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JUNO V SPACE VEHICLE
DEVELOPMENT PROGRAM
(Status Report - 15 November 1958)

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JUNO V SPACE VEHICLE DEVELOPMENT PROGRAM
(STATUS REPORT - 15 NOVEMBER 1958)

By

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SUMMARY CONFIDENTIAL

This report is the second in a series of reports on the JUNO V Space Vehicle Development Program and indicates the present status of the overall program. The objective of the overall program is to provide a reliable, economical, and flexible carrier vehicle with relatively large payload capability for orbital and space missions at the earliest possible date.

This report discusses the possibilities for extending the presently approved booster feasibility program into a second phase which is considered to be a mission capability demonstration of the first generation vehicle family. Potentialities of a second generation within the JUNO V program are also briefly discussed.

The report also gives the design philosophy as well as a description of the booster and possible vehicle configurations. In addition, a preliminary weight breakdown and preliminary performance characteristics are presented.

Because of the large payload capabilities offered by the JUNO V, many possible missions can readily be envisioned and these are outlined along with their potential users. Operational aspects such as static test requirements, handling and transportation considerations, fabrication procedures, and launching site requirements are also discussed in detail along with engineering, test, and flight schedules.

Based on the results of present studies, it appears feasible to design, develop, static-test, and launch four JUNO V single- and two-stage vehicles by the end of CY 1961 within the total funding of $72 million. There is a danger of schedule slippage early in the program, however, if there is a delay in the allotment of funds, which are considered extremely scarce.

If an uninterrupted continuation of the flight test program is desired after the present four-vehicle program, additional funding of a small amount will be required in FY 1960 and of a larger amount in FY 1961 for long lead-time items. The amount of funding required will result from the JUNO V systems study which is expected to be completed by March 1959.

Steps should be initiated for construction of an operational equatorial launching site to be available by summer 1962.

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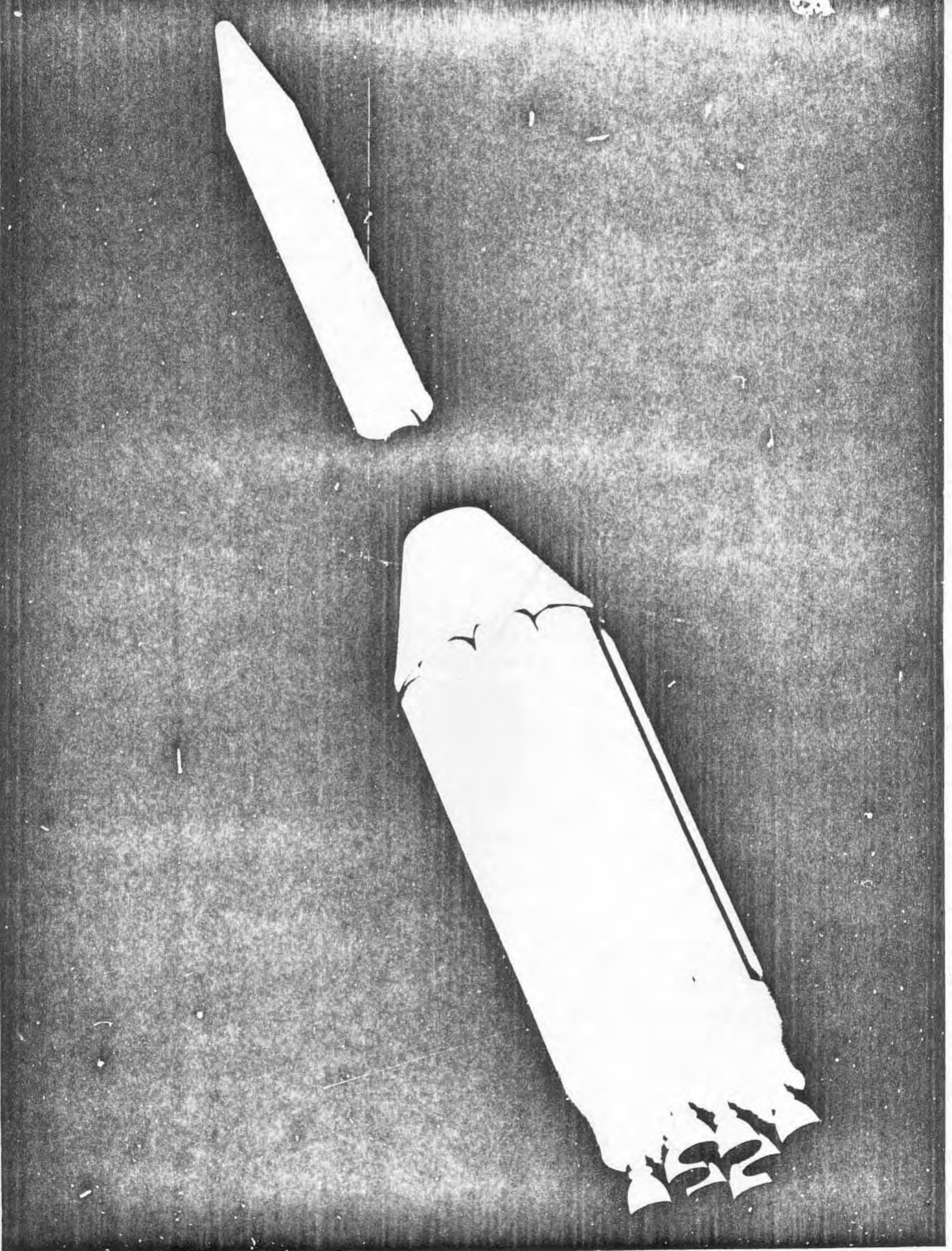

I. INTRODUCTION (S)

The present state of the art in the field of orbital carriers in the United States is represented by the VANGUARD and the JUNO I (JUPITER-C) vehicles. These require approximately 1000 and 2000 lb, respectively, of take-off weight per pound placed in orbit. This results in a transportation cost of approximately 1,000,000 $/lb for the VANGUARD and 100,000 $/lb into orbit for JUNO I, if the experienced reliability is taken into account.

The present satellite carriers on order, but not yet successfully flown (JUNO II, THOR-117L, and ATLAS-117L), will reduce the growth factor gradually to about 100-lb take-off weight per pound placed in orbit and the cost to about 3000 $/lb. However, the maximum payload capability of the orbital carriers above, without use of high-energy propellant, will be limited to about 3000 lb for the next two years. If required, use of high-energy propellants will extend the payload capabilities of ICBM-based orbital carriers to 5000 and possibly 10,000 lb by 1961/62.

The Army Ballistic Missile Agency was among the early groups who considered a payload capability of 20,000 to 40,000 lb for orbital missions and 6000 to 12,000 lb for escape missions as urgent requirements for space missions of the near future.

The Army Ballistic Missile Agency initiated studies on the booster required for this task in April 1957. These initial studies, based on a booster in the 1.5 million-pound thrust class, placed special emphasis on the propulsion system. At that time a cluster of four NAA E-1 engines, which were in the early stages of development, were considered. This booster, which in the beginning was designated the SUPER-JUPITER, and several upper stages were investigated by ABMA with the assistance of NAA. The total effort in this area from April 1957 until September 1958 was approximately 50,000 man-hours which enabled a fast start on this program. Reports resulting from these studies are listed in the bibliography.

In July 1958, representatives of the Advanced Research Projects Agency (ARPA), showed interest in a clustered booster with 1.5 million-pound thrust based on available engine hardware. The ARPA objective was to obtain a booster with approximately 1.5 million-pound thrust at the earliest possible date within the funding limitations. This requirement favored the use of existing engine hardware rather than the four E-1 engines considered earlier. This choice would result in a saving of approximately $60 million and about 2 years development time.

The vehicle based on this booster was given the unofficial designation JUNO V by ARPA. This vehicle will have an initial growth factor of about 50 which can further be reduced to 25 by use of high-energy propellants, and to about 10 by use of a nuclear-powered upper stage. The transportation cost can hopefully be reduced to 100 \$/lb payload by means of optimum booster recovery in due course of development.

ABMA's experience in the field, plus the availability of facilities and manpower, led to ARPA Order Number 14-59, dated 15 August 1958. The scope of this order is given in the following excerpt:

"Initiate a development program to provide a large space vehicle booster of approximately 1,500,000-lb thrust based on cluster of available rocket engines. The immediate goal of this program is to demonstrate a full-scale captive dynamic firing by the end of CY 1959."

Further studies for the extension of the big booster program past the feasibility demonstration resulted in a memorandum of agreement signed by Mr. R. W. Johnson, Director of ARPA, and Maj. Gen. J. B. Medaris, Commanding General of AOMC, on 23 September 1958. This memorandum provides for an extension of the program to include four booster test flights. The first two flights will be booster propulsion flight tests and the latter two flights will be with a second stage which will provide limited orbital capability.

Following the receipt of the memorandum of agreement, the first in a series of reports on the JUNO V Space Vehicle Development program was issued (Ref. 1).

On 4 November 1958, representatives from ARPA visited ABMA to discuss the further extension of the JUNO V program to include the capability of placing a communication satellite in a 24-hour equatorial orbit. The upper-stage configuration and the number of vehicles required to fulfill the additional ARPA requirement will be determined after a system study on the JUNO V vehicle family has been performed. The JUNO V system study is presently being approved and will be completed by April 1959.

This study will include consideration of (1) numerous upper-stage configurations, (2) various missions - ranging from surface-to-surface ballistic transports through orbital missions to planetary soft landings, (3) production requirements, (4) facility requirements for both testing and launching, (4) operational and logistic requirements, (5) schedules, and (6) funding requirements.

In addition to the JUNO V system study and overall design effort, specific investigations and studies are being performed as indicated below.

These studies are being included in this report for the purpose of indicating some of the problem areas and the extent to which effort is being expended on the program.

1. Jet deflector studies are in progress to determine characteristics of secondary flow in the vicinity of the missile base during main-stage burning while the booster is on the launching pad or captive test stand.

2. Booster base heating due to secondary flow is being studied, and various tests are planned using wind tunnels to simulate flight conditions. These studies and tests will determine the extent of the problem and will be used to establish the design criteria required to eliminate the heating condition, should it exist.

3. Model tests and studies are planned to investigate various characteristics of propellant flow such as, vortexing, tank interflow, and propellant utilization. These studies, for various flight conditions, will be complemented by an analogue computer program which is presently being set up.

4. Studies have been initiated to investigate the feasibility of biasing the cant of the outboard engines of the JUNO V booster in such a manner that the direction of the exhaust flames will be kept parallel to the centerline of the vehicle during lift-off and then programming the engine orientation to the desired cant angle after the vehicle is approximately 65 ft above the launcher. If such a maneuver is feasible, considerable savings could be realized since the burning or destruction of the launcher would be minimized during take-off.

5. Studies are being conducted to determine the most feasible method of transporting the first few boosters from ABMA to AMR. There are two basic possibilities:

a. Shipment by air in components as described in this report.

b. Shipment of the booster by water after it has been completely assembled and the checkout is complete. Regardless of the results of the study, the booster will be designed for air transportability. The question here is whether or not this design feature will be utilized for the early boosters.

6. Concurrently with the system study outlined in this report, which utilizes the conventional tandem staging configuration, a separate study will be performed utilizing the parallel staging principle for the complete JUNO V vehicle system. This will be incorporated in the JUNO V system study and will also be completed by April 1959.

This report presents a list of potential users and missions for the JUNO V vehicles, the design approach used in arriving at the proposed booster configuration, a description of the booster and tentative upper-stage configurations, and typical missions for the first 16 vehicles of the program. Also included are weight estimates and performance capabilities for various vehicles; operation considerations dealing with test stand, fabrication, assembly, transportation, and launching; facility requirements; program considerations as to schedule, funding, and reliability; and conclusions and recommendations of the JUNO V program as envisioned to date.

The major emphasis of the report is placed on the booster and the approved four-vehicle program. The present funding situation necessitates the limitation of the existing program to four vehicles and does not exploit the entire capability of the development team or the early availability of the JUNO V vehicle.

The OBJECTIVES OF THE REPORT are summarized in these two points:

A. To familiarize all organizations and personnel within the development team with the present status of the JUNO V program including assumptions, suggested approach, anticipated development problems, and schedule.

B. To inform the potential users of the expected capabilities and availability of the JUNO V, as well as the technical details of the design configuration as presently envisioned.

II. JUNO V SPACE VEHICLE DEVELOPMENT PROGRAM (S)

A. Proposed Designation

Although not yet approved, the popular name proposed by Dr. von Braun for the space vehicle resulting from the JUNO V development program is "SATURN". The SATURN is considered to be the first real space vehicle as the Douglas DC-3 was the first real airliner and durable workhorse in aeronautics. Is is expected that the JUNO V vehicle will serve all national and possibly international space programs as the workhorse for more than a decade.

B. Program Objective

The objective of the program is to develop for operational use a reliable, economical, and flexible carrier vehicle for orbital and space missions within the shortest possible time. The orbital payload capability should be in the 20, 000 to 40, 000-lb class and, for escape and similar missions, in the order of 5000 to 10, 000 lb. The space vehicle under consideration should also have a capability to carry at least 1000 lb of useful instrumentation for soft-landing missions on the Moon or Mars.

C. Potential Users and Missions

The following organizations are considered as potential users with possible missions listed accordingly:

1. ARPA, as representative of the Department of Defense for all military services:

a. Carrier vehicle for research and development of offensive and defensive space weapons.

2. U. S. ARMY

a. Orbital carrier vehicle tor space defense missions against offensive enemy space vehicles.

b. Orbital carrier vehicle for communication and meteorological satellites.

c. Emergency supply carrier for surface-to-surface supply operations such as:

(1) 300-mile single-stage carrier vehicle.

(2) 4000-mile two-stage carrier vehicle.

3. U. S. AIR FORCE

a. Orbital carrier vehicle for the DYNA-SOAR III weapon system.

b. Manned orbital carrier for man-in-space program.

c. Orbital carrier for reconnaissance satellites.

d. IRBM and ICBM for special missions with multiple nuclear, chemical, or conventional warheads and/or for transportation of propaganda material.

4. U. S. NAVY

a. Orbital carrier for navigation satellites.

5. NASA

a. Orbital carrier for scientific research by means of instrumented satellites.

b. Space vehicle for the exploration of outer space, Moon, and planets.

c. Orbital carrier for establishment and maintenance of civilian space stations.

d. Flying test bed for F-1 engine, nuclear propulsion, and other systems.

6. UNITED NATIONS

The JUNO V space vehicle family might be offered as a carrier vehicle for any international space-flight program decided upon by the United Nations.

7. COMMERCIAL CUSTOMERS

It is anticipated that the economics of the JUNO V orbital carrier vehicle will approach the \$100 per pound figure by 1970 and attract private organizations for commercial applications of orbital transportation.

D. System Parameters

The JUNO V space vehicle system is considered a very important member, but only one member, of a family of carrier vehicles which must be available within the national military and civilian space organization.

Therefore, the "transportation system" point of view will be considered during the design phase of this vehicle. Among others, the following major points are being considered:

1. Reliability and safety
2. Economy
3. Early availability
4. Test facilities
5. Launching facilities
6. Propellant production capacities
7. Production requirements
8. Maintenance and serviceability
9. Logistics (general)
10. Mobility
11. Crew engineering and psychological factors
12. User requirements

All these items are subject to detailed investigation for the optimization of the transportation system under consideration.

III. DESIGN APPROACH (S)

A. Primary Design Parameters

Reliability and crew safety play the primary roles in the development of this carrier vehicle since it is anticipated that it will be the first space vehicle to be used frequently for personnel transportation on a larger scale. In general, it is realized that this vehicle should approach aircraft reliability. Before men can be flown in this vehicle, a reliability of at least 90 per cent should be demonstrated. Proven hardware will be used where possible and weight penalties will be accepted to obtain the necessary reliability. Although economic considerations are generally considered overriding, reliability must not be sacrificed for economy and/or performance.

Performance and schedule are the next most important design parameters. As has been noted, the achievement of a large payload capability at the earliest possible date is one of the primary objectives of this development program.

Due to the large number of potential missions, firing rates up to about two per week are expected. Therefore, the recovery of the costly first-stage booster will be an economical requirement. Booster recovery will reduce the long-range program expenditure and, at the same time, will assist in obtaining good reliability at an early date.

These design parameters, as well as others, are discussed in the next several paragraphs.

B. Propulsion System (Cluster vs. Single Engine)

In order to fulfill the program objective of providing the U. S. with a large payload capability at the earliest possible date, the use of existing propulsion systems is mandatory. Since a booster thrust level of 1500K is desired and no single engine of this level is available, a cluster of smaller engines is required. In reviewing the availability of the single engine and clustered engine booster of the 1500K thrust class, it appears that the clustered booster could be flight-tested at least 3 to 4 years earlier.

The cluster concept also yields a shorter vehicle - this is desirable from structural design and launching preparations standpoint - and a simpler control system. Simplification of the control system results from the elimination of the requirement to gimbal an extremely large thrust chamber. In addition to the above design considerations, the clustered engine concept eliminates the immediate need for additional large test and production facilities and also reduces the handling and transportation problems associated with a large single engine.

