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A NATIONAL SPACE VEHICLE PROGRAM (U)

A Report to the President

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A NATIONAL SPACE VEHICLE PROGRAM

Prepared by
The Propulsion Staff of the
National Aeronautics and Space Administration

In consultation with the
Advanced Research Projects Agency
of the
Department of Defense

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A NATIONAL SPACE VEHICLE PROGRAM

SUMMARY

Under the National Space Act of 1958 (Public Law 85-568) the President of the United States is responsible for developing a continuing program of aeronautical and space activities to be conducted by agencies of the United States. The National Aeronautical and Space Administration is recommending such a program to the President in the area of space flight. The Administrator presents in this report his proposal for a National Space Vehicle Program. This program plan is a continuing effort to be reviewed annually and revieed as needed.

This National Space Vehicle Program was formulated after discussion and consultation with agencies of the Department of Defense, principally the Advanced Projects Research Agency, the Department of the Air Force, and the Department of the Army. Existing and planned projects of the Department of Defense in this area, including those intended for military missions, have been taken into account with the purpose of avoiding any unnecessary duplication of effort.

The present generation of space flight vehicles is being used primarily to place small payloads in close orbits around the earth and to propel very small instrument packages into space. The current group of booster vehicles, namely, Vanguard, Jupiter C, Juno II, and Thor-Able, were all hurriedly assembled under pressure of meeting the threat of Russian Sputniks and none of them possess the design characteristics required by future needs of the National Space Program. The Vanguard, which has the best basic design philosophy, has yet demonstrated no flight reliability. The Jupiter C, which has had the most flight success, has such a low load-carrying capability as to be no longer of interest. The Juno II vehicle has a low injection altitude for satellite use, and requires that it be spun for stability. The Thor-Able booster that has been used in the Air Force moon shots has no attitude control system for the second stage during coast, so that the injection altitude for satellites is on the order of 150 miles. The Atlas-Able being prepared for deep space missions has the best potential load-carrying capability but suffers, as do the others, from being designed for a specific mission.

Our approach up to this time has been much too diverse in that we fire a few vehicles of a given configuration, most of which have failed to achieve their missions, and then call on another vehicle to take the stage. In this situation no one type of vehicle is tested with sufficient thoroughness and used in enough firings to achieve a high degree of reliability.

The National Space Vehicle Program is directed toward avoiding past and present errors. The central idea is that one vehicle type, when fitted with the guidance and payload appropriate to the mission, can serve for most of the space missions planned for a given 2 to 4 year period. By designing the vehicle with this purpose in view and by using it again and again for most of the space work, it appears inevitable that this one vehicle type will achieve a high degree of reliability. Therefore, this program presents a series of space-flight vehicles of increasing payload capability for successive periods of use. Each vehicle of the series will be useful for satellite work including low and high circular orbits. highly elliptical earth orbits, lunar exploration, planetary exploration, and deep space probing.

The first general purpose vehicle of the National series is the ATLAS-VEGA. This is one of three vehicles based on the use of Atlas as a primary stage. The second or VEGA stage is powered by the Vanguard first stage engine modified for high altitude operation. This engine has an excellent record of performance under Vanguard. The tanks are made up principally of standard Atlas parts, thus providing an early availability of the VEGA stage. When used for lunar or planetary missions, a third or terminal stage with solid or storable liquid fuels will be employed. ATLAS-VEGA should see considerable use in the period from 1960 through 1964. It can boost two men into a close earth orbit with enough equipment to sustain them for several weeks. Its principal function, however, may be the exploration of the moon for which it is ideally suited. It should be possible in the next few years to take very high resolution photographs, first of the front or visible side of the moon and eventually of the back or heretofore unseen side. A close approach to a planet will require at least 1000 and probably 2000 pounds of equipment devoted principally to guidance and communication. VEGA is the first vehicle that can carry payloads of this magnitude to the vicinity of Mars or Venus and should pave the way for the use of Atlas-Centaur which is better adapted to the planet mission.

The second general purpose vehicle of the National series is the ATLAS-CENTAUR which is well suited to be a successor to Vega, because it can replace Vega with no change in the Atlas booster. CENTAUR will be useable during the period from 1962 through 1966 for performing the same missions as Vega but with from 50 to 100 per cent more load-carrying capability. CENTAUR is the first vehicle to employ hydrogen as a fuel, and, if successful, should pave the way for use of this highest energy fuel in future vehicles of the National series. The payloads planned for JUNO V and NOVA, more advanced vehicles of the National series, would have to be substantially reduced if a lower energy fuel had to be substituted for hydrogen. There is every expectation, however, that CENTAUR will be successful, owing to the background of experience with hydrogen in industry and also within NASA.

ATLAS-HUSTLER is being developed by the Air Force for military missions. It should be available about six months prior to Vega, but will have only about half Vega's load-carrying capability. It could serve, however, as an interim version of the Atlas boosted series.

The third general purpose space vehicle of the National series is the JUNO V. Actually JUNO V designates the first stage booster of a large multi-stage vehicle. This booster is being achieved by clustering eight ICBM-type engines and nine ballistic missile type tanks to form a vehicle with a gross weight of about 3/4 million pounds. Second and third stages will have to be provided in order to make a complete vehicle of JUNO V. The second stage is about the size of an ICBM, will use conventional fuels and will be designed for high altitude operation. The third stage is roughly the size of an IRBM. It will use conventional fuels at first, but is planned ultimately for hydrogen as a propellant. This vehicle will be capable of placing very large payloads (10-15 tons) in orbits around the earth. A typical mission would involve sending a crew of 5 men into orbit with enough facilities to sustain them for a long period of time, say several months, and the necessary equipment to permit them to perform experiments and make observations. This vehicle may well become the basic vehicle for orbital supply missions, involving the transport of food and supplies to crews in orbit, the exchange of crew members, and the transport of additional fuel and equipment to the orbiting vehicle. In order to perform these latter functions, techniques of navigation and rendezvous will have to be worked out. When used for lunar and planetary exploration, unmanned of course, the JUNO V boosted space vehicle has a load-carrying capability of between 1 and 4 tons. Starting about 1963 this vehicle should see use for at least 5 and perhaps 10 years and may, in time, become one of the most versatile vehicles in the National series.

The fourth general purpose vehicle of the National series is the NOVA, an entirely new vehicle based upon use of the one and one-half million pound thrust engine recently initiated. The earliest possible use of the large engine would come about by using a single unit to propel a first stage booster. In this configuration, however, it would be about the same size as JUNO V and would be competitive to it. Therefore, the first use of the large engine is planned for NOVA, the first stage of which employs a cluster of four of the large engines yielding a total thrust of six million pounds. The vehicle's second stage will be powered by a single million and one-half pound thrust engine and the third stage will be about the size of an ICBM, but will use hydrogen as a fuel. As presently conceived, this vehicle would stand 260 feet high. Despite its immense size, NOVA is the first vehicle of the series that could attempt the mission of transporting a man to the surface of the moon and returning him safely to the earth.

With advances in the state of the art which must surely occur over the next 5 to 10 years, it is conceivable that the NOVA would be improved to transport say 2 or 3 men on the earth-moon and return missions. Four additional stages above the three already mentioned are required for the lunar return mission including the rockets for landing on the moon, taking off from the moon, and for reentry into the earth's atmosphere. NOVA has the capability of transporting, if it is needed, very large payloads, on the order of 75 tons, into earth orbits.

NASA is now supporting project ROVER in anticipation of using nuclear engines in the 1965 to 1975 period. KIWI-A, KIWI-B, and DUMBO-A, low power reactors, are currently under development. These reactors should form the basis for low power space engines that would be useful for propelling upper stages of the vehicles in the National series, starting with Juno V. By increasing the reactor power and power density, it should be possible to produce reactors for high thrust engines useable in booster vehicles, specifically as second stages for Juno V and NOVA.

Succeeding sections of this report are devoted to (1) existing vehicles and their capabilities (2) new vehicles and their missions (3) engine developments and (4) schedule and cost considerations.

