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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Office of Program Planning and Evaluation

THE LONG RANGE PLAN OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

December 16, 1959

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INTRODUCTION

The long term national objectives of the United States in aeronautical and space activities are stated in general terms in the enabling legislation establishing NASA. It is the responsibility of NASA to interpret the legislative language in more specific terms and to assure that the program so generated provides an efficient means of achieving the following objectives expressed in PL 85-568, Sec. 102(c) as:

"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 non-military 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."

In operational terms, these objectives are instructions to explore and to utilize both the atmosphere and the regions outside the earth's atmosphere for peaceful and scientific purposes, while at the same time providing research support to the Department of Defense. These objectives can be attained only by means of a broad and soundly conceived program of research, development and operations in space. In the long run, such activities should make feasible the manned exploration of the moon and the nearby planets, and this exploration may thus be taken as a long-term goal of NASA activities. To assure steady and rapid progress toward these objectives, a NASA Long Range Plan has been developed and is presented in this document.

In interpreting the Plan, it must be remembered that the implications for the national economy reach far beyond the specific program goals. For example, the space science activities cover the frontiers of almost all the major areas of the physical sciences, and these activities thus provide support of the physical sciences in general. In a similar manner, the technological developments for specific applications in the fields of electronics, materials, propulsion, etc., will contribute, directly or indirectly, to all subsequent military weapons developments and to many unforeseen civilian applications. Reciprocally, the NASA program is provided with support, direct or indirect, from all the related research and development activities outside NASA.

The Plan is presented at a level of effort which corresponds to an efficient and steadily growing capability. The rate of progress could be improved by an increased funding level, primarily by improving the certainty of the timely completion of the many essential engineering developments. On the other hand, a significantly lower scale of funding could be accommodated only by arbitrarily limiting the activities to a narrow line and by greatly reducing the rate of approach to the long term goals.

GENERAL DESCRIPTION OF LONG RANGE PLAN

The NASA Long Range Plan is presented here in broad outline with significant milestones listed in Table I. The anticipated funding requirements over the next ten years are summarized in Figure I and Table II, and the expected vehicle launching program is summarized in Table III. Each element of the Plan is discussed in greater detail in the remaining sections of this report.

In any long range funding projection the clearly foreseen near term items are gradually completed and the more distant funding extrapolation tends to level out and frequently to decrease. The funding pattern shown in Table II, illustrates this typical phenomena. It must be expected that factors will arise in this new field of technology which will make it desirable to initiate new programs or to increase the emphasis on existing programs. For this reason, an arbitrary increment in funding for these modifying factors is included under the heading Advanced Projects in Table II and Figure I for the later half of the decade. Two typical items which may require substantial additional funds are the following:

(1) The nuclear rocket or electric propulsion research may develop fast enough to justify large scale flight development activities soon.

(2) The Manned Space Flight program may discover important applications which justify a rapid expansion of the program.

It is the purpose of the Long Range Plan to identify specific objectives to be reached within the next several years, identifying dates by which individual objectives should be possible of attainment and setting forth the program for the current and next fiscal years and the approximate plan for research and development necessary in the longer-term future to accomplish the objectives of the nation as set forth broadly in the National Aeronautics and Space Act of 1958. This Plan, like any such document, is subject to continuous review, and it is expected that a general revision will be produced annually.

The time period which the Plan treats is the oncoming decade. A ten-year interval has no special significance; yet it is considered to be an appropriate interval since past experience has shown that the time required to translate research knowledge into operationally effective systems in similar new fields of technology is generally of this order. The long lead times required for planning and defining space missions and for the development of payloads as well as vehicles, also makes it desirable to plan activities on a long term basis. An extrapolation over significantly longer intervals must be expected to be radically modified by as yet unanticipated research developments. On the other hand, a plan covering a significantly shorter interval cannot be expected to cover the life period of operational systems already far advanced in the development phase.

During the coming ten years, NASA activities will involve extensive programs of engineering development and scientific research. Equipment and facilities often requiring major advances over current engineering practice must be designed and built. Achieving adequate reliability over substantial periods of unattended operation in a severe environment will require extensive testing on the ground and in flight of both vehicles and their payloads. These circumstances bring about the long lead times associated with space activities and, together with the inherent high complexity of the equipment involved, contribute to the high dollar cost of the space programs.

The Plan outlines the currently approved and funded FY 1960 program, the program which has been submitted by NASA for inclusion in the Federal Budget for FY 1961, an estimate of activities for FY 1962 through FY 1964, and concludes with an extrapolation of these programs for the period through FY 1969.

The Plan is divided, for convenience, into four separate, but strongly interrelated categories. They are: (1) Space Vehicle Development; (2) Manned Space Flight; (3) Engineering and Scientific Research; and (4) Space Flight Operations.

Space Vehicle Development

This category is subdivided into three principal areas: (1) launching vehicles; (2) space propulsion technology; and (3) vehicle systems technology. This category of activities, Space Vehicle Development, must receive primary emphasis for several years until a vehicle with a payload capacity adequate to support a variety of missions and a guidance system adequate for both orbital and deep-space missions has reached a state of reasonable reliability.

Manned Space Flight

A key element in the overall NASA program, Manned Space Flight, has as its long term objective, acquiring the vehicles and technology necessary for man to move freely through space. As a significant initial step toward the attaining of this objective, the program for the next ten years is directed toward providing the means for manned flight to the moon. Project Mercury is the first phase of the Manned Space Flight program, and it has been assigned the highest national priority.

Engineering and Scientific Research

This category has three principal subdivisions: (1) research activities to be conducted in a space environment; (2) development activities leading to the establishment of space-based operational systems which may be expected to contribute to the general economy of the nation; and (3) the supporting research program, carried out primarily in laboratory research facilities, covering all the fields of engineering and science which contribute to aeronautical and space activities.

Space Flight Operations

This category provides the general logistic support of the flight research and development effort, the required launching facilities and the tracking and telemetering facilities and operations.

Scientific research plays a dual role in NASA activities. The engineering developments necessary for space activities must be based on a firm foundation of scientific knowledge. On the other hand, a primary end product of space activities is to furnish the scientist new and unparalleled opportunities for acquiring fundamental knowledge. In the conduct of scientific research, each new inquiry is in part suggested by and depends upon the results of previous experiments; consequently to exploit fully research opportunities as they unfold, it is necessary to provide considerable program flexibility. General areas of interest can be specified on a long term basis, but detailed programming should be done over a shorter period.

In order to view the problem for the next decade in a proper perspective, it is appropriate to consider first the current situation. In the field of aeronautics the United States has a mature, efficient and effective industry which is supported by a highly skilled scientific and academic community and by well equipped and effective Government laboratories, many of these being operated by NASA. The aeronautical phase of the responsibilities of NASA has a long and stable history which need not be reviewed at this point. On the other hand, the new responsibilities in the field of space activities concern a technological area just becoming organized and in a state of flux. The present remarks are thus directed toward the space field.

The fact that we are in the very early developmental phases of our engineering technology for space activities is clearly shown by a review of the results of our various satellite and space probe launching efforts. Prior to 1 December 1959, the DOD and NASA have attempted to launch 37 major satellites or space probes using seven different types of launching vehicles. The number of launchings with a given type vehicle has been limited, varying from a high of eleven with Vanguard, to a low of one, with an Atlas (Project Score); consequently, the flight test experience accumulated on any single vehicle type has been low. Approximately one-third of the launchings have successfully placed the payload in a trajectory nominally equivalent to that planned where the instrumentation and telemetering systems carried out usefully the function for which they were installed. This level of success closely parallels that achieved in guided missile programs during their early developmental phases, and as additional flight test experience is accumulated on individual vehicle types, the reliability can be expected to improve.

While our operational history to date clearly demonstrates the feasibility of undertaking space flight activities, it also emphasizes, by the relatively low reliability so far attained and also by the very small payload capacity realized with currently available launching vehicles, that we are only in the first phase of the development of this new branch of engineering technology. Under these circumstances, a primary goal for NASA activities in space for several years to come must be:

The development of a limited number of types of reliable launching vehicles, together with the development and establishment of tracking and telemetry systems adequate for the space missions expected to be undertaken.