A better chance of crew survival during booster powered flight is gained since failure of one engine does not render the entire vehicle powerless as would be the case with a large single engine. Failure of one engine would still permit the vehicle to accomplish a limited mission. Loss of 2 or 3 engines would still leave the vehicle controllable and provide adequate stability to allow crew bailout, which is a major design consideration. Considering the reliability of the clustered vehicle, it is believed that this method, since it employs existing smaller engines, offers greater safety for crews in manned flights than the large single engine in the same time period. The use of a cluster requires larger production rates and thus greater reliability will be developed earlier. In addition, many development problems can not be foreseen for the large single engine because of the large jump in thrust level over present experience. Thus, the schedule of the large single engine is considered to be quite uncertain.

Another important consideration in designing this vehicle is economy. Because of the large payload capability, many possible missions can be envisioned. Some of these have already been described in Section II C. This variety of missions will require a large number of firings. To make a program of this size economically feasible, booster recovery must be used. The clustered engine approach is more suitable for booster recovery than the single engine approach. Should engine damage occur during the recovery operation, only the damaged engines or parts thereof must be replaced in the clustered arrangement rather than the one large and costly single engine.

C. Tankage Design

Several different tankage designs can be envisioned for a booster of this size. Four of the most promising are shown in Fig. 1.

The first configuration given consists of a single large tank, 216 in. in diameter, with an internal bulkhead to separate the LOX and RP-1. The main advantages of this method are minimum overall dimensions, minimum plumbing, and utilization of existing design experience since this is the conventional tankage approach. However, in a booster of this size, conventional tankage has certain disadvantages. The handling of the tank would be complicated since it could not be broken down into smaller components. The only available means for transporting a 216-in. diameter cylinder cross-country is by water. New tooling, as well as production and possibly assembly facilities, would have to be provided, and placement near a water transportation system would be required. The fuel feed lines would extend through the LOX container. In addition, an insulated bulkhead and heavier anti-slosh structure would be required.

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COMPARISON OF POSSIBLE JUNO V BOOSTER TANKAGE DESIGNS

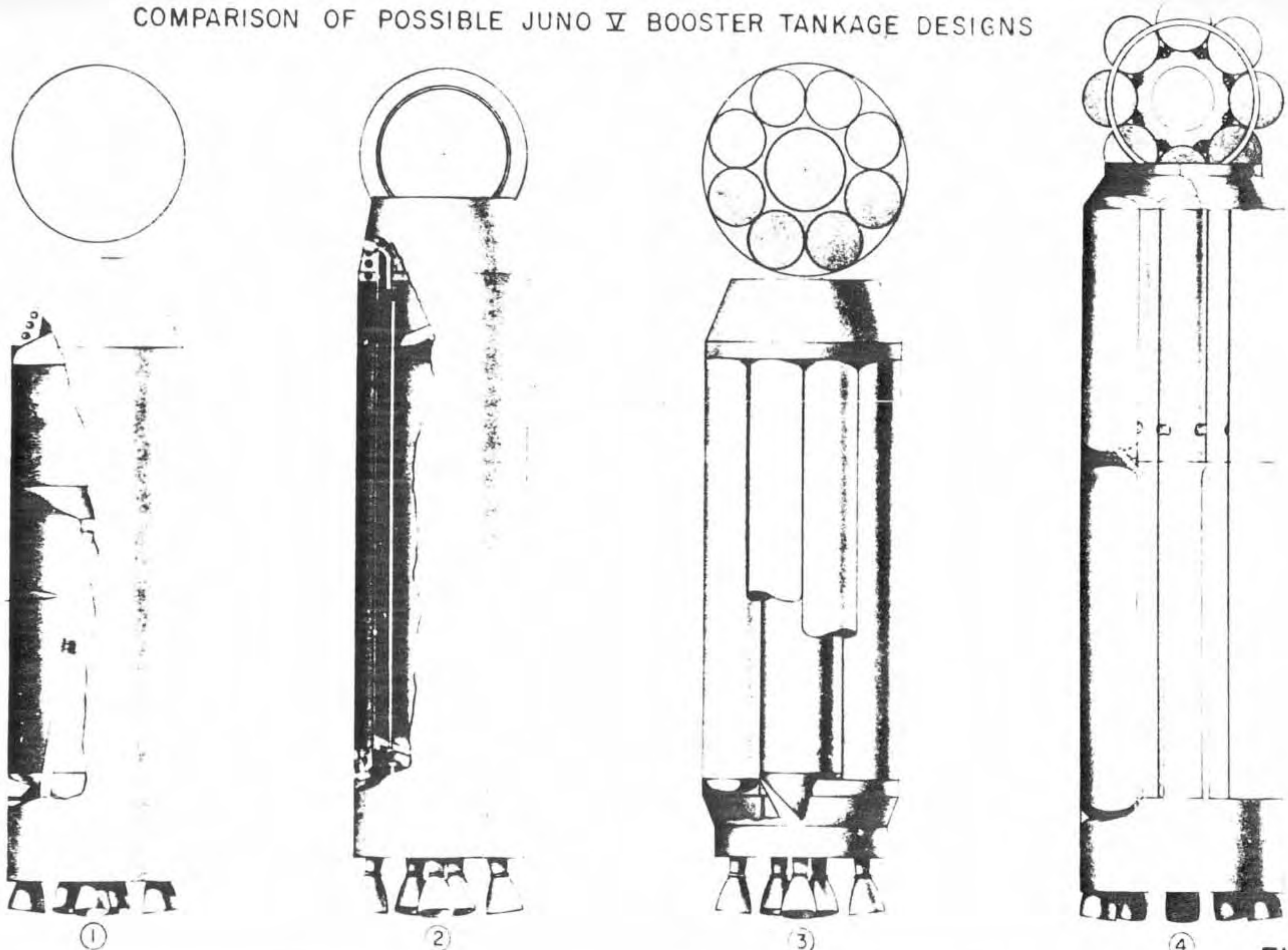

FIG. I

[redacted]

The concentric tank arrangement (number 2, Fig. 1) consists of an inner LOX container and an outer fuel container. The outside diameter would be the same as the single tank. The major advantages of this design are the elimination of fuel lines running through the LOX tank and the reduction of the slosh problem. Due to such items as double cylindrical walls and insulation between LOX and fuel containers, the concentric tank design would be approximately 20% heavier than the conventional design (number 1, Fig. 1).

The third configuration given in Fig. 1 is comprised of nine tanks - a center tank of JUPITER diameter (105 in.) surrounded by eight tanks of REDSTONE diameter (70 in.). These diameters were chosen to take advantage of existing tooling and production facilities and to reduce initial cost. The outside diameter of the arrangement is 256 in. LOX is carried in the center tank and four of the outer tanks. Fuel is carried in the four remaining outer tanks. The advantages of this system include easier handling and transporting because the booster tankage can be disassembled and each tank handled and shipped separately. Since off-the-shelf hardware can be used, shorter fabrication time and lower manufacturing costs can be realized. Center bulkheads and fuel lines through the LOX tanks will not be required and the well-proven JUPITER anti-slosh design can be used. The disadvantages include larger outside diameter, more structural members required, and the need for additional pressurization and vent manifolds.

The fourth configuration shown in Fig. 1 consists of eight REDSTONE-diameter tanks in a circular arrangement with an outside diameter of approximately 256 in. Each tank would contain both LOX and fuel and would require a center, insulated bulkhead. In this design longer tanks would be required; however, by omitting the center tank, sufficient space is gained to permit the placing of fuel lines in the center opening, thus eliminating the need of running them through the LOX containers.

After preliminary study, the multiple-tank arrangement of one center tank surrounded by eight outside tanks (number 3, Fig. 1) has been selected as the most advantageous design for the Phase I of the JUNO V program.

D. JUNO V Staging Considerations

In any new design the possibility of introducing various concepts exists. In the JUNO V vehicle development the possibility of using a different type of staging was investigated.

This principle, shown in Fig. 2, is called parallel staging (Ref. 2) and differs from the conventional staging, Fig. 3, as follows. All of the

PARALLEL STAGING DESIGN FOR JUNO V

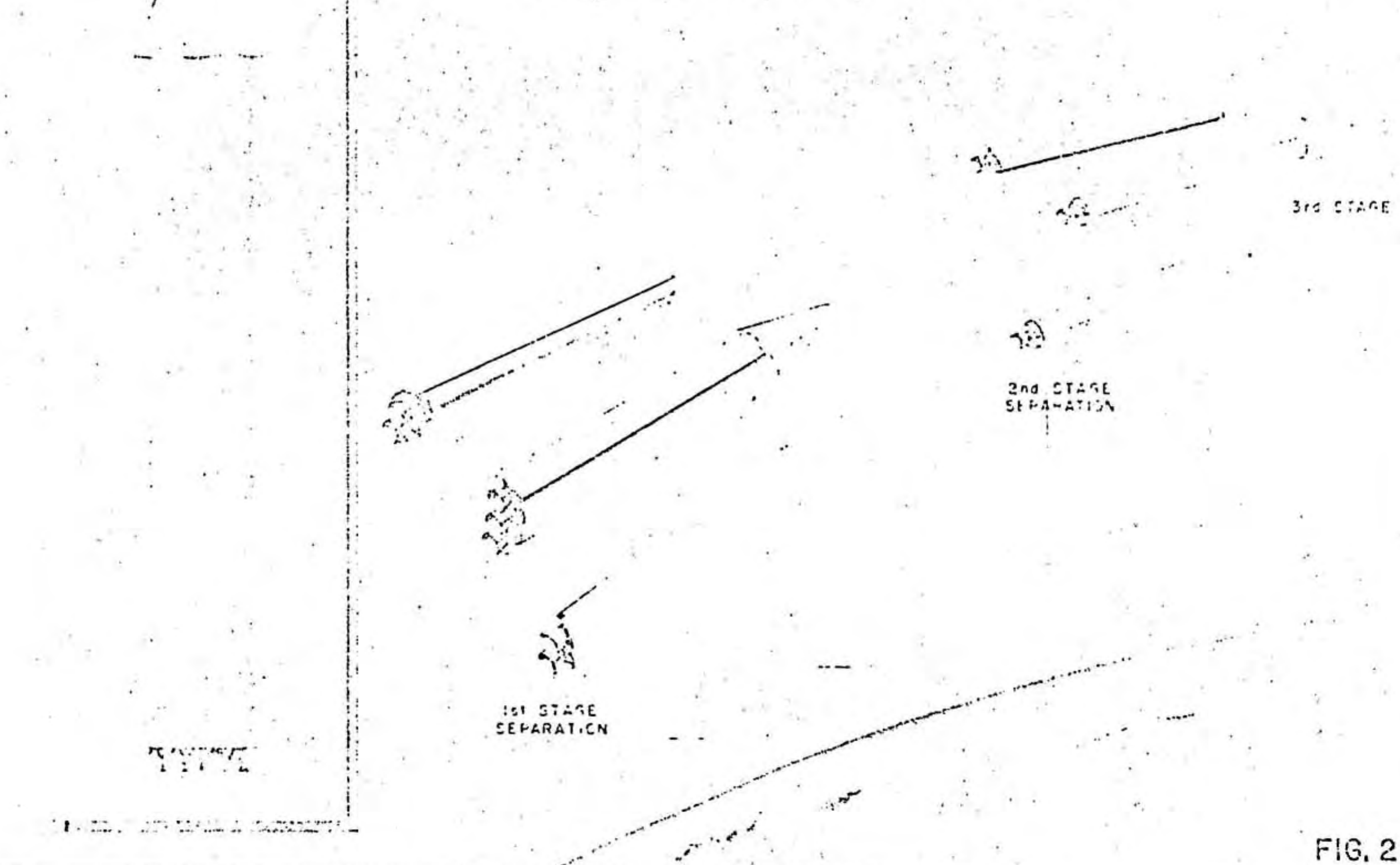

FIG. 2

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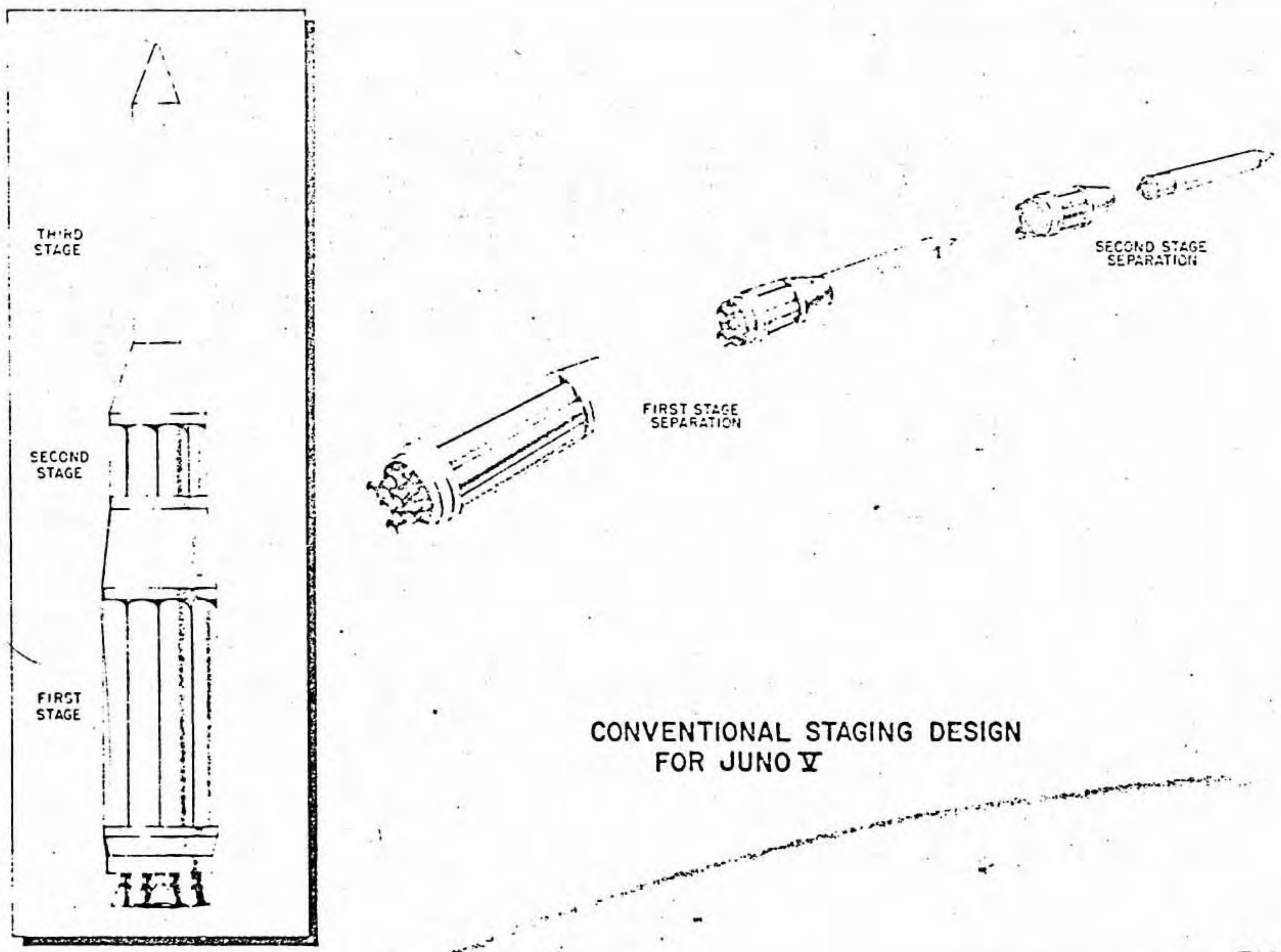


CONVENTIONAL STAGING DESIGN
FOR JUNO V

FIG. 3

vehicle engines are mounted parallel to each other and all are ignited and burn with full thrust from the ground. Engines and tanks are dropped off as the stage requirements are fulfilled with the remaining tanks and engines continuing as the next stage. The propellants used during the first-stage burning are supplied from the tanks that are dropped at first-stage separation.

The parallel staging arrangement has several advantages over the conventional staging. It allows for more flexibility in burning times for individual missions. It also eliminates the problem of altitude ignition which is inherent in the conventional staging. A smaller total number of engines is required to perform the same mission and the engines are better utilized since the center engines burn for a greater time. With all engines burning from launch, a shorter total burning time is required and thus less gravity losses are incurred. A smoother acceleration throughout powered flight is also achieved which may be more desirable for manned space flight. Parallel staging would result in a shorter, more compact vehicle and could reduce the assembly, launching, and handling problems.

Several disadvantages of the parallel staging over the conventional arrangement should be mentioned. Since some engines will burn throughout the powered flight of the vehicle, they cannot be used at their optimum expansion ratio. Also the last stage will be somewhat heavier because of the additional valves and thrust frame attached resulting in performance loss. A new technique satisfying all reliability requirements must be developed and tested which may result in a longer development time and higher cost. Separate feed systems will be required to provide maximum propellant utilization and modifications will be required for the use of high-energy or storable propellant in the upper stages. Due to the above-mentioned required developments, the parallel-staged vehicle would probably not be available as early as a conventional-staged vehicle; however, experience gained from the ATLAS program might be applicable.

Since the parallel staging principle would require additional manpower, funds and time, the initial boosters will be of conventional design with clustered tanks. Further studies will be made to determine the potentialities of the parallel staging concepts for the JUNO V program.

E. Guidance and Control

The JUNO V space vehicle booster will be controlled by the use of techniques and components similar to those employed on the JUPITER missile. However, the control system will impose some requirements on the overall design. Two basic requirements will be discussed and are shown in Fig. 4.