EXISTING VEHICLES - CHARACTERISTICS

The existing vehicles are those which are now operational or which will be launched within a period of six months. Their principal characteristics are briefly described below and the vehicles are shown on the following two charts.

VANGUARD is the three stage vehicle designed for the U.S. - I.G.Y. effort. At launching, the Vanguard weighs 22,600 pounds. The first two stages use liquid propellants to boost the third stage and payload to orbital altitude. After the desired altitude is reached the solid propellant third stage accelerates the payload to orbital velocity. Several of the Vanguard stages appear in other vehicles currently in use; such as Thor-Able and Atlas-Able.

JUPITER-C is the four stage rocket which placed the first U.S. - I.G.Y. satellite, Explorer I, into orbit. The first stage of the Jupiter-C was based on the Army's Redstone which boosted the remaining three stages and the payload to orbital altitude. Stages two, three and four (made of clusters of solid rockets) accelerated the payload to orbital velocity. The latter stages were spin stabilized.

JUNO II uses the same upper stage configuration as Jupiter-C. Juno II, however, employs the Jupiter IRBM missile as its first stage, giving a higher payload capability. The gross weight of Juno II is 110,500 pounds; whereas the Jupiter-C had a gross weight of 62,500 pounds.

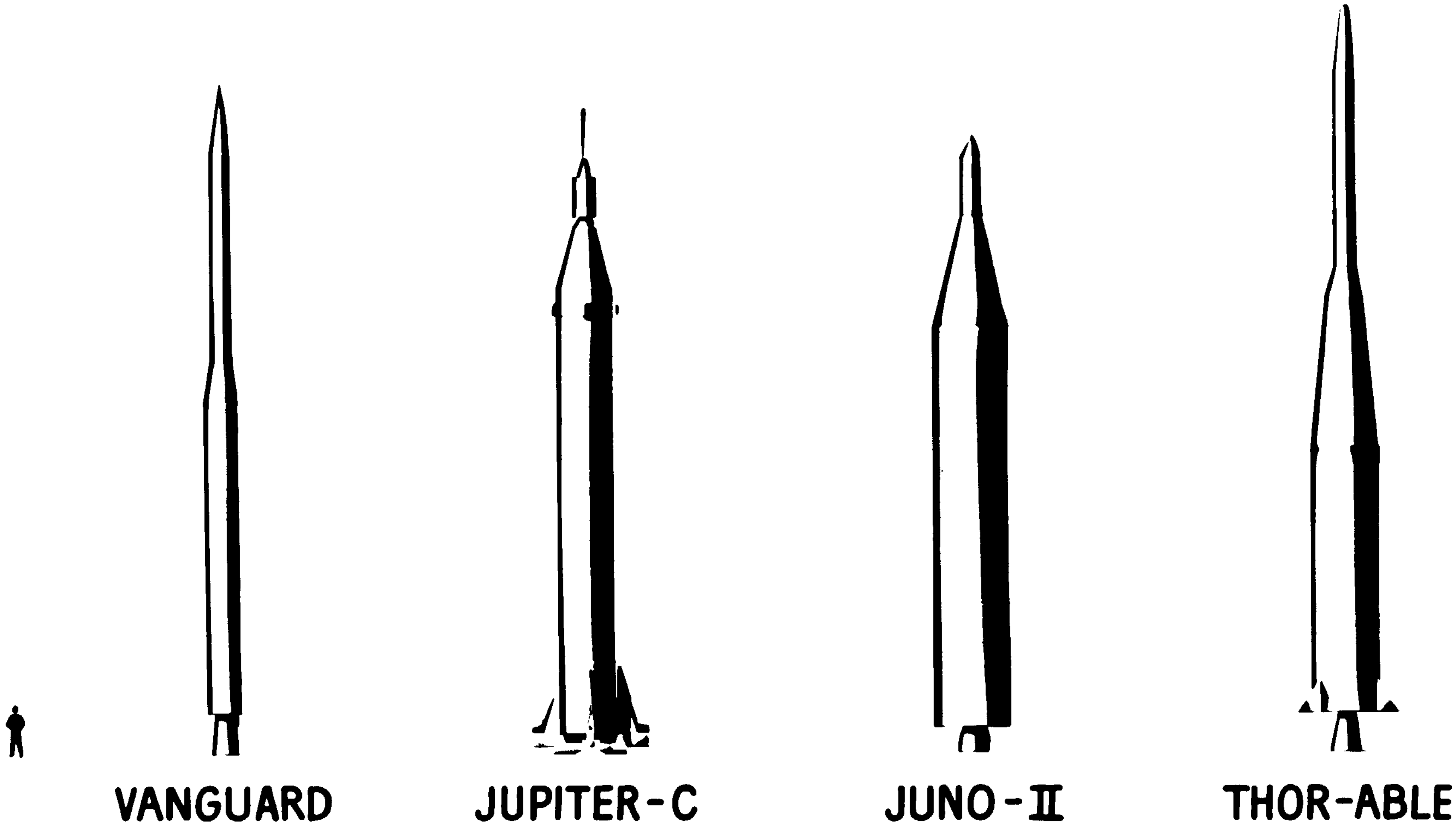
THOR-ABLE uses the Thor IRBM as a first stage and the Vanguard second stage, (Able). At launching, the Thor-Able weighs approximately 110,000 pounds compared to Vanguard's 22,600 pounds. Therefore, greater payload capability is provided. The two stages (Thor and Able) provide orbit capability. Two other versions are available, Thor-Able-I which employs the Vanguard solid third stage and Thor-Able-II which will use the high performance solid third stage developed for future Vanguard launchings.

THOR-HUSTLER is the Thor IRBM combined with a liquid propellant stage employing the Hustler engine. The Hustler second stage contains nearly twice the weight of propellants carried by the Vanguard second stage (Able). Therefore, Thor-Hustler will have increased mission capabilities over the Thor-Able.

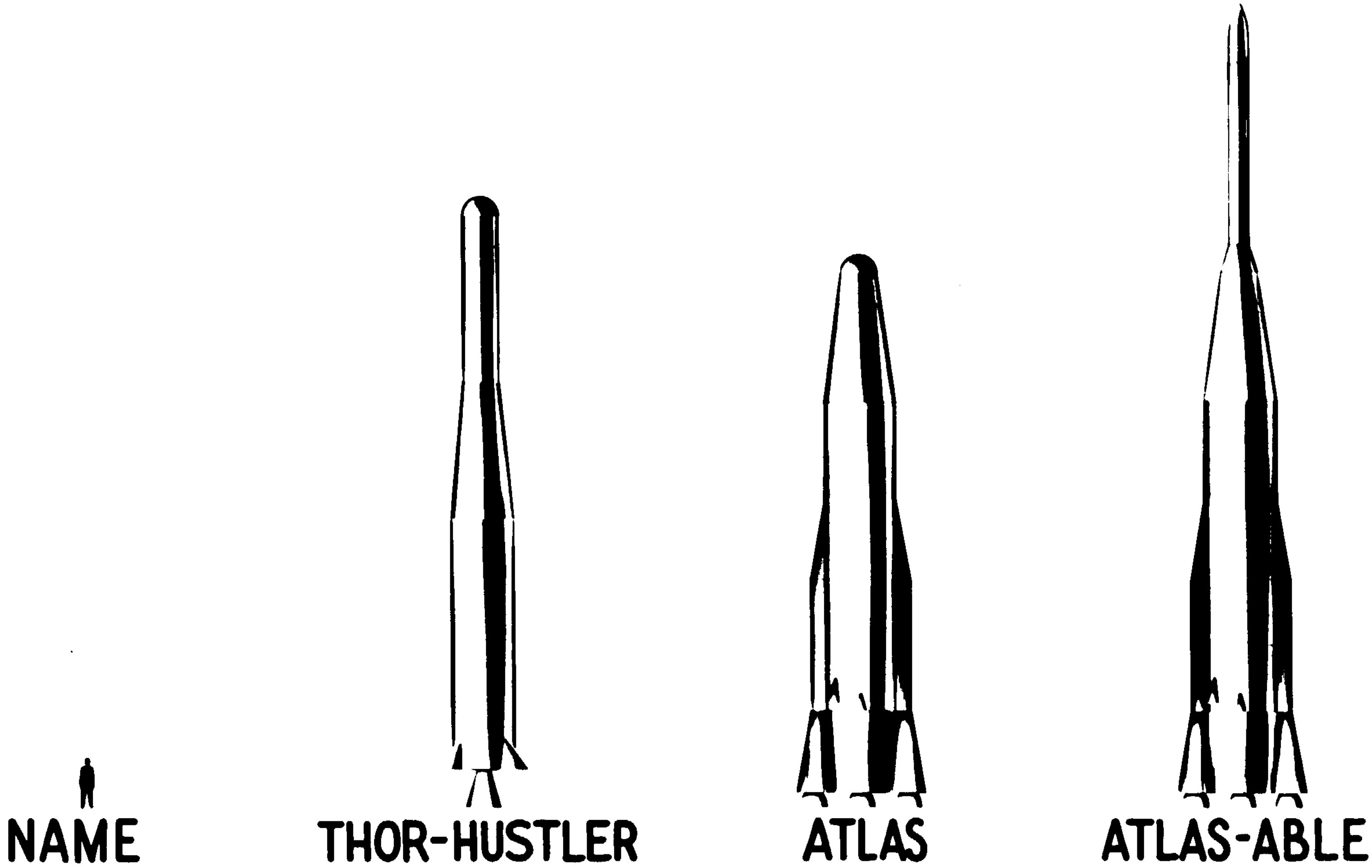
ATLAS is nearly operational and is included as a space vehicle since it is capable of placing payloads into orbit. The Atlas weighs 262,000 pounds at launching and is powered by two booster engines which separate after 135 seconds, and one sustainer engine which continues to operate. Accordingly, Atlas is usually referred to as a stage and a half vehicle.

