding is shown in Table VI–2. Development of stages using the nuclear rocket engines are included in the vehicle program for Manned Space Flight.

2. *Electric Propulsion*

Electric propulsion engines are under development for various spacecraft applications. Typical applications are:

- Vernier corrections,
- Interorbital transfer,
- Transfer from earth orbit to lunar orbit,
- Interplanetary and deep space probes.

The three classes of electrical thrust units which are under investigation are the electrothermal (arc jet), the electrostatic (ion), and electromagnetic (magnetohydrodynamic). The development goals, in terms of thrust, are shown in Figure VI–5 as a function of calendar year. Many development problems must be solved to meet these goals. At the present time, laboratory investigations of the three types of engines are directed toward determining their feasibility at the 30 KW level. The electrothermal thrust device (arc jet) will be developed to operational use only in the 30 to 60 KW size. After the development of the 30 KW electrostatic (ion) and electromagnetic (MHD) types, it should be possible to determine which merits development in the 1500 KW size. Future requirements are expected in the 10-20 MW size.

The development and flight test schedules are given in Figure VI-6. Testing of the electric propulsion units will be accomplished in conjunction with nuclear power generation development.

3. *Nuclear Electric Power Generation*

The power requirements for spacecraft utilizing electric propulsion systems range from 60 KW to 10-20 megawatts. The turboelectric and thermionic generators utilizing a nuclear energy source are the only systems that can fulfill these requirements in the foreseeable future. When these power sources are not required for propulsion they can furnish power to the spacecraft. In addition they can be used as a stationary power source for a lunar base.

a. *SNAP 8*

The SNAP-8 (System for Nuclear Auxiliary Power) nuclear turboelectric system will deliver 30 or 60 KW depending on whether a single or dual turboelectric generator is used with the reactor. The development is based on present technology and the development flight tests will be conducted with a 30KW system. The flight tests are scheduled for 1966, 1967 and 1968. The three electric propulsion systems under development at the 30KW level will be flight tested with the SNAP-8. Initial emphasis will be on the power source rather than the electric propulsion device. Successful completion of the development flight tests at the 30 KW level will lead to useful spacecraft propelled by electric propulsion systems at the 60KW level. It is estimated that an electrically propelled spacecraft boosted into earth orbit by a Centaur could place 4000 to 6000 lbs. in orbit about Mars.

b. *Advanced Technology Pertinent to Turboelectric Systems*

For electrical propulsion systems boosted into Earth orbit by the Saturn C-1 and larger follow-on vehicles, it is necessary to develop systems capable of delivering powers in the megawatt levels. A planetary Saturn electric mission is planned for 1972. Because of the critical requirement for light weight, extremely high temperature systems are required. The goal is to provide reliable power at a specific weight of as low as 10 pounds of engine per electrical kilowatt for continuous operation of a year or longer as required by the intended planetary missions. Such a weight specification requires operation at temperatures of approximately 2000° F. This is beyond the present state of the art.

Present opinion is that the turboelectric system will be supplanted by the thermionic system. It is essential, however, that adequate applied research be conducted on both systems at this time so that more conclusive data will be available when a decision is required in regard to the megawatt systems. The technology program includes work on thermodynamic and transport properties of alkali metals at high temperatures, corrosion properties of materials, and high temperature materials.

c. *Advanced Technology Pertinent to Thermionic Systems*

Research has been initiated in nuclear direct conversion systems. The reactor direct conversion systems, if successful, offer promise of increased reliability and light weight over turboelectric systems. It is anticipated that the state-of-art will permit the start of development of a direct conversion device in FY 1966. This project will provide the experience required to evaluate the problems in direct conversion high power devices and to compare their performance and promise with turboelectric systems before deciding on the type of megawatt systems to be developed for specific missions.

d. *1 to 20 MW Nuclear Power Generation System Development*

The results of the above applied research program, together with the experience gained under SNAP–8, will permit a decision to be made in Fiscal Year 1966 to proceed with the development of a 1500KW nuclear electric system. It is planned to flight test this system in a Saturn vehicle during Calendar Year 1969. With the experience gained from the 1500KW conversion system and the successful resolution of the increased material and safety problems it should be possible to begin the early phases of development of even higher powered electrical conversion systems in Fiscal 1968 for use with follow-on vehicles during the period beyond 1970.

e. *Facilities for Testing High Power Nuclear Electric Generating Systems*

It will be necessary to support 1 to 20 MW work with suitable test facilities. They must be started about Fiscal 1964 to enable the testing of high power prototype reactor-conversion systems on the ground. Proper facilities will include a vacuum environment to permit full electric propulsion system testing.

The development plan and flight schedule for nuclear electric power generation systems are given in Figure VI–7.

E. ADVANCED SPACECRAFT TECHNOLOGY

The technology required to support the spacecraft effort involves all scientific disciplines. The primary reason for requiring a large effort in this area is that the spacecraft must operate in an environment quite foreign to most previous experience. Instruments, subsystems and materials of the spacecraft must operate in an environment characterized by extremely high vacuum, electromagnetic radiation, high energy particle radiation, meteorite bombardment, and in some instances high levels of acoustic energy. When equipment will not operate under the natural environment of space, an induced or man-made environment must be provided.

Added to the requirement for satisfactory operation of the spacecraft in a space environment is the requirement for extended operating life. This requirement demands that emphasis be placed on design simplicity.

The effort in spacecraft research and technology is directed at broadening the spacecraft operating base rather than toward improving spacecraft already underway for specific missions. The effort is broken down into the following broad categories:

1. Materials, structures, and mechanical elements.
2. Applied physics and chemistry.
3. Reentry aerodynamics and heat transfer.
4. Landing and recovery systems.

The work to be accomplished under these categories is quite varied and is illustrated by the following typical examples:

1. Materials and Structures

The solid matter in space varies over a wide range of size, mass, density and velocity. The three classes of meteorites generally encountered are iron-nickel, stoney, and pithball (dust and frozen gases) with densities of approximately 3.4, 0.05 and 0.03 grams/cc respectively. The meteorite velocity in the vicinity of the earth ranges from 7 to 45 miles per second. Damage to a spacecraft by this space matter results from penetration and erosion.

Additional meteorite experimental data must be obtained from earth orbiting spacecraft to truly permit simulation of penetration and erosion conditions in ground based facilities.

2. Environmental Simulation and Testing

In general, environmental testing has been directed toward determining the effects of temperature, altitude, humidity, vibration, etc. Spacecraft are subjected to these and additional environmental conditions previously discussed. The facilities for ground research in spacecraft and their components therefore require radically new techniques. In addition, the trend will be toward facilities which combine many of the environmental conditions such as low pressure combined with thermal and ionizing radiation. Technical considerations may limit the number of environmental variables that can be combined. Tests in such facilities will include but not be limited to the following:

(a) Space heat sink to predict equilibrium temperatures.

(b) Instrumentation performance studies.

(c) Bearing and lubrication tests.

(d) Material and structure tests including meteorite damage experiments.

Since the problems associated with spacecraft technology are such that complete simulation cannot be accomplished in ground test facilities, a series of engineering satellites are proposed to extend the tests to the actual environment. The engineering spacecraft are as follows:

Name	Max. Weight lb.	Orbit N.M.	Launch Vehicle
• Model A	200	150 to 400	Scout or Delta
• Model B	5000	2000	Atlas-Agena B
• Model C (Recoverable Mercury Capsule)	2500	120	Atlas
• Model D	10,000		Saturn

The launch schedule for engineering spacecraft is given in Table VI-3.

F. CHEMICAL PROPULSION AND POWER GENERATION

The chemical propulsion and power generation program is planned to provide the technology for future chemical rockets and non-nuclear power generation systems. The program is designed to provide a maximum input to the manned lunar program and at the same time to support the unmanned program.

1. Chemical Propulsion

Decisions on the vehicle as well as the spacecraft for manned lunar missions are based on the assumption that extension of current technology will rapidly lead to suitable operational propulsion systems. Typical areas which must receive increased attention are:

- Engine clustering,
- Thrust vector control,
- Combustion instability,
- Variable thrust,
- Ignition and restart,
- Propellant handling,
- Thrust build-up and decay characteristics,
- Reliability,
- Components such as pumps, valves, sensors.

A typical problem which arises as a result of clustering engines is base heating and recirculation. Vector control in large engines is a problem due to their size and thrust level. A promising concept is fluid injection in the nozzle to divert the exhaust jet. This concept eliminates the need for gimballing large liquid rocket engines and swiveling the nozzle in solid rockets. Another problem in large engines is combustion instability. At present baffles are used to overcome certain instabilities. An interesting concept for large engines is to cluster several small combustion chambers and use a single nozzle and pump.

The above problems and concepts apply to large engines and require a strong technology effort. Similarly, many problems and concepts require investigation in smaller engines used for rendezvous, lunar landing, lunar takeoff and reaction control motors.

The responsibility for the technology and development of large solid rocket engines has been assigned to the Air Force by a NASA-DOD agreement. This effort will be followed closely for possible application to the Atlas, Saturn and Nova class boosters.

A continuing NASA effort in solid rocket technology will be aimed at exploiting the simplicity and reliability of solid rockets.

2. Power Generation

The special requirements of the space program and the military have sparked a tremendous interest in the development of all types of electrical power conversion systems. Figure VI–8 gives an estimate of the power requirements for the space effort versus years and the estimated output of the more promising techniques for space application.

The types of power supplies that have been used in spacecraft to date are:

(a) Photovoltaic solar cell

(b) Electrochemical battery

(c) Radioisotope-thermoelectric generator

The *space power program* will sponsor work in the following areas (Nuclear power generation is covered under Nuclear Systems.):

(a) Electrochemical battery

(b) Mechanical power conversion

(c) Photovoltaic solar cell

(d) Fuel cell

(e) Thermionic generator

(f) Thermoelectric generator

The space power effort is coordinated throughout the various government agencies by means of the Interagency Advanced Power Group and its Power Information Center.

The NASA effort in the areas listed above is as follows:

(a) *Battery*

The use of battery supplied power for satellites and probes uncovered serious deficiencies in sealed rechargeable batteries. It has therefore been necessary to sponsor work to correct these deficiencies by product improvement and development of new and improved types. The product improvement work consists of improving separators, seals, mechanical design and uniformity of electrical characteristics. Work is also under way to improve the watt-hour per pound ratio for the nickel cadmium and silver cadmium batteries. A continuing effort for several years in this area is anticipated.

(b) *Mechanical Power Conversion*

A 3 KW solar power system called "Sunflower" is now under development. The system uses a 32-foot diameter focusing solar energy collector to heat mercury which drives a multistage turbine and alternator. The mercury vapor is condensed and returned to the boiler. The design requirement in regard to life is 10,000 hours and it is estimated that it will be available for flight test in 1965 or 1966.

(c) *Photovoltaic Solar Cell*

One method of utilizing solar energy is by means of photovoltaic material which absorbs photons and causes a current to flow in the external circuit.

The majority of spacecraft to date have used the silicon solar cells. The major problems are efficiency, cost and radiation damage. Today the efficiency is between 11 and 13% and cost $250 to $300 per watt. The major effort therefore consists of improving efficiency, reducing cost and making them less prone to radiation damage. One method of increasing the efficiency is to concentrate more sunlight on the solar cell. Practical limits exist, however, since increasing the concentration of sunlight increases the temperature of the cell which reduces its output. It is this type of problem that must be investigated to obtain the objectives of better efficiency. Similar problems must be solved to lower cost and withstand radiation environment.

(d) *Fuel Cell*

The fuel cell is a method of converting chemical energy directly into electricity. A fuel is oxidized, products of oxidation are discharged and energy of the chemical reaction is released as electricity. The primary differences between a battery and a fuel cell are that the electrodes in the fuel cell are inert and the fuel and oxidant are fed continuously. A battery generates electricity only until the oxidant and reducant are used up.

The space power program is supporting the development of a regenerative hydrogen-oxygen fuel cell for possible application with solar cells for energy storage. In addition a contract has been let for the development of a flight prototype hydrogen-oxygen fuel cell system in support of the Apollo manned spacecraft program. Work on liquid metal fuel cells may also offer interesting possibilities.

(e) *Thermionic Generator*

The thermionic generator is based on the fact that every material surface emits charged particles, including electrons, in proportion to the material's temperature. The exciting possibilities of the thermionic device are that it holds great possibilities of converting heat directly to electric power. The heat source may be focused sunlight, radioactive isotopes or a high temperature nuclear reactor.

The success of the effort in thermionics is highly dependent on a high temperature heat source, availability of materials to withstand the temperatures, etc. This technology work will be coordinated with the Nuclear Power Generating effort since the nuclear reactor is the most promising high temperature energy source.

(f) *Thermoelectric Generator*

The basis of the thermoelectric principle is that when two different materials are joined a difference of potential appears at the exposed terminals which will cause a current to flow in an external circuit. The potential difference increases as the temperature of the joint increases in relation to the temperature of the materials away from the joint. While both the thermoelectric and thermionic systems depend on the flow of electrons little overlap in application is expected. The electrons in the thermoelectric devices flow from one solid to another and operate at relatively low temperatures and therefore have a relatively low potential output. The thermionic devices depend on high temperatures and have a high potential output.

The thermoelectric generator can use any heat source. The powering of two transmitters in the Navy's Transit IV–A navigation satellite represents the first application of a thermoelectric generator, using a radioisotope as a heat source.

The details of the NASA effort in this area will be determined in the future by coordination with the efforts of other agencies and future spacecraft requirements.

G. ELECTRONICS AND CONTROL

The Electronics and Control Program is divided among the following four functional areas:

1. Guidance and Navigation
2. Controls and Stabilization
3. Communications and Tracking
4. Instrumentation and Data Processing

The status of the technology in these areas is a pacing or limiting factor in many NASA projects. The objective of work is to develop the technologies so as to reduce the limitations and improve the efficiency.