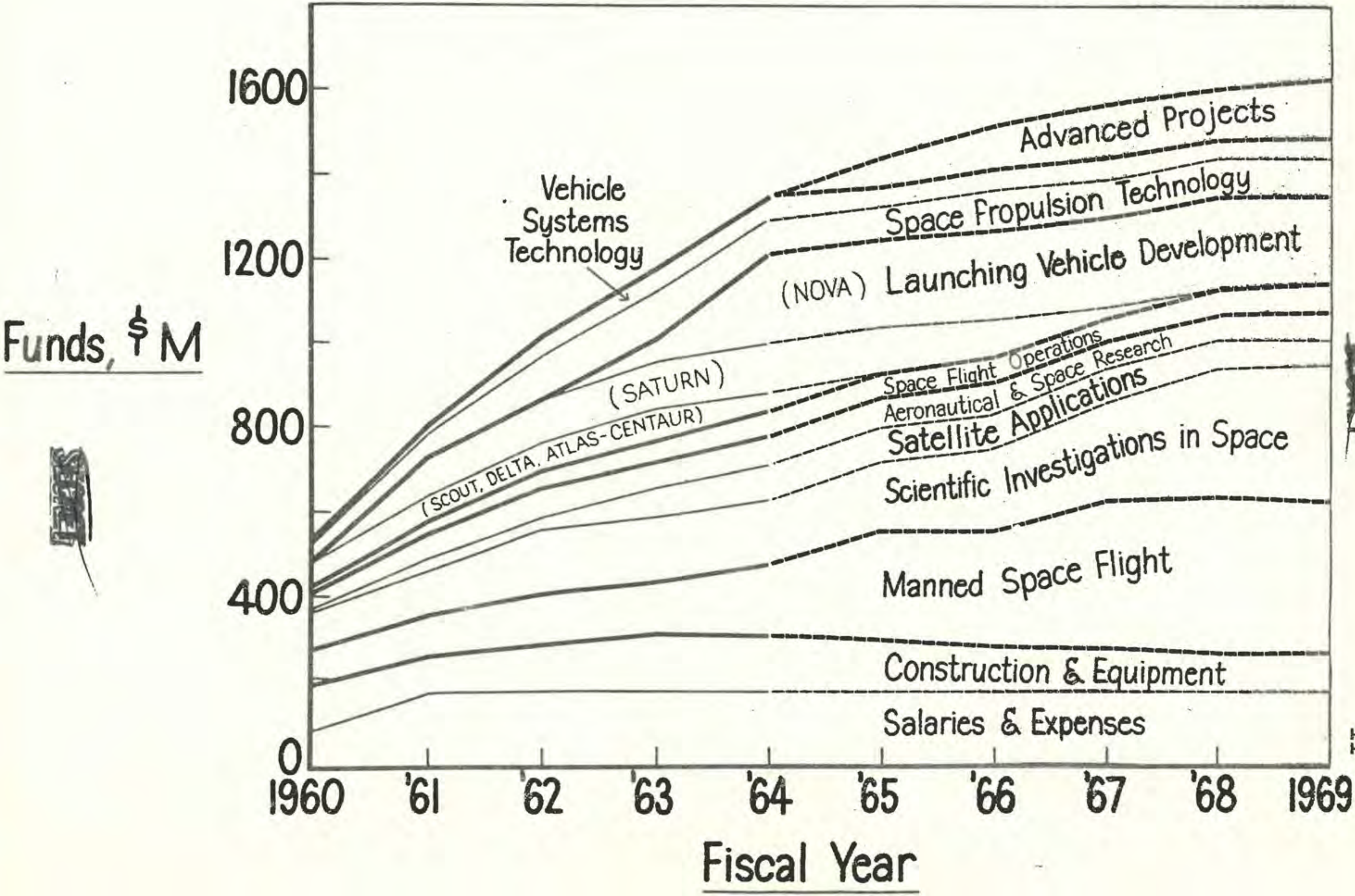
To the extent possible, this goal must be supported, not only by the development resources available to NASA, but also by basic and applied research activities, both "in-house" and contract. Further, the number of types of launching vehicles developed should be kept small in order to speed the attainment of acceptable levels of reliability by concentrating flight experience as much as possible. Also, the launching vehicles should be large enough to carry, together with substantial payloads, guidance systems having sufficient accuracy and flexibility for the various missions contemplated over the next several years.

Year	
1960	First launching of a Meteorological Satellite.
	First launching of a Passive Reflector Communications Satellite.
	First launching of a Scout vehicle.
	First launching of a Thor-Delta vehicle.
	First launching of an Atlas-Agena-B vehicle (by the Department of Defense
	First suborbital flight of an astronaut.
1961	First launching of a lunar impact vehicle.
	First launching of an Atlas-Centaur vehicle.
1961-1962	Attainment of manned space flight, Project Mercury.
1962	First launching to the vicinity of Venus and/or Mars.
1963	First launching of two stage Saturn vehicle.
1963-1964	First launching of unmanned vehicle for controlled landing on the moon.
	First launching Orbiting Astronomical and Radio Astronomy Observatory.
1964	First launching of unmanned lunar circumnavigation and return to earth vehicle.
	First reconnaissance of Mars and/or Venus by an unmanned vehicle.
1965-1967	First launching in a program leading to manned circumlunar flight and to permanent near-earth space station.
Beyond 1970	Manned flight to the moon.

… FUNDING REQUIREMENTS

Fiscal Year	1960*	1961	1962	1963	1964	1965	1966	1967	1968	1969
Research & Development						*Extrapolated*				
Launching Vehicle Development	57	140	163	230	375	325	295	235	210	210
Space Propulsion Technology	39	51	118	120	90	75	95	95	95	95
Vehicle Systems Technology	13	30	47	49	50	50	50	50	50	50
Manned Space Flight	87	108	120	135	180	260	260	340	360	360
Scientific Investig. in Space	82	95	140	145	150	165	215	230	300	300
Satellite Applications	11	27	36	60	75	80	75	70	65	65
Aeronautical & Space Research	28	61	70	70	70	70	70	70	70	70
Space Flight Operations	16	33	42	50	55	60	60	60	60	60
Total Research & Development	333	545	736	859	1045	1085	1120	1150	1210	1210
Construction & Equipment	100	89	113	137	130	125	110	105	95	95
Salaries & Expenses	91	168	175	175	175	175	175	175	175	175
Advanced Projects						70	100	120	120	120
Total Funds Required	524	802	1024	1171	1350	1455	1505	1550	1600	1600

*Includes 1959 Supplemental and 1960 Supplemental Request



Funds, $M
1600
1200
800
400
0
1960
'61
'62
'63
'64
'65
'66
'67
'68
1969
Fiscal Year
Vehicle Systems Technology
Advanced Projects
Space Propulsion Technology
(NOVA) Launching Vehicle Development
(SATURN)
(SCOUT, DELTA, ATLAS-CENTAUR)
Space Flight Operations
Aeronautical & Space Research
Satellite Applications
Scientific Investigations in Space
Manned Space Flight
Construction & Equipment
Salaries & Expenses

ANTICIPATED LAUNCHING SCHEDULE
MAJOR VEHICLES

FISCAL YEAR	1960				1961				'62	'63	'64	'65	'66	'67	'68	'69
Redstone				1	2	3	2									
Atlas				1	2	1	2	1	6	1						
Juno II			1		1	3										
Thor-Able			2													
Atlas-Able				1	1											
Scout				4	2		2		6	6	6	6	6	6	6	6
Thor-Delta			1	1	1	2	1	1	5							
Thor-Agena B									1	6	6	6	6	6	6	6
Atlas-Agena B							1		3	4	5	6	3	12	12	12
Atlas-Centaur								1	5	4	5	6	9			
Saturn									2	2	3	4	4	4	4	4
Nova Type															1	2
TOTAL	12				29				28	23	25	28	28	28	29	30

SPACE VEHICLE DEVELOPMENT

A primary responsibility of NASA is to develop an engineering capability in space activities which can provide the propulsion required to carry significant payloads into space, together with guidance which permits the desired missions to be performed, and with a level of reliability which characterizes all mature engineering activities. Such an engineering capability is clearly required to carry out an effective program of research and exploration in space. The space vehicle* systems which are now operating are deficient in all three counts - propulsion, guidance, and reliability. The plan for developing the required vehicle capability is given below in three parts: Launching Vehicle Development; Space Propulsion Technology; and Vehicle Systems Technology.

Launching Vehicle Development

The goal of the NASA launching vehicle development program is to develop a series of vehicles of sufficient capacity and reliability to launch appropriate spacecraft into the desired space missions. The spacecraft will vary in size from the present levels of up to several hundred pounds to manned spacecraft of many tons. The missions planned during the next ten years vary from probes travelling a few hundred miles vertically into space to exploration of the moon and the nearer planets.

The size and staging required of a launching vehicle depends both on the weight of the spacecraft to be launched and the required injection velocity for the start of the space mission. The number of types of launching vehicles and types of vehicle stages developed should be kept at a minimum in order to increase reliability through the repetitive use of a few vehicle systems and components. The ballistic missiles developed by the Department of Defense are used as launching vehicle components wherever possible, particularly in the years immediately ahead.

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* In the following discussion a launching vehicle is considered to consist of a first stage booster rocket and the upper stages required to inject a spacecraft into a space trajectory. A spacecraft includes the guidance and propulsion equipment needed for post-injection mission usages as well as the basic payload. The launching vehicle plus the spacecraft constitute a space vehicle.

The experience of the last fifteen years in the development of guided missiles provides an important and valid guide to the course of development to be expected in space vehicles; however, one significant difference in the development pattern is to be expected. Typical missile development programs have frequently been initiated with a series of special propulsion test vehicles since the appropriate guidance equipment required a substantially longer lead time before guidance flight tests could be made. In the last few years, sufficiently advanced guidance components have been developed that it now appears feasible to introduce developmental guidance systems in initial vehicles. The initial development flights of space vehicles can thus carry a reduced scientific payload and be assigned a specific space mission; however, the initial development status must be expected to carry with it a relatively low reliability.

Each new launching vehicle development program will require a certain number of flights for vehicle development. The exact number depends upon many factors, but will probably vary between ten and twenty. During this period a substantial amount of vehicle oriented instrumentation must be carried on each flight, and considerable engineering support will be required for component evaluation, redesign, and test. On most of these flights, spacecraft will be launched into specific missions. However, until adequate reliability is achieved, launching vehicle development will be the primary purpose of each flight, and the instrumentation required for this purpose will not be sacrificed in the interest of the spacecraft being launched. During this development period, the vehicle reliability - which must be expected to be low initially - will gradually improve. The end of the development period is marked by the attainment of an acceptable level of reliability. The funding estimates shown in Table V are for vehicle development only. Vehicle procurement beyond the initial series is funded by the using project.