ATLAS-ABLE uses the Vanguard second stage as a second stage for the Atlas. This vehicle is being prepared to send a probe to Venus in June 1959.

EXISTING VEHICLES



EXISTING VEHICLES



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EXISTING VEHICLE - MISSION CAPABILITIES

VANGUARD, as originally designed, is capable of placing a 21.5 pound satellite into a 300 nautical mile orbit. Up to the present time, the vehicle has placed a 3.5 pound payload into a highly stable orbit with an estimated life of 200 years. Three more Vanguards are scheduled for flights in 1959 with the 21.5 pound payload. The three satellites will measure cloud cover, earth's magnetic field and air density, and the radiation balance in earth's atmosphere. A fourth Vanguard, using the advanced solid third stage, will orbit a 50 pound payload, carring experiments on solar radiation, meteors, and earth magnetic fields.

JUPITER-C vehicle launched the Explorer I and III satellites which weighed approximately 19 pounds. These satellites carried instruments to measure total cosmic ray intensity, density of meteoric matter in the satellite orbits, and temperatures both within and on the skin of the satellites. These satellites provided U.S. scientists with the first indication of the presence of a high intensity radiation belt at altitudes above 1100 kilometers.

JUNO II has sufficient energy to place payloads of 100 pounds in a 300 nautical mile orbit, but is limited by its guidance to lower orbits. Its previous use has been to launch the moon probe. It supplied the data used in defining the great radiation belts which surround the earth. Four Juno II vehicles are scheduled through Fiscal Year 1960 for satellite launchings. Studies of cosmic rays, meteors, air density and structure, and the ionosphere are some of the studies planned for these satellites. In addition, four Juno II vehicles are planned for launching space probes instrumented to explore the great radiation belt around the earth.

THOR-ABLE is capable of placing 200 pound payloads into the 300 nautical mile orbit and probing the moon and near planets with small payloads. The Thor-Able I carried the Moon probe (Pioneer I) approximately 70,000 nautical miles away from earth. Up to 12 space probe launchings by the Thor-Able class of vehicles are planned through Fiscal Year 1960. Nine satellite launchings are also planned for the Thor-Able vehicle. Meteorology and communications are among the areas of interest to be explored with these satellites.

THOR-HUSTLER is essentially a test vehicle to develop the Hustler stage. It can be used for satellite payloads and planet probes.

ATLAS can launch a payload of 150 pounds into a 300 mile orbit. With planned modifications, it will launch the payload of more than 2000 pounds into a lower orbit. Project Mercury will utilize the Atlas for orbital flights of the manned satellite capsule.

ATLAS-ABLE is programmed for a Venus probe mission in June 1959. Other uses are the deep space probes with payloads larger than 50 pounds.

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EXISTING VEHICLES
MISSION CAPABILITY - POUNDS

	300 N.M. ORBIT	24 HOUR ORBIT	PLANET PROBE	LUNAR SOFT LANDING
VANGUARD	20-50	–	–	–
JUPITER -C	25	–	–	–
JUNO II	100	–	20	–
THOR-ABLE	200	–	75	–
THOR-HUSTLER	400	–	98	–
ATLAS	150 (2000)	–	–	–
ATLAS-ABLE	2,200	–	320	–

NEW VEHICLES

CHARACTERISTICS

The vehicles included in the National Space Vehicle Program are the Scout, Atlas-Hustler, Atlas-Vega, Atlas-Centaur, Juno V-A, Juno V-B, and Nova. Their principal characteristics are described below and on the next chart.

SCOUT is a new development designed to exploit the unique properties of solid propellants and to provide a relatively simple vehicle suitable for a wide range of space research needs. It is a four-stage rocket employing solid rocket engines of advanced designs. The Scout will weigh approximately 34,000 pounds.

ATLAS-HUSTLER, ATLAS-VEGA, AND ATLAS-CENTAUR -- These vehicles have in common the use of the Atlas ICBM as the first stage. The differences appear in the type of second stages employed.

The Hustler second stage employs a 12,000 pound thrust motor and is designed for storable liquid propellants (WFNA and Hydrazine). This stage is being tested on Thor, - Project Discoverer.

The VEGA second stage uses liquid-oxygen and kerosene as propellants. A thrust of 33,000 pounds is produced by a rocket motor which is a modification of the Vanguard first-stage engine. The motor uses the pumps and injectors of the Vanguard motor; a new thrust chamber must be provided. Tankage for the Vega second stage can be conveniently constructed with Atlas tooling and parts.

The CENTAUR second stage employs a high-energy propellant combination -- liquid oxygen and liquid hydrogen. A new rocket motor, suitable for this combination and composed of a cluster of two 15,000 pound thrust engines, is now under development. Atlas tooling will also be used in the construction of Centaur tanks.

Advanced space missions require the common use of a third stage in all three vehicles. This stage will use the 6,000 pound thrust rocket motor currently being developed at the Jet Propulsion Laboratory. In addition, a fourth stage, a low thrust solid rocket, will be required for the lunar landing mission.

JUNO V-A AND JUNO V-B -- With the development of the Juno V vehicles the United States will have the capability of launching vehicles which weigh 1,000,000 pounds at lift-off. The first stage will be the cluster rocket under development at the Army Ballistic Missile Agency. The JUNO V employs

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NEW VEHICLES - CHARACTERISTICS

STAGE	1	2	3	4	5
	Propellant Thrust	Propellant Thrust	Propellant Thrust	Propellant Thrust	Propellant Thrust
SCOUT	Solid 120,000	Solid 58,000	Solid 13,000	Solid 3,000	
ATLAS-HUSTLER	LOX-RP-1 360,000	Storable 12,000	Storable 6,000	Solid 500	
VEGA	"	LOX-RP-1 33,000	"	"	
CENTAUR	"	LOX-H_2 30,000	"	"	
JUNO V-A	LOX-RP-1 1,500,000	LOX-RP-1 200,000	LOX-RP-1 80,000	Storable 20,000	Solid 1,000
JUNO V-B	"	"	LOX-H_2 80,000	Storable 20,000 or 6,000	"
NOVA	LOX-RP-1 or Storable 6,000,000	LOX-RP-1 or Storable 1,700,000	LOX-H_2 320,000	LOX-H_2 80,000	Storable 20,000

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eight rocket motors which will eventually produce a total of 1,500,000 pounds of thrust. The tankage of the JUNO V is constructed of one Jupiter tank surrounded by eight Redstone tanks. The outside diameter of the cluster is 21.5 feet and its length is 60 feet.