Following are some examples in general terms of the type of work which will be done in the Electronics and Control Program.

1. Guidance and Navigation

Flight paths are of primary importance in space exploration. Therefore the study of the mechanics of trajectories is fundamental. The studies conducted will include the constraints imposed by mission timing and duration, radiation belt problems, fuel limitations, planet times of opportunity, and so on. Availability of continuous low-thrust mechanisms for propulsion will present new problems. Simple and rapid methods and mechanisms for computation will have to be developed for use in actual flights. This will in turn necessitate work in the field of computer components, circuitry, and logic.

Guidance may be divided into injection, midcourse, and terminal phase, with various degrees of trade-off depending on mission and trajectory constraints. The take-off point for work in this area is the radio and inertial techniques and devices developed by the missile industry. When continuous thrust becomes available, continuous guidance may prove desirable. The general objectives in guidance sensors are sensitivity (both high and low), accuracy, reliability, low power consumption, and long life. Both passive (gyroscopes, accelerometers, radio) and active (radar and radio) sensors will have to be developed for special purposes.

2. Control and Stabilization

Examples of the type of control and stabilization problems which have been or may be engendered by NASA projects are:

(a) An Orbiting Astronomical Observatory requirement for orientation to 0.1 seconds of arc for periods of hours;

(b) A possible requirement for even greater stability, if the potential for high gain from the pencil beams of LASER communications systems in deep space is to be realized.

Solving control and stability problems of this type requires both "eyes" and "muscles," sensors to determine deviations, and torqueing devices to remove the deviations. The general remarks made about sensors in the preceding section can be repeated here, although the sensing devices themselves will probably be different. Star trackers will require extensive effort. As for torqueing mechanisms, the standard devices are mass expulsion jets and various inertial reaction wheels, etc., all of which will merit effort for improvement. Non-standard methods using effects like solar radiation pressure, magnetic fields, and gravity gradient will also be investigated.

NASA's manned flight projects demand extensive investigation of the optimum role of man in space. This is and will be a complex function of the capabilities of man and equipment. Also involved in the man-machine interface will be the problem of developing information displays to optimize the human absorption of available data.

Mechanization of control systems will require extensive analytical effort in servomechanism theory.

3. Communications and Tracking

Effort in these areas will be concentrated in the direction of improving the technology in problem areas which are unusual and would not ordinarily be treated by the communications and electronics industries. The basic general problems in this category involve:

(a) Methods for more efficient coding and transmission of data, that is, more bits of useful (as opposed to redundant) information per unit time per unit of power;
(b) Efficient transmission of data over distances ranging from a few hundreds of miles for low earth orbiting satellites to interplanetary, and ultimately greater, free space distances;
(c) The effects of ionospheres, both terrestrial and planetary, on data transmission and tracking accuracy;
(d) Improved accuracy in measuring time, range, and range rate of spacecraft at planetary (and ultimately greater) distances from the earth.

The foregoing problems will require effort in:

(a) Information theory and its application.
(b) Modulation and demodulation techniques.
(c) Solid state physics and molecular electronics.
(d) Network theory.
(e) Radio communications technology, including the optical range.
(f) Antennas, both vehicle and earth based.
(g) Propagation phenomena in space.

4. Instrumentation and Data Processing

These two areas have to be looked on both independently and in relation to each other. Instrumentation is fundamental to scientific investigations, and the ultimate assimilation of the data acquired from the sensors is the objective of the investigations. The data processing between acquisition and assimilation is an area which will be of increasing importance as NASA's projects grow more complicated and more numerous. As matters stand at present, the data from successful space missions will saturate the receivers unless adequate data handling is designed and provided. For example, processing large numbers of cloud cover photographs from weather satellites in time to be of value in weather forecasting poses a problem both in volume of data and speed of handling. Another example is the complex checkout procedure in a prelaunch countdown, where a tremendous number of interrelated variables have to be reduced to a simple decision between go and no-go.

The areas that will be worked on in connection with the foregoing type of problems include:

(a) Models of and tests with physical (including biological) sensors and transducers;

(b) Physical references and standards for space, including planetary atmospheres;

(c) Analog-to-digital and digital-to-analog transducers;

(d) Automated equipment, including special purpose computers;

(e) Sampling techniques and devices;

(f) Data processing techniques, components, and devices in general (magnetic and electrostatic tape, cores, transducers, logic processes and mechanisms, and information retrieval circuitry).

H. TOTAL NASA ADVANCED RESEARCH AND TECHNOLOGY

In addition to the Advanced Research and Technology discussed in this Chapter, each of the four major program offices conducts a certain amount of such work under its own direction. This work is done both in-house and under contract. The contract research and development has been listed as appropriate in each of the previous chapters. The amount that is done in-house has to be estimated since it is difficult to determine in many cases whether a project is of a general nature or is directly connected with a specific development. Making certain assumptions in this regard, estimates have been made of the total part of the NASA Plant Operation that should be assigned to Advanced Research and Technology.

Based on the above information and estimates the total NASA Advanced Research and Technology funding is as shown in Figure VI–9. It is noted that the amounts range between 15 and 20 percent of the NASA total budget, leveling off at a figure of 17 percent.