There are currently four launching vehicles in use by NASA and four vehicles being developed by NASA. In addition, there are two launching vehicles under development by DOD that will be used by NASA. Summaries of the performance of these ten vehicles are given in Table IV while the development program is outlined in Table V. As these development programs mature, it is expected that the number of launching vehicle types in use by NASA during the next ten years will be standardized at four, one vehicle type in each performance class as identified by the first stage, Scout, Thor, Atlas and Saturn.

The Redstone and Atlas vehicles will be used to launch the development and operational spacecraft in Project Mercury. Seven Redstone and twelve Atlas launchings are scheduled.

The Juno II and Thor-Able projects were transferred to NASA from the Department of Defense at the time NASA was activated. The Juno II and Thor-Able vehicles will not be used beyond the presently scheduled flights, five and two, respectively.

Scout is being developed as a relatively low cost launching vehicle, capable of placing reasonable scientific payloads in a low earth orbit. Thor-Delta, of which twelve are on order, is being developed as an interim launching vehicle for somewhat greater earth orbit spacecraft than provided for by Scout and for limited deep space missions. Thor-Agena B, being developed by DOD, will be suitably modified by NASA as a greater capacity replacement for Thor-Delta.

An adequately staged Atlas using conventional propellants in each stage will permit considerably greater weight spacecraft to be launched than have been placed in space by the United States to date. Such staging is reasonably well represented by the Atlas-Agena B vehicle which, as currently being developed, consists of the Atlas plus one additional stage.

The Atlas-Centaur vehicle provides considerably greater spacecraft launching capacity than does the Atlas-Agena B. This greater capacity results from the substitution of a hydrogen fueled stage for the more conventionally fueled upper stage of Atlas-Agena B. A modification of the hydrogen fueled Centaur stage is suitable as an upper stage for Saturn. Certain problems inherent in the use of hydrogen in an upper stage lead to appreciable uncertainties in estimates of the development time required. However, upon the successful completion of the Centaur development, Atlas-Agena B will be phased out, leaving a single Atlas based launching vehicle.

As Table IV shows, Saturn has about four times the first stage thrust capacity of Atlas. At the present time only the first stage of Saturn is being fabricated. A decision on the configuration of the upper stages is currently being made. The payload capacity of Saturn will vary according to this upper staging.

Space missions such as a manned landing on the moon and return to earth, will require launching vehicles having a performance capacity beyond that of a single Saturn. To achieve this greater capacity, one or more of the following courses of development must be successful: (1) the development of a chemically fueled launching vehicle of several times the capacity of Saturn; (2) the solution of the problems of space rendezvous; or (3) the application of nuclear energy in thermal rockets.

The development of a vehicle of several times the capacity of Saturn will require a larger thrust engine than is now available. The 1.5 million pound thrust Nova rocket engine under development by NASA provides such an engine.

To launch a spacecraft, directly from the surface of the earth, suitable for a manned landing on the moon and return to earth will require a capacity of about four times that of a single Saturn. Preliminary design studies for an appropriate Nova launching vehicle, together with a preliminary mission analysis and a vehicle development plan will be completed by 1963. For this purpose of the Plan, it is assumed that a Nova vehicle development will be initiated and will reach the initial flight phase by the end of the decade.

Design studies on the problems of space rendezvous are currently under way as a part of the Saturn vehicle lunar mission analysis. Research on the application of nuclear energy in thermal rockets is being carried out as a part of the space propulsion technology program.

VEHICLE	1ST STAGE THRUST 1,000 LBS.	MISSION		
		LOW EARTH ORBIT	MOON PROBE	PLANET PROBE
IN USE:		SPACECRAFT WT. LBS.		
REDSTONE	80	USED IN PROJECT MERCURY DEVELOP.		
ATLAS	360	PROJECT MERCURY CAPSULE		
JUNO II	150	100	20	
THOR-ABLE	150	200	80	
ATLAS-ABLE	360		370	
UNDER DEVELOPMENT				
SCOUT	100	200-240		
THOR-DELTA	150	400-500	60	
THOR-AGENA B (1)	150	1,200-1,500	350 (2)	200 (2)
ATLAS-AGENA B (1)	360	4,500-5,500	750-1,000	350-500
ATLAS-CENTAUR	360	8,000-9,000	2,300-2,700	1,500-1,900
SATURN (INITIALLY)	1,500	28,500	9,000	7,000

1. DOD Development
2. With additional stage

LAUNCHING VEHICLE DEVELOPMENT

Fiscal Year	60	61	62	63	64	65	66	67	68	69
Scout										
Flights	4	2 2								
Funds, $M	2.8									
Thor-Delta										
Flights	1 1	1 2 1 1	5 (a)							
Funds, $M	13.3	12.5	3							
Atlas-Vega										
Funds, $M	4.0									
Atlas Centaur										
Decision Points			Δ1							
Flights		1	5	4	5	5				
Funds, $M	37.0	47.0	55	65	50					
Saturn										
Configuration Analysis	▬									
Decision Points	Δ2									
Flights			2	2	3	4	4	4		
Funds, $M	(70) (b)	81 (c)	105	115	115	115	85	25		
Nova										
Feasibility Studies	▬	▬	▬							
Decision Points				Δ3						
Flights									1	2
Funds, $M				50	210	210	210	210	210	210
Total R&D Funds, $M (d)	57.1	140.5	163	230	375	325	295	235	210	210

(a) Beginning in 1962 Thor-Delta replaced by Thor-Agena B

(b) Funded by Department of Defense

(c) Total FY 1961 funding for Saturn $140 M - includes $46 M for S&E and 13 M for C&E not shown

(d) Vehicle Procurement beyond development phase shown on this table is funded by the using project.

1. Decide time of replacement of Atlas-Agena with Atlas-Centaur

2. Select upper stages for the Saturn vehicle

3. Determine configuration of the Nova vehicle

Space Propulsion Technology

The objectives of NASA's activities in the space propulsion technology area are the development of propulsion systems suitable for the nation's immediate and future needs for orbital and deep space flight and the support of the research needed to precede and to guide the development activities.

These developments are in the areas of liquid propellant, solid propellant, nuclear and electric propulsion. They are coupled with the necessary supporting research projects which will assure a steady growth in the "state-of-the-art" and back up the propulsion developments. Table VI shows the major areas of endeavor and indicates the funding required.

The 1.5 million pound thrust engine is the present major development item in this area. It is scheduled to be ready for flight test by 1964. The development currently is in the injector development phase and a "work horse" chamber has been fired.

By mid 1963 a general propulsion system review and evaluation will be carried out as an element of the Nova vehicle preliminary design studies. In this review and evaluation large liquid or solid engines and clusters of smaller engines will be considered as well as the merits of promising new engine configurations such as the plug nozzle.

In order to use properly the full potential of presently planned large boosters, it will be necessary to develop high thrust, high energy upper stage engines. An example is the 150K, LH_2-O_2 engine being considered as a possible second phase Saturn development. Alternatively, adaptions of conventional LOX-JP or storable propellant engines must be carried out.

The research and advanced development program on liquid propellant systems includes propellant evaluation, evaluation of novel propulsion system concepts - particularly those adaptable to space applications, injector design and component design and evaluation.

In the solid propellant field, NASA is conducting research and development on thrust modulation of solid rockets, materials, solid propellant propulsion systems and high energy propellants.

The objective of this program is an extension of solid rocket technology, in order to increase the versatility and performance of solid rockets for those space missions for which solid propellant rockets have preferred characteristics. Advanced development work will be directed primarily toward the relatively small, special purpose rockets needed for payload uses and advanced missions.

The nuclear rocket program is a joint NASA-AEC venture with the AEC responsible for the reactor and the NASA for power plant and systems hardware. This work is presently in the supporting research stage and is directed toward evolving an experimental nuclear heat transfer rocket for space propulsion. The major purpose of the present nuclear program is the evaluation of all the thermal, nuclear, mechanical and logistic factors of a nuclear system. The present KIWI reactor tests and "Rover" pump development are scheduled to be completed by 1964. The nuclear heat transfer program will be reviewed continuously to determine when the full development of a flyable nuclear rocket system is appropriate. A general design analysis of a flyable system will be made to provide basic engineering information for this review. A 1000 megawatt reactor, capable of being launched by Saturn, is currently being considered.

The entire electric and solar propulsion program is in the early experimental research phase. It is the objective of NASA, through a program of research and experimentation, to determine the characteristics of these high specific impulse, but generally low thrust, propulsion systems. If the research results are promising, these systems will be used for space vehicle attitude stabilization, orbit correction and position control, and main propulsion for high altitude satellites and deep space probes.

It appears at this time that several years of research will be required to reach an initial evaluation of the development potential of ion and plasma propulsion system. This type of propulsion system will also be reviewed continuously to determine when the program should proceed into a development phase. The ion and plasma propulsion systems for space flight will require an electrical power source of at least 30 KW, the SNAP VIII power level. Therefore, ion and plasma schemes, suitable for space propulsion are very much dependent on the successful outcome of the SNAP VIII development. It is expected that the development of this device will require about 4 - 5 years.