Second and third stages of the Juno V-A will be modifications of ICBM vehicles. For example, the two stages of the Titan ICBM have been considered for this application in the calculations of mission capabilities. To employ the Titan first stage as an upper stage, the structure must be strengthened and the present two thrust chambers should be replaced by a single high-altitude chamber of 225,000 pounds thrust.

JUNO V-B is a more advanced vehicle and incorporates a liquid-oxygen-liquid-hydrogen stage of 80,000 pounds of thrust as a third stage. Otherwise, Juno V-B is similar to Juno V-A. Development of this high energy stage will be aided by the experience gained with Centaur.

The first three stages of the Juno V-A and B vehicles will provide sufficient energy to place payloads into earth orbits. For the more advanced mission, planet probes and lunar landings, a fourth stage having a thrust of 20,000 pounds is to be developed. This stage will employ storable liquid propellants to minimize the problems associated with transporting cryogenic propellants long distances in space.

<u>NOVA</u> -- The development of NOVA will provide for launching weights of 4,500,000 pounds. The basic building block of this vehicle is the 1,500,000-pound-thrust rocket motor. A cluster of four 1,500,000 pound motors and associated tankage will constitute the first stage of NOVA. The second stage will use one of the same 1,500,000 pound motors. Liquid-oxygen and kerosene or storable liquids are being considered for the first two stages.

In keeping with the principle of multiple usage of the rocket stages employed in the development program, the third and fourth stages of the NOVA vehicle will be based on the high-energy motor (80,000 pounds of thrust) intended for use first in the Juno V-B vehicle. The third stage of NOVA will employ four of the 80,000 pound thrust motors; the fourth stage will use one motor.

NEW VEHICLES

MISSION CAPABILITIES

The estimated mission capabilities of the various vehicles are shown in the following chart and additional information is provided below.

SCOUT will have a range of uses such as: launching 150 pound payloads into a 300 nautical mile orbit, high altitude probes, high velocity re-entry tests, and providing targets for anti-missile research and identification experiments. Because of its simplicity in on-site handling and transportability in the loaded condition, the SCOUT can be launched from many sites without large-scale preparations. In addition, these factors establish the Scout as a vehicle that can be made available to NATO nations and other friendly powers interested in their own space research program. ATLAS-HUSTLER (WS-117L) is being developed to provide reconnaissance satellites for military applications. In addition, this vehicle will provide useful payloads for scientific missions, particularly for planet probes of far greater capabilities than existing vehicles.

ATLAS-VEGA, with the potential of placing 5800 pounds in an earth orbit, will allow for the establishment of a small two-man space laboratory. The laboratory can be housed in the oxygen tank of the Vega stage with a manned capsule provided for use by the passengers during launching and return to earth. With the payload of 740 pounds available for the 22,000 mile orbit, experiments on communications relay satellites can begin.

ATLAS-CENTAUR provides sufficient payload to consider manned satellites capable of glide re-entry and landings. Controlled landing of re-entry vehicles will provide greater flexibility and safety in manned satellite missions. Sufficient payload (730 pounds) is provided by Atlas-Centaur to permit installation of adequate control for landing equipment on the surface of the moon. Attempts at landing instruments on the moon may be accomplished with Atlas-Vega in order to obtain preliminary data; however, the more sophisticated experiments on composition of the lunar surface and atmosphere and lunar seismology will require the larger payloads provided by the Atlas-Centaur and Juno V vehicles.

JUNO V vehicles, which have high orbital payload capability and high reliability resulting from the multi-engined first stage, afford many possibilities for manned space missions. Ferry vehicles for supplying and manning permanent space stations appear as distinct possibilities with the Juno V vehicles. On a smaller scale, Juno V-A can boost a 19,000 pound manned scientific satellite into orbit around earth.

Additional missions which can be foreseen with the Juno V-B include the placing of large communications satellites (6,900 pounds) in the 22,000 mile

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VEHICLE DEVELOPMENT PROGRAM

Estimated Mission Capability, Pounds

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		300 N. MI. ORBIT	24 HOUR ORBIT	PLANET PROBE	LUNAR SOFT LANDING	LUNAR LANDING AND RETURN
SCOUT		150[1]	—	—	—	—
ATLAS-HUSTLER		3,100[2]	—	720[4]	300[4,5]	—
VEGA		5,800[2]	740[4]	1,300[4]	430[4,5]	—
CENTAUR		7,400[2]	1,600[4]	2,610[4]	730[4,5]	—
JUNO V	A	19,000[3]	2,800[6]	4,500[6]	1,700[6,7]	—
	B	33,500[3]	6,900[6]	8,000[6]	2,700[8]	—
NOVA		150,000[3]	42,000[9]	53,000[9]	19,900[9,10]	2,100[9,10,11]

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VEHICLE DEVELOPMENT PROGRAM

Estimated Mission Capability, Pounds

1 - Four-stage vehicle

2 - Two-stage vehicle

3 - Three-stage vehicle

4 - Requires a 6000 pound thrust third stage (storable propellants)

5 - Soft lunar landing with small solid fourth stage

6 - Requires a 20,000 pound thrust fourth stage (storable Propellants)

7 - Soft lunar landing with 6,000 pound thrust fifth stage (storable propellants)

8 - Soft lunar landing with 6,000 pound thrust fourth stage (storable propellants)

9 - Requires high-energy fourth stage of 80,000 pound thrust

10 - Soft lunar landing with fifth stage of 20,000 pound thrust

11 - Return to earth with sixth and seventh stage (12,000 pounds and 2,000 pounds).

orbit and the landing of mobile robot explorers (2,700 pounds) on the surface of the moon.

The Juno V vehicles will also be useful in providing Mars and Venus probes of weights up to 8,000 pounds. This weight will allow for the installation of instruments, power supplies, and powerful transmitters as well as the guidance necessary for establishing accurate trajectories.

The NOVA vehicle presents a large improvement in mission capabilities over the earlier vehicles. In fact, with NOVA, a manned lunar landing and return first becomes possible, although the 2100 pound payload which returns to earth is the minimum amount which should be considered for such a mission. However, advancements in techniques of guidance, re-entry, and aerodynamic braking will allow the 2100 pound figure to be doubled or tripled. The manned lunar landing will then become practical; that is, when staged directly from the earth.

NOVA will also land at least 4500 pounds on Mars, a payload which can contain instruments to study and transmit data on the Martian surface and atmosphere. A NOVA-launched solar probe weighing 4500 pounds could approach within 9,000,000 miles of the sun and perform worthwhile experiments with the power supply and transmitter required to send data back to earth.

The NOVA vehicle could place a 43,000 pound payload in orbit around the Moon and return 12,000 pounds to the surface of the earth. These payloads are sufficient to send a two-man vehicle to explore the Moon from an orbiting vehicle prior to the attempt at a manned lunar landing.

The succeeding three charts provide pictorial representations of some of the typical vehicles of the National Space Program.