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FIGURE VI-1

MAXIMUM SPEEDS OF AIRCRAFT

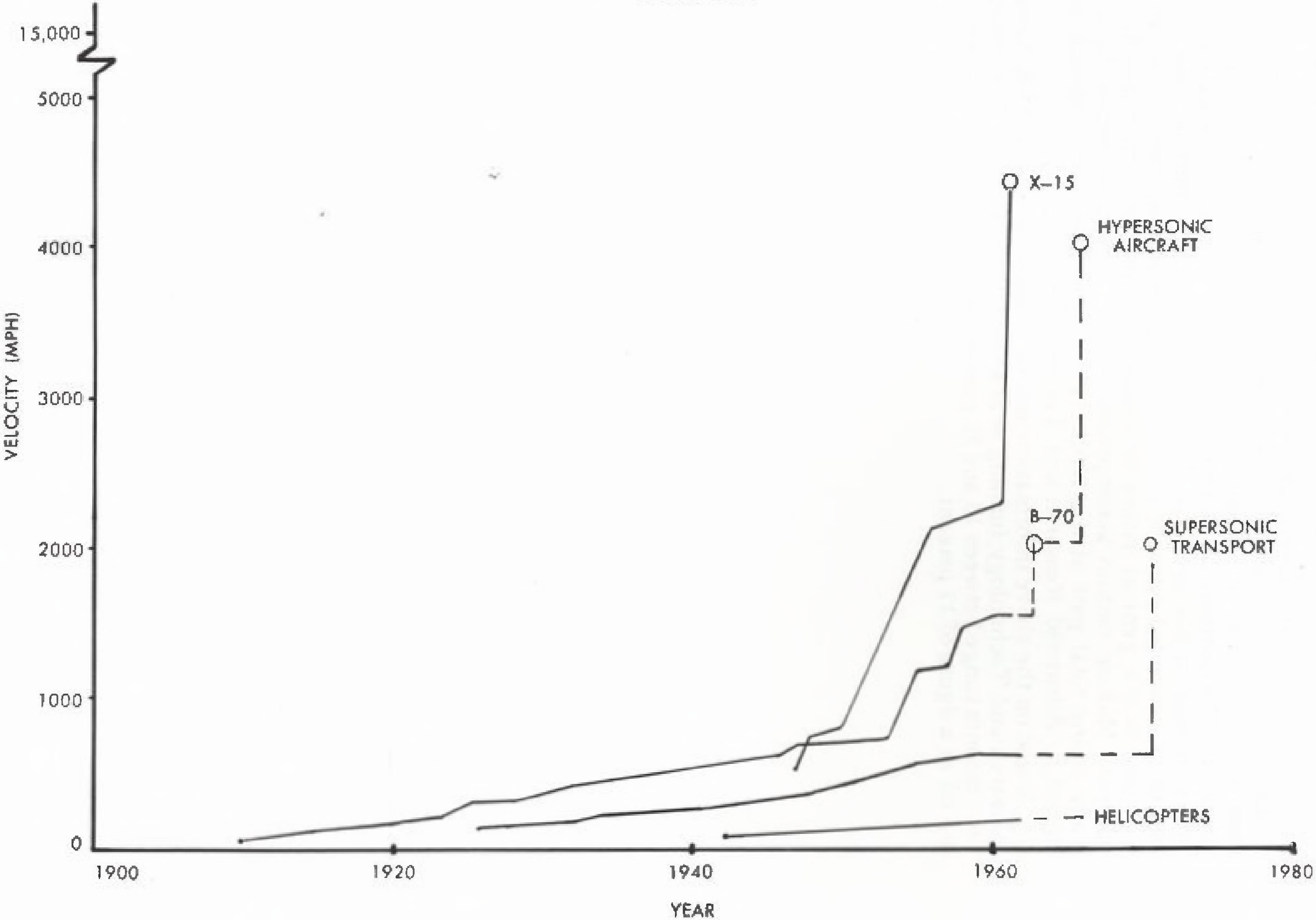

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FIGURE VI-2
ALTITUDE-VELOCITY
REGIME OF X-15 RESEARCH AIRPLANE

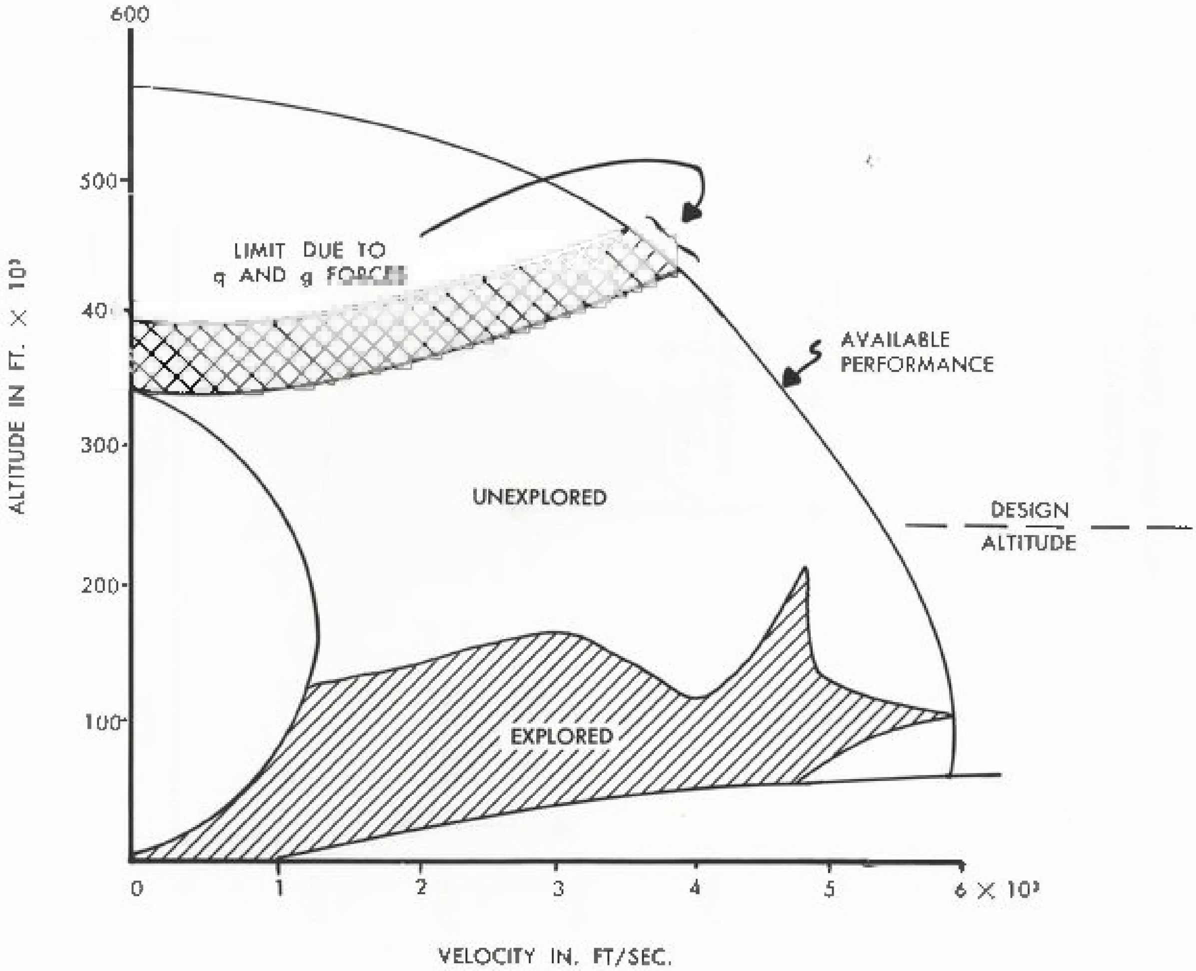

FIGURE VI–3

MAXIMUM OPERATING TEMPERATURE OF MATERIALS, & REQUIREMENTS

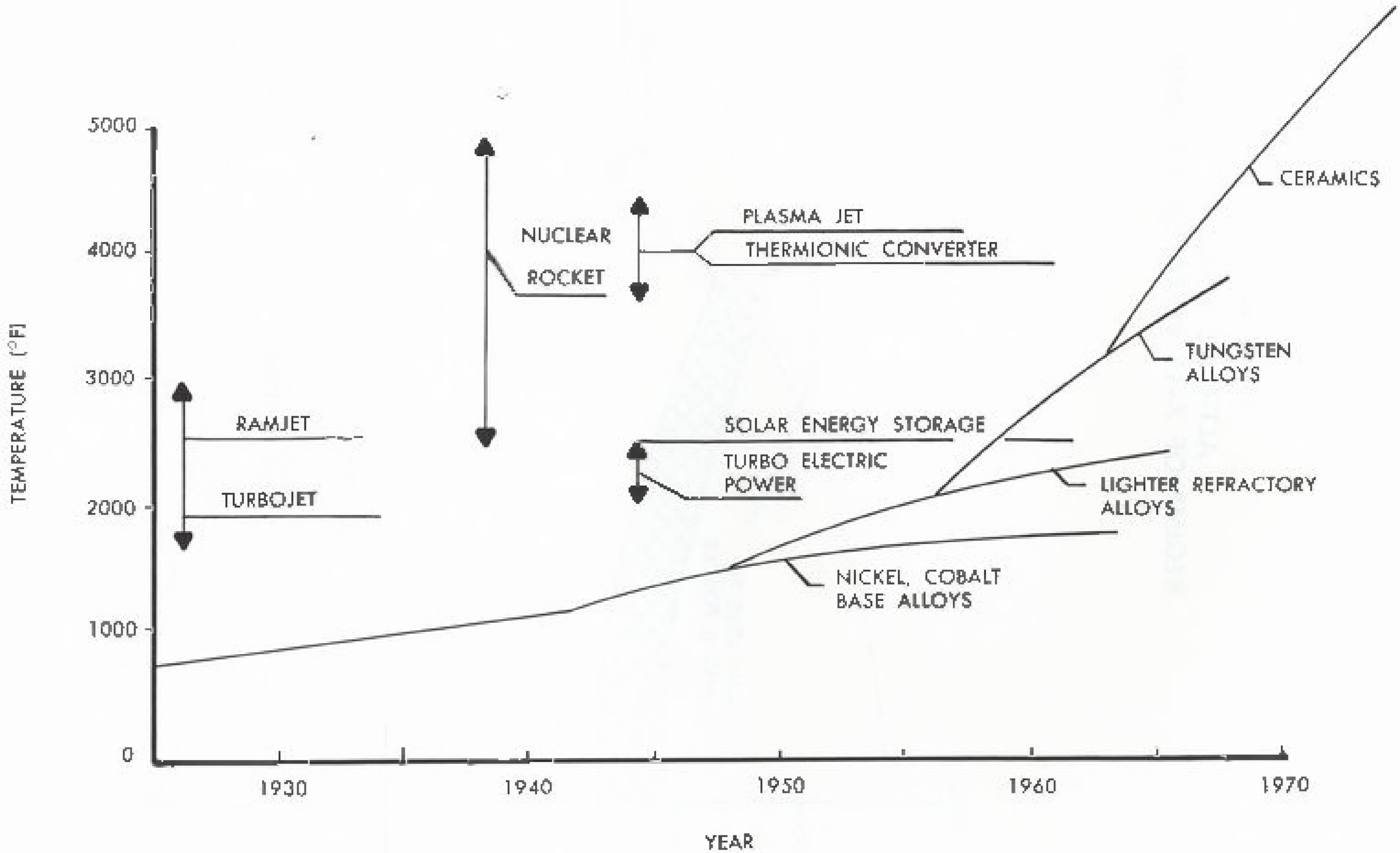

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FIGURE VI-4

NUCLEAR ROCKET ENGINE DEVELOPMENT

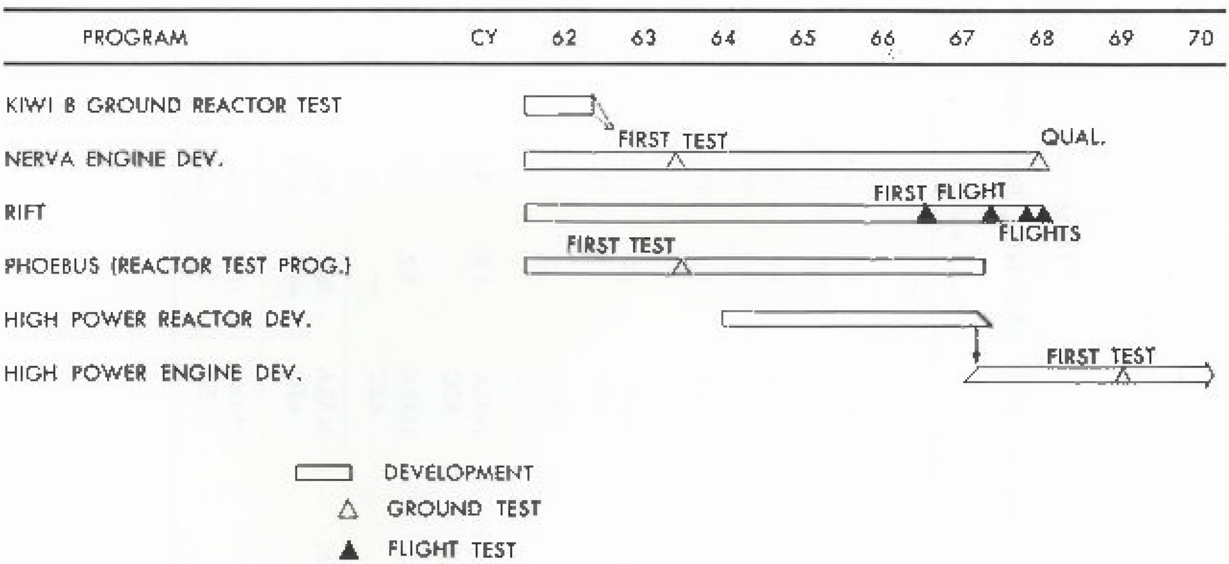

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TABLE VI–2

NASA AND AEC NUCLEAR ROCKET FUNDING

Cost in Millions of Dollars

PROGRAM	FY	62	63	64	65	66	67	68	69	70
KIWI	NASA	3.8	2.4							
	AEC	36.6	13.9							
NERVA	NASA	15.0	35.0	45	45	39	35	20	15	10
	AEC	7.1	46.1	60	60	55	30	30	5	5
RIFT (including boosters)	NASA	1.0	25.0	74	90	70	33	30		
	AEC	—	—	—	—	—	—	—		
PHOEBUS & HIGH POWER REACTOR	NASA	2.5	2.6	9	10	12	12			
	AEC	.5	21.3	28	25	30	35	25	12	5
HIGH POWER ENGINE	NASA						10	32	66	78
	AEC						10	30	60	50
HIGH TEMPERATURE REACTOR & ADV. TECH.	NASA	1.0	5.0	6	5	5	5	5	5	5
	AEC		0.5	16	16	28	15	10	10	10
PROPELLANTS	NASA	2.2	10.0	12	15	20	35	33	29	22
	AEC	—	—	—	—	—	—	—	—	—
RESEARCH & TECHNOLOGY TOTAL	NASA	25.5	80	146	165	146	130	120	115	115
	AEC	44.2	81.8	104	101	113	90	95	87	70
FACILITIES	NASA	16.2	41	25.8	5.5	5	5	25	20	10
	AEC	7	10	23	5	—	—	—	—	—

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FIGURE VI-5

DEVELOPMENT GOALS
ELECTRICAL PROPULSION ENGINES

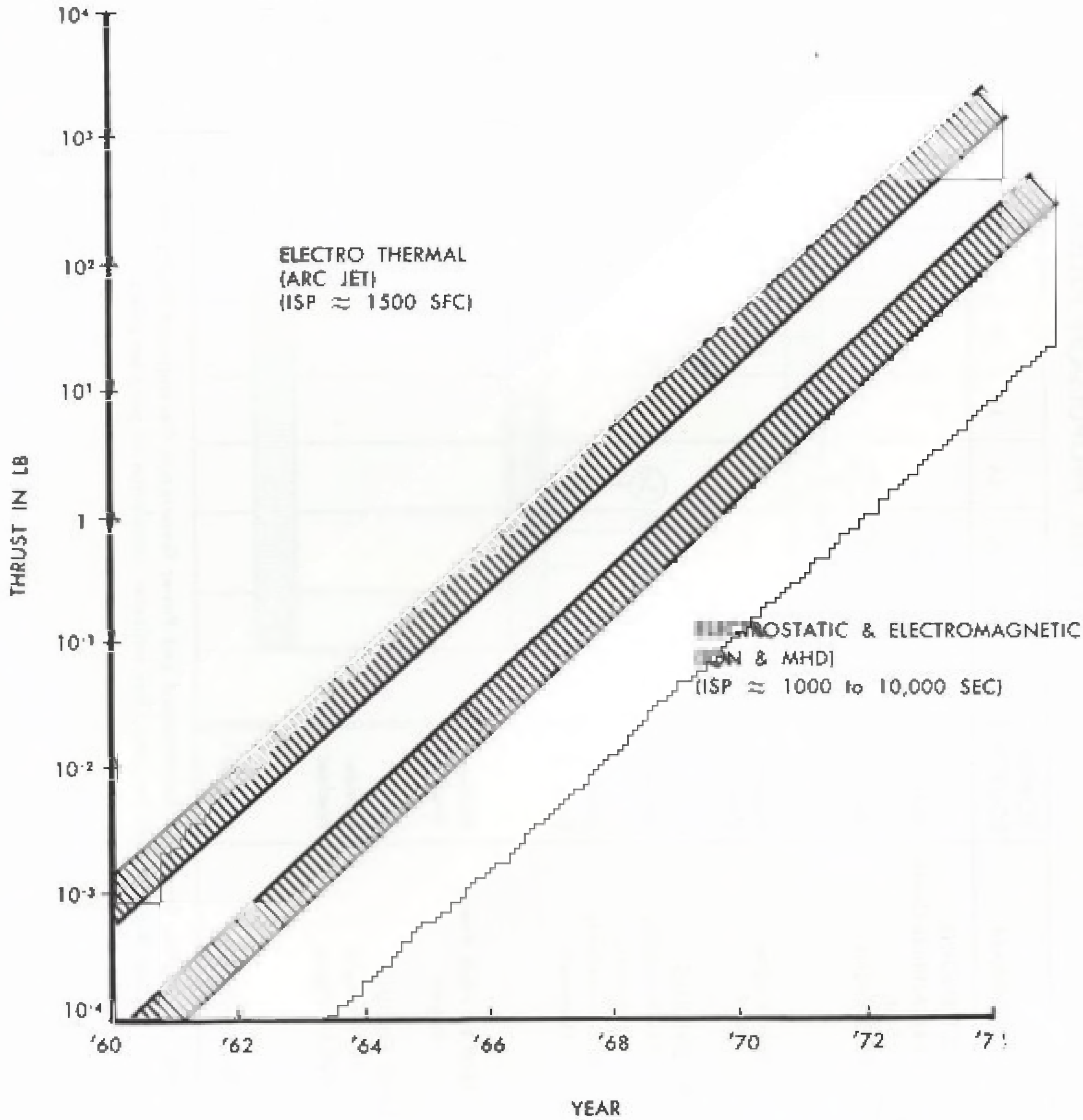

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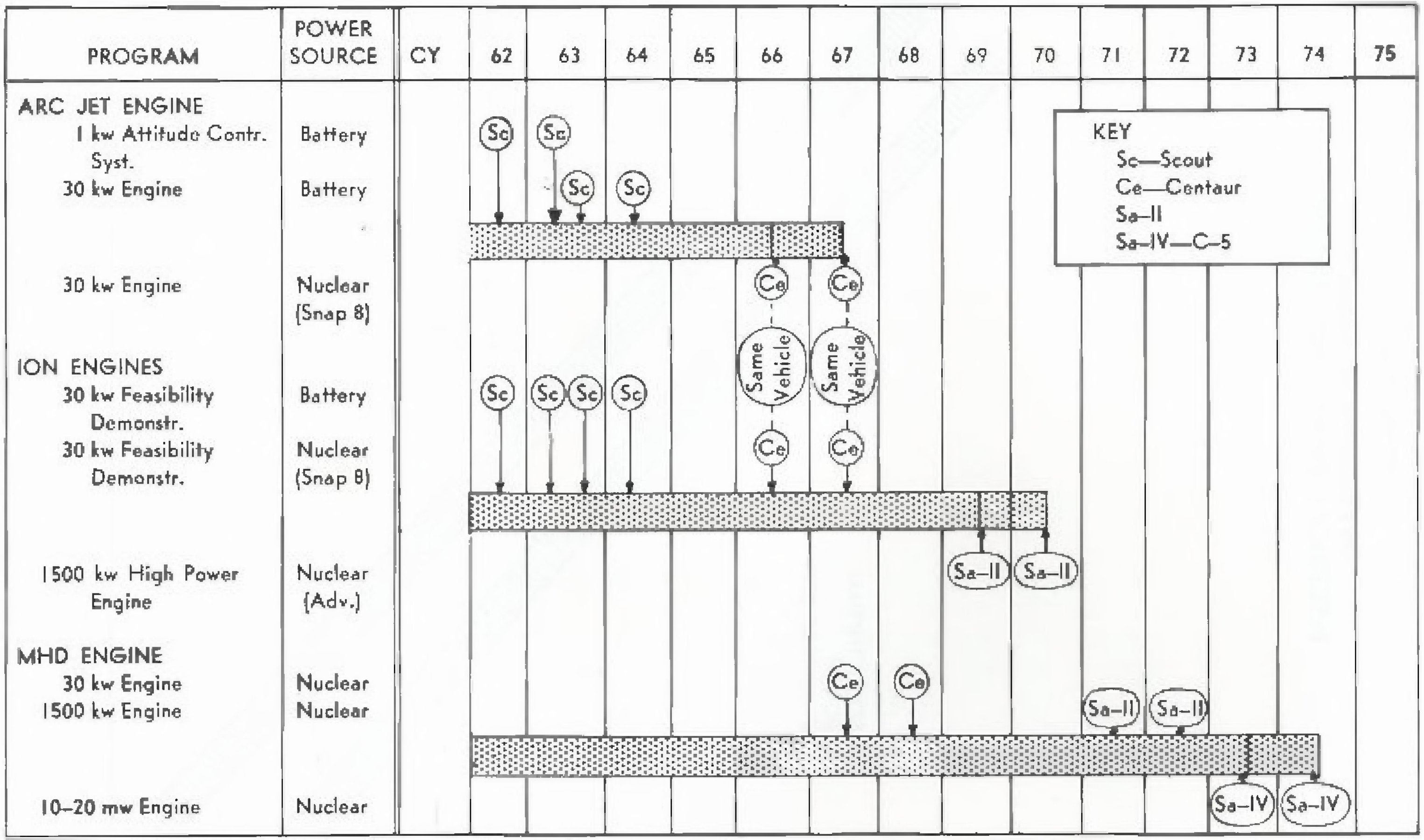
FIGURE VI–6

ELECTRIC PROPULSION PROGRAM



NOTES: 1. Electric Propulsion Development and Power Generation Development flights are the same.
2. Last flight in each horizontal line indicates completion of program phase.