SPACE PROPULSION TECHNOLOGY

Fiscal Year	60	61	62	63	64	65	66	67	68	69
Development										
✓ 1.5 Million Pound Engine	24.2	26.0	60	60	30	10	5	5	5	5
✓ Upper Stage Engines	1.7	8.0	30	25	25	10	3	3	3	3
✓ Decision Point					△[1]					
Advanced Propulsion System						20	50	50	50	50
Research										
Liquid Propulsion	4.4	6.0	8	10	10	10	10	10	10	10
Solid Propulsion	3.8	2.8	3	5	5	5	5	5	5	5
Nuclear Propulsion	4.1	5.5	10	10	10	10	10	10	10	10
Electric Propulsion	1.3	3.2	7	10	10	11	12	12	12	12
Total R&D Funds, $M	39.5	51.5	119	120	90	76	95	95	95	95
Propulsion C&E Funds, $M	9.9	0	10	10	10	10	10	10	10	10

1. Establish Advanced Propulsion System Development (Chemical, nuclear or electric) based on comprehensive analysis of status of propulsion technology

Vehicle Systems Technology

The objective of the vehicle systems technology program is to develop the components and the technology of guidance, control, orientation, and auxiliary power units required to permit the timely development of advanced vehicle and spacecraft systems. A substantial development program for these devices is being carried forward by the Department of Defense and NASA plans take full advantage of this support.

The role of NASA in the vehicle systems technology area will be to engage in a continuing program of research and advanced development in order to advance the state-of-the-art and to improve the subsystem elements of guidance, control, and auxiliary power systems. Due to the fact that the system requirements for these components are strongly mission or vehicle oriented, the development of hardware items in this area will be carried only to the point where the feasibility and operation of critical portions of the system have been demonstrated. The development of such devices will not be carried to the state of complete operational units until a specific need has been generated by a vehicle or payload program. At that time, the hardware development and integration into the payload or vehicle will be undertaken.

The vehicle system technology program is divided into two major areas, guidance and control and electrical power generation. The overall program and funding schedule are shown in Table VII.

The guidance and control activities for the present and the near future are based on a study made for NASA in the early part of 1959. This program consists of the development of light-weight inertial guidance with a follow-on improvement program for the injection guidance of the Agena B, Centaur, and possibly the Saturn vehicle. For early usage in mid-course guidance, earth-based command systems using the deep-space tracking net will be developed. For later applications, particularly for planetary approaches, the spacecraft will use a vehicle borne celestial guidance system. Terminal guidance and attitude control are extremely mission oriented and require a specific design related to the requirements of each mission.

Key items which will be developed to the point of being ready for initial flight tests in order to fit specific payload or mission needs are: Agena B and Centaur injection guidance by early 1961, crude payload attitude stabilization by early 1961, ground-based radio mid-course guidance by mid 1961, vehicle-based celestial mid-course guidance by mid 1962, improved injection guidance by mid 1962, soft landing terminal guidance lunar or planetary spacecraft by 1963, injection guidance for a two stage Saturn vehicle by 1963, accurate payload attitude stabilization (0.01° or better) for the orbiting astronomical observatory by 1964, and rendezvous terminal guidance for orbital staging by 1965 or later.

Considerable supporting research and advanced development is required to support the guidance and control program. Areas which will be investigated include small, lightweight precision (10^{-5}g) accelerometers, cryogenic, electromagnetic, and electrostatic support systems for gyros and attitude control inertia wheels, long life gyroscope spin axis bearings, and attitude control and system integration of payloads having large solar collectors or antennas.

The present electrical power generation program is divided into three major areas, nuclear, solar and chemical. This program for the next few years will be largely one of a supporting research and advanced development nature.

The need for large nuclear power sources stems primarily from the requirements of providing large amounts of electrical power for electrical propulsion devices of reasonable thrust. A secondary need is to supply the power demands for payloads requiring higher power levels than can be supplied conveniently by solar or chemical means. These power levels, generally taken to be greater than 5 to 10 kilowatts, might be required, for example, for a wide bandwidth active communications satellite in a 24-hour orbit or a meteorological satellite using radar.

The current major problem area in the nuclear electric program is the development of the technology of high temperature liquid metal closed cycle power generation systems. To satisfy this need, a program of research and analysis is underway on the problems of liquid metal corrosivity, boiling and condensing heat transfer, the emissive properties of radiators in space, radiator penetration by micrometeorites, and shielding techniques. It is expected that this program will continue for the next several years.

The present NASA nuclear electric power generation program has one advanced development effort, the Snap VIII, a 30 KW reactor turboelectric power system in which the reactor will be supplied by the AEC and NASA will develop the conversion system. It is expected that the program goals will be accomplished by about 1965.

In addition to the 30 KW power system mentioned above, there is need for a reliable power unit in the 50 watt to 5 KW level which is not dependent on accurate attitude orientation and the use of solar energy. Such a unit would find use for a lunar or Venusian soft landing or a non-oriented spacecraft. NASA interest in such units has been expressed to the AEC so that it may be taken into consideration in the AEC's current research and development program on small nuclear electric power generation systems.

A study of the hazards associated with the use of nuclear power supplies in space vehicles is presently being made by a joint NASA-AEC committee. The recommendations of this committee are expected to be submitted to the Administrator by February 1960, and the NASA nuclear power generation program will be reviewed at that time in the light of these recommendations.

The remaining NASA needs for electrical power generation in space can be satisfied by application of solar or chemical energy. Solar power is best suited for providing low to moderate amounts of electrical power for long durations while chemical power is better suited to supplying a wide range of energy levels for short times or for energy accumulation and storage.

The research and advanced development program on solar power will provide support in areas such as photovoltaic cells, solar collector structures, thermionic, thermoelectric, and turboelectric conversion devices, and thermal energy storage. The present solar power program has one major development effort, Sunflower I, which will combine the AEC SNAP II turbo electric conversion system with a solar heated mercury boiler located at the focus of a 30 foot diameter parabolic mirror collector.

Chemical or electrochemical power generation devices are used to supply or store electrical energy in practically all launching vehicles and spacecraft. Most of the NASA requirements for primary and secondary batteries can be met with units which are already in an advanced state of development by industry. Research and advanced development will be provided, however, in the areas of high performance primary batteries and high efficiency, low weight energy storage systems. An item in which NASA has a specific interest is the hydrogen-oxygen fuel cell. The NASA program in this area should be implemented as soon as possible.

The miscellaneous category in Table VII covers the experimentation and analysis required preparatory to establishing a development program. In FY 1962 and beyond funding for this activity is assumed to be distributed among the development programs.

FISCAL YEAR	60	61	62	63	64	65	66	67	68	69
Guidance & Control										
Agena/ Centaur										
Injection Develop & Test										
Improve										
Mid Course-Develop & Test [a]										
Terminal-Develop & Test [b]										
Saturn/ Nova										
Study										
Develop & Test										
Attitude Control										
Develop & Test										
Refine (0.01°)										
R&D Funds, $M	3.2	18.2	29	25	22	19	17	16	15	15
Power Generation										
Nuclear										
Snap VIII Develop										
Upper Stage Study										
Possible Develop										
R&D Funds, $M	1.9	4.5	12	17	21	24	25	27	28	28
Solar										
Sunflower Develop										
R&D Funds, $M	2.6	4.7	5	6	6	6	6	6	6	6
Chemical										
R&D Funds, $M			1	1	1	1	1	1	1	1
Miscellaneous, $M	5.0	3.0								
Total R&D Funds, $M	12.7	30.4	47	49	50	50	50	50	50	50

(a) Initial flight use in Mid-1961, refined and improved by 1963. (b) Initial flight use in 1963, refined and improved by 1965.

SECRET

SECRET

IANNED SPACE FLIGHT

Manned space flight, a key element in the overall NASA program, has as its long term objective acquiring the vehicles and technology necessary for man to move freely through space. Project Mercury, the first phase of the manned space flight program, has been assigned the highest national priority.

Corollary to Project Mercury are the joint NASA-DOD projects, X-15 and Dyna Soar. Both of these research projects will place a man in the space environment for a period of minutes. By mutual agreement between the Department of Defense and NASA, the DOD has assumed funding responsibility for both projects. NASA is technical manager of the X-15 research program and the DOD is technical manager of the Dyna Soar research program. Each organization will assist the other with technical counsel and advice as required.

The manned space flight program for the next ten years consists of a continuing bio-medical research program and three interrelated engineering phases: (1) Project Mercury; (2) a research and advanced development phase; and (3) an advanced projects phase.

The NASA bio-medical program has two parts, the life support systems required for manned space flight activities and the basic scientific research made possible by access to the free space environment. The bio-medical area is currently being studied by an advisory group which will recommend a preferred program by January 1960. Since this study is not yet completed, only a funding estimate, based primarily on the life support systems requirements, is presented here.

As the manned space flight program proceeds from Project Mercury to the more advanced phases, the large and complex operations anticipated can be expected to require an integration of all the engineering experience developed in earlier phases of the space program. In addition, a project such as a permanent manned space station could provide the opportunity for the integration of many of the currently foreseen uses of space flight; in particular, it could provide a site not only for an engineering and scientific research laboratory, but also for applied meteorological and communications activities.

In order to minimize parallel developments, a technical policy will be followed of using as many as possible of the other projects in the NASA space flight program for the initial development and flight testing of manned space flight subsystems.