JUNO V-A

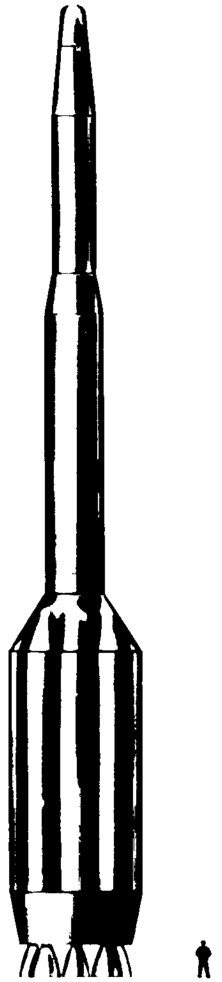
5th STAGE
STORABLE PROPELLANT

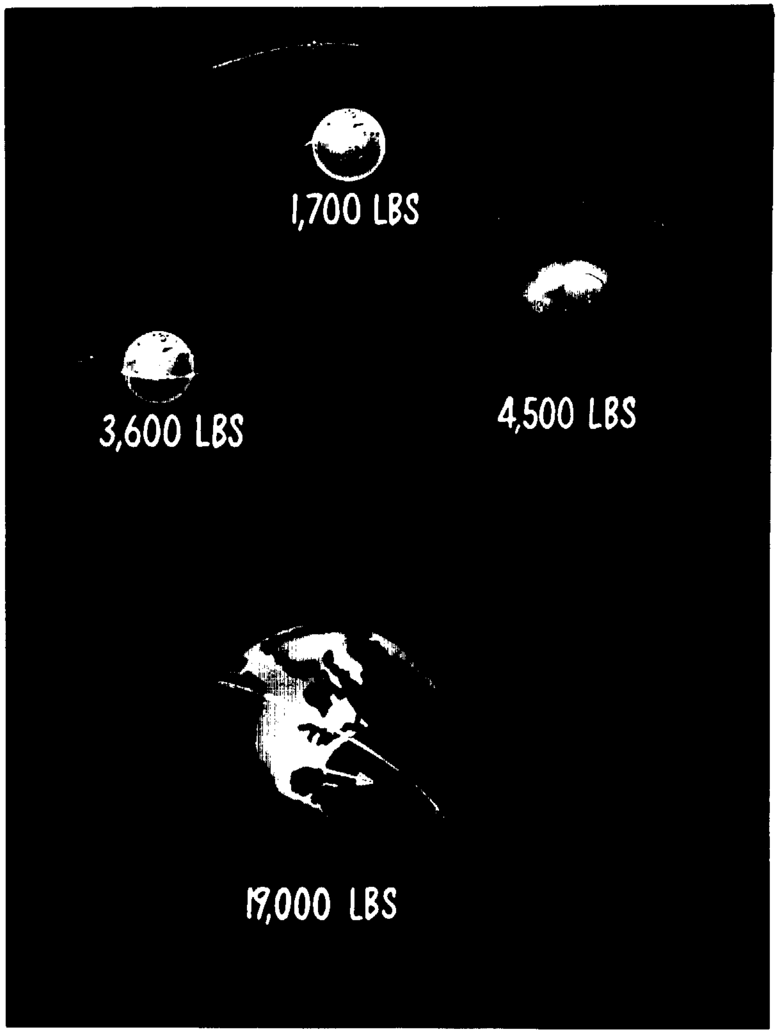
4th STAGE
STORABLE PROPELLANT

3rd STAGE
LOX - KEROSENE
WEIGHT -62,000 LBS.
THRUST -80,000 LBS.

2nd STAGE
LOX -KEROSENE
WEIGHT - 240,000 LBS.
THRUST - 450,000 LBS.

1st STAGE
LOX - KEROSENE
WEIGHT - 960,000 LBS.
THRUST -1,200,000 LBS.





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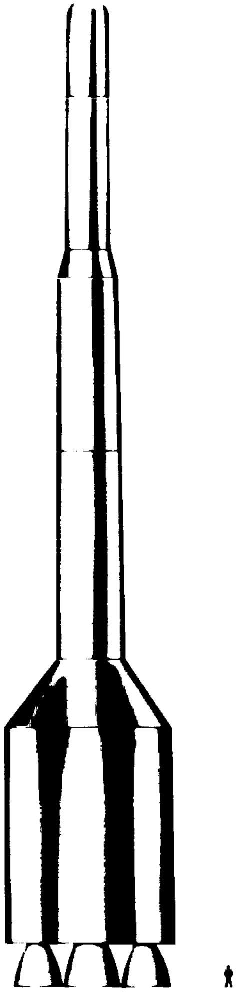
5th STAGE
STORABLE PROPELLANT

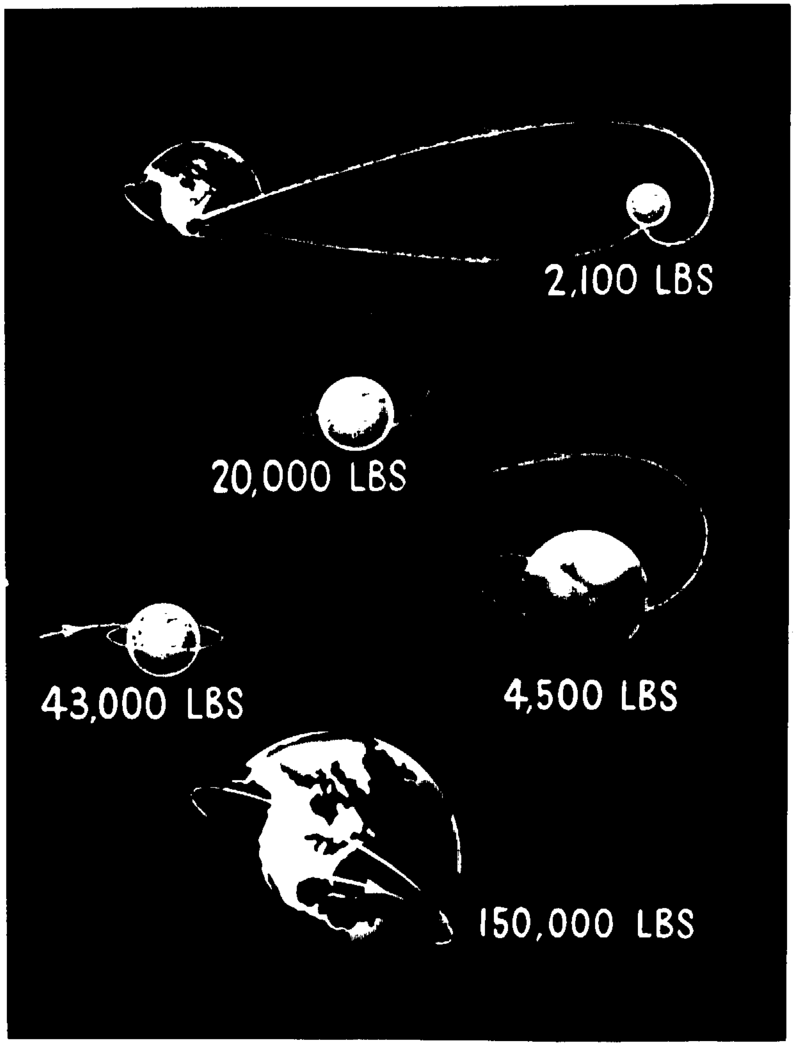
4th STAGE
LOX - HYDROGEN
WEIGHT-150,000 LBS.
THRUST - 80,000 LBS.

3rd STAGE
LOX - HYDROGEN
WEIGHT-370,000 LBS.
THRUST-320,000 LBS

2nd STAGE
LOX - KEROSENE
WEIGHT-1,300,000 LBS.
THRUST-1,700,000 LBS.

1st STAGE
LOX - KEROSENE
WEIGHT - 4,800,000 LBS.
THRUST - 6,000,000 LBS.





ENGINE DEVELOPMENT PROGRAM

The engine development program is aimed at developing the least number of rocket engines that will fulfill the requirements of the National Space Program. The total number of new engine developments is five. Two additional engines required are modifications of existing and tested engines. The five new engines will be so developed as to permit clustering if needed, or operation at high altitude for upper stage uses.

On the first chart following this page is shown the five new engines that are to be developed. The second chart on the engine development program shows the new engines, the engines which are to be modified and the engines for which cluster arrangements are planned. Below are brief descriptions of each engine.

6,000 pound thrust storable propellant engine - First on the chart is the 6,000 pound thrust storable propellant rocket engine. Development of the engine was initiated late in 1958 and is expected to require 18 months and be completed in July 1960.