In addition to the monetary savings realized through recovery, valuable information can be gained from studies conducted on boosters which have been recovered. These studies should result in reducing the number of flight tests required and also in arriving at a more reliable booster at an earlier date. Since, by use of recovery, fewer booster units will be needed to conduct the proposed flight test program, the Fabrication Laboratory of ABMA can easily handle this requirement. This plan would facilitate the optimization of the vehicle design and of the production methods before proceeding to large-scale production of the operational workhorse-type vehicle.

Various types of systems could be employed to recover a booster of this size. Since an early orbital capability is of prime concern and available funds limited, it appears that some type of parachute recovery system would be utilized for the flight test boosters for feasibility demonstration. (See Fig. 5.) This approach would permit the design of a simple, inexpensive, and reliable system within the allowable time period. Design studies based on this method of recovery are nearing completion, and are considered feasible. It is desirable to incorporate some type of brake, or retro-rocket, to reduce the final water impact velocity to zero. Various methods of incorporating brake rockets are presently being studied.

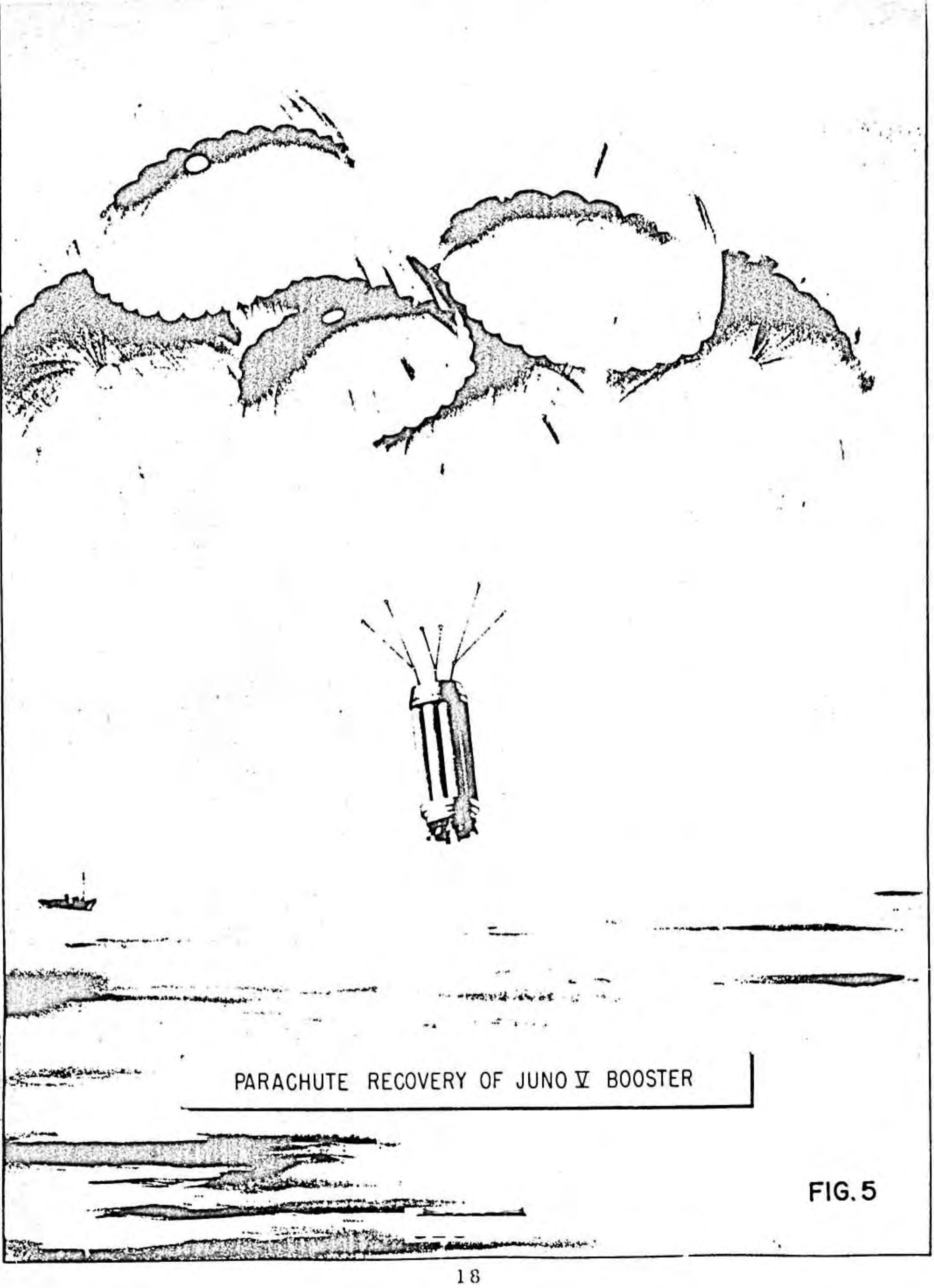
For the operational production boosters, a more sophisticated system would be in order if the firing rate is expected to be high enough. This system could provide a return flight capability for the booster to the launching site. A study is now in progress to determine the optimum means of recovery for a large-scale space exploration operation as a function of firing rates. This study will be completed by summer 1959 to provide a basis for selecting the final system to be used.

G. Upper Stage Design Criteria

The design philosophy of the booster provides the basis for a reliable and versatile vehicle. Because of the booster versatility, design criteria for the upper stages can be determined by specific mission requirements, thus providing a near optimum vehicle for each specific mission. Primary criteria for the upper stage designs are reliability, economy, performance, and growth with the advancing state of the art.

Numerous upper-stage configurations can be envisioned; however, every effort should be made to utilize developed and proven vehicles or components to insure early reliability and, at the same time, to minimize cost.

In missions where the payloads are manned, the upper stages may include an extension of the X-15 experiment and the DYNA-SOAR development. The upper stages will probably retain the well known and already proven LOX/RP-1 propulsion components in the early phase.



PARACHUTE RECOVERY OF JUNO V BOOSTER

FIG. 5

The payload increases to be gained by using propellant such as $LOX-H_2$, $F_2-N_2H_4$, and F_2-H_2 warrant their immediate development for third stage application. Initially, these high-energy-propellant (HEP) stages will be used only in unmanned space probes and cargo vehicles. As reliability is demonstrated, the high-energy-propellant third stage could be used for manned missions. This approach provides a continuing increase in performance, yet maintains reliability in the critical manned mission area.

The joint requirements of reliability and economy suggest the utilization of a previously developed storable-propellant fourth stage for missions requiring orbital maneuvering or terminal trajectory corrections such as space probes and landing vehicles.

The upper stages under consideration demonstrate the design philosophy of reliability and economy achieved by maximum utilization of existing developments, and the basis for growth with the advancing state of the art, without sacrifice of reliability in critical missions.

Several months will be required for a systems study and detailed investigations before any recommendations with respect to the choice of the total vehicle configuration can be made.

H. Mobility and Flexibility

It is necessary to establish the required mobility for the JUNO V vehicle and design the system to meet these requirements. Since this vehicle will probably be the workhorse of space travel for the next 10 years, all possible applications of the system should be considered in establishing these requirements.

Battlefield-type mobility is not considered feasible or necessary. However, the necessary mobility to allow firing from several launching sites in various parts of the world should be achieved. Due to the limitation of launching facilities during the early part of the R&D program, the firings will probably be restricted to AMR. For operational deployment of the JUNO V vehicle, an equatorial launching site is very desirable, if not mandatory, for most space and orbital missions. The military use of the subject vehicle may require launching sites within the zone of the interior to provide adequate defense for the launching sites.

The mobility or transportability of this vehicle system should be based on present or planned transportation capability and not require the development of new systems. With the trend toward air transportation, the JUNO V vehicle should be designed so that the complete vehicle system is air transportable to insure maximum mobility. This can best be achieved with a vehicle of this size by using a multiple-tank configuration, thus permitting disassembly into several sections which may be transported separately and reassembled at the launching site. Figure 6 illustrates the air transportability of a clustered-tank booster design broken into its components.

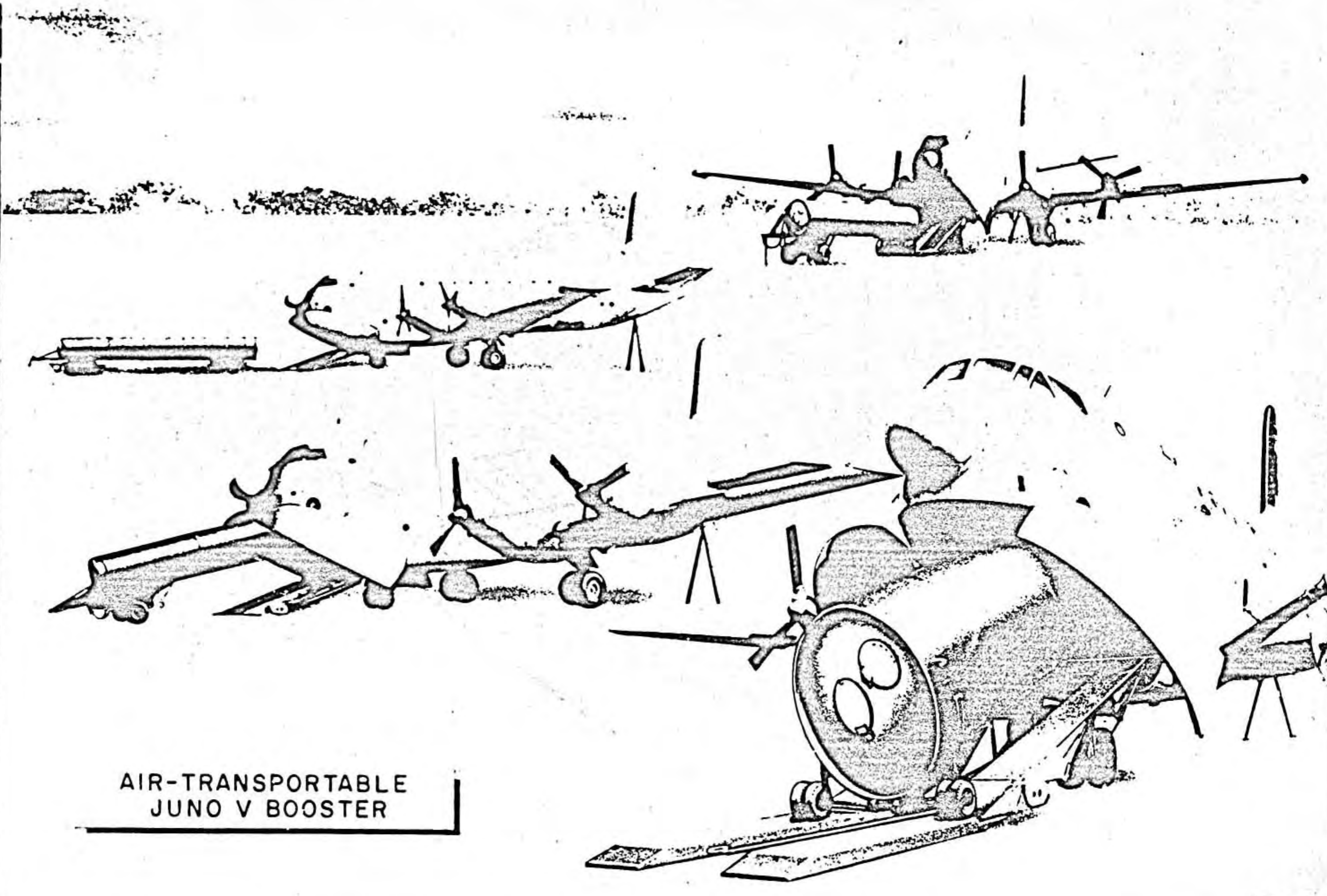
During the early phases of the program; however, it may be desirable to transport the booster as a single unit due to economic reasons or non-availability of facilities and manpower at the test site to provide the required reliability during the final assembly and checkout.

With the increasing cost of missile and space vehicle systems, it has become evident that unless a future vehicle has considerable mission flexibility it will not be economically feasible. Since this vehicle will be utilized as a basic transportation unit of the 1.5 million-lb thrust class for the next decade or longer, it should fulfill the transportation needs for all possible missions mentioned earlier in the report (Section II C). Flexibility in terms of hardware must also be designed into the system. For example, all booster engines should be completely interchangeable. The booster should also be designed with a capability to accommodate varying upper-stage configurations such as a modified JUPITER, modified TITAN, modified ATLAS, or possibly newly developed upper stages, including the X-15 and DYNA-SOAR.

I. Crew Safety and Reliability

To insure complete success of any mission is impossible, but the insurance of a high degree of success of a manned venture into space is mandatory. This high probability of completion of mission can be accomplished only by consideration of all parameters involved. These parameters include mechanical factors and human characteristics. Not only must each component of the vehicle meet the desired reliability, but the overall reliability must equal the required figure. This imposes very high requirements upon the reliability of individual mechanical parts. There is no component which is less important than another if the success or the failure of the mission depends upon it. However, this does not imply that in each mission failure there will be subsequent loss of life. The present expected reliability of mechanical factors is 90%. In each of the 10% failures, the desired intact recovery of the crew is at least 90%. Therefore, a 99% factor can be applied to human conservation in space flight. The human characteristics will dictate certain vehicle characteristics, such as maximum accelerations, so that the two must be optimized.

One of the most important contributions to a reliable booster is the engine cluster arrangement and its control characteristics which keep the vehicle stable even if one engine is shut off.



AIR-TRANSPORTABLE
JUNO V BOOSTER

FIG. 6

Reliability of components can be increased, but generally only at a cost—cost in terms of money, time, and payload. These penalties must be accepted, for the prime consideration is success of the mission. Optimization will be accomplished, but not to the point where reliability is endangered.

J. Growth Potential

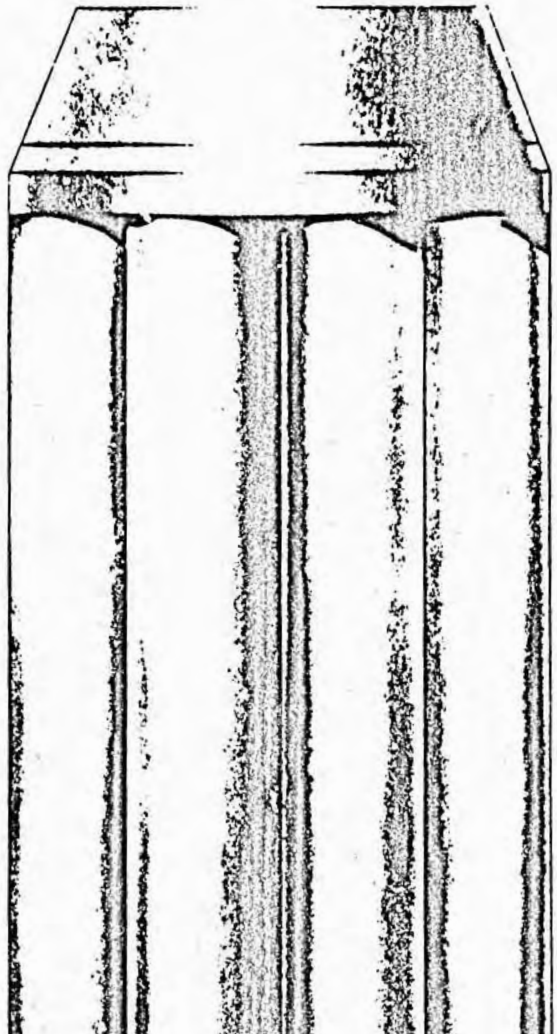
The JUNO V vehicle first stage, as well as the total vehicle, is designed for growth potential. The design approach, however, is to establish the required reliability first and improve performance later without losing reliability. This seems to be the only logical approach since this vehicle eventually will be used for personnel transportation, and crew safety aspects have first priority.

The propulsion system arrangement allows the replacement of the four inboard engines by one large (i. e., the 1000 to 1500K F-1) engine as shown in Fig. 7. This can be done with any larger engine with approximately the same dimensions. The use of the same propellants (LOX/RP-1) would be desirable but is not mandatory due to the parallel tankage arrangement.

The tanks provide a capacity up to 750,000 lb of useful propellants based on the density of a LOX/RP-1 mixture (2.3:1). This allows the use of a total of 650,000 lb of usable propellant for the single- and three-stage vehicles, which is near optimum for booster recovery, and the use of 750,000 lb of usable propellant for the two-stage vehicle. Basically, it will be very easy to enlarge the tank volume by lengthening the tanks. Since each tank will be filled with only one propellant component, and since the basic diameter of the booster is large enough, changes in propellant volume will present no problem.

This flexibility is highly desirable if the take-off thrust should be increased or if the effective take-off acceleration should be increased. The installation of a fixed 1.5 million-pound thrust single chamber (F-1) engine would raise the total thrust up to 2.3 million pounds with the assumption that the four control engines would be uprated to 200K at that time. This is very likely since it is expected that the F-1, or a similar engine, will not be available for flight testing before 1963 or 1964. A 2.3 million-pound thrust level would allow take-off weights up to 1.75 million pounds which, in turn, would allow propellant weights up to 1.2 million pounds in the first stage if desirable. Thus, this growth potential of the booster and, therefore, the entire vehicle is considered highly desirable.

The present approach of parallel tankage design, but conventional staging, allows the best possible flexibility with respect to upper staging.



PROMISING GROWTH POTENTIAL
OF JUNO V BOOSTER

FIG.7

Initially it is expected to use upper stages with conventional propellants, such as LOX/RP-1, in connection with the most reliable hardware available. Later as improved engines with high-energy propellants become available (provided these have at least the same reliability) the upper stages can be changed. Thus, a large growth potential with respect to performance is available which can easily exceed payload capabilities of 50,000 lb at a 300-mile altitude for orbital missions.