Project Mercury has as its objective demonstrating the feasibility of manned space flight by achieving the safe recovery of the astronaut after a three orbit mission. The plan for accomplishing this goal is summarized in Table VIII. Outstanding milestones will be the manned suborbital flights, the first orbital flight of the unmanned capsule and the achievement of the program goal. The manned suborbital flights are scheduled to occur during the interval August 1960 through March 1961, and the first orbital flight of the unmanned capsule is scheduled for November 1960.

The research and advanced development phase, already under way and expected to last for the next three or four years, will provide the background for advanced manned space flight systems. The development of free space mid-course and terminal guidance and control systems is being carried out in conjunction with the lunar and planetary exploration program. The desired configuration and the aerodynamic, structural, guidance and control characteristics of the re-entry (or ferry) vehicle are being studied as part of the aeronautical and space research program. The remaining portion of this phase of the program is directed toward planning the advanced projects phase by defining the mission problem, the injection vehicle development requirements and the re-entry vehicle development requirements.

In order to plan adequately the advanced projects phase, a mission study based on the use of the Saturn vehicle is now under way and should be completed by mid 1961. This study will cover the various possible missions, and will present a recommended program with an estimate of the appropriate schedule and the funding requirements. For the present, it is assumed that the study will recommend a program based on the Saturn vehicle leading toward manned circumlunar flight in about 1966-1967 and the establishment of a permanent near-earth space station in about 1968-1969. Manned exploration of the moon and the nearer planets must remain as the major goals for the ensuing decade.

A strongly interrelated re-entry vehicle study currently under way also is expected to be completed by mid 1961. This study will consider the various configuration and system problems, will take into account any information gained in the Mercury and Dyna Soar programs, and will present a recommended program with an estimate of the appropriate schedule and funding requirements. For the purpose of the present Plan, it is assumed that a single re-entry vehicle can satisfy the requirements for both the lunar and the near-earth missions and can be used with an advanced booster system.

As an essential step in the preparation for manned exploration of the moon and the nearer planets in decades to come, a preliminary Nova vehicle mission study will be undertaken in conjunction with the Nova vehicle configuration analysis, and it is estimated that these studies will be completed by 1963. For the purposes of this Plan it is assumed that these studies will recommend a Nova vehicle development for manned lunar explorations and for larger scale space station activities leading toward manned planetary explorations, and that a Nova vehicle system development will be initiated in 1963.

Upon initiation of the Nova vehicle development program, a comprehensive Nova vehicle mission analysis will be undertaken to specify the manned space exploration program based on the Nova vehicle together with its schedule and funding requirements.

TABLE VIII

MANNED SPACE FLIGHT

FISCAL YEAR	60	61	62	63	64	65	66	67	68	69
Project Mercury										
Flights:										
Capsule Development	1 2	3								
Astronaut Training		1 3 2								
Orbital		1 2 1	6	1						
Funds, $M	87.0	108.0	100							
Adv. Manned Projects										
Saturn Mission Study	████	████								
Re-entry Vehicle Study	████	████								
Nova Mission Study:										
Preliminary	██	████	████							
Comprehensive				████	████	████	████	████	████	████
Biosciences Program Analysis	██									
Decision Points	△1	△2			△3					
Flights(a)					4	6	8	7	7	5
Funds, $M			20	125	180	260	260	340	360	360
Total R&D Funds $M	87.0	108.0	120	135	180	260	260	340	360	360

a. Vehicles of Atlas-Agena, Atlas-Centar, Saturn and Nova Classes

1. Establish life support and bio-science program
2. Establish manned space flight program based on Saturn vehicle
   Establish reentry vehicle development program
3. Establish manned space flight performance requirements for Nova vehicle. Establish manned space flight program based on Nova vehicle.

ENGINEERING AND SCIENTIFIC RESEARCH

Another primary responsibility of NASA is to conduct a program of research which will contribute materially to the expansion of human knowledge of phenomena in the atmosphere and space and to the improvement of the usefulness, performance, speed, safety and efficiency of aeronautical and space vehicles. To fulfill this responsibility, NASA has a threefold program of (1) Scientific Investigations in Space to extend man's knowledge of phenomena in the atmosphere and space; (2) Satellite Applications to exploit the discoveries of space science and to develop those aspects of aeronautical and space technology which are of potential economic and social benefit and (3) Aeronautical and Space Research to provide the broad foundation of scientific and engineering information needed to insure the successful development of the national aeronautical and space program. Plans in these three areas of activity are discussed below.

Scientific Investigations in Space

While space science activities consist primarily of investigations made possible by rockets, satellites and space probes, it is supported by essential "earth-bound" laboratory research programs which are discussed more fully under the heading Aeronautical and Space Research. In the space science program as in other programs of scientific research, each new inquiry depends in part upon the results of previous experiments. While gross areas can be identified which are likely to have long term research interest, detailed planning can be projected effectively only a short distance into the future and should be strongly influenced by research results as they are accumulated. For the purposes of this Plan, the space science activities are grouped in the following subareas:

1. Sounding Rockets
2. Scientific Satellites
3. Lunar and Planetary Exploration

Sounding Rockets

The sounding rocket program is a continuing investigation of geophysical and related phenomena in the region from the earth's surface through satellite altitudes. Continuing studies and investigations will be made of the structure of the atmosphere; the ionosphere and the geomagnetic field; the origin, nature, motion and distribution of energetic particles; and the chemistry of and solar-dynamical effects in the upper atmosphere. The sounding rocket program is currently being carried out at a rate of approximately 100 launchings per year. It is expected to continue at about this rate at a funding level of approximately 10 million dollars per year.

Scientific Satellites

Scientific satellite activity is a continuing program of research in geophysics, observational astronomy and solar physics.

The program of geophysical research includes investigation of the structure, composition and dynamical behavior of the earth's atmosphere and ionosphere; investigation of the nature and origin of the Great Radiation Belts; investigation of the relations between solar activity, the earth's atmosphere and surface meteorology; and investigation of phenomena associated with photons, ions, cosmic rays, other energetic particles, magnetic, electric and gravitational fields, micrometeorites and other matter.

The observational astronomy program consists of several interrelated projects whose objectives are to establish and operate astronomical observatories orbiting above the absorbing atmosphere of the earth. Precision telescopic observations, with ground control, will be made of the emission and absorption features of the sun, stars, planets and nebulae in the unexplored ultraviolet, infrared and X ray regions of the electromagnetic spectrum. Gamma ray emissions from the sun, stars and interstellar space will be studied and observations of the planets, sun, radio stars and the galactic background will be made at radio frequencies which are absorbed by the earth's atmosphere and ionosphere. Several effects predicted by general relativity which cannot be investigated adequately on the surface of the earth will be tested.

The solar physics program encompasses the establishment and operation of unmanned solar observatories above the earth's atmosphere to make photometric and spectographic observations of the sun and the solar atmosphere in the ultraviolet, X ray and infrared regions of the electromagnetic spectrum. Eventually, probes will be employed to penetrate the solar atmosphere to make direct observation of its properties.

Scientific satellite activity is expected to build up to approximately 12 launchings per year by fiscal year 1962 at an anticipated annual cost of 75 million dollars for the program from Fiscal Year 1964 on.

Lunar and Planetary Exploration

During the next ten years NASA's program of lunar and planetary explorations will emphasize initially the study of the moon. While manned flight to the moon is not a goal expected to be achieved during the next ten years, in a sense the manned space flight program, the space vehicle development program and the program of unmanned lunar and planetary exploration are all oriented toward the ultimate objective of manned flight to the moon and the nearby planets. The program described here is one of the essential preparatory activities, the unmanned exploration of the moon and planets.

The scientific objectives of the unmanned lunar and planetary exploration program are: the exploration of the surface and nearby environment of the moon and the nearer planets; and the determination of the physical and chemical properties of the lunar and planetary atmospheres, surfaces and interiors. Major experiments are planned to determine the physical characteristics of the lunar surface both for basic scientific information and for the future selection of landing sites. The program includes lunar and planetary probes, orbiters, rough landings, soft landings and mobile vehicles for unmanned exploration. It is recognized that the program will make ever increasing demands on vehicle and guidance capabilities.

The unmanned exploration of the moon and near planets will proceed in roughly three phases. The first phase, preliminary lunar flights, has as its objective the obtaining of initial information about the lunar surface and environment. Three additional flights are scheduled to be launched in this first phase program, a Thor Able Deep Space Probe in early 1960, an Atlas Able Lunar Probe (with backup) in the middle of 1960, and a Thor Delta Space Probe in late 1960.

The second phase has as its objectives the collection of detailed data on lunar surface characteristics, including studies with contact instrumentation, and may include initial flights to the vicinity of the nearer planets. This phase makes use of the more advanced vehicles, Atlas Agena B and Atlas Centaur. Planetary probes to the vicinity of Venus and/or Mars in late 1962 will be flown, provided the 1960-1962 experience with vehicle development has been favorable. The level of effort during this second phase will build up to about four flights (Atlas Agena or Atlas Centaur) per year. The early flights (1961-1962) will have payload experiments consistent with the guidance developments of that period which will be limited to injection and (later) mid-course systems. By the end of 1962 or the beginning of 1963, initial experiments based on lunar terminal guidance should become feasible. Later, the 1964 opportunities to launch vehicles toward Mars and Venus will be exploited.

The third (advanced) phase of the unmanned Lunar and Planetary Explorations program has as its objective, the exploration and investigation of the lunar atmosphere, surface and interior in sufficient detail to provide large-scale research and development leading to the manned lunar landing operation and the initiation of a more intensive planetary exploration program.