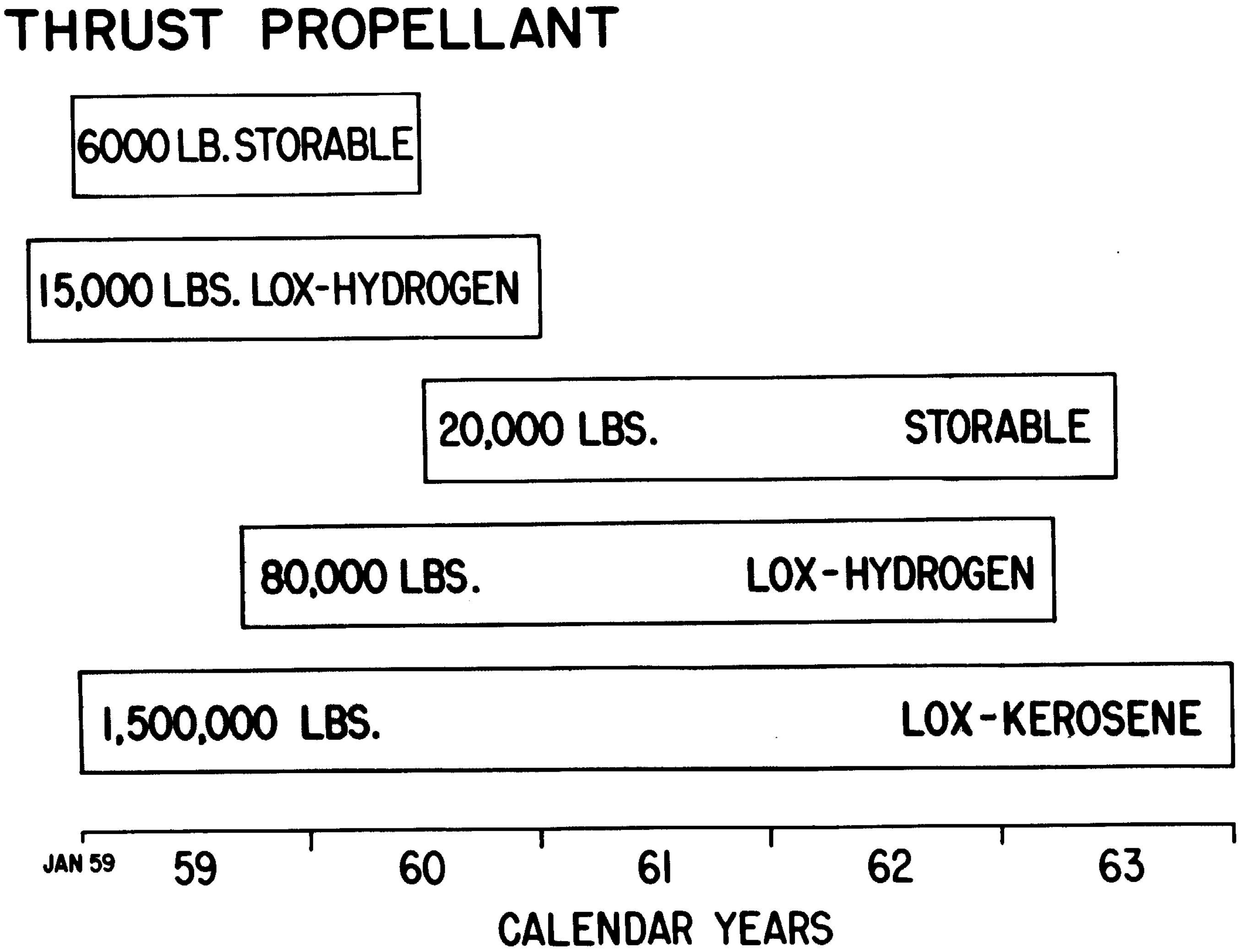
15,000 pound thrust hydrogen-oxygen engine - The second engine listed on the chart is the 15,000 pound hydrogen-oxygen rocket. The development of this engine was started in September of 1958. Propulsion for Centaur will require a cluster of two engines of 15,000 pounds thrust each for a total of 30,000 pounds of thrust. The engine development will be continued during Fiscal Year 1960, and is expected to be completed in July of 1960.

20,000 pound thrust storable propellant engine - The third engine on the chart is a 20,000 pound thrust storable propellant engine. In contrast to the 6,000 pound thrust storable propellant engine now under development, it is expected that this engine may use a pumped propellant system rather than a pressurized propellant system. This project calls for the initiation of the development early in Fiscal Year 1961. The total development time will be somewhat greater than two years; final development should be complete late in 1962.

80,000 pound thrust hydrogen-oxygen engine - The fourth engine listed on the chart is an 80,000 pound thrust hydrogen-oxygen engine. In thrust level, this engine is equivalent to present ICBM sustainer engines, and may be considered an adaptation of such an engine to high energy propellants. In order to meet the needs of future vehicle projects, the development of this engine should be initiated in 1959. The development will require about 3 years and should be completed in 1962.

1.5 Million pound thrust oxygen-RP engine - The last of the chemical rockets listed on the first chart is the one and one-half million pound thrust engine. This approximately four year development project was initiated at the beginning of 1959.

NEW ENGINE DEVELOPMENT



A logical and necessary adaptation of the one and one-half million pound thrust engine is the development of a cluster of four such engines to give a total sea-level thrust of 6 million pounds. This clustering development should be initiated in 1960 and will require several years to complete.

33,000 pound thrust oxygen-RP engine - On the second chart, in addition to the new engine developments, is the 33,000 pound thrust oxygen-kerosene rocket engine. This engine is a modification of the existing Vanguard engine. The engine is to be used in Vega. It is expected that the altitude version of the Vanguard engine can be initiated in March 1959 and that the testing of the engine can be complete before the end of the calendar year 1959.

The Nova vehicle will require a third stage using high-energy propellant rockets of 300,000 to 400,000 pounds thrust. This thrust level can be accomplished by clustering four 80,000 pounds thrust hydrogen-oxygen engines. The development of such a cluster should be initiated in 1961 in order to meet a program schedule which is described later.

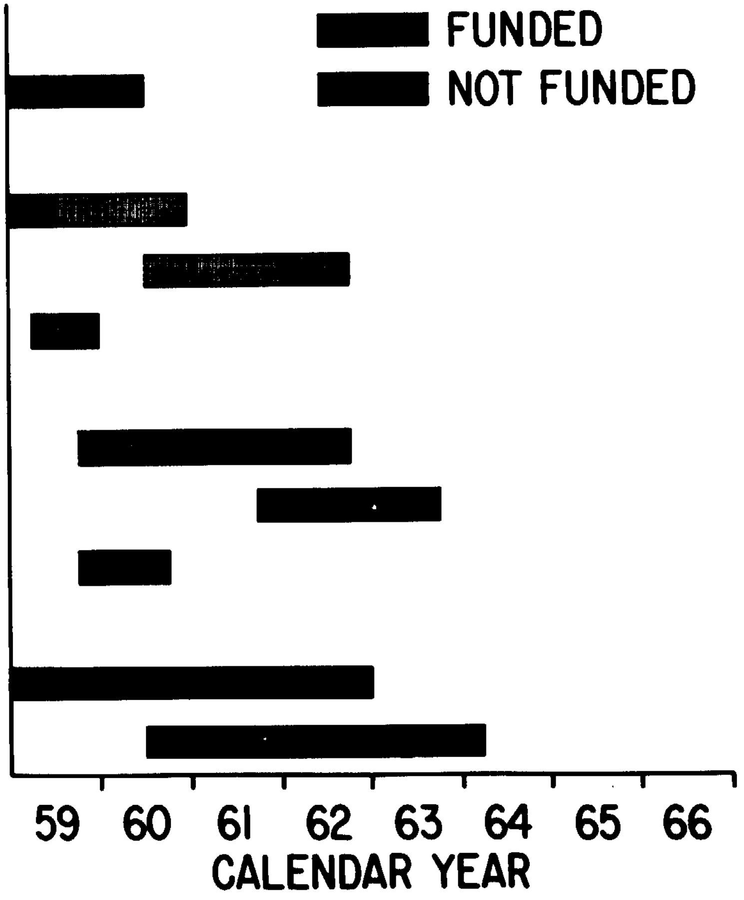
225,000 pound thrust oxygen-RP engine - This engine is a modification of an existing engine; in fact, an altitude version of an ICBM booster engine. The modification calls for the development of a new thrust chamber with a nozzle of large expansion ratio. In order to meet the need for a second stage engine to be used with the Juno V vehicle the development of the 225,000 pound oxygen-RP engine should be initiated in 1959. The total development time is estimated to be about one year.