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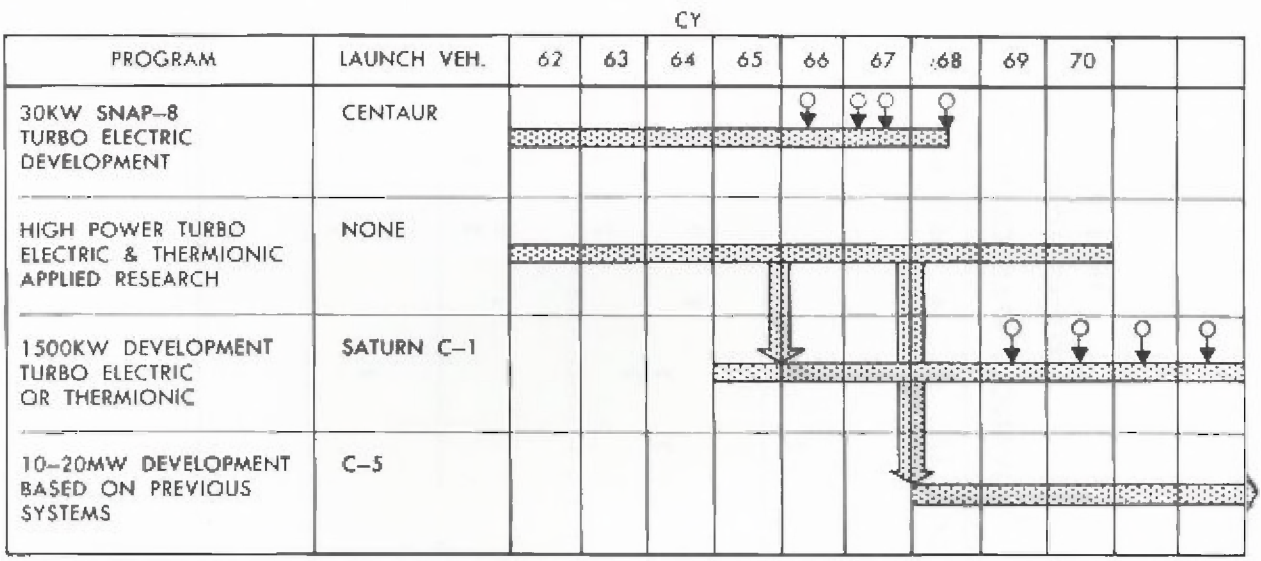
FIGURE VI-7

NUCLEAR ELECTRIC POWER GENERATION DEVELOPMENT AND FLIGHT SCHEDULE



O FLIGHTS

NOTE: NUCLEAR ELECTRIC POWER GENERATION FLIGHT TESTS TO BE USED TO TEST ELECTRIC PROPULSION ENGINES

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TABLE VI-3

FLIGHT SCHEDULE

ADVANCED SPACECRAFT TECHNOLOGY

VEHICLE/SPACECRAFT	CY	62	63	64	65	66	67	68	69	70	71	72	73	74	75
• AEROBEE-HI															
Paraglider Recovery of Meteorite Experiment		2	1												
• SCOUT															
Paraglider Recovery				2	2										
Supercircular Reentry		3	2												
Micrometeoroid Satellite			2												
Small Engr. Test Satellite					2	2	2	2	2	2	2	2	2	2	2
• ATLAS-AGENA-B															
Planet Reentry Test				1	1										
Intermediate Engr. Test Satellite					2	2	2	2		2		2			
• ATLAS															
Lunar Reentry Test			2												
Recoverable Engr. Satellite					2										
• SATURN (C-1)															
Large Engr. Test Satellite								1			1		1		

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FIGURE VI–8

ELECTRIC POWER FOR SPACECRAFT

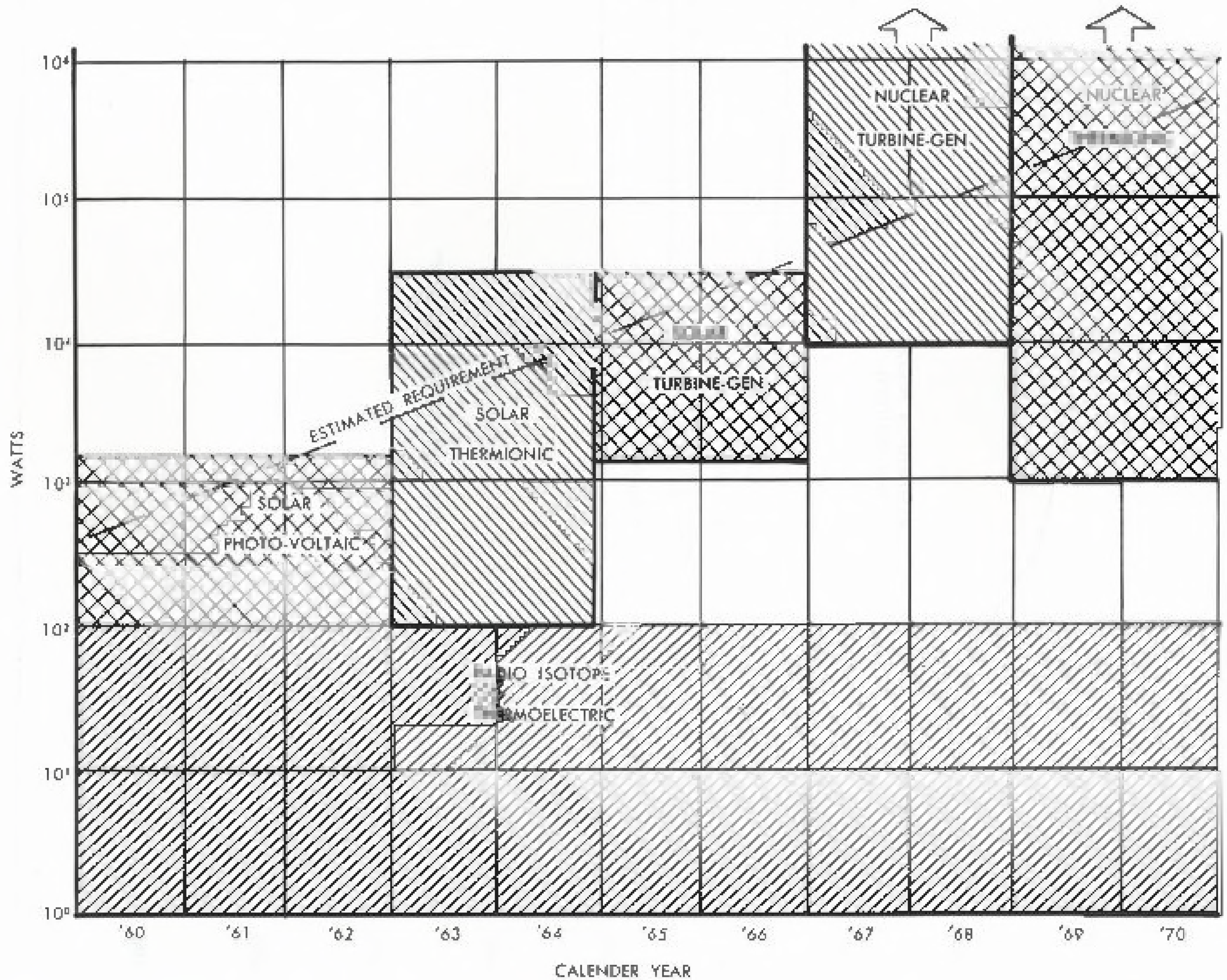

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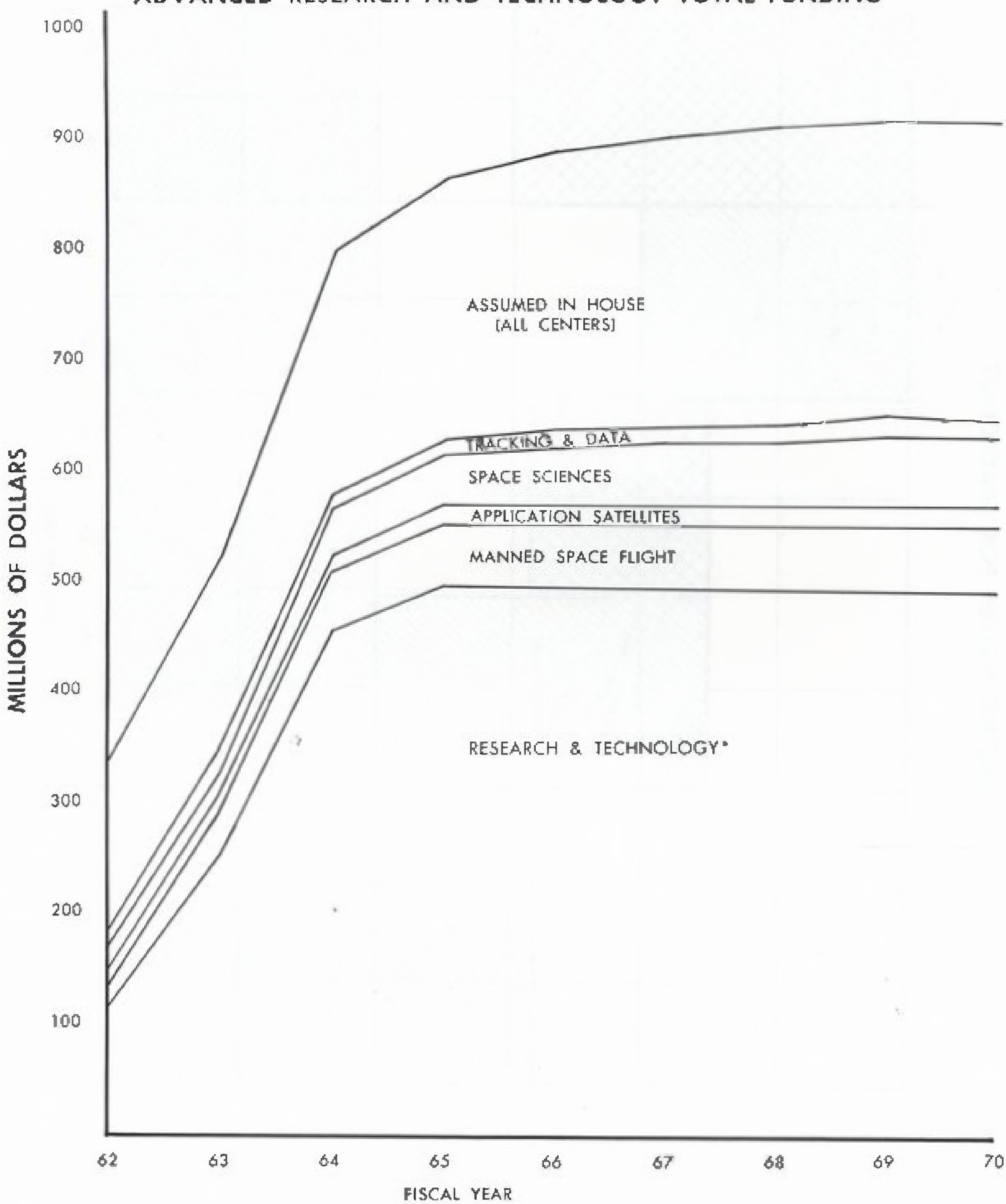
FIGURE VI-9