The most significant lunar and planetary missions starting in 1965 are expected to require relatively heavy payloads such as might be delivered with an advanced Centaur or a Saturn. An Advanced Lunar Exploration Mission Analysis leading to the specification of a recommended program for this phase will be completed in 1961. While the details of the program are not yet determined, it is expected that approximately 10 to 15 lunar flights will be required during the period from 1965 through 1969.

The planetary missions have, as their scientific objectives, the study of the origin and evolution of the solar system, the study of the nature of planetary surfaces and atmosphere, and the search for life on the planets. Vehicles with at least the performance of a three stage Atlas Agena and preferably that of Atlas Centaur or Saturn will be required. A Planetary Exploration Mission Analysis to specify a recommended program for this activity will be completed in 1961. While the details of the program are not yet determined, it is expected that approximately 10 flights will be required during the period 1965 through 1969.

FISCAL YEAR	60	61	62	63	64	65	66	67	68	69
Sounding Rockets										
Flights	65	80	100	100	100	100	100	100	100	100
Funds, $M	8.8	8.0	10	10	10	10	10	10	10	10
Scientific Satellites										
Flights [a]	2 1	3 3 3 1	12	12	12	12	12	12	12	12
Funds, $M	23.8	41.7	65	70	75	75	75	75	75	75
Lunar & Planetary										
Flights [b]	1 1	1 1 1	3	4	4	4	4	5	5	7
Funds, $M	49.0	45.0	65	65	65	80	130	145	215	215
Advanced Lunar Mission Analysis										
Planetary Mission Analysis										
Decision Points				△ 1						
Total R&D Funds, $M	*81.6*	*94.7*	*140*	*145*	*150*	*165*	*215*	*230*	*300*	*300*

a. Juno II, Thor-Delta, Scout, and Thor-Agena B vehicles.
b. Thor-Able, Atlas-Able, Thor-Delta, Atlas-Agena B, Atlas-Centaur and Saturn vehicles.
1. Establish advanced lunar exploration program.
Establish planetary exploration program.

Satellite Applications

It is the purpose of the Satellite Applications program to exploit the discoveries of space science and to develop those aspects of aeronautical and space technology which are of potential economic and social benefit. Current programs call for the application of space techniques to communications, meteorology and navigation.

Communications

The objectives of NASA's activities in the communications satellite area are to conduct a program of research and evaluation on the use of satellites for communications purposes in order to demonstrate feasibility and to promote the development of an adequate and effective communications satellite technology.

Both the Department of Defense and NASA have active programs in this area with the DOD currently concentrating on the development of an active repeater communications satellite system and NASA doing research on a passive reflector system. NASA's experimental approach starts with the development of large inflatable spheres which form the satellite component of a passive system. Associated ground transmitting and receiving equipment will be used in a later phase to demonstrate the feasibility of passive communications systems and also to evaluate the quality of the construction, in the space environment, of the passive reflector.

Concurrent with the experimental program on passive communications systems, there will be a program of analysis directed toward a better understanding of national communications system requirements. This analysis will include consideration of military as well as civil communications satellite system requirements and feature a comprehensive survey of the research now going on in communications satellite technology, both privately and publicly financed. It is expected that the initial results of this analysis will be available early in 1961 to assist in formulating the program for further activity in the communications satellite area.

The nature of the communications satellite research program beyond the first year depends on both the results of the technical analysis and the policy finally adopted with respect to government-industry relations. In broad outline, it is expected that the future program will involve further research and analysis and an experimental research program involving on the order of one major vehicle per year, or the equivalent share of several payloads on satellites or sounding rockets. The funding estimate shown in Table X is based on the assumption that the policy adopted is such that private funds will cover all, or a major part, of the development program leading toward operational systems.

Meteorology

The major objective of the national meteorological satellite program is an increase in the knowledge and understanding of the atmosphere so that this knowledge can be applied to the forecasting of weather. It is the specific purpose of NASA in this national program to develop a meteorological satellite observational system which can be integrated into the meteorological operations of the United States.

The meteorological satellite program should develop into an observational system which will meet the information requirements of the two prime users of these data - the Weather Bureau and the Department of Defense. To insure that the program satisfies these needs, a joint Meteorological Satellite Advisory Committee has been established with representation from the Weather Bureau, the Department of Defense and NASA.

High altitude rocket photography has shown that adequate resolution of cloud systems can be obtained from several hundred miles altitude. With this background, a satellite program can proceed with assurance that operationally useful data in at least this limited category will be obtained.

While the Meteorological Satellite Program is now in a research phase, it is being carried out with the expectation of evolving into an operational phase. In the operational phase, the operational and funding responsibility will be carried either by the Weather Bureau or jointly by the Weather Bureau and NASA (and possibly DOD). The determination of the policy to be followed will be made as early as possible.

There are several research programs within NASA separate from the meteorological satellite program which have direct meteorological aspects; for example, a portion of the space sciences geophysical program is directed toward the determination of the composition and structure of the upper atmosphere. Three NASA geophysical satellites flown in 1959 carried experiments related to the meteorological program. These are the Vanguard II cloud cover experiment, the Explorer VI cloud cover experiment and the Explorer VII heat balance experiment.

At present, the meteorological satellite activity (see Table X) has both analytical and experimental research programs. The experimental program has currently scheduled two Tiros flights in early and mid 1960. Under the code name Nimbus, consideration is being given to a meteorological package for inclusion as part of the payload of advanced launching vehicles in 1961 and 1962.

The experimental research program is expected to continue, concurrent with any developmental or operational program, at approximately its present level, corresponding to two Thor Agena payloads per year or the equivalent in partial payloads in other vehicles.

The analytical phase of the meteorological satellite program is being carried out primarily by the Weather Bureau with NASA funding. A meteorological satellite research group has been established in the Weather Bureau to process and analyze meteorological satellite data, to assist in the design of experiments and instrumentation, to utilize the resulting satellite data to increase our knowledge of the atmosphere, and to develop techniques of applying satellite data to meteorological operations.

The present research program has as one of its principal purposes the obtaining of sufficient information to enable a decision to be made on the appropriate time to introduce an operational meteorological satellite system. A development plan for such an operational system will be prepared as soon as sufficient research information is available; the earliest possible date is estimated to be mid 1961. A decision to introduce an operational phase will be based on a review of observational satellite techniques developed in the experimental research program on the state of meteorological science at that time and on the need for a satellite system. For the present Plan it is assumed that a decision is made to introduce an operational phase in

FY 1963 based on simple, Vidicon type, cloud cover measurements, that the operational equipment can be flown in the same vehicles being used for research purposes, and that no additional tracking and telemetering stations will be required. It is further assumed that the funding policy finally adopted will be one where NASA will fund flight operations and preliminary data processing and the Weather Bureau will fund the final data analysis and exploitation.

Navigation

The objective of NASA activities in the navigational satellite area is to investigate the potentialities of applying space flight techniques to the development of a practical all weather navigation system.

As an initial step to determine whether NASA should support an active navigational satellite program, a feasibility study should be made to determine to what extent, if at all, space techniques should be exploited to develop a commercially useful navigation system. This analysis should take advantage of any information resulting from the Department of Defense navigation satellite program, Transit, and should include consideration of the possibility of making use of the Transit system or some derivative of it for the commercial application. Further, the study should include a summary of appropriate existing knowledge, investigation of alternative techniques, preliminary design studies of competitive satellite systems, and an evaluation of the technical and economic feasibility of the alternative systems. This feasibility analysis should be completed by late 1960. The funding estimate does not presently provide for a separate NASA program.

FISCAL YEAR	60	61	62	63	64	65	66	67	68	69
Communications										
Analysis	▬▬	▬▬	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Flights	1	1	1	1	1	1	1	1	1	1
Decision Points		△1								
Funds, $M	3.2	5.6	16	25	25	30	25	20	15	15
Meteorology										
Flights[(a)]	1	1	2	2	2	2	2	2	2	2
Decision Point			△2							
Funds, $M	7.9	20.7	20	35	50	50	50	50	50	50
Navigation										
Analysis	▬▬	▬▬								
Decision Point		△3								
Funds, $M	0.1	0.3								
24 Hour Satellite [(b)]										
Communications Development Flights			3	4	4	4	2	2	2	2
Total R&D Funds, $M	11.2	26.6	36	60	75	80	75	70	65	65

a. Atlas-Agena vehicle or equivalent from FY 1962 on. Payloads are assumed to be partially research and partially operational from FY 1963 on.

b. Assumed to be funded by NASA, the Department of Defense and private industry.

1. Establish program for further activity in communications satellite area.

2. Review status of meteorological satellite reseacch program to initiate development of operational Meteorological Satellite System, if appropriate.

3. Determine appropriate role for NASA in development of navigation satellites.

Aeronautical and Space Research

The primary objectives of the aeronautical and space research program are to provide the broad foundation of basic and applied research required to insure the successful development of the national aeronautical and space vehicle program and to provide the new scientific knowledge and new concepts necessary for major technological advancements. In addition to these primary objectives, the aeronautical and space research effort provides advanced development and special testing support to the aeronautical and space programs of both the Department of Defense and NASA. This research activity will be accomplished largely by in-house efforts at the several NASA research centers supplemented by research grants and contracts, mainly to universities, government laboratories, and other nonprofit institutions. The NASA program of research at industrial laboratories is covered in the other sections of this Plan. The aeronautical and space research program is coordinated with the other research efforts of universities, industry, and that done as a part of the development programs of NASA and the Department of Defense.