VEHICLE DEVELOPMENT PROGRAM

ROCKET ENGINE DEVELOPMENTS

CHEMICAL ROCKETS

THRUST	PROPELLANTS	CONTRACTOR
6000#	STORABLE	JPL
	HYDROGEN-OXYGEN	P. & W. A.
	CLUSTER OF TWO = 30,000#	
20,000#	STORABLE	——
33,000#	OXYGEN-RP	G. E.
	(MOD. OF X405 VANGUARD ENG.)	
80,000#	HYROGEN-OXYGEN	——
	CLUSTER OF FOUR = 320,000#	
225,000#	OXYGEN-RP	——
	(MOD. OF ICBM ENG.)	
1,500,000#	OXYGEN-RP	ROCKETDYNE
	CLUSTER OF FOUR = 6,000,000#	

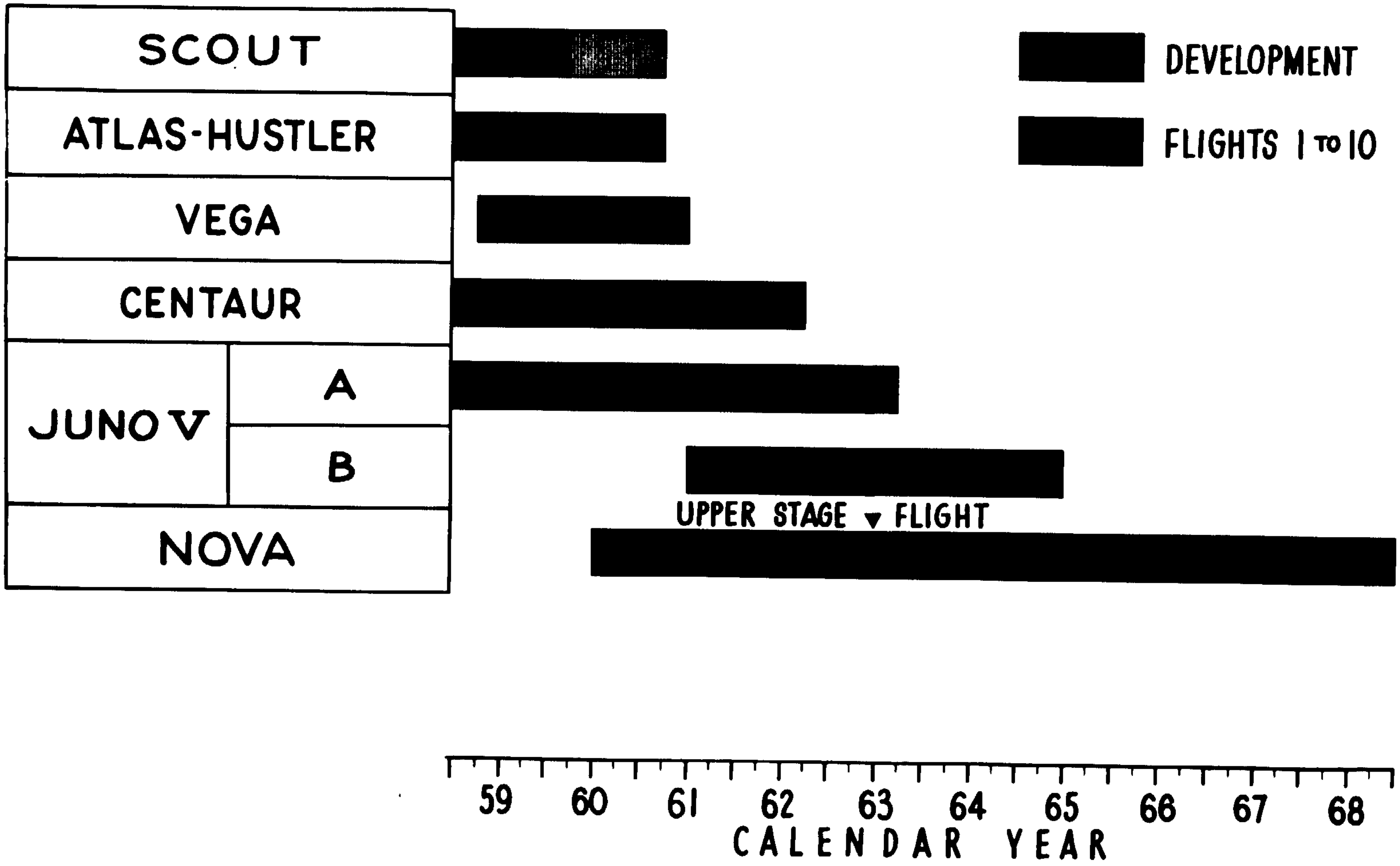


VEHICLE DEVELOPMENT PROGRAM

SCHEDULE

This portion of the report presents an estimated schedule of development of the various vehicles which have been previously described. The schedule is shown on the next chart. It is considered to be an optimistic but probably attainable schedule if it is prosecuted vigorously. The darker shaded bars indicate development periods, while the lighter shaded portion shows the period that will be required to launch ten vehicles. The first four or five vehicles may be considered as wholly developmental. The remainder of the ten vehicles will provide some mission capability. Beyond the tenth launching, it is assumed that full capability will be possible.

VEHICLE DEVELOPMENT PROGRAM
SCHEDULE



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VEHICLE DEVELOPMENT PROGRAM

COST ESTIMATES

The cost estimates shown in the following tables, especially for the later vehicles, must be considered as first order approximations of the actual cost. It must also be appreciated that recent projected cost estimates for the development of advanced aircraft, where much more background of experience is available, have been below the actual costs in nearly every case.

The cost of the Atlas-Hustler is not shown in these charts. The Atlas-Hustler program, at present, is directed entirely for military purposes and is funded wholly by the Department of Defense.

However, the ARPA planned funding for the Atlas-Centaur and Juno V program for Fiscal Years 1959 and 1960 are included in the following tables.

In the following pages a separate table of costs is shown for each Vehicle Program. A final chart shows the annual cumulative costs for the entire Vehicle Development Program including the cost of ten complete vehicles for every vehicle program.

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SCOUT

ESTIMATED COST (MILLIONS)

		FY 59	FY 60
Motors and vehicle development		5.4	5.9
	TOTAL	5.4	5.9

Remarks

Because the rocket motors in this four stage vehicle constitute major parts of the vehicle, rocket propulsion development costs and vehicle costs have been combined. The development costs also include the cost of procurement of 10 complete four stage vehicles with launcher.

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ATLAS - VEGA

ESTIMATED COSTS (MILLIONS)

	FY 59	FY 60	FY 61
Engine (X-405H)	4.5	1.5	0.0
Vehicle (1st & 2nd stages)	20.7	12.0	7.5
JPL, 6K engine and vehicle	2.0	3.5	2.0
TOTAL	27.2	17.0	9.5

Remarks

The estimated missions capabilities of the Atlas-Vega shown in the chart are in part based on a three stage vehicle, the third stage being the JPL, 6K stage. Since the Atlas-Vega appears to be the first of the vehicles to use the 6K stage, all the development costs are charged here.

Because it is difficult to separate the development costs from vehicle costs, in this case, the figures presented include not only the development, but also the cost of 4 complete three stage vehicles.

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ATLAS - CENTAUR

ESTIMATED COSTS (MILLIONS)

	FY 59	FY 60	FY 61	FY 62
Engine and propellants	13.0	16.7	10.0	2.0
Vehicle	9.3	24.3	35.0	5.0
TOTAL	22.3	41.0	45.0	7.0

Remarks

The Atlas-Centaur project was initiated by ARPA, and all the funds for the Fiscal Year 1959 are supplied by ARPA. This project will become an NASA program beginning in July 1959.

In this case, as well as in the Atlas-Vega estimates, it is difficult to separate development funds from vehicle costs. Therefore, the costs shown include the costs of 10 complete three stage vehicles.

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JUNO V-A

ESTIMATED COST

Remarks

At the present time only the first stage of the Juno-V is being funded. Development of the upper stages has not as yet started.