ADVANCED RESEARCH AND TECHNOLOGY TOTAL FUNDING



*Includes funding for all nuclear systems and electric propulsion systems

CHAPTER VII

MANPOWER PROJECTIONS

CHAPTER VII
MANPOWER PROJECTIONS

CHAPTER VII

MANPOWER PROJECTIONS

A. Manpower Requirements

B. Relation of Manpower Expansion to NASA Centers

MANPOWER PROJECTIONS

A. MANPOWER REQUIREMENTS

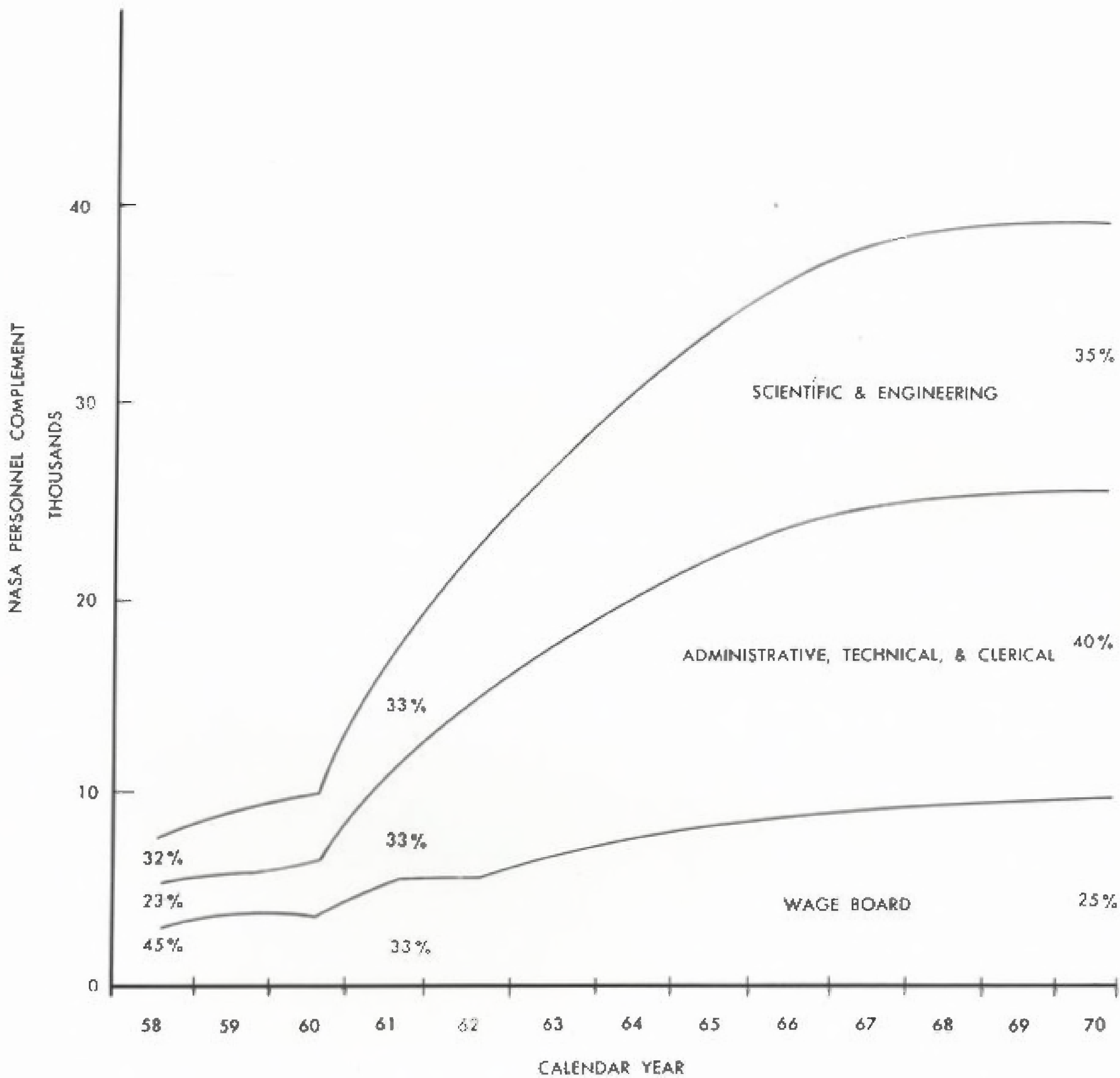
The NASA operation consists of both in-house and contract activities. In FY 1963 the in-house activity is estimated to be 13.5 percent of the total NASA effort. In FY 1965 it is estimated to be about 10 percent of the total.

The NASA establishment consists of the staff and facilities to conduct these in-house operations plus the staff required to monitor the contract operations. The estimated future NASA staff together with some past staff history is shown timewise in Figure VII-1. All data are for July 1 of the year listed, except that 1958 is for October 1, the date NASA was activated. The 10% increase (from 32% in 1958 to 35% in 1970) in the scientific and engineering portion of the staff and the 75% increase (from 23% in 1958 to 40% in 1970) in the administrative and clerical staffs reflect the trend toward greater contract operation.

FIGURE VII–1

NASA STAFF
(Excluding JPL)

Actual & Projected



CHAPTER VIII

IMPLICATIONS AND INFORMATION

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CHAPTER VIII

IMPLICATIONS AND INFORMATION

IMPLICATIONS AND INFORMATION

A. SYNOPSIS

NASA's Long Range Plan must also treat the broad but highly significant considerations posed by the international, economic, political, and social implications of space exploration. Related to these broad implications is the need to disseminate the findings from space science investigations and the advancement in technology.

The impact of space exploration upon American society very likely will present economic, political and social problems requiring study. A schedule for long-range pilot studies is contained in Figure VIII-2. Studies in the various areas outlined will be initiated only after careful consideration of the need and potential benefits.

B. INTERNATIONAL PROGRAMS

The international programs of the National Aeronautics and Space Administration demonstrate the peaceful purposes of space research and exploration by the United States, enlist the constructive participation of scientists of other countries in the task of increasing man's understanding and use of his spatial environment, and support NASA operating requirements for the launching, tracking and observation of sounding rockets, satellites and space probes.

Authority for NASA's international program activities rests in The Aeronautics and Space Act of 1958, Sec. 102(c).*

Present and planned international activities include satellite programs, sounding rockets, ground-based programs and overseas operations. Some of these have been previously presented in appropriate NASA program areas. The actual and anticipated programs are shown graphically in Figure VIII–1.

In the *satellite program*, two nations, Britain and Canada, are preparing satellites for launching by NASA in 1962. Additional satellites have been proposed by France, Italy and England and are currently under consideration. It is reasonable to expect additional proposals from the European Space Research Organization (ESRO), West Germany and Japan.

Two to three launching vehicles per year of the Scout class are provided for support of this program. This level should be adequate for the remaining portion of the decade, since a number of foreign nations may be expected to develop independent booster capability. Also, availability of large NASA satellites toward the middle of the decade should permit some development of more integrated cooperative arrangements in place of the early "self-contained" European satellites boosted by NASA.

Joint sounding rocket programs have been arranged with ten nations, from Sweden in the north to Argentina in the south, and from Italy in the west to Pakistan and Japan in the east. Launchings have already taken place in half of these. The mode of cooperation in these cases is flexible, with each nation contributing and financing its own portion of a given program, whether payload, rocket launcher, ground equipment or services.**

It may be expected that the general level of NASA support through contributions of equipment and technical guidance in joint programs will continue through the decade with some 12 to 15 countries.

A projection of the probable international programs (which should involve Canada, France, Italy, Japan, New Zealand, Norway, Pakistan and Sweden) indicates that some 25 sounding rockets should be launched in joint activities during 1962. In addition, a significant proportion of those rockets which NASA will launch in its domestic program are designated as contributions toward international programs of interest to COSPAR.*** This brings the probable launchings of international character to some 40-50.

The program will accelerate very considerably in 1963 and 1964 on the assumption that organization of an Indian Ocean meteorological sounding

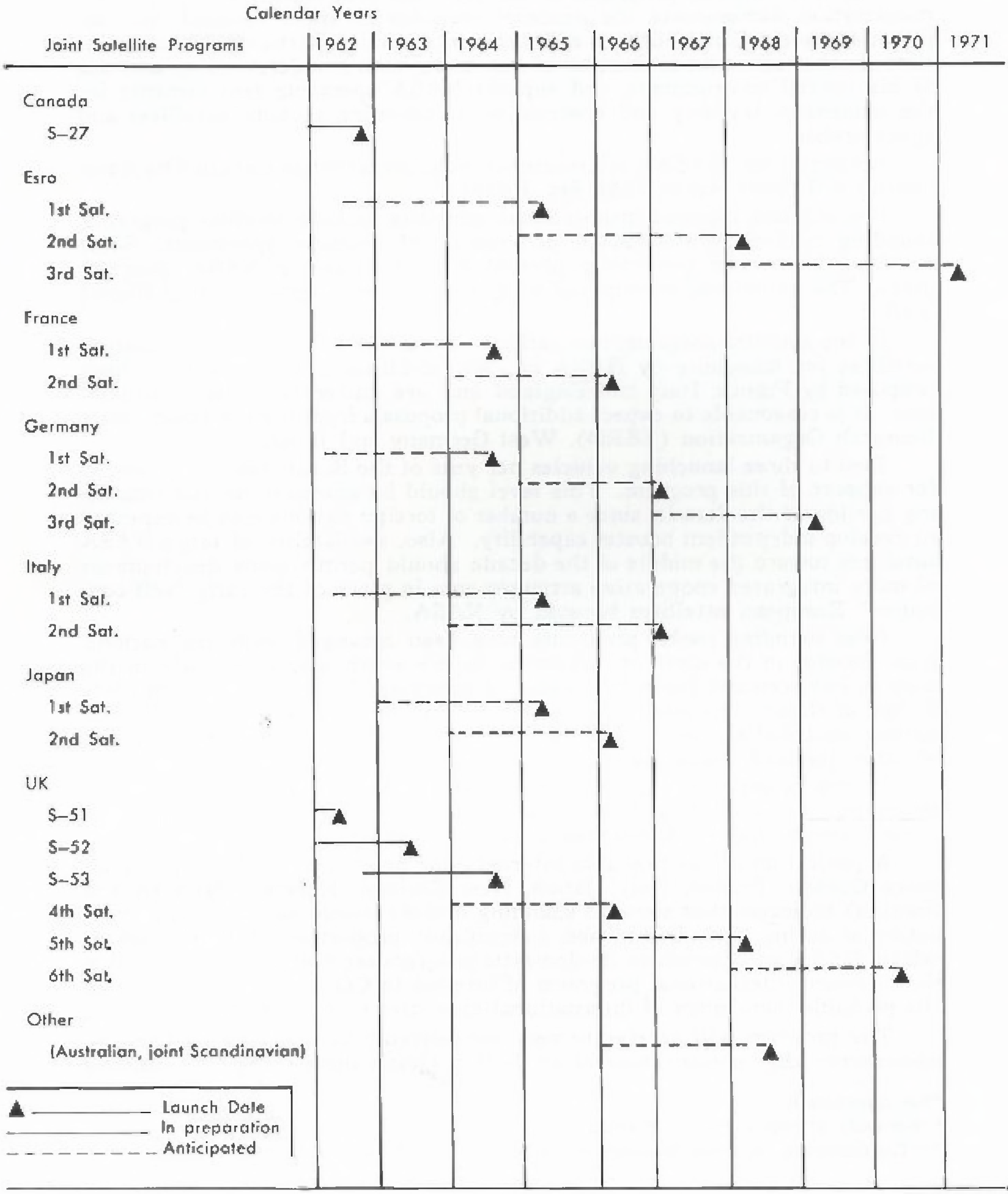
*See Appendix A

**Normally without exchange of funds.

***The Committee on Space Research of the International Council of Scientific Unions

FIGURE VIII-1

INTERNATIONAL PROGRAMS



rocket project in support of the International Oceanographic Expedition is successful. Under this program, some 300 rockets may be fired by some 7 countries during each of 1963 and 1964.

Ground-based research by foreign scientists in support of orbiting experiments increases the scientific value of satellite programs and increases the number of competent scientists attacking problems of data analysis and correlation.

Extensive ground-based cooperation in the communications and meteorological fields has been arranged and is planned for extension during the decade as the meteorological and communications programs increase in their scope and activity leading to global operational systems. Similar ground programs are planned in support of scientific satellites and probes.

NASA overseas operations for tracking and/or communication stations, located in or near foreign communities, present a unique opportunity for contributions to the pattern of open cooperation in space research. Training for increased participation by foreign nations in these operations is underway and planned.

Personnel exchange programs, bothe funded and non-funded, include (1) the provision of fellowships for foreign graduate students in US university laboratories engaged in space research and (2) support for extended lectures abroad by US university professors in the field. Some 25-35 US universities and 100 foreign students may participate by 1962-3.

In the area of international organizational activities, direct or indirect support is provided in the formulation and conduct of US policy relating to the space interests of the United Nations, NATO, WMO, ITU, COSPAR, and other world and regional organizations. The long-range responsibilities of NASA in this area may be expected to multiply with the increasing concern of international organizations for space activities.

C. IMPLICATIONS OF SPACE EXPLORATION: PILOT STUDIES

General

Section 102. (c) of the Space Act of 1958 states: "(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

> (4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;".

From time to time it is planned to undertake studies on the economic, social and political implications of space explorations. Not all studies listed in Table VIII-1 will be undertaken at once nor will they be continuous over the time period of the plan. A selective approach is planned initially and various studies will be repeated as new trends and new activity create a need for a reassessment.

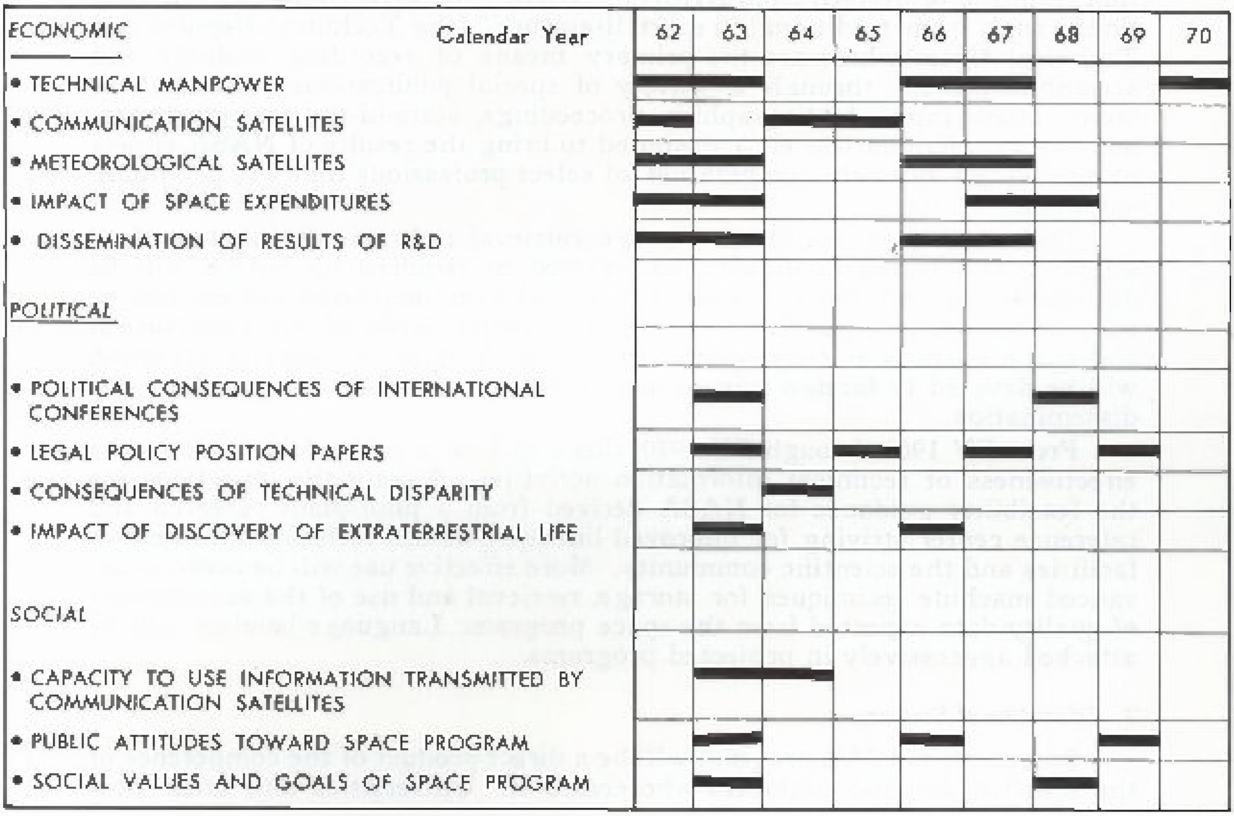
1. Studies on Economic Implications:
   - a. Scientific and Technical Manpower
   - b. Communication Satellite Systems
   - c. Meteorological Satellite Systems
   - d. Impact of NASA Expenditures upon the National Economy
   - e. Dissemination of the Results of Government Aerospace R&D into the Civilian Economy.