A detailed description of the planned aeronautical and space research program would be valid only for a short distance in the future since the nature of the program is highly dependent on the results of previous research. The aeronautical and space research program can best be identified by describing the present effort and the gross long term trends in terms of distribution of effort. Figures II and III indicate the current and projected distribution of the aeronautical and space research effort by problem area and vehicle application, respectively. Although a large portion of the research work has general applicability, the vehicle type to which the research is presently most applicable is shown.

In Figure II, the Materials Sciences, Structures, and Operating Problems category consists of research on problems of the environment, statistics, and dynamics of structures, the science and applications of materials, and operating problems related to life support and optimum use of humans in aeronautical and space flight. The current major problem areas in materials and structures research are to improve the properties of high strength, low weight structures at high temperature, vacuum and combined environments. In the area of human factors, the main research emphasis is on life support and man's tolerance and capabilities in various physical environments. The level of effort trend for this category of activity is an immediate increase in rate of effort followed by a more gradual long term expansion.

The Propulsion and Energy Conversion program consists of ·esearch in the fields of chemical, nuclear, and electrical ·ockets, electrical power generation, and air-breathing engines. 'he present critical research areas are the investigation of :ombustion, heat transfer, and storage problems of high energy :hemical rockets, the study of heat transfer, pumping, and control ıf nuclear propulsion systems, initial phases of ion and plasma ·esearch, and solar, chemical and nuclear electrical power genera- :ion. It is expected that research in this overall category will .ncrease slightly over the next decade due to a marked increase .n electrical power generation and nuclear rocket work. The ıresent relatively large amount of chemical rocket research is :xpected to decrease toward the end of the ten year period and .ir-breathing engine research is expected to be substantially ·educed during the decade.

The Flight Mechanics category includes research in trajec- ory analysis, control and stabilization, guidance and naviga- ion, pilot problems including flying and handling, instrumenta- ion, and data acquisition and transmission. Research in this rea will center on lunar, planetary and satellite trajectories, utomatic navigation and control systems, interrelationships etween the pilot and the control system, and flight instrumenta- ion and data telemetering systems, including erectable space ntennas and attenuation of radio signals by ionized gases. The ajor shift in emphasis will be due to a factor of four increase hroughout the decade in the level of effort being applied to he electro-mechanical activities of data acquisition, instru- entation, guidance and navigation.

The research area, Aerodynamics and Environmental Physics, ncludes supersonic and hypersonic aerodynamics, subsonic and ransonic aerodynamics, flow physics, magnetogasdynamics, and pace environment physics. At present, research is being done n VTOL/STOL aircraft, subsonic transport and cargo aircraft, ake-off, landing and heating problems of supersonic and hyper- onic aircraft, dynamics and heating of re-entry bodies, oundary layer, dynamics, physics, and chemistry of heated gas low, magnetic and electric properties of ionized gases, and he nature and behavior of the space environment. The most sig- ificant shift of emphasis in this category is a threefold ecrease in the amount of aerodynamic research by the end of ne decade accompanied by an increase of the level of effort in ne magnetogasdynamics and environmental physics areas.

Figure III shows that approximately 40% of the research ffort is now primarily applicable to space vehicles, 15% to issiles, and about 45% to aircraft. The projection to the ıture indicates that the major trend is a reduction of missile nd aircraft research and an increase in support of space ehicles.

The aeronautical and space research program is expected to be of a continuing nature, supported at approximately the present level of R & D funding. The R & D funding shown in Table XI includes the research grants and contracts program in addition to all nonproject oriented work at the centers. The C & E funding shown covers facilities at JPL, ABMA, and the centers which are not funded elsewhere as part of a vehicle, operation, or propulsion development program. This funding rises slightly above the present level for the next few years reflecting the facility changes required as a result of the reorientation of center activity toward space research.