K. Manufacturing Considerations

It would be very desirable to have the booster design compatible with the existing ABMA fabrication facilities; however, this is no requirement and should not compromise the design. The clustered tank design recommended in Section III C satisfies this condition since both 70-in. and 105-in. fabrication facilities are available.

Although any type of tankage could be fabricated in time to meet the required time schedule, clustered tankage will help to ease this schedule by decreasing the fabrication time required. The proposed tankage, by using REDSTONE (70 in.) and JUPITER (105 in.) diameters, will make use of present tooling and facilities, such as welding fixtures, head dies, hydrostatic test stand, X-ray facilities, and handling equipment. This method also makes use of the vast experience which has been built up by the fabrication and assembly personnel in producing REDSTONE and JUPITER missiles.

Since the proposed design is made up of several identical parts, it lends itself to production line techniques where many major components can be processed at the same time using many crews. This method will help to reduce the fabrication and assembly time and will yield more reliable and less expensive boosters. A design based on a large single tank would impose working space restrictions which would not be compatible with large working crews, thus eliminating production-line methods and requiring longer fabrication and assembly time.

In case of mobilization, the production of the clustered-tank booster could be dispersed over a large area to prevent destruction of more than a limited number of major subassemblies or fully assembled boosters. The components could be shipped from the production plant to the launching site and assembled there for firing.

IV. JUNO V DESCRIPTION AND PERFORMANCE (S)

A. Vehicle Family Description

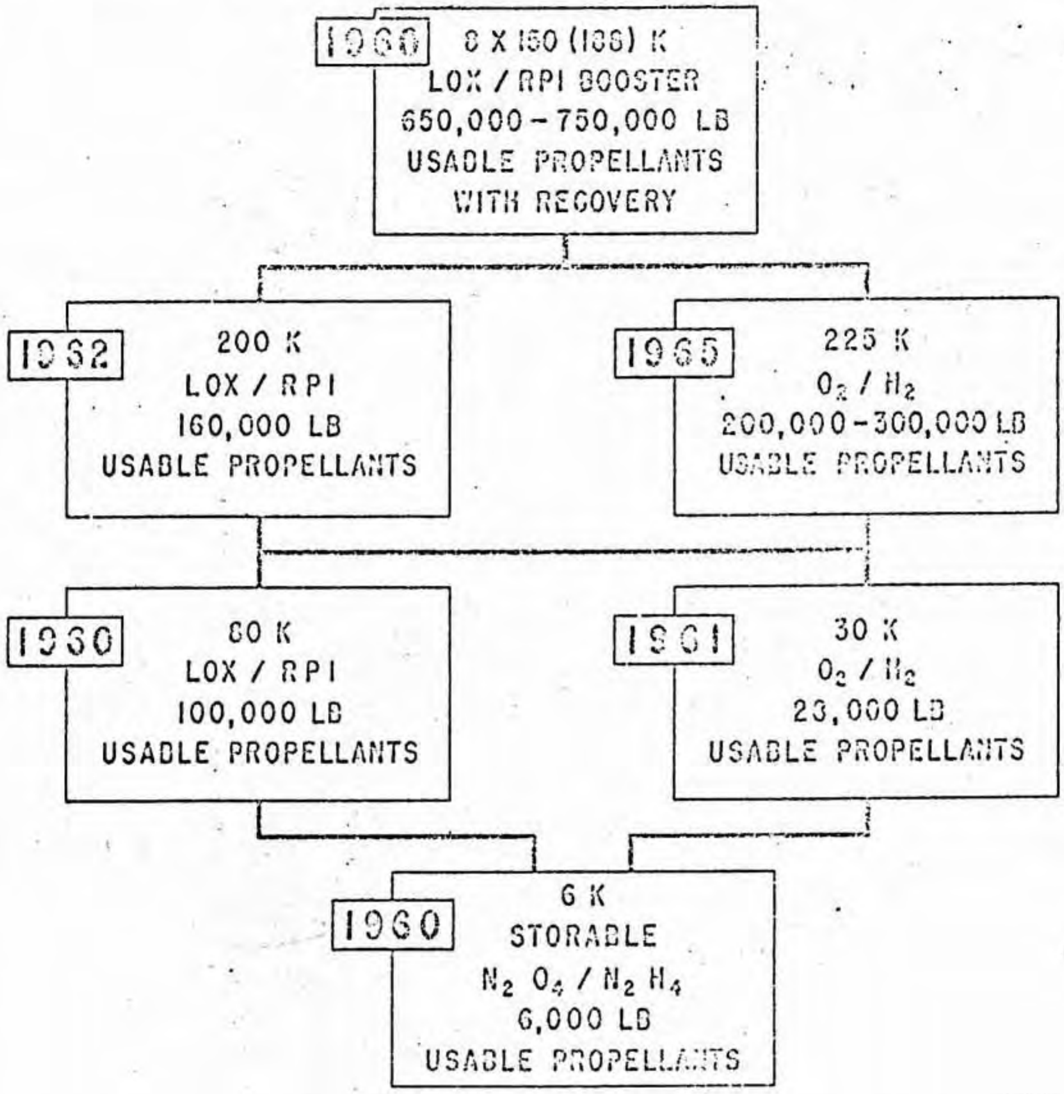
The Basic Design Philosophy in the JUNO V space vehicle program is to provide a flexible transportation system which is applicable to all potential orbital and space missions and, at the same time, has sufficient growth potential built-in to insure its use for a long time to come. This is the only approach which can be taken without overburdening the national economy of the approaching space age. Dead-end developments must be foreseen and avoided whenever possible.

Two generations of vehicle configurations are anticipated for the JUNO V; the first generation is based primarily on conventional propellants with alternate high energy upper stage (or stages) and a simple booster recovery system. This vehicle system will be used mainly in the decade from 1960 to 1970. In the second half of this decade the second generation building blocks will be developed. These are a high thrust (more than 2000K) booster with a sophisticated, highly economical recovery system and a hydrogen/oxygen second stage with a nuclear stage as an alternate. Available top stages in the small thrust class (high energy or storable propellants) will be used for specific maneuvers as the individual missions require.

If parallel staging is found desirable during the present system analysis study and is decided upon, the overall picture would not change in principle. The first and second stages would be replaced by parallel thrust units which would also give a low-altitude orbit capability based on conventional propellants. Such an approach would also use a high energy upper stage and a storable propellant stage where required. The resulting vehicle would be considerably shorter; however, the second-generation second stage using the hydrogen/oxygen combination would not be feasible. The second generation of vehicles based on parallel staging has approximately the same growth potential as the tandem arrangement. A detailed qualitative comparison is not yet possible due to lack of accurate weight and performance data. A final conclusion concerning the comparison of the two staging principles will be available by April 1959 when the overall JUNO V systems study is completed.

1. Building Blocks

a. First Generation. The JUNO V Space Vehicle Family in its first generation is comprised of six building blocks which represent individual stages and can be used for assembling the various combinations required for the large number of different missions. These building blocks are illustrated in Fig. 8. The first generation of vehicles will use the booster stage with a



6 BUILDING BLOCKS WITH ALTERNATE 2ND AND 3RD STAGES WITH THE FOLLOWING MISSION CAPABILITIES:

1. SHORT AND LONG RANGE SURFACE TO SURFACE MISSIONS.
2. LOW, MEDIUM AND HIGH ORBIT ALTITUDE MISSIONS.
3. SPACE PROBES AND INTERPLANETARY PROBES.
4. LUNAR SATELLITE AND LANDING MISSIONS.
5. PLANETARY SATELLITE MISSIONS.

FIG. 3

cluster of eight 188K modified JUPITER engines (NAA H-1) in all applications. The initial second stage will be a modified TITAN or ATLAS structure preferably powered by one engine with approximately 200K vacuum thrust. Later in the development, a conversion of this stage to H_2O_2 as proposed by ROCKETDYNE might be very attractive and should be considered as an alternate for missions requiring large payload capabilities.

Two alternate approaches, again with modified hardware from the ATLAS or TITAN program, can be chosen for the third stage. Initially, an 80K LOX/RP-1 stage appears to be the most logical choice. Shortly thereafter a 30K H_2O_2 stage, presently being developed, will be available for third-stage application.

Whenever maneuvering is required in the final stage, a small propulsion system using storable propellants such as the 6K JPL N_2O_4/N_2H_4 engine will be used.

The individual building blocks of the first generation standard vehicle are described in some detail as follows:

(1) Booster Configuration

The basic booster structure consists of eight 70-in. diameter tanks arranged around a central 105-in. diameter tank. The total diameter of the booster is 21-1/3 ft. (See Fig. 9.) The basis for this selection of tank arrangement has been discussed in Section III. The central tank and four of the outer tanks will contain LOX and form the load-carrying structure of the booster while the remaining four outer tanks will contain fuel. The design usable propellant capacity is 750, 000 lb. Due to thermal contraction in the LOX tanks, the four outer fuel tanks will not be used as basic structural elements, since they will have a gliding upper bearing to allow for LOX tank contraction. The engine-mounting structure transmits thrust and gimballing loads into the center LOX tank structure and partially into the outer LOX tanks, which carry thrust loads and bending moments into the adapter structure for the upper stages. ABMA analysis confirms the findings of Ref. 4 and indicates that there are no aerodynamic objections concerning the open tank arrangement; however, if some unforeseen problem should arise, a thin skin can be added around the tanks.

The basic single engine will be the NAA H-1 designed for 188K. The H-1 is a greatly simplified and repacked S-3D engine which is used in the JUPITER, THOR, and ATLAS missiles. All the components have been thoroughly developed and have extensive static test times accumulated. Some components have been extensively flight-tested. All components have been successfully static-test fired at thrust levels exceeding 188K. The

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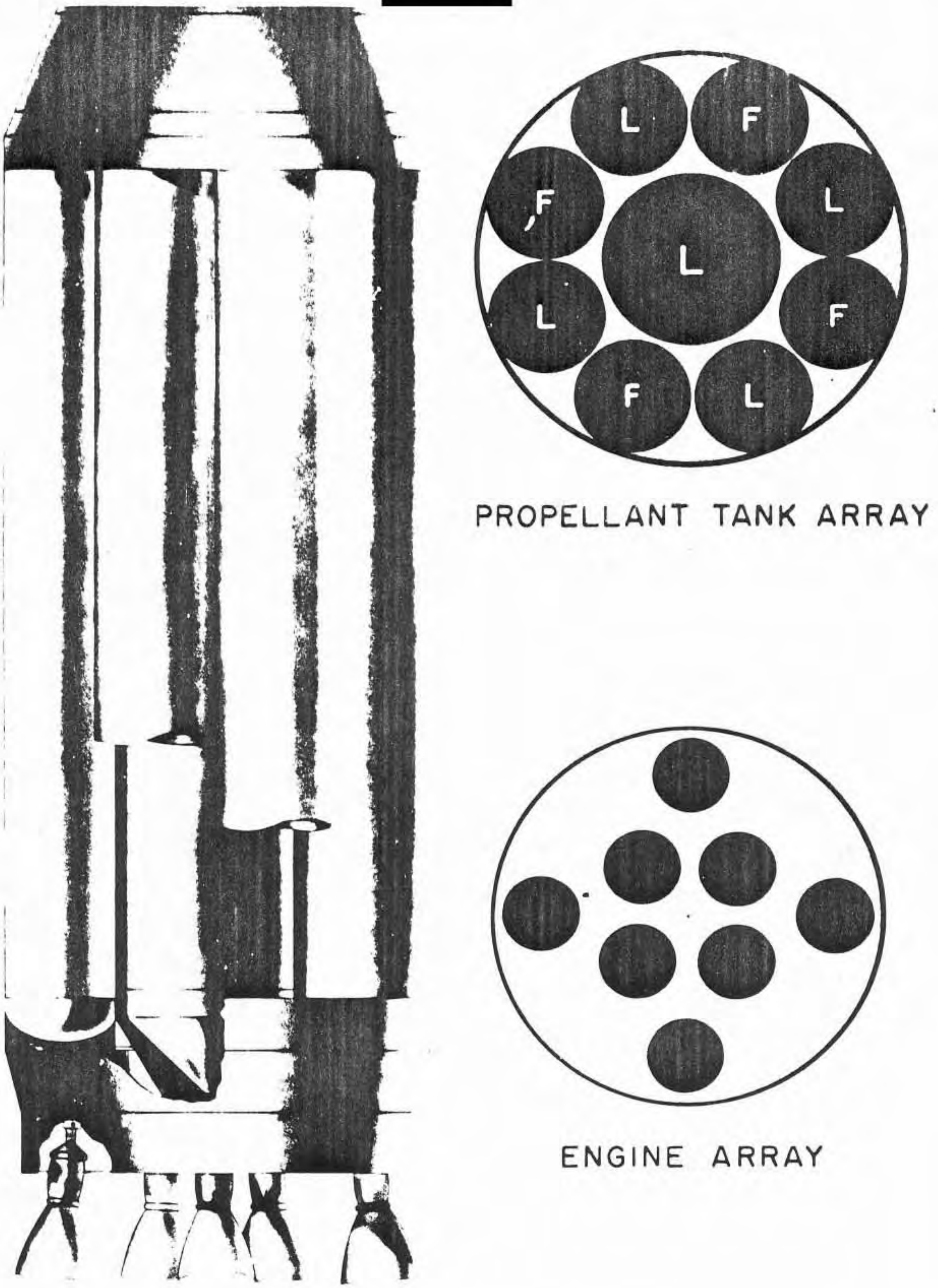

JUNO V BOOSTER

[redacted]

FIG. 9

simple pressure sequencing start system and the improved turbopump design were developed and extensively tested under the X-1 engine development supported by Air Force contracts. This modified S-3D engine, improved by a large number of static and flight tests within the ballistic missile programs, provides a thrust chamber and accessories that are truly reliable workhorse items.

The turbopumps are mounted on the thrust chambers in such a manner that each engine is an integral unit. The reliability and economy inherent in the utilization of thoroughly developed and tested components from other programs provide, within a short period of time, a reliable improved engine specifically adapted to clustering.

Eight of these modified S-3D engines will be incorporated into the booster cluster. They are arranged with four fixed engines mounted in the center with the remaining four mounted outside and gimballed for roll, pitch, and yaw control. This design will give sufficient control forces even if one engine should fail during powered flight. All engines are canted so that their lines of thrust pass through the critical vehicle center of gravity. The exact angles of cant will be determined during the final vehicle design.

For crew safety, individual fire walls and a fire extinguisher system will be provided for each engine so that in case of fire only the affected engine need be shut down and the remainder can continue to burn. Vents will also be provided to eliminate any accumulation of combustible gases in the tail section.

The new eight-engine propulsion system will have only 10 major components per engine as compared to the 68 components of the original S-3D engine. This is the major advantage of using the modified engine. Proven propellant-tank pressurization methods are being studied to determine the optimum methods with respect to simplicity and reliability. A simple nitrogen pressurization system will be used in the first four boosters.

The single booster, as well as the final booster for a multistage vehicle, is designed for recovery due to the valuable hardware involved. A recovery of the first two flyable boosters would also tend to accelerate the development schedules since any trouble which might develop could be thoroughly investigated after recovery. Moreover, some of the recovery hardware will be used for further testing resulting in considerable savings of money and hardware lead time.

The simplest recovery system available will be used in the early flight tests. This consists of six 100-ft diameter parachutes, attached to the top of the booster, which will be ejected at about 7000 ft altitude, after the booster speed has become subsonic due to its own aerodynamic drag. The parachute package, weighing approximately 1800 lb, will reduce the booster velocity to about 35 ft/sec.

This final velocity will be reduced to near zero by 12 brake rockets (FALCON solid-propellant motors or similar) each providing about 5000-lb thrust for 1.4 sec. These brake rockets will be ignited by a proximity fuze when approaching the water surface. The booster will be floated into an LSD and brought back to the Cape Canaveral harbor. It is hoped that the feasibility of recovery of big boosters can be demonstrated in this way. The optimization of the recovery system will be carried out in due course of development, as soon as the expected firing rates and other specifications for the entire transportation system have been determined.

(2) Second Stage With Conventional Propellants

The diameter of the second stage, using approximately 150,000 to 200,000 lb of propellants, should be kept at 120 in. due to the available tooling at the CONVAIR and MARTIN plants. A larger diameter would be desirable to obtain a more favorable slenderness ratio; however, a change of the 120 in. diameter for this version is neither mandatory nor economically feasible due to the very limited initial funding for this program. The propulsion system for this second stage might be either an ATLAS or a TITAN booster engine, modified to have high-altitude ignition capability and a larger expansion ratio (between 1:20 and 1:25). A slight preference exists for the modified ATLAS engine due to the present and potentially better reliability (more accumulated test and manufacturing experience) and due to the fact that the same engine with a smaller expansion ratio will also be used in the booster. The engine would be gimballed, and roll control would be provided by the turbine exhaust of the engine.

(3) Second Stage With High Energy Propellants

It is becoming more and more apparent that improvement of the upper stages shows a better payoff with respect to performance than modification of the booster. Upper stage modification is also easier to achieve.

The present thinking favors the use of hydrogen and oxygen rather than fluorine and hydrazine as a high-energy propellant combination. The latter combination is more expensive and hazardous, and both have approximately the same flight performance. The main disadvantage of the hydrogen/oxygen combination is its low density. In the case of the JUNO V, the low density is of minor concern because the diameter of the second stage can easily be enlarged up to the booster diameter of 256 in. without being too troublesome. In addition, the elements for the feeding system (H_2 pump,

O_2 pump, turbine, and gear case) for such an engine are available from other programs. Thus, such an engine might be obtainable in a short time with reasonable cost.