2. Studies on Political Implications:
   - a. Political, Diplomatic and Military Consequences of International Space Science Conferences
   - b. Legal Policy Position Papers to Meet a Variety of Space Technology and Political Circumstances
   - c. International, Political, and Economic Consequences of Space Technology Disparity between the USA and the USSR on the one Hand, and the Other Nations
   - d. Political Implications and Consequences of the Discovery of Extraterrestrial Life

3. Studies on Social Implications:
   - a. Capacity of Various Language, National and Cultural Groups to Understand and Use Information and Knowledge Transmitted by Communications Satellite Systems
   - b. Public Opinions or Attitudes about the National Space Program
   - c. Social Values and Goals of the National Space Program

FIGURE VIII-2

SCHEDULE FOR PILOT STUDIES ON ECONOMIC, POLITICAL, AND SOCIAL IMPLICATIONS



D. INFORMATION AND EDUCATION

General

Section 203 (a) (3) of the Space Act of 1958 states: "The Administration, in order to carry out the purpose of this Act, shall—(3) provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

1. *Technical and Public Information*

Major elements of NASA's long range technical information program concerns the preparation, publication, and distribution of technical information resulting or derived from NASA or NASA-supported endeavors. Publications range from traditional "report literature" (the Technical Reports and Technical Notes which are the primary means of recording findings and accomplishments) through a variety of special publications (technical reviews, monographs, bibliographies, proceedings, state-of-the-art summaries, handbooks, dictionaries, etc.) designed to bring the results of NASA efforts to the widest possible combination of select professions that will profitably use those results.

The acquisition, indexing, storage, retrieval and rapid distribution of all scientific and technical information created or required by NASA will be directed to the end that the over-all technical communication system can be fully and rapidly responsive to the informational needs of the aeronautical and space sciences as they relate to any NASA interest. Special attention will be devoted to foreign science and technology, including translation and dissemination.

From FY 1963 through FY 1970, there will be a gradual increase in the effectiveness of technical information activities. Among the objectives are the feasibility guidance for NASA derived from a pilot-plant research and reference center striving for improved linkage between technical information facilities and the scientific community. More effective use will be made of advanced machine techniques for storage, retrieval and use of the vast amount of quality data expected from the space program. Language barriers will be attacked aggressively in projected programs.

2. *Educational Services*

Success of NASA's program will be a direct product of the competence of the scientist and the engineers who create it. Universities and other academic institutions must be encouraged to supply the scientific and engineering talent that will be needed in addition to substantive research contributions. Materials of instruction will be developed for use by teachers and students at all age and grade levels to assist them in understanding the scope and challenge of space exploration. In addition, pamphlets and booklets on NASA programs and projects for distribution to teacher education and science education agencies will continue to be developed.

NASA plans to continue to participate in education programs and social movements to motivate youth to pursue scientific careers, and to stimulate their participation in space-science-oriented activities out of school. Some of the major groups and educational programs involved are: The National Science Fair—International; The Future Scientists of America Awards Program sponsored by the National Science Teachers Association; the Boy Scouts of America; Amateur Rocketeers of America; American Rocket Society, Youth Education Program; and the Aerospace Education Council (Air Force Association).

In general, long-range planning in NASA's educational services will be subject to change as critical needs develop. Cooperative efforts with all other federal agencies that have responsibilities and interests in promoting science education in and for the Space Age will be fully developed.

NASA has had a continuing program to communicate the objectives and results of its program to the general public through the medium of exhibits, which has educational, historical, technical, and scientific benefits over the long term.

3. *Historical Documentation and Analyses*

NASA's milestones are widely noted throughout the world; however, the full appreciation of the pace and complexity of scientific progress and technological accomplishment will be lost without a proper historical documentation and production program.

The first responsibility of the historical function instituted in government is to preserve, collect, and organize the information and data of historical significance. History provides a common frame of reference equally meaningful to the physical sciences, the social sciences and the humanities as well as the general public.

It is the long range plan in the historical program to provide chronological and narrative reports and monographs on major NASA programs, their origin, problems, and accomplishments. The reports will also cover related scientific and technological activities in which NASA participates or contributes. A permanent NASA Historical Archives will be established and maintained.

4. Public Information

The long range aspects of the NASA public information activities are designed to increase effectiveness of current efforts. These serve the immediate and high demand for general and specific knowledge concerning space exploration on a timely basis for use by all news media. Some attention must be given, as yet only under preliminary study, of timely communication to the general public of space science discoveries and general technological applications and complications. This new knowledge will be developed by program offices for dissemination by public information specialists. Specific opportunities in this area, such as demonstrated by the global impact of Echo I, must be fully anticipated and used in the best national interest.

2

APPENDICES

APPENDICES

APPENDICES

A. National Objectives in Space: Excerpts from the National Aeronautics and Space Act of 1958, July 29, 1958

B. National Policy in Space: Excerpts from the Special Message to Congress by the President of the United States, May 25, 1961

C. National and International Implications of NASA's Program: Excerpts from Speech by the Deputy Administrator of NASA, December 30, 1961

D. Long Range Economic Impact of the Lunar Program: Letter by the Deputy Administrator of NASA, June 22, 1961

E. NASA Organization

APPENDIX A

NATIONAL OBJECTIVES IN SPACE

Excerpts from the National Aeronautics and
Space Act of 1958
(Public Law 85-568), July 29, 1958

* * * * *

DECLARATION OF POLICY AND PURPOSE

Section 102.

(a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declared that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201 (e).

(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

1. The expansion of human knowledge of phenomena in the atmosphere and space;
2. The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;
3. The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;
4. The establishment of long-range studies of the potential benefits

to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

5. The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;
6. The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;
7. Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and
8. The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

(d) It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), and (c).

DEFINITIONS

Section 103. As used in this Act—

(a) The term "aeronautical and space activities" means:

1. Research into, and the solution of, problems of flight within and outside the earth's atmosphere;
2. The development, construction, testing, and operation for research purposes of aeronautical and space vehicles; and
3. Such other activities as may be required for the exploration of space.

(b) The term "aeronautical, and space vehicles" means aircraft, missiles, satellites, and other space vehicles, manned and unmanned, together with related equipment, devices, components, and parts.

* * * * *

APPENDIX B

NATIONAL POLICY IN SPACE

Excerpts from the Special Message to Congress
by the President of the United States
on May 25, 1961

* * * * *

IX. SPACE

Finally, if we are to win the battle that is now going on around the world between freedom and tyranny, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere, who are attempting to make a determination of which road they should take. Since early in my term, our efforts in space have been under review. With the advice of the Vice President, who is Chairman of the National Space Council, we have examined where we are strong and where we are not, where we may succeed and where we may not. Now it is time to take longer strides—time for a great new American enterprise—time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on earth.

I believe we possess all the resources and talents necessary. But the facts of the matter are that we have never made the national decisions or marshalled the national resources required for such leadership. We have never specified long-range goals on an urgent time schedule, or managed our resources and our time so as to insure their fulfillment.

Recognizing the head start obtained by the Soviets with their large rocket engines, which gives them many months of lead-time, and recognizing the likelihood that they will exploit this lead for some time to come in still more impressive successes, we nevertheless are required to make new efforts on our own. For while we cannot guarantee that we shall one day be first, we can guarantee that any failure to make this effort will make us last. We take an additional risk by making it in full view of the world —but as shown by the feat of astronaut Shepard, this very risk enhances our stature when we are successful. But this is not merely a race. Space is open to us now; and our eagerness to share its meaning is not governed by the efforts of others. We go into space because whatever mankind must undertake, free men must fully share.

I therefore ask the Congress, above and beyond the increases I have earlier requested for space activities, to provide the funds which are needed to meet the following national goals:

First, I believe that this nation should commit itself to achieving the goals, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish. We propose to accelerate development of the appropriate lunar space craft. We propose to develop alternate liquid and solid fuel boosters, much larger than any now being developed, until certain which is superior. We propose additional funds for other engine development and for unmanned explorations—explorations which are particularly important for one purpose which this nation will never overlook: the survival of the man who first makes this daring flight. But in a very real sense, it will not be one man going to the moon—if we make this judgment affirmatively, it will be an entire nation. For all of us must work to put him there.

Secondly, an additional 23 million dollars, together with 7 million dollars already available, to accelerate development of the ROVER nuclear rocket. This gives promise of some day providing a means for even more exciting and ambitious exploration of space, perhaps beyond the moon, perhaps to the very end of the solar system itself.

Third, an additional 50 million dollars will make the most of our present leadership, by accelerating the use of space satellites for world-wide communications.

Fourth, an additional 75 million dollars—of which 53 million dollars is for the Weather Bureau—will help give us at the earliest possible time a satellite system for world-wide weather observation.

Let it be clear—and this is a judgment which the Members of Congress must finally make—let it be clear that I am asking the Congress and the country to accept a firm commitment to a new course of action—a course which will last for many years and carry very heavy costs of 531 million dollars in fiscal 1962—an estimated seven to nine billion dollars additional over the next five years. If we are to go only half way, or reduce our sights in the face of difficulty, in my judgment it would be better not to go at all.

Now this is a choice which this country must make, and I am confident that under the leadership of the Space Committees of the Congress, and the Appropriating Committees, that you will consider the matter carefully.

It is a most important decision that we make as a nation. But all of you have lived through the last four years and have seen the significance of space and the adventures in space, and no one can predict with certainty what the ultimate meaning will be of mastery of space.

I believe we should go to the moon. But I think every citizen of this country as well as the Members of the Congress should consider the matter carefully in making their judgment, to which we have given attention over many weeks and months, because it is a heavy burden, and there is no sense in agreeing or desiring that the United States take an affirmative position in outer space, unless we are prepared to do the work and bear the burdens to make it successful. If we are not, we should decide today and this year.

This decision demands a major national commitment of scientific and technical manpower, material and facilities, and the possibility of their diversion from other important activities where they are already thinly spread. It means a degree of dedication, organization and discipline which have not always characterized our research and development efforts. It means we cannot afford undue work stoppages, inflated costs of material or talent, wasteful interagency rivalries, or a high turnover of key personnel.

New objectives and new money cannot solve these problems. They could in fact, aggravate them further—unless every scientist, every engineer, every serviceman, every technician, contractor, and civil servant gives his personal pledge that this nation will move forward, with the full speed of freedom, in the exciting adventure of space.

* * * * *

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APPENDIX C

NATIONAL AND INTERNATIONAL IMPLICATIONS OF NASA'S PROGRAMS

Excerpts from Speech by the Deputy
Administrator of NASA to A.A.A.S.
Denver, Colorado

December 30, 1961

* * * * *

NATIONAL SIGNIFICANCE OF PROGRAM

The space program represents an important milestone with respect to the role of the Government in the development of science and technology and their utilization as instruments of governmental policy.

Past scientific and technological developments, beginning with the Industrial Revolution of the last century, have had a profound impact on every aspect of human affairs, including government itself. At the turn of the century we had reached the automotive age, to be followed by the air age and the nuclear age. Each of these developments provided in essence a mere change in the tools which man had at his disposal to change his physical environment, but each had important and direct effects on the economic development of the Nation, on national defense, on education, on law and religion, and on governmental policy in every field.

During these developments the role of government changed profoundly. Through the automotive age, scientific and technological development were accomplished mainly by private initiation with little direct governmental participation. As aviation progressed, largely because of national defense needs but partly because of the desire to actively promote the civil use of aircraft, the Government established a civilian research agency to advance the scientific and engineering bases of aeronautics at government expense for the benefit of all. This wise decision soon established the United States in a leading position in both military and civil aviation. Through ad hoc commissions at first, but ultimately by special governmental agencies, the Government established policies for the promotion of civil aviation. The Government thus played a more active role.

The nuclear age began wholly as a Government-sponsored activity, first by a secret military agency for weapons development. Following World War II and after extensive debate, the civil uses of nuclear energy were formally recognized and a civilian agency was established to carry on both weapons development in secrecy and civil or "peacetime" applications with wider dissemination of information. The Government began to use nuclear science and technology as instruments of policy, particularly in the international field. Within the Nation, steps were taken to promote widespread research in universities, industrial laboratories, and in centralized national laboratories, and to foster medical and other applications, including the private development of nuclear power plants. There remains in this field some opportunity for private initiative subject to various controls related to public safety.