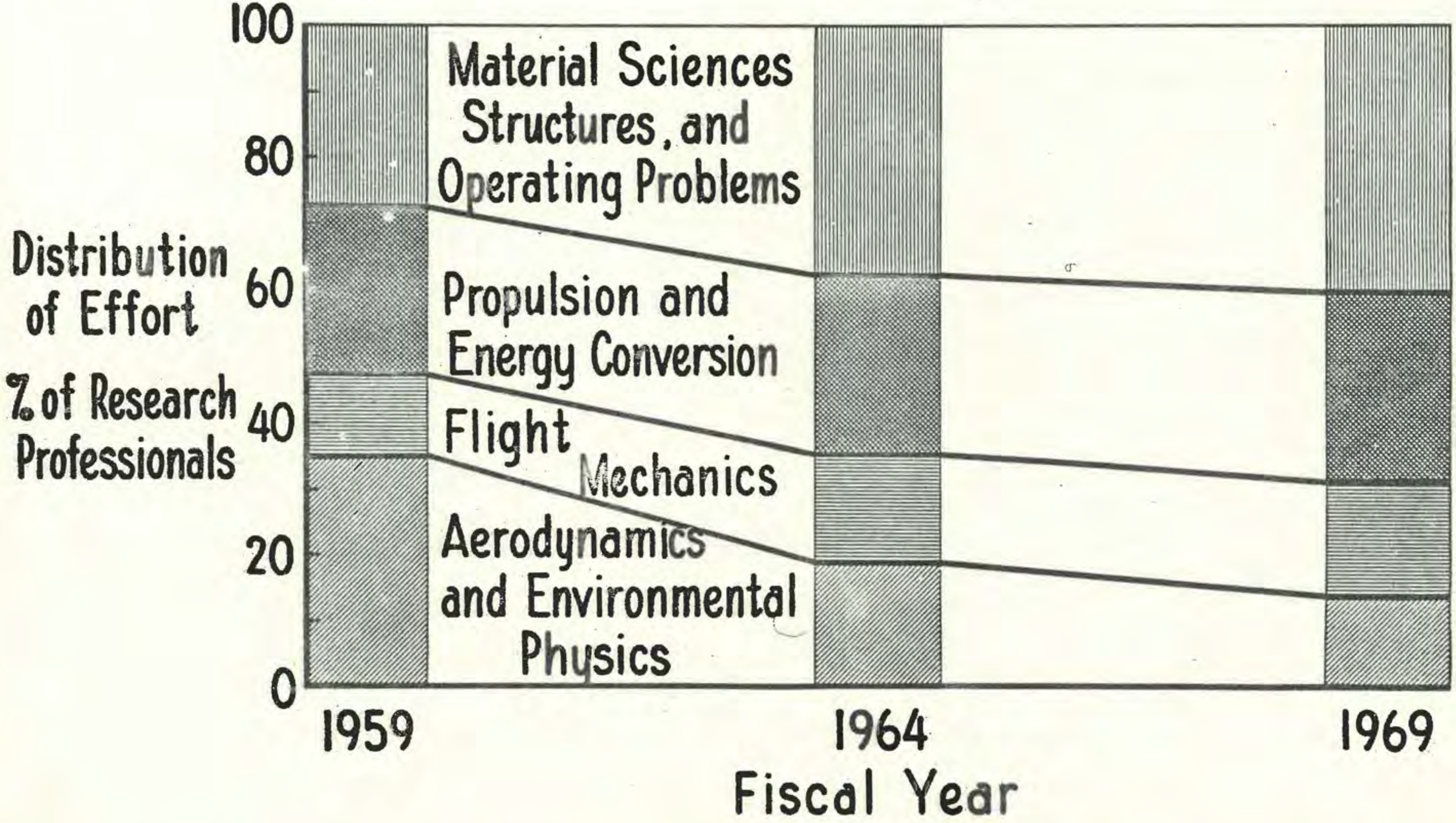
TABLE XI

AERONAUTICAL AND SPACE RESEARCH

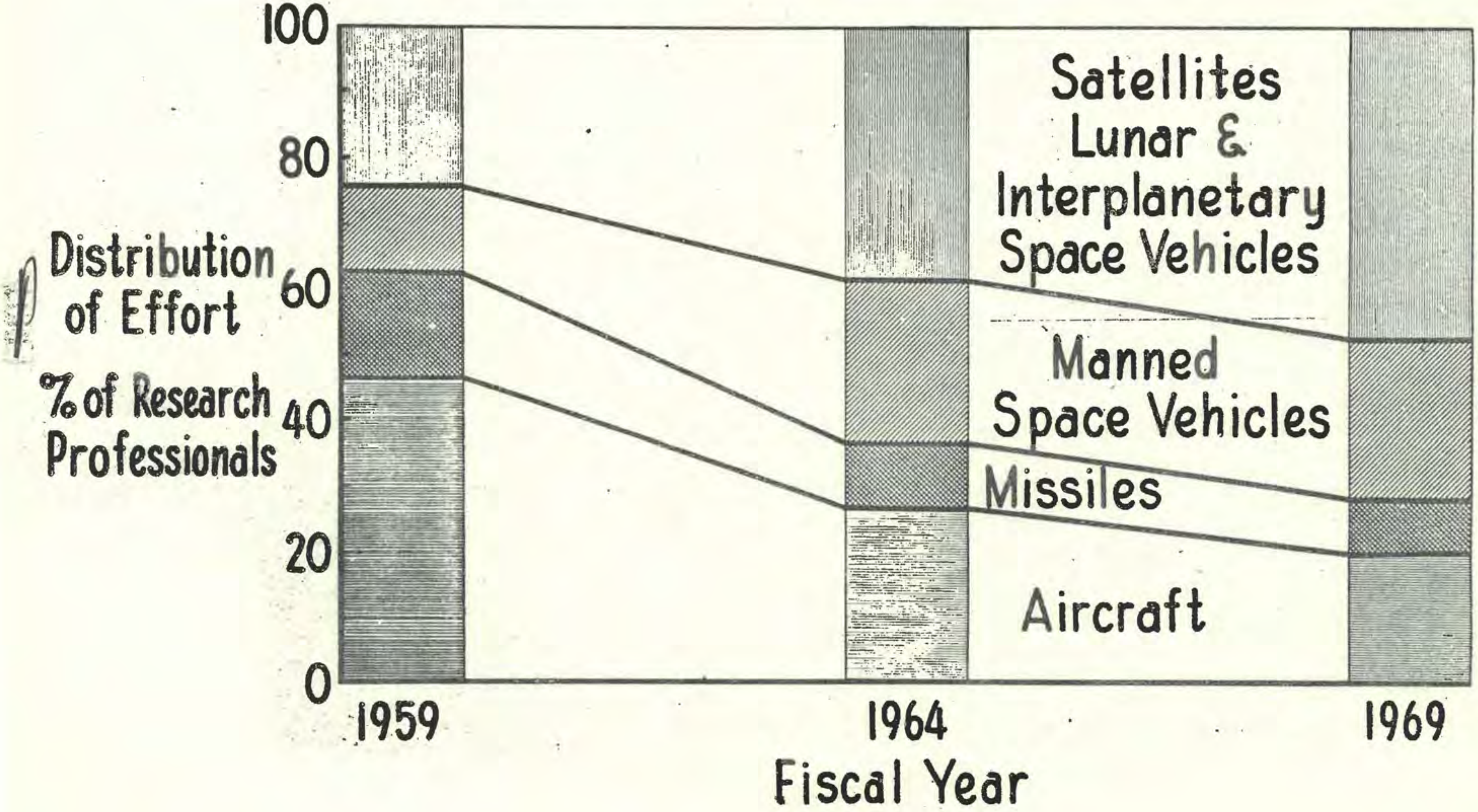
Funding Requirements in Millions of Dollars

Fiscal Year	60	61	62	63	64	65	66	67	68	69
Research and Development	27.6	61	70	70	70	70	70	70	70	70
Construction and Equipment	32.7	59.4	65	70	65	60	55	50	50	50

BY PROBLEM AREA



BY VEHICLE APPLICATION



SECRET

SPACE FLIGHT OPERATIONS

The objective of the space flight operations activities is to provide the logistic support needed to satisfy the requirements of the space flight research and development program in the areas of communication, tracking, data acquisition, computing, command, and launching. One major function of the space flight operations effort is to integrate the requirements for these facilities in order to minimize duplication, achieve timely availability at low cost, maintain flexibility, and provide growth capability.

At the present time, and for sometime to come, the satellite and space activities of NASA are strongly oriented toward research and development. Therefore, the NASA policy will be to provide facilities which are general purpose and easily adaptable for multiple uses, rather than equipment designed for a unique program.

The national program in the area of tracking and data acquisition is based on a joint NASA/DOD study made in early 1959. This study led to an agreement between DOD and NASA that a flexible, general purpose world network of satellite and space vehicle tracking and telemetering stations would be established to meet the R&D needs of both the DOD and NASA except for certain operational intelligence programs of the military. The portions of the world complex for which NASA is responsible are: the Earth Orbit net, including the Minitrack and Baker-Nunn installations; the Deep Space Net; the Mercury Net; and a continuation and expansion of the Vanguard data reception and analysis center.

The Minitrack portion of the Earth Orbit net consists of a group of stations along the 75th meridian for low inclination orbit satellites supplemented by some additional stations at outlying locations to track polar and high inclination orbits. The present stations have the capability of receiving telemetry, angle tracking by means of an inteferometer antenna, and, at some stations, transmitting commands to the satellite. With suitable updating and modification to improve accuracy and sensitivity, these stations can satisfy most of the R&D scientific satellite needs for the decade.

The Baker-Nunn portion of the Earth Orbit net consists of 12 precision optical camera stations located at sights between

30° north and 30° south lattitude, a few colocated with Minitrack stations. These cameras provide tracking data which are more accurate than that of Minitrack, but which require considerably longer to reduce and interpret. It is not planned to expand the Baker-Nunn camera net; however, studies are underway to determine the need for additional shutter-type ballistic cameras located at some of the tracking sights.

The Deep Space net is in the process of construction at this time. It will consist of three to five large tracking dishes with associated receiving and data handling equipment. At the present time, one station at Goldstone Lake, California is essentially complete. A second station, to be located at Woomera, Australia is in the last stages of fabrication and is expected to be in operation toward the last part of 1960. A third station is to be located in South Africa. This station should be capable of partial operation by the beginning of 1961. The requirements for additional receiving stations, such as one located on the east coast of the United States are being studied at this time. A transmitter and large dish, not discussed in the DOD/NASA agreement, is being installed at Goldstone for purposes of ranging and command to deep space vehicles. The Deep Space Net, with suitable updating and the possible addition of one more station and of transmitting facilities at each site, should be able to satisfy most of the NASA R&D tracking and data acquisition requirements for deep space and wide bandwidth satellite data acquisition for most of the decade.

The Mercury net consists of 17 ground and ship stations located along the path of a 33° inclination orbit starting at AMR. Most of the stations have equipment for telemetering and communicating with the capsule, while a smaller number have C or S band tracking radars and command transmitters. The net is expected to be in operation toward the end of 1960. Although the Mercury net is being designed primarily for the manned space flight satellite program, many of the stations are portable and can serve the needs of tracking and telemetering the launching of other space vehicles. It is expected that elements of this net, modified or supplemented, will be used for other programs throughout the decade.

The computing, communications, and data handling center for the Vanguard program is being modified and relocated at the Goddard Space Flight Center to form a central NASA facility in time to be used with the Mercury program. It is planned that this central data handling system combined with the communications network, originally established for Minitrack and supplemented for Mercury, will form a nucleus for handling the majority of the NASA R&D requirements. Studies to determine the NASA requirements for world timing signals, interstation data transmission, a central data reduction facility, and long range research will be completed by mid 1961.

In order to suit the changing needs of an R&D program, flexible launching facilities will be provided, particularly with regard to such items as growth capability and ease of modification of blockhouse and gantry equipment. Close liaison will be maintained between groups planning the launching facilities of similar programs so that, as in the instance of Atlas-Agena and Atlas-Centaur, mutual use may be made of launching and handling equipment.

The present launching facility plans call for completion in the near future of one pad for Scout at Wallops with a capacity of about 12 vehicles per year, two pads at AMR for the Atlas-Agena B/ Centaur class and the use of a third pad at PMR (yielding a capacity of 36 vehicles per year), a Thor Delta (or Thor Agena B) pad at both AMR and PMR (resulting in a capacity of 24 vehicles per year), and one pad (with space for a second) for Saturn at AMR (giving a capacity of 12 vehicles per year). These capacities appear to be adequate to fulfill the program requirements for these vehicle classes for the next decade. As indicated in Table XII, the need for special recovery facilities, and the second Saturn pad will be determined as a part of the Saturn mission studies which should be completed by mid 1961.

A review will be made in the early part of 1961 to determine the need for an equatorial launching range. While there is no present need for such a facility, the question will be reviewed periodically in the light of new program developments. A review of the requirements for a Remote Nuclear launch site will be completed by mid 1964 in coordination with an advanced propulsion systems review.

The research and advanced development required to support space flight operations activity is primarily concerned with the problems of communication, tracking, and data acquisition. The present low level of activity in this field will be expanded over the next few years to provide additional support. The work to be done in the next few years will include research in low noise receivers, masers, parametric amplifiers, and infrared communications.

The funding estimated for space flight operations activities is shown in Table XII. The assumptions used in estimating the C&E budget are that additional Saturn/Nova launching facilities will be required, but that neither a remote nuclear nor an equatorial range will be needed within the decade.

Tracking & Communication										
Mercury Network										
Develop & Test										
C&E Funds	36.0	15.0								
Deep Space										
Goldstone										
Wide Band Receiver										
Transmitter [(a)]										
Modify for Midcourse Guidance										
So. Africa (DOD) Transfer / Australia										
Improve [(b)]										
C&E Funds	3.5	8.0	8	10	8	8	8	8	8	8
Earth Orbit										
New Stations -136 mc. Modifications										
Studies (Central Reduction Interstation Data)										
Possible Development										
C & E Funds, $M	4.3	4.8	7	10	7	7	7	7	7	7
Launch Facilities										
Centaur - Develop. & Test										
Saturn - Develop. & Test - DOD										
Rqts Study										
Additional Facilities										
Equatorial Range										
Study										
Nuclear Remote Range										
Study										
C&E Funds	5.5	0	23	37	40	38	30	29	20	18
TOTAL C & E FUNDS, $M	49.3	27.8	38	57	55	53	45	44	35	33
TOTAL R & D FUNDS, $M	16.4	32.6	42	50	55	62	65	62	60	60

(a.) Presently a part of the Communications Satellite Program.

(b) Overseas stations made identical to Goldstone.

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