As a matter of fact, ROCKETDYNE has proposed such an engine at 225K vacuum thrust level. This engine could be developed in about 3 years at a cost of approximately $30 million including propellants. Such a development is very promising for increasing the JUNO V payload capability considerably and should be initiated at the earliest possible time. Therefore, this alternate high energy second stage would be available for operational use as soon as the required reliability has been established.

(4) Third Stage With Conventional Propellants

The most logical choice for a third stage again is available hardware such as the ATLAS sustainer engine or the TITAN second stage engine both with 80K lb thrust at altitude. Due to the large payloads required, the largest possible diameter should be chosen, in this case 120 in. The desired amount of propellants seems to be in the range of 60,000 to 100,000 lb and varies with the particular mission. Thus, modified TITAN or ATLAS hardware seems to offer an acceptable solution, from both the economical and performance standpoints.

(5) Third Stage With High Energy Propellants

A decision has been made recently to develop a 30K hydrogen/oxygen engine with approximately 30,000 lb of propellants. This pump-fed twin-chamber propulsion system is being developed by PRATT-WHITNEY with the objective of flight testing this system on an ATLAS missile by end of 1960. The tankage will be designed and developed by CONVAIR, who is also to integrate this propulsion system into the high energy stage. This same 120 in. stage will also be a very desirable third stage for the JUNO V vehicle, specifically for high altitude orbit and space missions.

(6) Vernier Stage With Storable Propellants

Many missions require small impulses after long time periods. Examples are the adaption maneuver when arriving at the altitude for the 24-hr orbit, midcourse guidance corrections, and lunar satellite or landing maneuvers. The JPL 6K engine using N_2O_4 and N_2H_4 with a vacuum impulse of 300 sec is a very attractive choice. This engine is presently under development.

[redacted]

b. Second Generation. The second generation of JUNO V vehicles represents the growth potential of this space transportation system. Such growth potential is obtainable, for example, by replacing the fixed inner engines by a single 1500K LOX/RP-1 engine which would result in a take-off thrust of up to 2300K if the thrust of the four outer control engines can be increased to 200K at the same time, which seems to be feasible. Such increased booster performance might be available by 1965.

At this time, the hydrogen/oxygen second-stage engine could have sufficient reliability to be used as a twin engine (225K lb thrust each), hence propellant loadings up to 450,000 lb, which would be desirable due to the thrust increase of the first-stage booster.

A few years later a nuclear second stage might be available from the ROVER program which would be very attractive for lunar and interplanetary missions. Such an alternate solution could be selected if found desirable and when the required reliability has been established.

A third and fourth stage on such a higher performance combination of first and second stages will be needed only if the mission requires larger maneuvers after excessive time periods. Such a maneuver, for example, would be a lunar landing operation from a lunar orbit. The JPL 45K and 6K engines using storable propellants might prove to be very attractive propulsion systems for such specific missions.

2. Typical Missions Chart

Table 1 illustrates a representative mission chart typical of a program without preference for a specific mission. It gives the missions as anticipated for the first four flights (which are approved), and possible missions which might be assigned for the continuation of the early development program.

The first two flights with single-stage vehicles serve mainly for the testing of the booster propulsion system with an attempt to recover the booster. Initial recovery is required to improve reliability in the shortest possible time with minimum funding.

The second two flights also have as the primary mission propulsion testing; but have as a secondary mission, a low-altitude orbital capability in the order of a few thousand pounds. This is achieved by using a third stage with an inert dummy second stage. The prototype guidance system will provide the accuracies required for a near circular orbit.

These four vehicles represent the presently approved program.

Table I
TYPICAL JUNO V SCHEDULE AND MISSION CHART

Vehicle Number	Tentative Proposed Firing Date	Vehicle Description	Flight Missions
1 2	Oct 60 Jan 61	(a) 8 x 150K Booster 650,000 lb Usable Propellant (b) 120-in. Dummy Stage II 120-in. Dummy Stage III (c) 120-in. Instrument Compartment (d) Nose Cone	(1) Propulsion Test Stage I (2) Structural Test (3) Control System Test (4) Booster Recovery System Test (5) Launching Facility Checkout Test
3 4	Jun 61 Oct 61	(a) 8 x 150K Booster 750,000 lb Usable Propellant (b) 120-in. Dummy Stage II (c) 80K 120-in. Diameter 80,000 lb Usable Propellant Stage III (LOX/RP-1) (d) 120-in. Instrument Compartment (e) 120-in. Payload Compartment	(1) Propulsion Test Stage I and III (2) Orbital Guidance Test Without Transfer Ellipse (3) Structural High g Test (4) Secondary Short Lifetime Orbital Payload Mission With Attempt of Recovery
5 6 7	Dec 61 Feb 62 Apr 62	(a) 8 x 165K Booster 650,000 lb Usable Propellant (b) 120-in. Dummy Stage II (c) 80K 120-in. Diameter 80,000 lb Usable Propellant Stage III (LOX/RP-1) (d) 6K Storable Kick Stage 6000 lb Usable Propellant (e) 120-in. Instrument Compartment (f) 120-in. Payload Compartment	(1) Propulsion Test Stage I and II and Kick Stage (2) Guidance Accuracy Test for 96-min (306 N. M.) Circular Orbit With Transfer Ellipse and Kick Maneuver (3) Booster Recovery Test (4) Complete Control System Test (5) Research Instrumentation for 306 N. M. Orbit
8 9 10	Jun 62 Jul 62 Aug 62	(a) 8 x 165K Booster 650,000 lb Usable Propellant (b) 200K Stage II (120-in. Diameter) 160,000 lb Usable Propellant (LOX/RP-1) (c) 80K Stage III 80,000 lb Usable Propellant (LOX/RP-1) (d) 6K Storable Kick Stage 6000 lb Usable Propellant (e) 120-in. Instrument Compartment (f) 120-in. Payload Compartment	(1) Complete Propulsion System Test (2) Guidance and Control Test for Space Missions (3) Booster Recovery (4) Secondary Space Probe Missions such as: Lunar Satellite Lunar Hard Landing Interplanetary Probe (5) Checkout of Equatorial Launching Site
11 12 13	Sep 62 Oct 62 Nov 62	(a) 8 x 165K (188K) Booster 650,000 lb Usable Propellant (b) 200K Stage II 160,000 lb Usable Propellant (LOX/RP-1) (c) 30K Stage III (120 in.) 30,000 lb Usable Propellant (H_2O_2) (d) 6K Storable Kick Stage (e) 120-in. Instrument Compartment (f) 120-in. Payload Compartment	(1) Propulsion System Test (2) Guidance and Control Test for 24-hr Orbit (3) Booster Recovery (4) Payload Control System Test (5) Communication Payload Component Test in 24-hr Orbit
14 15 16	Jan 63 Feb 63 Mar 63	(a) 8 x 188K Booster 650,000 lb Usable Propellant (b) 200K Stage II 160,000 lb Usable Propellant (c) 80K Stage III 80,000 lb Usable Propellant (d) 6K Kick Stage 6000 lb Usable Propellant (e) Instrument Compartment (f) Payload Compartment	(1) Propulsion Test (2) Guidance and Control Test for Rendevous Maneuver in 306 N. M. Orbit (3) Flight Mission Test for Orbital Rendevous and Return (Biological Specimen)

The remaining twelve vehicles shown in Table 1, although considered tentative with respect to configuration, missions, and firing dates, represent a logical second-phase follow-on program which is geared to produce a multipurpose space vehicle. Whereas the first two orbital test vehicles are only capable of reaching a low-altitude orbit, the next three will be capable of reaching a 306.6 N. M. (96.00 min) orbit. This is obtained by adding a Kick stage which will be employed as a fourth stage in the final configuration. The next group of three vehicles is tentatively earmarked for space probes as the secondary mission. The primary mission would be the development of vehicle components. This group carries for the first time the second stage as described above. The next group of three vehicles of this initial development program consists of the complete four-stage system with the primary mission of testing the guidance accuracy in a 24-hr orbit. Instrumented packages or payload components may be added as secondary missions. The remaining three vehicles of the typical 16-vehicle program outlined would be a four-stage configuration with a primary mission of propulsion system test and could have as secondary missions guidance and control test for rendezvous maneuvers in a 306 N. M. orbit and orbital return test.

The continuation of the 16-vehicle development program (Phase I and II) will depend somewhat on the priority of missions assigned to this vehicle program. Due to the fact that this vehicle will be a research carrier rather than a military vehicle to be deployed in the field, chances can be taken for incorporating payloads early in the development program. It should not be overlooked, however, that a reasonable reliability with respect to completion of the mission cannot be expected before the 50th flight, and this only if the program is properly funded.

The initial development program as illustrated in Table 1 can be considered as typical and should be used for initial planning purposes only. A more extensive initial development program which more or less doubles the number of flights in each category (totaling 32 vehicles) would be much more desirable from the technical point of view. But, such a program will very likely not be considered feasible due to limitations in funding, facilities, and time. Thus, a low probability of a successful flight in the initial phase of the program will have to be accepted. It seems to be within reach, however, to obtain a mission reliability of approximately 75 per cent with 50 flights, if the development program is properly supported.

3. Test Vehicles

The JUNO V program embodies vehicles used solely for test purposes and operational vehicles. The first group, of only transient importance, includes the following vehicles, which are considered as interim test carriers only:

a. Single-Stage Booster. This will serve as test carrier for eight engine cluster and will be used for feasibility test of cluster scheme at a thrust of 150K per engine. It will also be used for early recovery tests. Two sets of hardware are on order. Flight tests are expected in the fall of 1960.

b. Two-Stage Interim Orbital Test Vehicle. This version will be used for a propulsion test of the third stage and also for an orbital guidance test. The size of the orbital payload for a low-altitude near-circular orbit is of minor importance. Two sets of hardware for the booster are on order. A decision as to which upper stage should be used has not been made yet, and is due in a few months in order to meet the desired schedule (mid 1961).

c. Three-Stage Interim Orbital Test Vehicle. This vehicle is essentially the same vehicle as described under 3b (above), but a Kick stage for providing the required velocity increment at apogee is incorporated. The JPL 6K engine is presently favored for this version. The BELL 117L engine might also be an acceptable solution in case the 6K engine is not available. This configuration will allow the establishment of a 96-min orbit at 306.6 N. M. with a payload of several thousand pounds.

d. Single Stage Advanced Power Plant Test Vehicle. This version is essentially the standard booster where the four inner engines can be replaced by any engine to be flight tested. Such a flying test bed is very desirable for the development of a 1000K to 1500K single chamber engine. If such a test program can be connected with a booster recovery system which eliminates a water landing, a near optimum test vehicle for all kinds of programs will be available. A test vehicle of this kind is expected to be mandatory in the years 1964/65 and thereafter. Another use of the booster as a test vehicle is anticipated for the flight-testing of a nuclear upper stage required at a later date within the second generation of the JUNO V vehicular program.

4. Payload Considerations

Because of the large payload carrying capabilities of the JUNO V family of space vehicles, it is necessary to consider the volume requirements for the payloads.

A study of payload compartment length for payloads up to 40,000 lb is shown in Fig. 10 for various payload densities. Three standard payload configurations were considered: 95-in. diameter (TITAN), 105-in. diameter (JUPITER), and 121-in. diameter (ATLAS). Payload specific gravity values of 1.0 and 0.2 were used. The specific gravity value of 1.0 would be for

JUNO V PAYLOAD VOLUME REQUIREMENTS

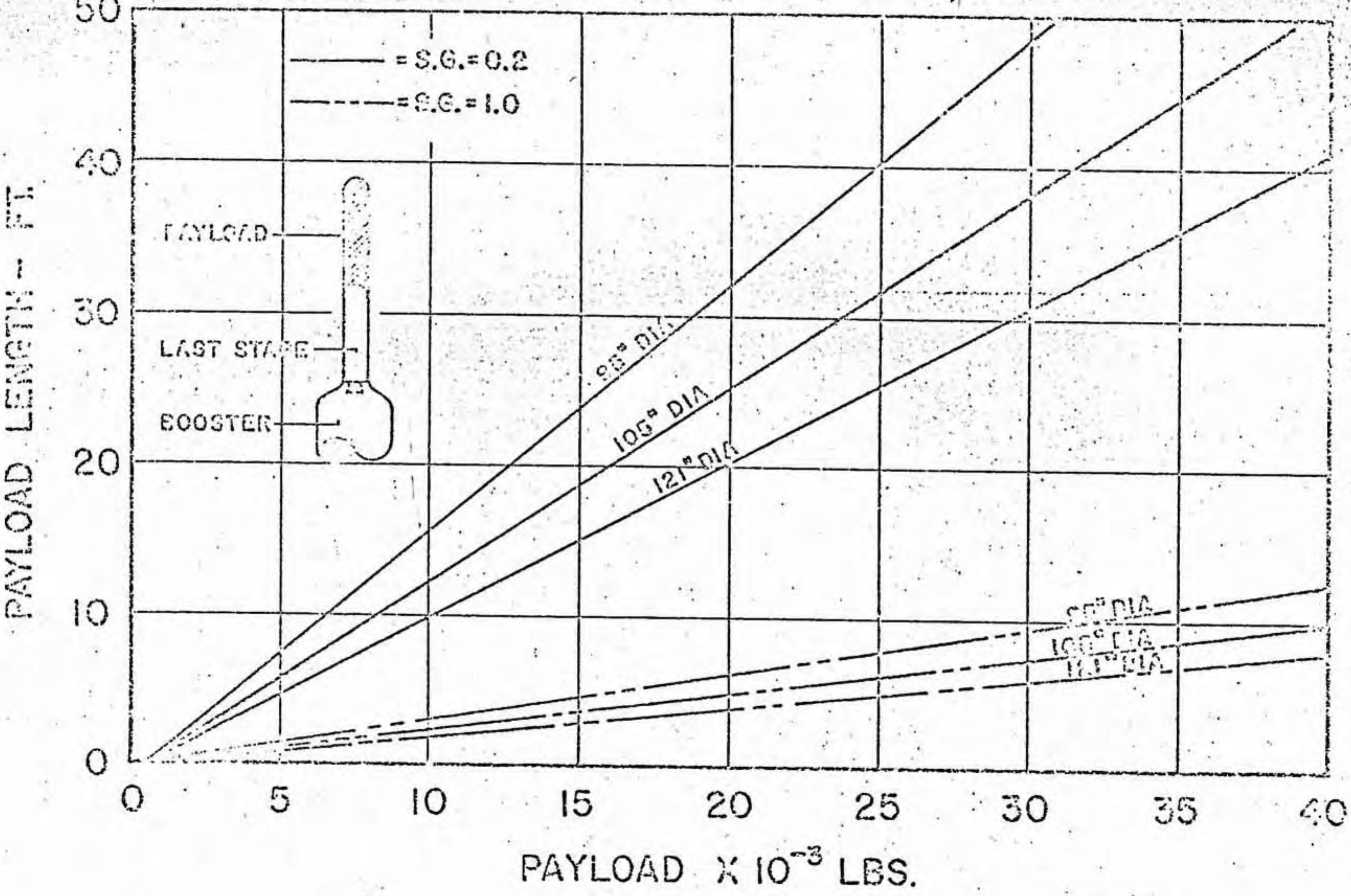

FIG. 10

high-density cargo type payloads; the 0.2 would more nearly represent the value for instrumented manned or unmanned satellites or probes.

The consideration of volume requirements is of prime concern since it will dictate to a great degree the design of the ground-handling equipment, the control system of the vehicle, and the number of vehicle configurations which will be required.

As can be seen from Fig. 10, the use of conventional payload designs for the small-diameter upper stages, with payload weights of over 20,000 lb and specific gravity of 0.2, will add excessively to the overall length of the vehicle. Therefore, in these cases, consideration should be given to other approaches, such as a "doughnut" design where the payload is wrapped around the last stage, or some other unconventional design.

B. Vehicle Performance and Weight Information

1. First Generation Family

a. <u>General.</u> The standard JUNO V configuration for the first generation is shown in Fig. 11. The illustration shows the 256-in. booster, the conical shroud, the upper stages, the instrument compartment and finally the payload compartment. The latter three all have a diameter of 120 in. The length of the three and four-stage versions is approximately 188 ft, varying slightly with the density of the payload. The third stage can be omitted, providing more room for a bigger payload compartment. The diameter of the second stage will be increased to 256 in. in all cases where the hydrogen/oxygen high energy version is required.

Table 2 summarizes the weight and performance assumptions which were used for the calculation of payload capabilities. The weights were estimated and will have to be verified after the design is frozen and accurate weights are available. Only the operational versions of the first generation are given. Some engine performance data have been included. The standard version as given in the first four columns of Table 2A illustrates the case for the 306.6 N. M. orbit where the fourth stage, as presently envisioned, provides the apogee kick only.

The high energy version (hydrogen/oxygen in the third stage only) is summarized in columns 5 through 8 and represents the vehicle parameters for a typical 24-hr orbit. In both cases, an equatorial launching site has been assumed.