The space activity is at present wholly financed by the Government, and from the beginning overall governmental policy considerations have determined the nature, scope, and rate of advance of space science and technology and of their application to fulfill various national needs. A positive decision was made to entrust the development of space science and technology and their civil applications to a civilian agency while reserving applications to national defense as the responsibility of the Department of Defense. It becomes apparent that the Government has full power to set the national goals in space. In fact, it already has established goals which motivate large elements of the Nation to expand the new science and technology as rapidly as possible. It is also clear that the wise direction of the space effort may be used as an instrument of social change in many areas of economic and social development of the Nation, if so desired. Finally, it is clear that such policy decisions are established through the cooperation of the legislative and executive branches of the Government and must ultimately receive the support of the public. Thus the primary significance of the national space program is that it is a powerful instrument of governmental policy, such that the social and economic impact of the new technology can be channeled to desirable ends.

The sheer magnitude of the manned lunar exploration program, amounting as it will to three billion dollars or more, represents a significant application of the Nation's resources. These billions of dollars will be spent in the laboratories, workshops, and factories of the Nation and thus constitute a significant factor in the Nation's employment and economy generally. The personnel in the space program are not all scientists and engineers but come from every walk of life.

The ultimate and practical purpose of these large expenditures is twofold: (1) insurance of the Nation against scientific and technological obsolescence in a time of explosive advances in science and technology; and (2) insurance against the hazard of military surprise in space.

The first result can be accomplished because of the technical nature of the program and the demonstrated transferability of scientific and engineering knowledge to other industrial applications. Manned exploration of the moon requires the most advanced engineering and technological developments at the very frontiers of knowledge. Major advances are occurring in electronics and communications, new materials, energy sources, and energy conversion devices, data collection and handling, computers, knowledge of the behavior of the human body under stress, protective equipment for man in hostile environments, and many other areas.

These developments at the frontiers of science and technology are transferable to other applications in industry. Because of the newness of the space age it is difficult to give specific examples at this early date. It is easier to recognize this process in relation to the automotive age, the air age, and the nuclear age. For example, the development of the automobile has brought us the concept of simplification for the operator through complication of design, a concept now widely applied in the operation of a modern steel mill or oil refinery and in such modern consumer products as automatic washers and ovens, where automatic controls program the entire operation. The automobile is largely responsible for the development of alloy steels, new fuels, synthetic rubber, quick drying finishes, and other new materials.

Similarly the air age brought us great supplies of aluminum and the basis for building light-weight structures, not only for airplanes but also for trains, buses, and ships. The nuclear age brought applications of isotopes in medicine and in the inspection of materials. Nuclear developments brought remote manipulators and sealed pumps for hazardous liquids and gases. The space age has brought to maturity the concept of systems analysis and optimization of designs involving many branches of science and engineering. In addition the space age has given us high-temperature ceramics, ablating materials for heat protection, pressure-stabilized light-weight tanks, computers handling large amounts of data, and many other developments which are finding applications throughout industry.

While the technological developments offer the earliest contributions to economic development, in the long run the contributions from the scientific knowledge obtained in the great unknown environment of the celestial bodies and interplanetary space may bring much greater returns. Today not only the prestige of a nation but also its true greatness and strength depend upon mastery and control of man's physical environment; and the extension and perfection of scientific knowledge is fundamental to that mastery and control. What benefits the new knowledge of the universe may ultimately bring to mankind no one today can predict. Judging from past experience, advances in scientific knowledge are the foundation of advances in technology and advances in technology are a key factor in economic development.

The manned lunar exploration program constitutes essential insurance against finding ourselves with a position in the new technology inferior to that of a possible enemy. The freedom of space combined with the great power of nuclear energy for destruction forecasts the future development of weapons systems now only dimly understood. There are many defense applications already evident and under way as a responsibility of the Department of Defense. The components, vehicles, techniques, and knowledge developed in the civil program are constanly available for defense applications.

Time is not available to discuss the national significance to modern education and to human thought and aspirations. At this meeting of the American Association for the Advancement of Science I do wish to say a few words about the significance of the lunar exploration program to science itself. Some scientists have feared that space activities may be exploited at the cost of other scientific work of higher priority and have questioned specifically the role of man in space exploration. These fears emphasize the fact that activities in space have other objectives as already described in addition to the increase of scientific knowledge. The space program, in my opinion, will greatly benefit science by stimulating popular interest in the frontiers of science and by bringing broader support for the advancement of all science and technology. In the past the nuclear developments have been charged with undue distortion of research and education in physics, but I am convinced that in the presence of both nuclear and space activities all branches of science receive greater support than they would have received had these activities been absent.

INTERNATIONAL SIGNIFICANCE OF PROGRAM

Space exploration is a significant factor in international policy. From the beginning space activities have had an impact on the climate of world opinion with respect to national strength and prestige. As stated by the President's Science Advisory Committee in March 1958: "To be strong and bold in space technology will enhance the prestige of the United States among the peoples of the world and create added confidence in our scientific, technological, industrial, and military strength."

There are no short cuts to the attainment of the desired position of strength. We have made great progress, and our policies of openness and sharing with other nations are bringing growing appreciation of the significance of our program to the free world.

In March 1959 the United States offered through the Committee on Space Research of the International Council of Scientific Unions to cooperate with other nations in making available launching vehicles, spacecraft, technical guidance and laboratory support for orbiting individual experiments for complete satellite payloads developed in other countries. The first satellites under this international program are being prepared by the United Kingdom and Canada and will be launched in the first half of calendar year 1962. Discussions are in progress with several other governments which have expressed interest in cooperative satellite projects.

In his recent speech before the United Nations, President Kennedy said: "We shall urge proposals extending the United Nations Charter to the limit of man's exploration in the universe, preserving outer space for peaceful use; prohibiting weapons of mass destruction in space and on celestial bodies, and opening the mysteries and benefits of space to every nation. We shall propose further cooperative efforts between all nations in weather prediction and eventually in weather control. We shall propose, finally, a global system of communication satellites linking the whole world in telegraph and telephone, and radio and television." At its current session, the United Nations adopted a resolution which represents a forward step in cooperation along the lines recommended by the President.

Some social scientists have speculated that the exploration of space might become in time a substitute for war. Hope would be that the absorption of energies, resources, imagination, and aggressiveness in the exploration of space might contribute to the maintenance of peace. Whether or not this speculation is warranted, I am sure from personal experience that international cooperation in the exploration of space does contribute to friendship and understanding among nations.

The international impact of the United States space program appears in unexpected ways. Thus Russell Howe reported in a dispatch from Kaduna, Northern Nigeria, appearing in the Washington Post for December 3rd, 1961, as follows:

> "[The Sardauna of Sokota and Premier of Northern Nigeria] has welcomed on his soil Black Africa's only space tracking station. A few miles outside Kano, in a spot only visited until recently by camel trains and woodchoppers on their mules, NASA's Tracking Station Five now stands with aluminum brightness in the savannah."

* * * * *

"Even Tracking Station Five has helped to enhance the Sardauna's great, semi-spiritual prestige. Said the Hausa driver who took me out to the station, when he had finally understood what my destination was: 'Ha, you mean the place the Sardauna built to get the message from the stars!' "

CONCLUSION

We must not underestimate the significance of space exploration to the ordinary citizen in every country. You recall the complaint of the Russian workman in the U.S.S.R., who asked, "What do Sputniks give to a person like me?" To this question frequently asked by men in many countries, including our own, we can of course reply with discussions of practical benefits from weather and communication satellites and from technological developments as described in the earlier part of this paper. But perhaps a better reply would be: "The exploration of space can give you new interests and new motivations arising from an expansion of your intellectual and spiritual horizons as you take a longer view of man's role in time and space at this point in the history of the human race."

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APPENDIX D

LONG RANGE ECONOMIC IMPACT OF THE LUNAR PROGRAM

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June 22, 1961

The Honorable Robert S. Kerr
Chairman, Senate Committee on
Aeronautical and Space Sciences

My dear Senator Kerr,

As you suggested during my recent discussion before the Committee, I will attempt to put in writing the remarks I made as to the significance of the program recommended by the President for landing a man on the moon and his safe return by the end of the decade to the present and future welfare of this nation.

The attainment of the goal stated by the President requires extensive research and development in almost every branch of science and technology at the frontiers of knowledge in these various fields. New materials and components must be developed to function in the extreme cold and the extremely low pressures of outer space, at the extreme speeds, and at the extreme temperatures attained in rocket combustion chambers and on the outer surface of bodies reentering the atmosphere at high speed. New developments in propulsion, in electronics in communications, in guidance and control techniques, in computer techniques, are necessary in order to accomplish the task. New information in the life sciences, including the effects of the radiations encountered in outer space, the effects of long periods of weightlessness, and long exposure to a completely closed environment—all these are required and will provide new basic information about the performance of the human body under adverse conditions. This new knowledge and experience in the space sciences and technologies will provide the sound basis for applying our new-found knowledge to the design of space vehicles for a variety of purposes, some now foreseen, others unthought of at present. These applications include not only space vehicles for scientific research, for communications systems, for meteorological observation, and presently unforeseen civil uses, but also space vehicles for potential applications in the national defense. Space technology, like aeronautical technology, can be applied to military systems, and we must be well advanced in this technology to avoid its possible exploitation against us.

Equally important is the fact that these developments in science and technology are transferable to other applications in our industrial society. We have had repeated evidence in the history of the development of the automobile, the airplane, and the nuclear reactor of the transferability of developments in these fields to other industrial applications. The development of space science and technologies strengthens our whole industrial base and serves as insurance against technological obsolescence. Education will profit. The discipline of cooperation in a great national effort may well be an area where all the nations of the world may learn to work together for the benefit of all men.

The setting of the difficult goal of landing a man on the moon and return to earth has the highly important role of accelerating the development of space science and technology, motivating the scientists and engineers who are engaged in this effort to move forward with urgency, and integrating their efforts in a way that cannot be accomplished by a disconnected series of research investigations in the several fields. It is important to realize, however, that the real values and purposes are not in the mere accomplishment of man setting foot on the moon but rather in the great cooperative national effort in the development of science and technology which is stimulated by this goal.

The billions of dollars required in this effort are not spent on the moon; they are spent in the factories, workshops, and laboratories of our people for salaries, for new materials, and supplies, which in turn represent income to others. It is unfortunate that space exploration is still so new that journeys of man to the moon are synonymous with foolish or visionary enterprises as described in science fiction. Fifty years ago flying through the air had the same connotations—risky, expensive, useful only as a sport. Our lack of appreciation of the potentialities of aeronautics extended through the early years, forcing the Wright Brothers to go abroad. We entered the first World War with no design capability and no manufacturing experience, dependent completely on foreign designs. Only after the war did we begin to devote effort to research in the new aeronautical technology. We must not undergo the same experience in space science and technology. The national enterprise involved in the goal of manned lunar landing and return within the decade is an activity of critical impact on the future of this nation as an industrial and military power, and as a leader of the free world.

/s/ Hugh L. Dryden
Deputy Administrator

APPENDIX E

NASA ORGANIZATION

The organization and program management requirements of NASA are unique because of the interrelation of:

1. The size of the space effort.
2. The high proportion of engineering and scientific manhours required.
3. The extensive interdependency of all programs.
4. The complication of the systems involved.

NASA does about 15 percent of its work in-house (mostly in the fields of flight vehicle research and technology) while the other 85 percent is done by industry, universities and non-profit organizations under contract, or in certain of the universities under grants.

The NASA effort can be divided into (using approximate percentages):

	Current	*1965*
1. Scientific Investigations in Space	15%	15%
2. Applications Satellites	5%	5%
3. Manned Space Flight	25%	40%
4. Launch Vehicle Development	40%	25%
5. Flight Vehicle Research and Technology	15%	15%

About 90 percent of the Launch Vehicle Development is in support of the manned program.

These are the major functional (program) responsibilities of NASA. In addition there is the operational responsibility of managing the NASA Centers and stations. These are listed in Table E–1 together with appropriate information regarding them. Although each Center and station has a major responsibility aligned with one of the five programs, it also has responsibilities in one or more other programs. There are also the normal operating functions (procurement, etc.) common to all Centers and stations.

Initially NASA operations were organized under Program Offices each reporting to the Administrator and Deputy Administrator. Each NASA Center reported to that Program Office having cognizance of the major center responsibility. The organization was as shown in Figure E–1.

After an interim period, it was decided that because of the pressure on the Administrator and Deputy Administrator in regard to policy and intergovernmental matters, there should be appointed a general manager with the title of Associate Administrator. Later, because of the size of the launch vehicle program and because the life science programs were not getting sufficient emphasis, separate Program Offices were established for these functions. The organization then became that shown in Figure E–2.

The organization shown in Figure E–2 prevailed in general until about the time the planning started for the expansion in the NASA program covered in the recommendations made by the President in his Special Message (May 25, 1961) to the Congress. Essentially it became advisable to separate the primary NASA activities into separate offices of Manned Space Flight, Scientific Investigations in Space, and Space Applications (i.e., meteorological and communications satellites, etc.). In addition the launch vehicle development program could be reasonably well divided into vehicles for the manned and the unmanned programs. The launch vehicles for the manned program are so intimately associated with the manned spacecraft that it became advisable to place their development under the Office of Manned Space Flight. For convenience the devolpment of the other (that is smaller) launch vehicles was placed under the Office of Space Sciences In the interest of overall program coordination, another major change was warranted. In the previous organization each office conducted its own vehicle component state-of-the-art development (termed vehicle technology). This work is similar to that (termed vehicle research) conducted at the Langley, Ames, Lewis, and Flight Research Centers, but is in general closer to direct applications. It was decided to place the coordination of all vehicle research and technology under one Program Office with all vehicle research and technology not a specific part of the development of a vehicle or vehicle component under the management of this office.