The estimated costs shown on the next page for the first stage include the costs of the first four firings, which are not complete vehicles, but have all or some dummy upper stages. The cost of engineering the complete assembly is also assumed included in the development cost.

The cost of a complete five stage vehicle, excluding guidance equipment and payload, is estimated to be ten million dollars.

JUNO V-A

ESTIMATED COSTS (MILLIONS)

	FY 59	FY 60	FY 61	FY 62	FY 63	FY 64
1st Stage Engine (1.5M Cluster) and Vehicle	34.0	70.0	40.0	15.0	5.0	
2nd Stage Engine (225K, LOX-RP) and Vehicle	6.0	15.0	25.0	15.0	5.0	
3rd Stage Engine (80K, LOX- RP) and Vehicle			9.0	14.0	5.0	2.0
4th Stage Engine (20K-Storable) and Vehicle			7.0	12.0	5.0	
5th Stage Engine (1K Solid)			.5	.5		
TOTAL (Development)	40.0	85.0	81.5	56.5	20.0	2.0
Procurement of 10 - five stage Vehicles			10.0	30.0	40.0	20.0
TOTAL (Development and Procurement)	40.0	85.0	91.5	86.5	60.0	22.0

JUNO V-B

ESTIMATED COST

Remarks

The Juno V-B Vehicle requires the development of an 80-K, oxygen-hydrogen third stage engine and Vehicle. Both items are entirely new developments. The only prior art will be the Centaur second stage which is a much smaller scale, both in engine thrust and size of vehicle tankage. It will be necessary to engineer the entire assembly of the Juno V-B in addition to developing the third stage completely.

JUNO V-B

ESTIMATED COSTS (MILLIONS)

	FY 59	FY 60	FY 61	FY 62	FY 63	FY 64	FY 65
1st Stage Engine (1.5M Cluster) and Vehicle		Costs are charged to JUNO V-A No additional costs for JUNO V-B					
2nd Stage Engine (225K, LOX-RP) and Vehicle		Costs are charged to JUNO V-A No additional costs for JUNO V-B					
3rd Stage Engine (80K, H_2-0_2) and Vehicle	1.0	1.7	12.0	30.0	35.0	20.0	20.0
4th and 5th Stages Same as JUNO V-A		Costs are charged to JUNO V-A No additional costs for JUNO V-B					
Complete Vehicle Integration				5.0	10.0	10.0	5.0
TOTAL (Development)	1.0	1.7	12.0	35.0	45.0	30.0	25.0
Procurement of 10 - five stage Vehicles				10.0	36.0	36.0	38.0
TOTAL (Development and Procurement)	1.0	1.7	12.0	45.0	81.0	66.0	63.0

NOVA

ESTIMATED COST

Remarks

In the development of this Vehicle, the second stage is developed first. This approach provides a vehicle which can be used to test the 1.5 million pound thrust single chamber engine in flight. The entire vehicle then becomes the second stage of the NOVA Vehicle.

The cost of a NOVA Vehicle is estimated to be $45,000,000 per Vehicle excluding the guidance system and the payload.

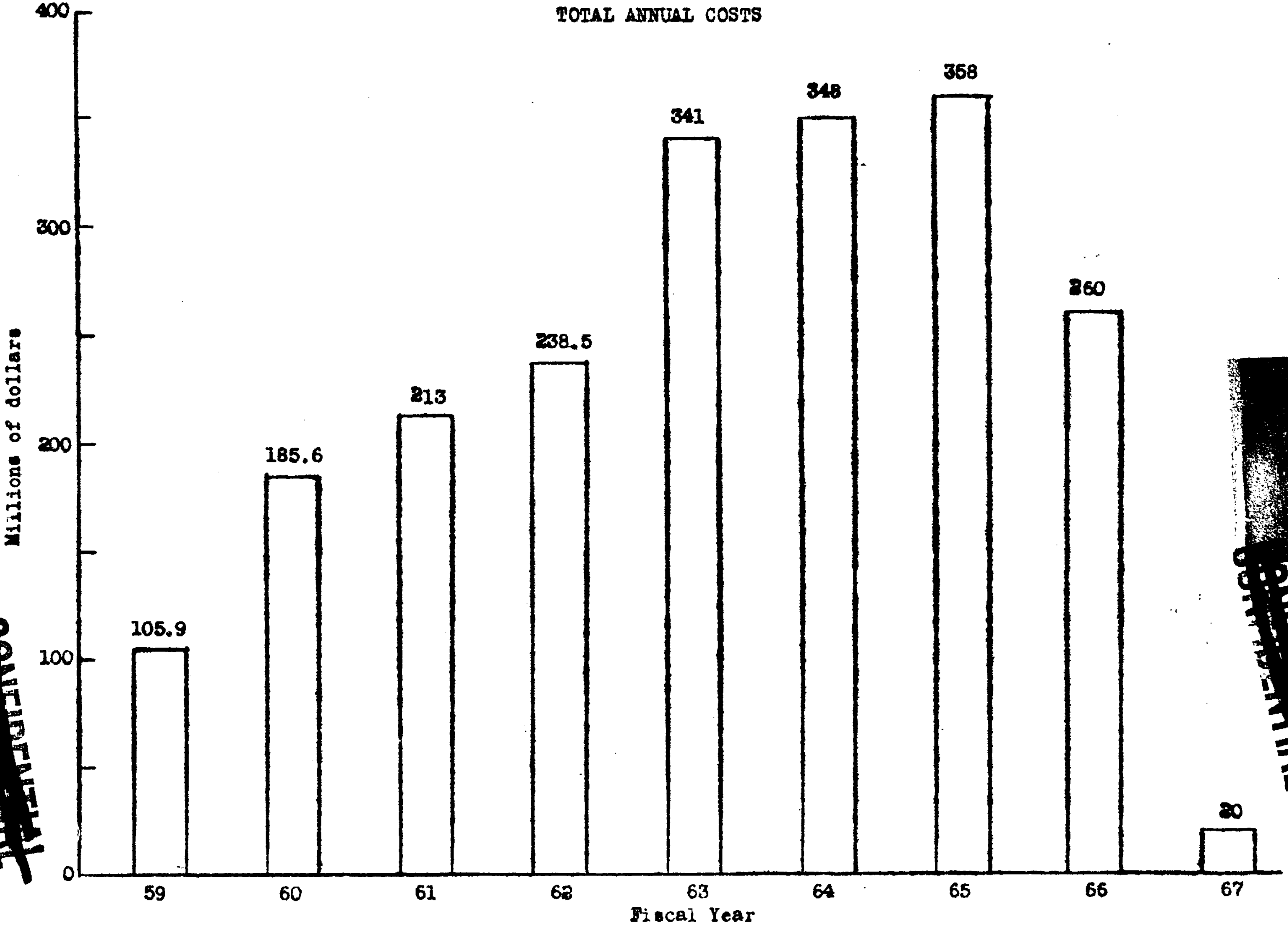
NOVA

ESTIMATED COSTS (MILLIONS)

	FY 59	FY 60	FY 61	FY 62	FY 63	FY 64	FY 65	FY 66	FY 67
1st Stage Engine (6M Cluster) and Vehicle			5.0	25.0	70.0	90.0	80.0	40.0	
2nd Stage Engine (1.5M Storable) and Vehicle	10.0	35.0	50.0	60.0	40.0	25.0			
3rd Stage Engine (320K, H_2-O_2) and Vehicle				15.0	35.0	35.0	30.0	15.0	
4th and 5th Stages	Costs for these stages have been charged to other vehicles								
Complete Vehicle Integration					10.0	20.0	50.0	25.0	20.0
TOTAL (Development)	10.0	35.0	55.0	100.0	155.0	170.0	160.0	80.0	20.0
Procurement of 10 - five stage Vehicles					45.0	90.0	135.0	180.0	
TOTAL (Development and Procurement	10.0	35.0	55.0	100.0	200.0	260.0	295.0	260.0	20.0

VEHICLE DEVELOPMENT PROGRAM

TOTAL ANNUAL COSTS



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