The last vehicle given in Table 2A is a three-stage orbital carrier with hydrogen/oxygen in the second stage and a storable propellant stage for

JUNO V VEHICLE
STANDARD FIRST GENERATION

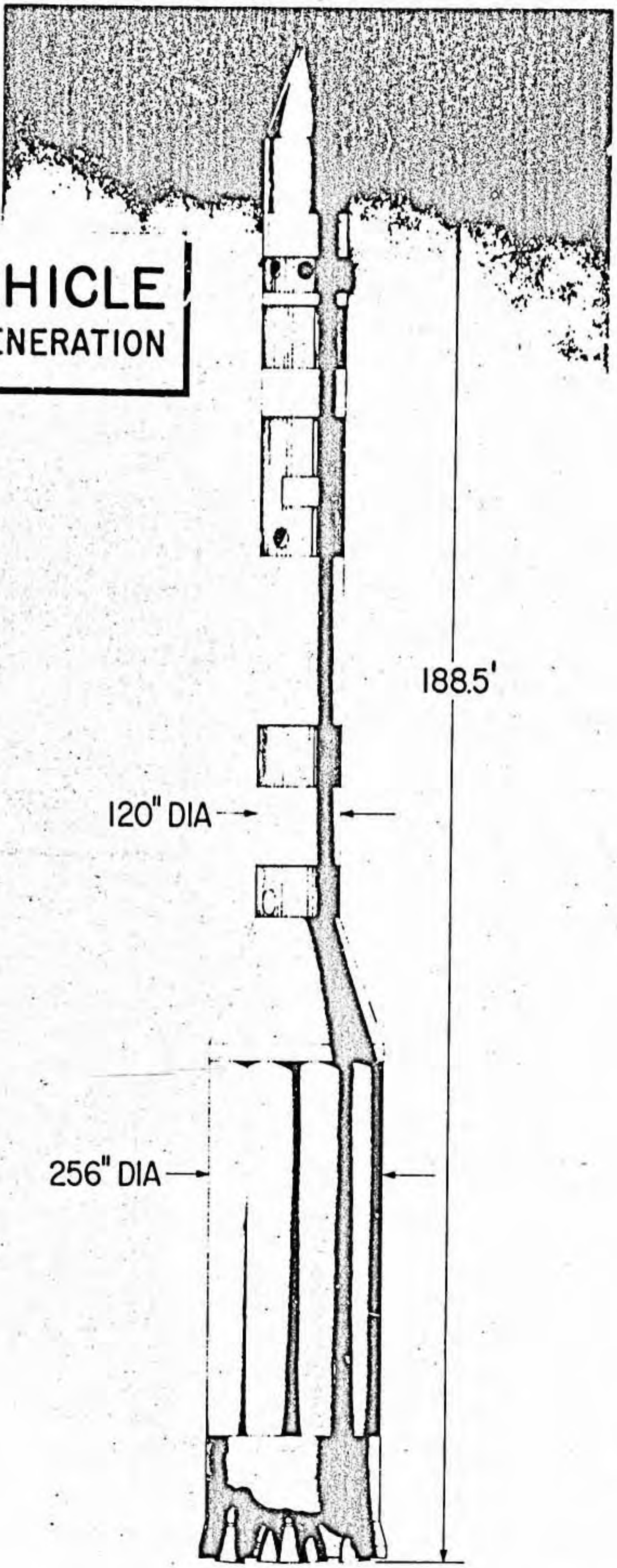

FIG. 11

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Table 2A
ASSUMPTIONS FOR PERFORMANCE CALCULATIONS

Symbol	Parameter	Vehicle IV A (306.6 N. M. Orbit)				Vehicle IV B (24-hr Orbit)				Vehicle II B (100 St. Mi. Orbit)		Vehicle III B (306.6 N. M. Orbit)		
		I	II	III	IV	I	II	III	IV	I	II	I	II	III
$W_{11,14,15}$	Net Payload, lb				20,000				4,700		23,400			30,500
W_{16}	Instrument Compartment, lb				800				800		500			500
W_1	Total Payload, lb	285,200	114,400	25,000	20,800	233,300	62,500	14,700	5,500	199,300	23,900	353,400	70,700	31,000
W_2	Guidance and Control, lb			500	1,500			500	1,500		2,000		500	1,500
W_3	Fuselage, lb	29,000	5,000	3,500	400	29,000	5,000	3,500	400	29,000	5,000	29,000	25,200	4,200
W_4	Propulsion, lb	19,000	3,000	1,500	550	19,000	3,000	1,000	550	19,000	3,000	19,000	3,500	1,000
W_5	Recovery Equipment, lb	3,500				3,500				3,500		3,500		
W_6	Trapped Propellant, lb	8,500	1,200	400	70	8,500	1,200	200	70	8,500	1,200	8,500	700	200
W_7	Usable Propellant Residuals, lb	6,500	1,600	3,500	680	6,500	1,600	1,600	680	7,500	4,200	6,500	2,500	2,300
W_8	Expected Propulsion Consumption, lb	650,000	160,000	80,000	1,000	650,000	160,000	41,000	6,000	750,000	160,000	650,000	250,000	30,500
W_s	Structure Weight, lb	51,500	8,000	5,500	2,450	51,500	8,000	5,000	2,450	51,500	10,000	51,500	29,500	6,700
W_w	Structure Net Weight, lb	60,000	9,200	5,900	2,520	60,000	9,200	5,200	2,520	60,000	11,200	60,000	30,200	6,800
W_n	Effective Structure Net Weight, lb	66,500	10,800	9,400	3,200	66,500	10,800	6,800	3,200	67,500	15,400	66,500	32,700	9,200
W_A	Stage Weight, lb	716,500	170,800	89,400	4,200	716,500	170,800	47,800	9,200	817,500	175,400	716,500	282,700	39,700
W_o	Take-Off Weight, lb	1,001,700	285,200	114,400	25,000	949,800	233,300	62,500	14,700	1,016,800	199,300	1,069,900	353,400	70,700
W_c	Cut-Off Weight, lb	351,700	125,200	34,400	24,000	299,800	73,300	21,500	8,700	266,800	39,300	419,900	103,400	40,200
A_o	Acceleration at Take-off, g	1.50	0.70	0.70	0.24	1.58	0.86	0.48	0.41	1.48	1.00	1.41	0.64	0.42
A_c	Acceleration at Cut-off, g	4.88	1.60	2.33	0.25	5.72	2.73	1.40	0.69	6.42	5.09	4.08	2.18	0.75
V_v	Individual Mass Ratio	2.8482	2.2780	3.3256	1.0417	3.1681	3.1828	2.9070	1.6897	3.8111	5.0712	2.5480	3.4178	1.7587
R	Overall Mass Ratio	22.4770				49.5293				19.3269		15.3158		
E_n	Effective Structural Factor	0.066	0.038	0.082	0.128	0.070	0.046	0.083	0.218	0.066	0.077	0.062	0.093	0.130
I_{spo}	Specific Impulse Sea-Level, sec	258				258				258		258		
I_{spvac}	Vacuum Specific Impulse, sec	294	310	310	300	294	310	420	300	294	310	294	426	420
F_o	Sea-Level Thrust, lb	1,504,000				1,504,000				1,504,000		1,504,000		
F_{vac}	Vacuum Thrust, lb	1,714,000	200,000	80,000	6,000	1,714,000	200,000	30,000	6,000	1,714,000	200,000	1,714,000	225,000	30,000
ΔU_v	Characteristic Velocity Increment, m/sec	2,872	2,498	3,650	120	3,165	3,519	4,390	1,540	3,739	4,926	2,610	5,130	2,320
$\Sigma\Delta U_v$	Overall Characteristic Velocity, m/sec	9,140				12,614				8,665		10,060		
Δt	Burning Time, sec	112	248	310	50	112	248	574	300	129	248	112	473	427
ε	Propellant Fraction	0.907	0.937	0.900	0.238	0.907	0.937	0.858	0.652	0.917	0.912	0.907	0.864	0.768

Table 2B
CHARACTERISTIC TECHNICAL DATA

Symbol	Parameter	IV A (306.6 N. M.)	IVB (24-hr Orbit)	II B (100 St. Mi. Orbit)	III B (306.6 N. M. Orbit)
M	Growth Factor	48.16	172.69	42.54	34.51
N	Net Growth Factor	3.24	12.17	2.57	2.83
R	Overall Mass Ratio	22.4770	49.5293	19.3269	15.3158
I_{sp}	Mean Specific Impulse, sec	300	331	299	377
$\sum\Delta t$	Total Burning Time, sec	720	1,234	377	1,012
$\sum\Delta U$	Total Characteristic Velocity, m/sec	9,140	12,614	8,665	10.060
$\sum\Delta V$	Total Velocity Increment, m/sec	7,576	11,294	7,375	7,118
$E_n(\Delta U)$	Mean Effective Structural Factor as to ΔU	0.066	0.086	0.073	0.093
N_v	Effective Propulsion Efficiency (for Equatorial Launching Site)	0.857	0.823	0.877	0.782

vernier and apogee Kick maneuver. This has been calculated also for a typical 306.6 N. M. equatorial circular orbit. Columns 9 and 10 of Table 2A depict a two-stage version with hydrogen/oxygen in the second stage for low-altitude orbital missions.

Table 2B summarizes the vehicle parameters given in detail in Table 2A.

b. Surface-to-Surface Missions. The JUNO V can be used for the transportation of large payloads over short and medium, as well as intercontinental, ranges. The single-stage version offers payload capabilities in the order of 100 to 150 tons over 200 to 300 miles; and, as a conventional two-stage vehicle, it offers payloads in the order of 20 tons over transatlantic ranges or 10 tons for very long ranges such as WASHINGTON-MOSCOW. Typical payload capabilities versus range for an optimized two-stage vehicle are shown in Fig. 12.

c. Orbital Missions. The orbital payload capability of the standard JUNO V vehicle for equatorial orbits plotted versus orbit altitude is depicted in Fig. 13. The version using conventional propellants shows payload capabilities up to 22,000 lb for low altitude orbits. If high energy propellants are used in the third stage, payloads of approximately 25,000 lb can be carried into a 100 N. M. orbit and 4700 lb into a 24-hr orbit. In case that the equatorial orbit has to be reached from AMR by "doglegging", the payload in a 24-hr orbit would be substantially reduced.

d. Space Missions. The capabilities of the JUNO V space vehicle using high energy propellants in the third stage are summarized in Table 3 for typical space missions. Gross payloads (including guidance) are given for various escape missions, lunar missions, and some interplanetary missions. These figures are, of course, preliminary and require further refinement.

2. Second Generation Family

The second generation of the JUNO V family will offer considerable performance increases, hence will be more economical. This objective will be reached around 1970 with the vehicles having about the same reliability as the first generation. The vehicles will have a smaller number of stages in the cases where the nuclear second stage will be used. It is presently anticipated that chemical propellants will be most economical for transportation from the earth's surface to low and medium altitude orbits. Nuclear propulsion in the second stage, however, will be very advantageous and will be more economical for all space missions than chemical propellants. Nuclear propulsion will make it feasible to transport substantial payloads to the surface of the moon without requiring orbital refueling.

TYPICAL JUNO V PAYLOAD CAPABILITY FOR LONG-RANGE MISSIONS

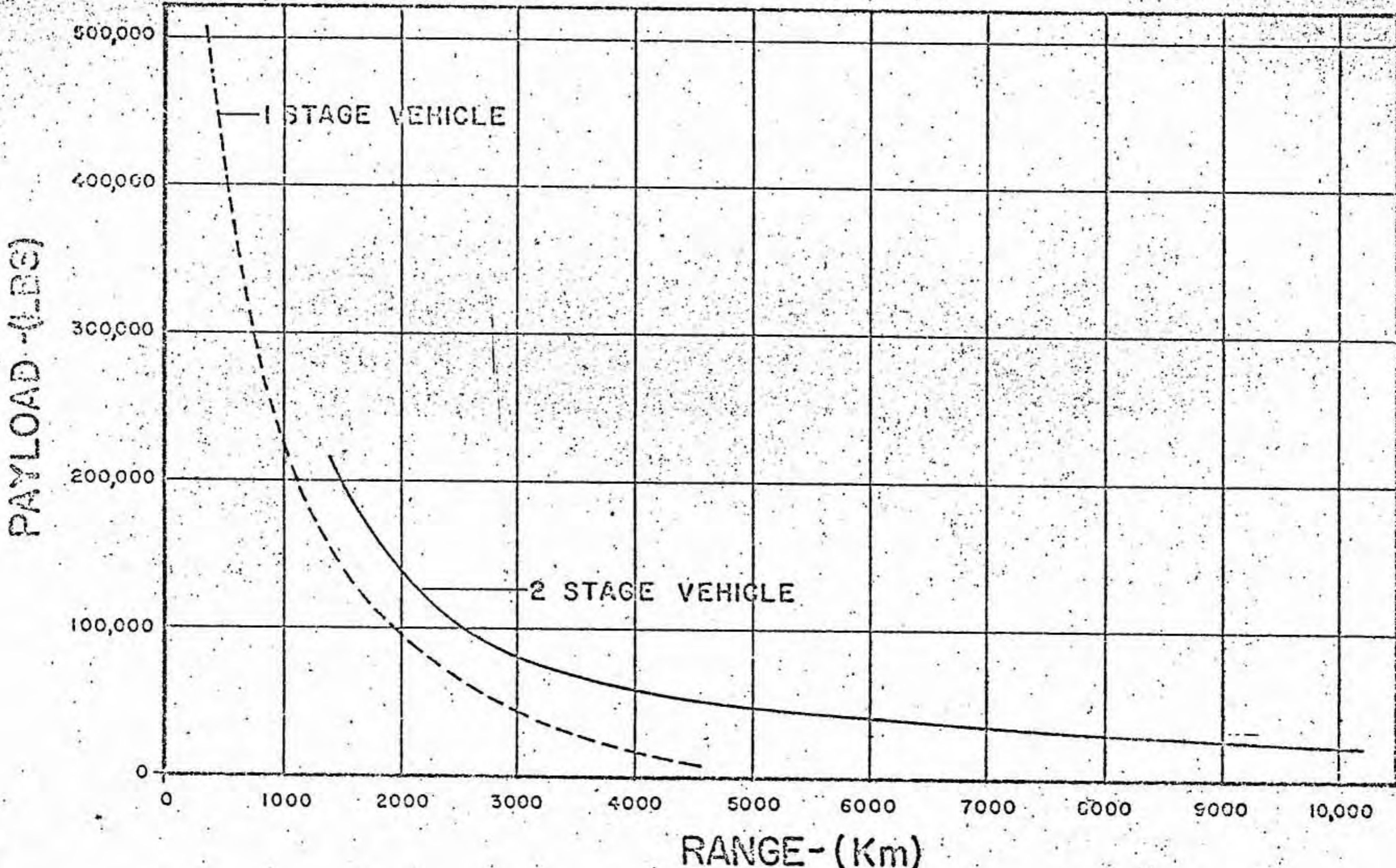

FIG.12

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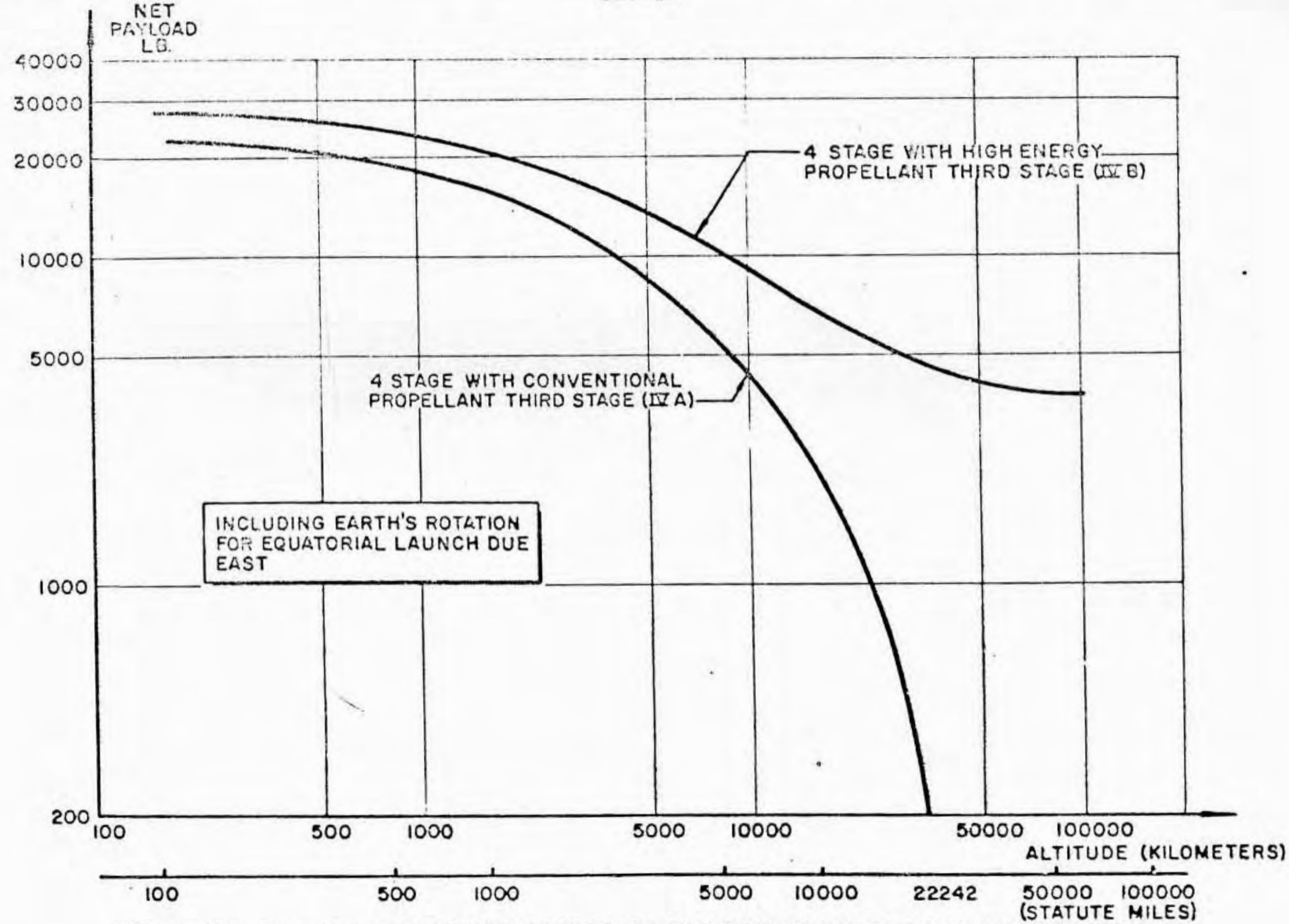

FIG. 13 TYPICAL JUNO V PAYLOAD CAPABILITY FOR ORBITAL MISSIONS (FIRST GENERATION)

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Table 3
PRELIMINARY ESTIMATES OF JUNO V PAYLOAD CAPABILITY
FOR SELECTED SPACE MISSIONS

Mission	Distance (km)	Flight Time (Days)	Total Mission Velocity Requirement (km/sec)	Gross Payload (lb)		
				3-Stage	4-Stage	5-Stage*
Space Probe	5×10^4 to 5×10^9	1 to 400	12.5 to 16.5	7500 to 600	7500 to 1500	
Lunar Probe	4×10^5	1.5 to 5	12.1	8700		
Lunar Circumnavigation	4×10^5	2 to 8	12.5	7500	7500	
Lunar Circumnavigation and Return	4×10^5	10 to 12	12.6	7200	7200	
Lunar Satellite	4×10^5	1.5 to 5 plus lifetime	12.8	6800	6700	
Lunar Soft Landing	4×10^5	1.5 to 5	15.5	1800	2100	
Lunar Soft Landing and Return	4×10^5	3 to 10 plus stay time	19		60	475
Mars Probe	4×10^8	260	12.7	7100	7000	
Venus Probe	2.6×10^8	146	12.7	7100	7000	
Mars Satellite	4×10^8	260 plus lifetime	15.5	1800	2200	
Venus Satellite	2.6×10^8	146 plus lifetime	16	1200	1700	

* Assuming solid propellant last stage for return.