Another matter for which a satisfactory solution had not been found was that of the lines of authority from NASA Headquarters to the Centers and Stations. The work at several of the Centers was becoming too diversified to warrant continued reporting to a single Program Office. For this reason the managerial responsibilities of NASA were separated into two parts:

1. Program management, which is the responsibility of four Program Directors reporting to the Associate Administrator.
2. General (institutional) management of each Center by the Center Director reporting to the Associate Administrator.

The program manager is responsible for planning, managing and evaluating the program under his cognizance. The programs are carried out through one of the Centers or stations. Restating the division: for general operation of the Center, the Center Director reports to the Associate Administrator; for operation of the program as such he is responsible to a Program Director who in turn reports to the Associate Administrator. Each Center or station will in general carry out parts of several programs. This organization, shown in Figure 3, became effective November 1, 1961.

TABLE E-1

NASA CENTERS & STATIONS

Establishment	Location	Personnel	Primary Objectives
		(Approved Complement)	
NASA Headquarters	Washington, D. C.	1403	Overall NASA direction
Langley Research Center	Langley Field, Va.	3628	Research to improve aircraft and space vehicles
Ames Research Center	Moffett Field, Calif.	1675	Research to improve aircraft and space vehicles and research in life sciences
Lewis Research Center	Cleveland, Ohio	3608	Research to improve aircraft and space vehicle propulsion and power generation systems
Flight Research Center	Edwards AFB, Calif.	494	Aircraft flight research, emphasis on supersonic aircraft
Goddard Space Flight Center	Beltsville, Md.	2310	Scientific research conducted in space by means of sounding rockets and earth satellites. Research on and development of meteorological and communications satellites.
Jet Propulsion Laboratory*	Pasadena, Calif.	2400	Exploration of the moon and planets. Scientific research conducted with spacecraft operating beyond the earth's gravitational field.
Marshall Space Flight Center	Huntsville, Ala.	6490	Development of launch vehicles. Staffs and operates Atlantic Missile Range and Pacific Missile Range NASA Field Offices.
Manned Spacecraft Center	Langley Field, Va.**	1640	Development of manned space flight systems.
Wallops Station	Wallops Island, Va.	399	Launch site for small spacecraft (200 lbs) and for flight reentry research vehicles and for tests of escape systems for manned flight.
Western Operations Office	Santa Monica, Calif.	119	General Administrative and Technical support.
		TOTAL 24,166	

* Contract operation, i.e., not under Civil Service.

** Being transferred to Houston, Tex.

FIGURE E–1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION ORGANIZATION CHART OCTOBER 24, 1958

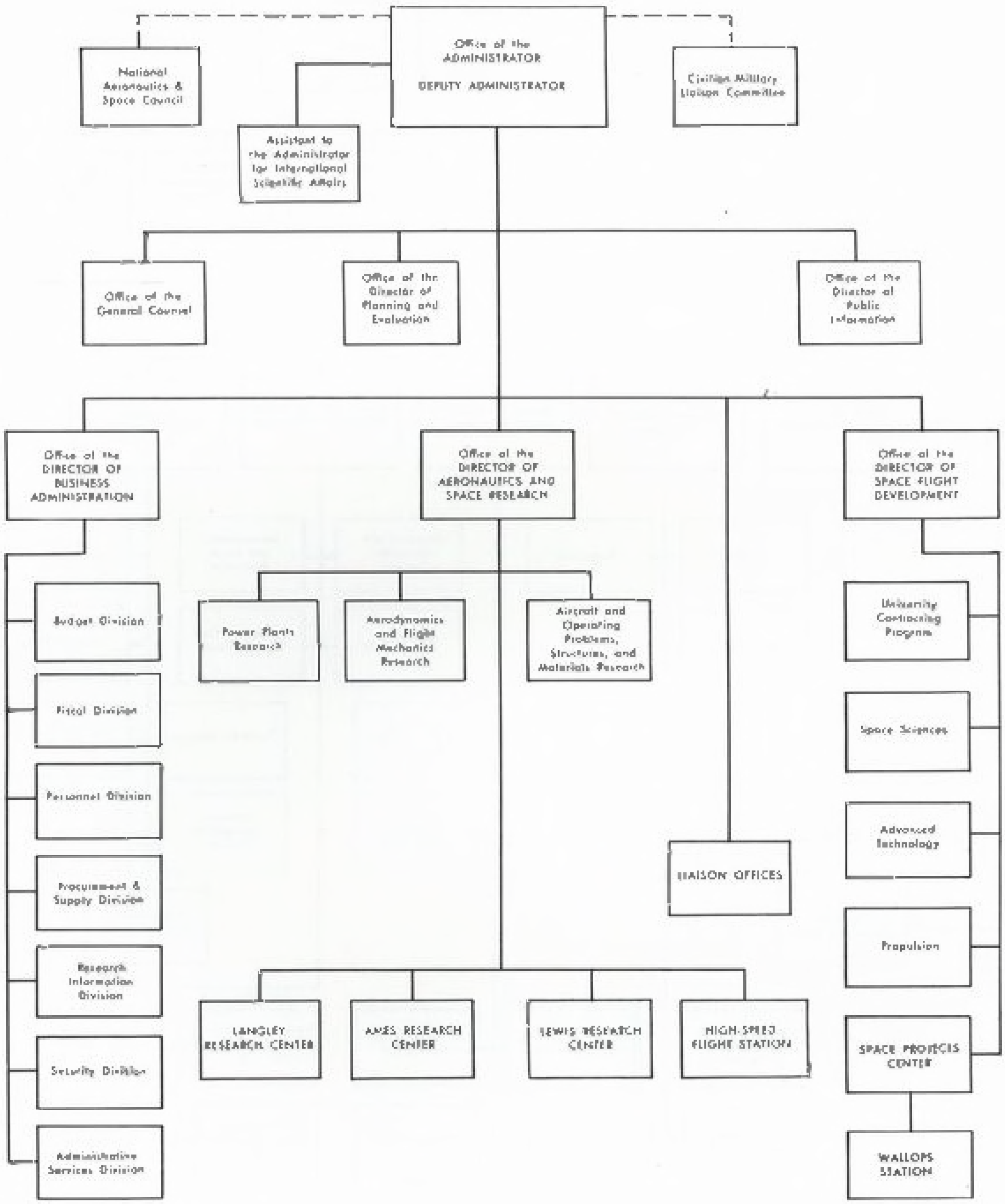

FIGURE E-2

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
4 APRIL 1960

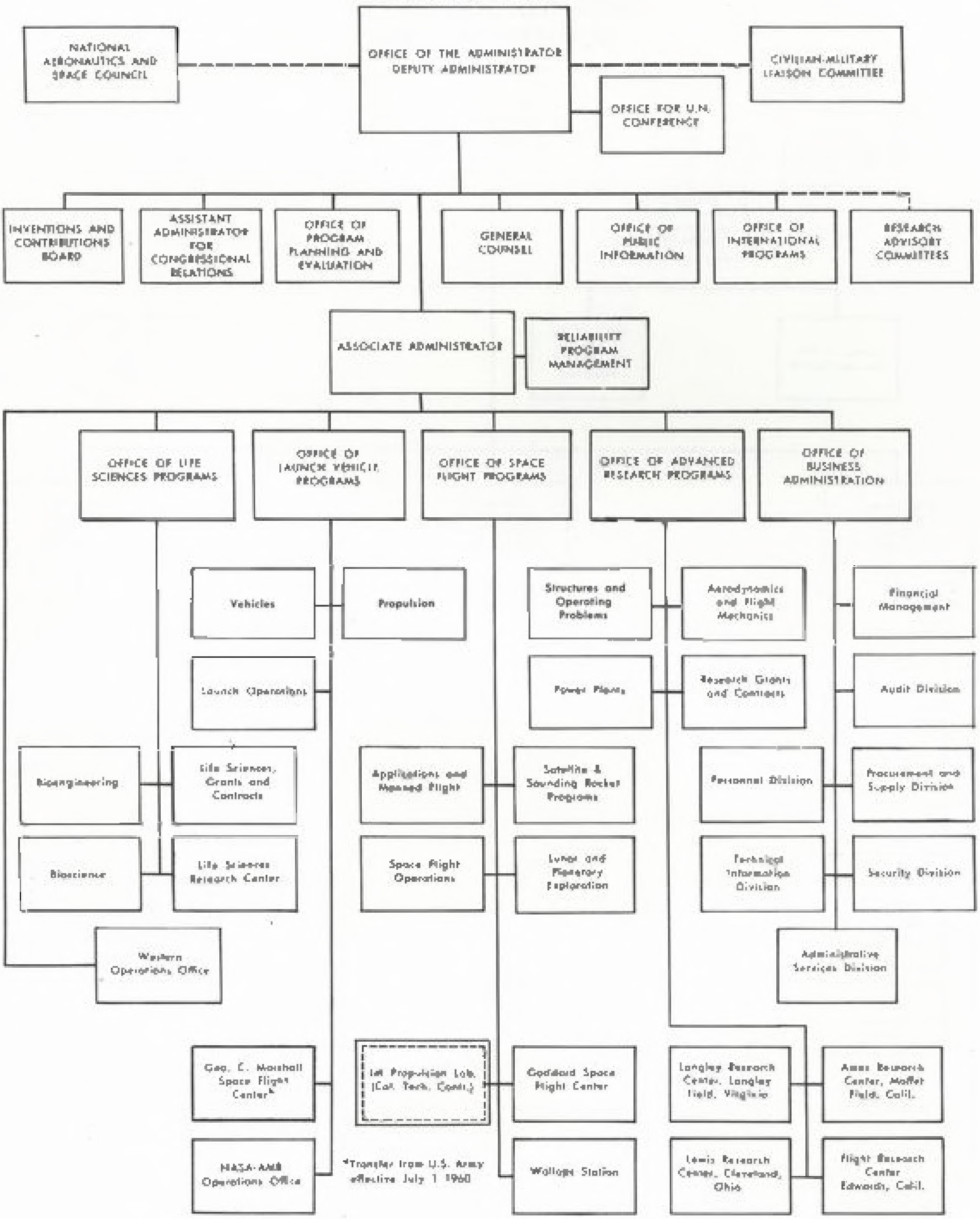

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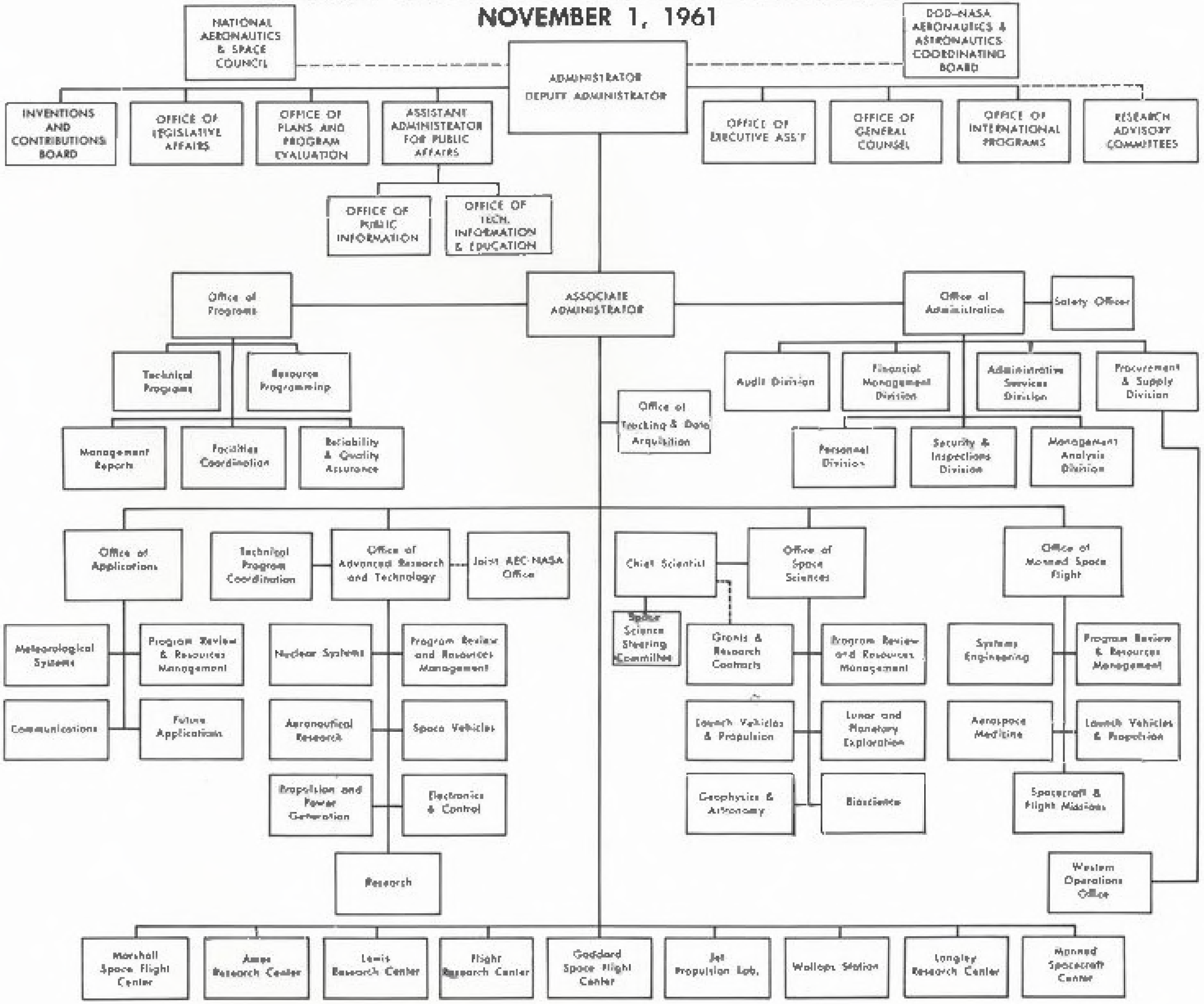
FIGURE E–3

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NOVEMBER 1, 1961



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