It is expected that the second generation of the JUNO V vehicle will gradually provide payload capabilities for orbital missions up to 100 tons and carry payloads in the order of 10 tons to the moon and neighboring planets. Such payload capabilities will take care of all requirements expected from space activities to take place in the next two decades.

The objective in the overall long range JUNO V space transportation program is to provide reliable transportation in the most economical way for a variety of space missions. Individual stages and subsystems will always be interchangeable and will be introduced into the system as they become available after thorough testing. No chances will be taken especially in case of personnel transportation. The entire design and development approach as presented herein will insure that the vehicle will not be obsolete when it becomes operationally available. Thus, it is expected that the taxpayer gets the most return for his money and that the overall effort will stay within the limits of the national economy. The program anticipated herein is expected to stay within the one billion dollar per year limit.

V. OPERATIONAL CONSIDERATIONS (S)

A. Test Stand Operation

The test stand operations required to support the JUNO V development program are based on the following objectives:

1. To provide or confirm performance data of components, sub-system, and complete booster system to the groups responsible for design, fabrication, and inspection.

2. To evaluate, by functional or simulated test, the hardware generated by the design decisions as soon as possible after the component, sub-system, or system is fabricated.

3. To establish, by study and complementary test programs, operational techniques, test facilities, test and support equipment, instrumentation, and organizational capability to execute the test program.

4. To accumulate technical confidence in the basic vehicle through the media of captive testing, and to apply this experience in establishing the operational capability and application of the subject booster.

These objectives form the basis of a test program predicated on accomplishing two goals. The first of these is to provide test data to resolve the problems involved in clustering a number of individually proven power plants into a booster system and to qualify the cluster for flight tests. The second goal is to refine the operational performance and reliability of the clustered booster to the point of establishing complete confidence in, and maximum return from, the flight test program.

It will be necessary to provide test stand positions, instrumentation, systems control networks, test and handling equipment, ground equipment, operational techniques and checkout and operating procedures. The largest single item will be the modification to the east position of the present static test stand. The modified stand with the JUNO V booster stage installed is shown in Fig. 14.

Water flow evaluation tests on the propellant supply manifolds will be accomplished as soon as possible and before the entire tankage has been fabricated. These early tests will afford a preliminary evaluation of the manifold and help in providing information for the development of the instrumentation for the complex flow system. Water flow tests on the complete booster tankage and manifold system can be conducted before the engine hardware is available. This approach again will provide the dual advantage

JUNO V BOOSTER ON ABMA TEST STAND

FIG. 14

of preliminary system evaluation and instrumentation and operation technique verification.

Single engine evaluation tests will be performed as soon as the modified JUPITER (H-1) engine is available. Besides acceptance tests, evaluations of ignition and cut off sequences, pump suction characteristics, engine accessories, gimbaling characteristics, engine instrumentation program, system control networks, vibration characteristics, reliability of components, ground and support equipment, operational procedures, thrust control, and gain factors, will be determined.

Cold flow tests on the entire boosters with water and propellants, will be the initial program conducted on the test stand. The technique of using the turbopumps in a bobtail configuration will be applied; both water and actual propellants will be used. Although time may preclude, it may be feasible to provide a plenum device on the pump outlets to simulate chamber build-up. This would enable the entire cluster to perform under operational conditions without the hazards involved in ignition and mainstage tests.

Following the cold flow program, LOX-water ignition sequence tests will be made, first on individual engines, followed by a group of four and then eight. The next step will be ignition and mainstage firings, starting again with an individual engine and then testing the inboard four, the outboard four, and finally the entire booster.

The test program required to support the JUNO V development program is an accumulation of experience, techniques, facilities, instrumentation, and equipment proven to be the most reliable and productive during past and current activities. It is felt that the above outlined approach will provide the maximum return to the program.

B. Fabrication and Assembly

The problems in the fabrication of the containers for the large clustered booster are not unique in that present fabrication techniques and tooling will be utilized. These techniques and tooling have been tried and proven, thus allowing more time and effort to be applied to the new problems that must be solved in the segmented thrust frame, LOX and fuel manifolds, and such problems associated with the clustering of many power plants into one booster.

In the assembly of the booster there will be many new, challenging problems to be solved. It is proposed that the large booster be broken down into as many large subassemblies as possible so that several crews can be employed at the same time, thus allowing work to progress at a more

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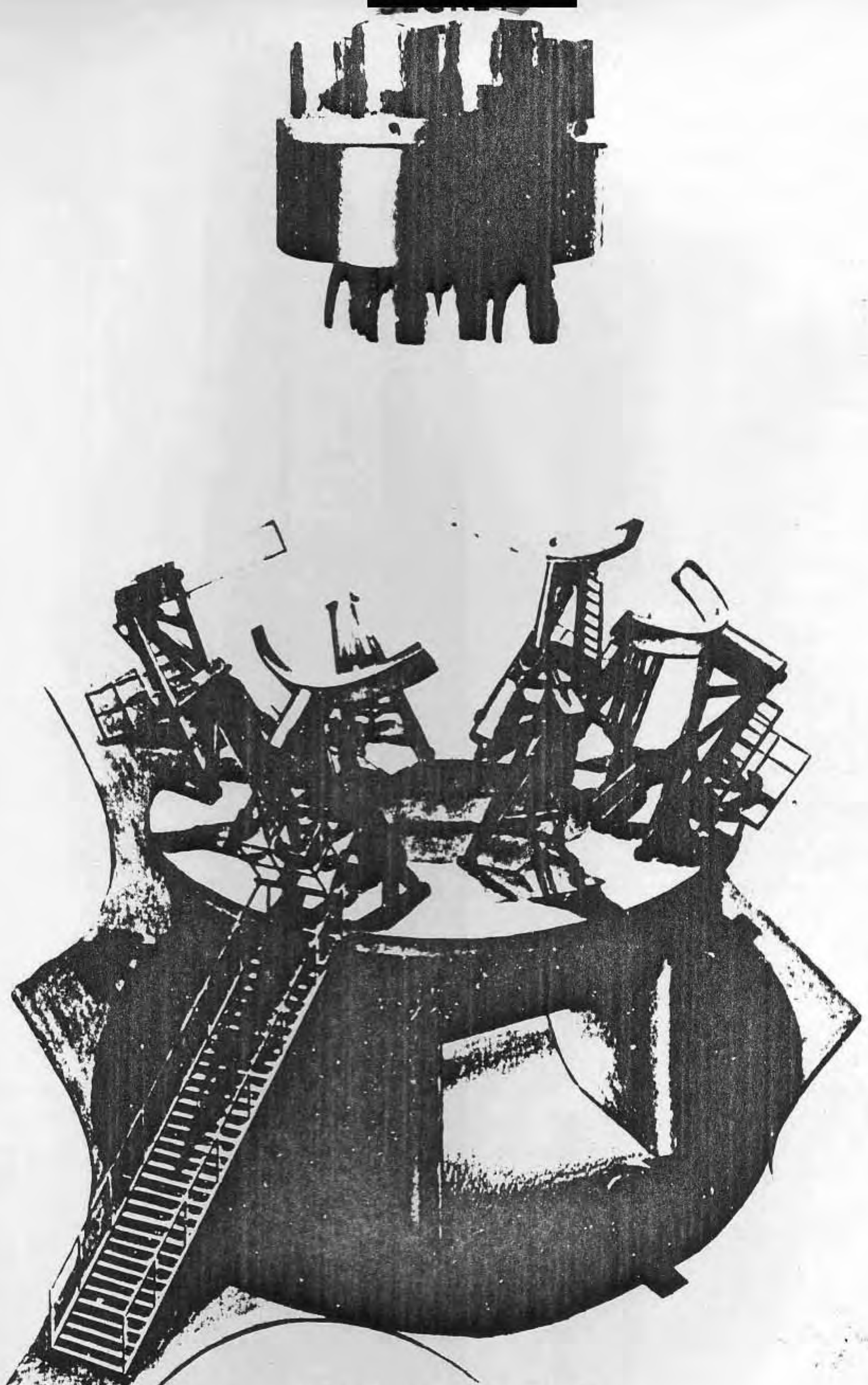

JUNO V VEHICLE
LAUNCHING

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FIG. 15

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follows:

(1) Maximum stability because of a self-freeing pneumatic release mechanism.

(2) Support structure, actuator controls, and accessories are in a naturally protected position.

(3) Maximum accessibility of engines and firing accessories is provided.

(4) Minimum damage possibility during firing. The flame deflector is relatively easy to exchange.

The ultimate transport scheme for the JUNO V booster will utilize the JUPITER and REDSTONE transporters of tactical design for land or air from the fabrication area to the launch site. Since no individual components will exceed the size and weight limitations, the design is consistent with the transporters presently being used.

As was mentioned in Section III H, air transportability is desirable since with booster recovery the need for shipping an entire booster to the launch site at one time is eliminated. Only components required to support the rejuvenation operation will be needed, and these can easily be air transported.

For the first few firings at AMR, it may be desirable to ship the booster by water to eliminate the need for reassembly at the launching site. This problem is presently being investigated to find its effect on vehicle reliability, cost, and schedule.

Hoisting and erecting of the completed second and third stages on the launcher can be accomplished with a 25-ton gantry crane. The heaviest anticipated load can be lifted by the hook on the main 100-ft boom. The height required for staging erection is facilitated by booming back the main boom until the 40-ft jib boom is over the working radius. Due to the size and height of the vehicle, it can be considered a stable column to which the servicing platform can be attached at the required working levels. The crane will be used in the assembly and dismantling of the service platforms surrounding the vehicle.

D. Launching Facilities

1. Atlantic Missile Range (AMR)

The site and launch facilities should be planned and built for the firing of the clustered first stage only, but should have inherent expansion capabilities to accommodate a full three- or even four-stage version. Because of the limited time available, development of this launch site should utilize existing plant facilities and utilities wherever possible; an AMR site was the only consideration for the first vehicles. The resulting firing azimuths will probably be between 45 and 100 deg east of true north.

The launch facilities will be designed for approximately a 2,000,000-lb reaction force, and will provide for preflight functional live engine tests up to 5-sec duration. The required beneficial occupancy date for the launching site is June 1960.

The TNT equivalent rule for ground safety (hazard considerations should be based on 50 per cent of total weight of liquid propellant as being equivalent in releasable energy to that amount of TNT) will be used in the design; and, applying this rule, the preselected radius of the ground safety zone is 5410 ft. This safety zone should be enforceable from X-30 minutes until firing during the initial firing and launch phase.

The launch pad should be reinforced concrete, 230 ft in diameter, with the following features: blast resistant area 160 ft in diameter; center mounting launch table and deflectors; surface level rail tracks for movement of service structure; subsurface instrumentation terminal room, fuel and LOX tanks; surface generator building, transformer vault, and camera pads; and necessary personnel accessways and cableways. The launch pad is to be provided with fire fighting deluge and flame coolant water supply and to be sloped to carry off fuel dilution water.

The blockhouse is to be of reinforced concrete design, positioned 1050 ft minimum distance from the launch pad with means for optical observation of operations on the launch pad. Also, it must be adequate for the missile test and launch console, instrumentation racks, remote-control fueling and high-pressure air panels, and operating personnel. Complete hazard protection of personnel is required and necessary. Air conditioning for equipment heat removal and for personnel must be provided with adequate flushing and ventilation means for buttoned-up operation in case of a missile failure. Estimated number of personnel stationed in blockhouse for operation is 130 persons including observers.

The LOX and fuel supply system will consist of one 100,000-gallon tank (LOX) and one 60,000-gallon tank (fuel) with pumps, valves, and accessories located behind revetments spaced to meet applicable safety distance requirement from launch pad. A water supply for fire fighting, pad flushing, and coolant will be required. The coolant supply may be utilized for flushing and fire fighting requirements.

Several sites at AMR were considered on the basis of cost, available facilities, and non-interference with other activities. The most promising solution to the problem is the construction of a new launching pad just north of VLF-20, a TITAN site on which construction has been stopped. The existing TITAN blockhouse could then be used thus keeping construction cost to a minimum (Fig. 16). It is estimated that this installation will cost approximately $4.2 million and will require a lead time of 22 months.

Location of the JUNO V launch pad next to VLF-20, an inactive site, will facilitate its construction since there will be no cross interference of firing operations caused by overlap of ground safety areas, etc. Also, this proposal would not require the removal of facilities presently in use or anticipated for future use.

Upon expansion of the JUNO V program to higher firing rates, the growth potential allowed in this proposal is ideal. Additional launch pads can be constructed to the north without difficulty.

2. Equatorial Launching Site

Because of the large payload capability of the JUNO V vehicle family, a great variety of missions can be accomplished. However, for many of these missions, an equatorial base is required. This requirement can be established from two standpoints - energy and timing.

Considering the energy needed to place a satellite into an equatorial orbit from AMR, a severe weight penalty is imposed due to the "dog-leg" maneuver. Both additional fuel and guidance equipment contribute to this penalty.

Timing becomes very important when establishing and maintaining a space station. Due to the earth's rotation and the perturbations affecting a non-equatorial, orbiting satellite, the chance for rendezvous would be sparse and at long intervals. In addition, the rendezvous problems multiply rapidly when the two vehicles are not in the same plane.

A detailed study of the necessity for an equatorial launching site and the best location for this site has been made by ABMA (Ref. 5). This report concludes that an equatorial orbit is necessary; that the only economical way to obtain this orbit is from an equatorial launching site; and that Christmas Island is the best location. The proposed equatorial launching site is shown in Fig. 17.

Since the exploration of space will be hampered without such a facility, steps should be taken as soon as possible to establish an equatorial launching site at Christmas Island.

RECOMMENDED JUNO V LAUNCHING SITE

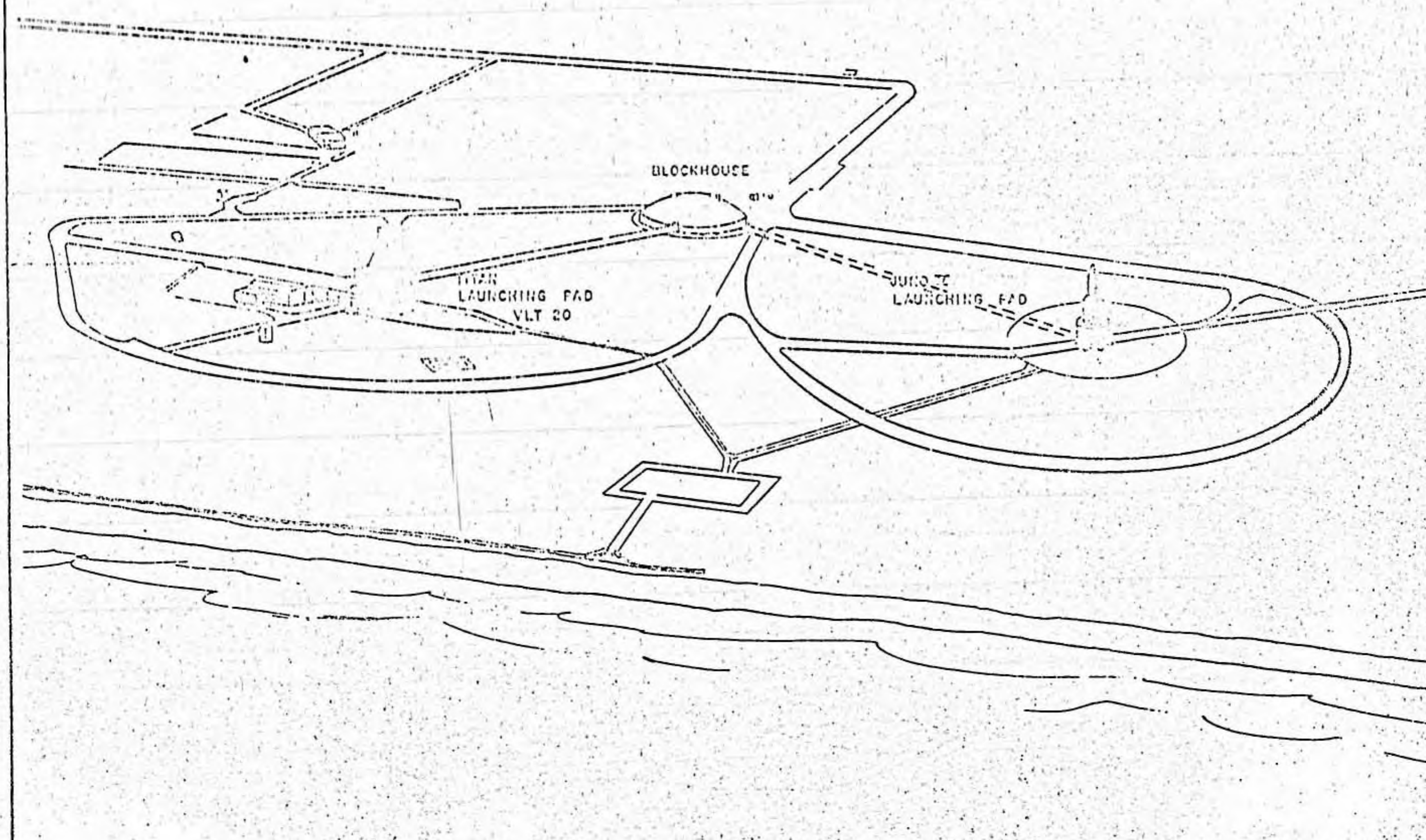

FIG. 16

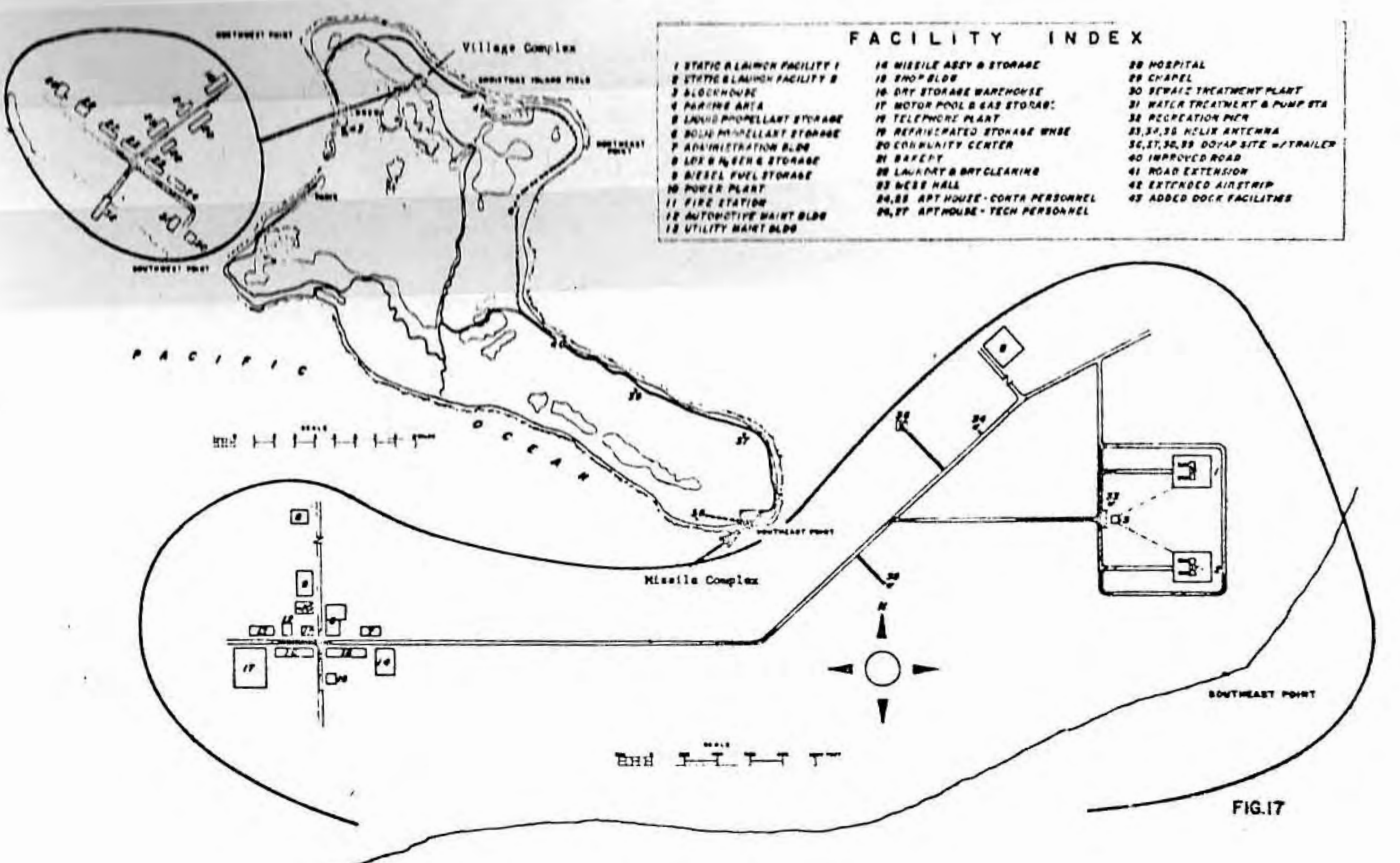

FIG.17

PROPOSED EQUATORIAL LAUNCHING SITE

3. Military Launching Site

Since the JUNO V family can satisfy many of the military requirements, it is proposed that a military launching base be established. This base should be located within the continental limits of the United States so that it can easily be defended. Missions such as the space defense system, global surveillance system, and DYNA-SOAR could be controlled from this central point. In addition, this base could be used for launching JUNO V multiple attack ICBM's and surface-to-surface transport vehicles as well as for training of military crews in all missions utilizing the JUNO V.

VI. PROGRAM CONSIDERATIONS (S)

A. General

In reviewing the design criteria for the overall JUNO V Space Vehicle Development Program, it becomes evident that reliability has been stressed throughout every phase. The reliability of a new development, such as the JUNO V, is dependent for the most part upon the available time for engineering and testing (schedule) and the availability of money to perform the required work (funding). There is an interrelationship between schedule, funding, and reliability which should be optimized. Such optimization requires that each of the variables be properly weighted. The JUNO V system study now underway has as one objective the optimization of the overall program with respect to schedule, cost, and reliability, as well as staging, performance, and other more technical criteria.

It should be understood, however, that if schedule and cost are considered to be independent variables and are established without properly evaluating their influence on reliability, the overall net return from the JUNO V development program may be drastically reduced.

B. Schedule

The schedules presented in this section are divided into three phases: (1) Captive Firing of the JUNO V Booster, (2) Approved Program for the First Four JUNO V Vehicles, and (3) Typical Expansion of the JUNO V Program.

1. Captive Firing of the JUNO V Booster

As shown in Fig. 18, the schedule for the captive firing phase of the booster program has been divided into four areas: (1) Design and Engineering, (2) Fabrication and Assembly, (3) Checkout and Test, and (4) Captive Firing. As indicated on the schedule, the first engine delivered will be utilized on a single engine test setup for engine familiarization and reliability tests. These tests will include both hot and cold, as well as short and long duration, runs during the five-month single engine test program.

The captive testing of the booster will be divided into three steps. In order to approach the complete vehicle configuration in steps, a test program of running the four inboard engines alone, then the four outboard engines alone, has been adapted before going to the firing of the entire eight engines.

The availability of components required to meet the schedule presented on the captive firing phase of the program has been verified with

SCHEDULE

JUNO V BOOSTER CAPTIVE FIRING SCHEDULE

		1958				1959												1960	
		S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
DESIGN AND ENGINEERING	PRELIMINARY SYSTEM STUDY																		
	MODIFY SINGLE ENGINE TANKAGE CONFIGURATION																		
	JUNO V BOOSTER																		
	JUNO V BOOSTER CONTROL SYSTEM																		
	TEST STAND MODIFICATION																		
	GROUND HANDLING & CHECKOUT EQUIPMENT																		
FABRICATION AND ASSEMBLY	ENGINE DELIVERY								1	1	1		2	2	2				
	MODIFY SINGLE ENGINE TANKAGE CONFIGURATION																		
	JUNO V BOOSTER																		
	JUNO V BOOSTER CONTROL SYSTEM																		
	TEST STAND MODIFICATION																		
	GROUND HANDLING & CHECKOUT EQUIPMENT																		
CHECKOUT	JUNO V BOOSTER CONTROL SYSTEM																		
	SINGLE ENGINE CONFIGURATION																		
	JUNO V BOOSTER												STAND AVAIL.						
	GROUND HANDLING & CHECKOUT EQUIPMENT																		
CAPTIVE FIRING	SINGLE ENGINE																		
	4 INBOARD ENGINES OF JUNO V BOOSTER																		
	4 OUTBOARD ENGINES OF JUNO V BOOSTER																		
	COMPLETE JUNO V BOOSTER																		

[redacted]

[redacted]

FIG. 18

the respective organizations involved and long lead-time items such as engines are presently covered contractually. Engineering designs and studies on the booster, test-stand modifications, and detailed planning in all areas of the captive firing demonstration are proceeding as indicated.

The manpower requirements to accomplish the captive firing of the booster by December 1959 is well within the capability of ABMA.

2. Approved JUNO V Program

The schedule shown in Fig. 19 outlines the approved program for the first four JUNO V vehicles. As indicated on the schedule, vehicles 1 and 2 will be fired as booster flights only, with dummy upper stages, and will be fitted with a parachute recovery system for the booster. Vehicles 2 and 3 will be flown as two-stage vehicles, and the booster will not be recovered due to the high re-entry velocity resulting from the performance required to provide orbital capability. The configuration of the vehicle will be as follows: JUNO V booster (8 x 150K), dummy tankage section in the second stage, and the second-stage propulsion system in the third-stage position. Since the second-stage propulsion system will be eventually used as a third stage it is proposed that all vehicles (1 through 4) be flown with the external configuration of a three-stage vehicle.

The schedule shown in Fig. 19 indicates that the same booster tankage used for the captive demonstration will be utilized for the flight test of vehicle No. 1. Due to funding limitations, this was felt to be the only possible way to provide four flights. It should be pointed out, however, that it would be very desirable to utilize the first set of tankage as a permanent captive test item in order to increase the overall booster reliability by expanding the captive test program. In addition, it is considered undesirable to utilize the first set of tankage for flight purposes since even the limited captive test program could cause fatigue failures in the structure.

If Booster No. 1 is used for the first flight-test vehicle, it will be fitted with a new set of engines, due to excess accumulated burning time on the original set of engines. The original set of engines will be reworked and phased back into the JUNO V engine test or flight program. The boosters for vehicles 2, 3, and 4 will involve the procurement and fabrication of three complete systems as flight test vehicles only. Due to time limitations in the static firing checkout, it is anticipated that little, if any, testing will be accomplished solely as engine development on the clustered configuration tankage.

The JUNO V flight test schedule is considered to be obtainable within the present manpower capabilities of ABMA; however, four items

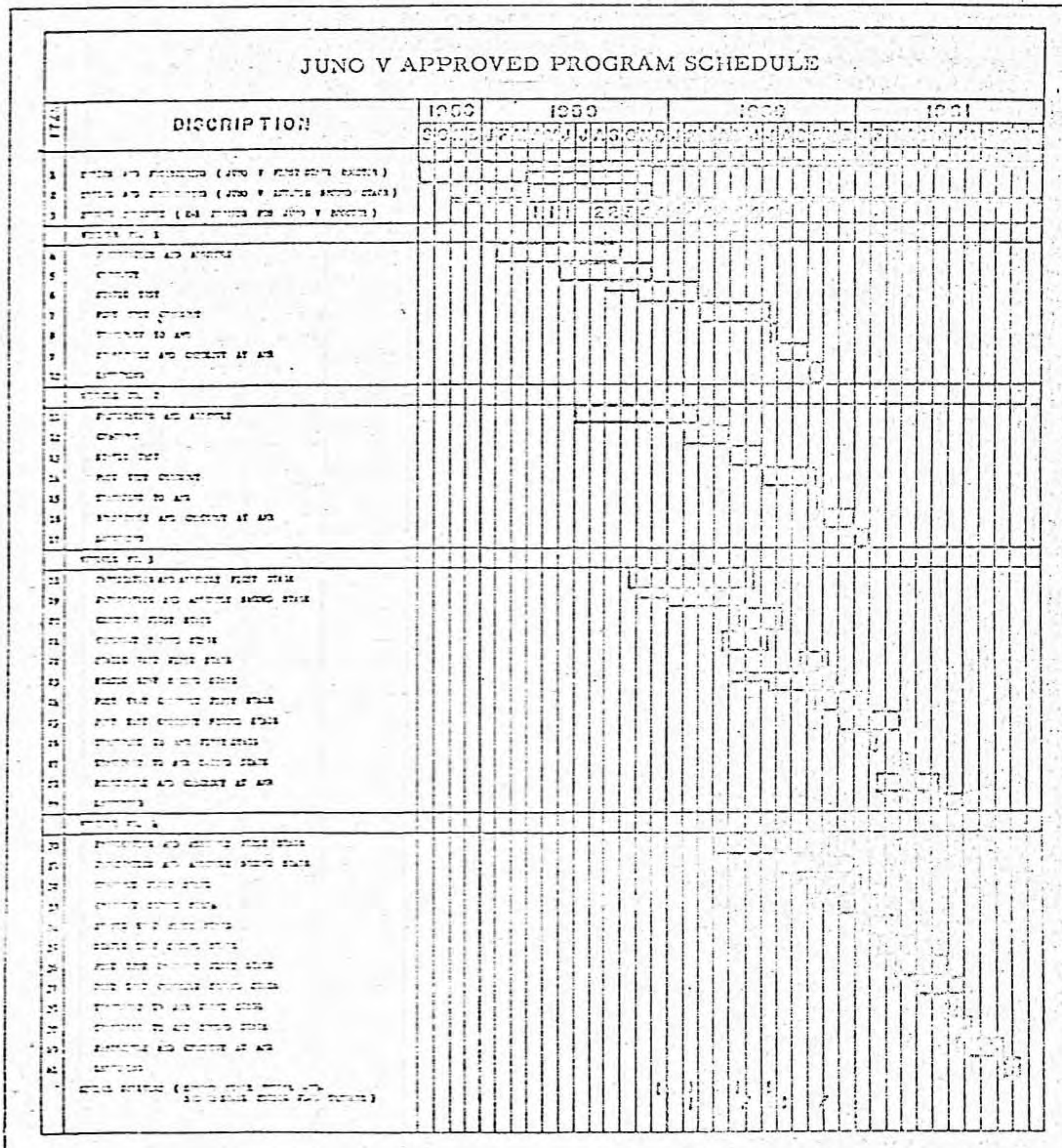

FIG. 19

are considered worthy of immediate attention:

1. The desirability of flying the first set of JUNO V booster tankage and/or the possibility of adding one additional set of tankage to increase the reliability of the early development phase of the program.

2. The possibility of reevaluating the schedule and funding established to date as a result of the JUNO V schedule, funding, and reliability system study as it progresses.

3. Engine delivery, Item 3 on Fig. 19, has been covered contractually for the first nine engines and long-lead items for the eight additional engines to be used for vehicle No. 1 flight test. Due to the long-lead time required for engine hardware, it will be necessary that immediate action be taken to insure delivery as indicated for the remainder of the engines. Present plans are to procure all engines, including the captive test engines, on an incremental funding basis to alleviate the requirement of complete funding at the time the engines are ordered.

4. Although no decision has been made as to which of several possible second stages will be used for vehicles 3 and 4, it is necessary that action be taken to provide funding to accomplish engineering, fabrication, and testing of the second-stage system. As can be seen on the schedule, engineering should begin the latter part of 1958 and be completed not later than November 1959. It will also be necessary to procure long lead-time items for the second stage early in 1959 to insure delivery of hardware to meet the proposed schedule. Item 42 on Fig. 19 indicates delivery dates of second-stage engines, or propulsion units, required to meet the proposed schedule.

3. Typical Expansion of the JUNO V Program

The extension of the JUNO V program should be made in three general areas: type of vehicles (2, 3, and 4 stage), missions, and number of flights. The first two areas have been discussed in detail in Chapter IV. The expansion of the JUNO V family in terms of the number of vehicles or flights is shown in Fig. 20.

The number of flights has been divided into four types: test vehicles for both the first and second generation of the JUNO V family, orbital vehicles, space mission vehicles, and vehicles which may be used for the establishment of a multipurpose space station. It should be understood that the missions assignment is for illustration purposes and is indicated only to show one logical division.

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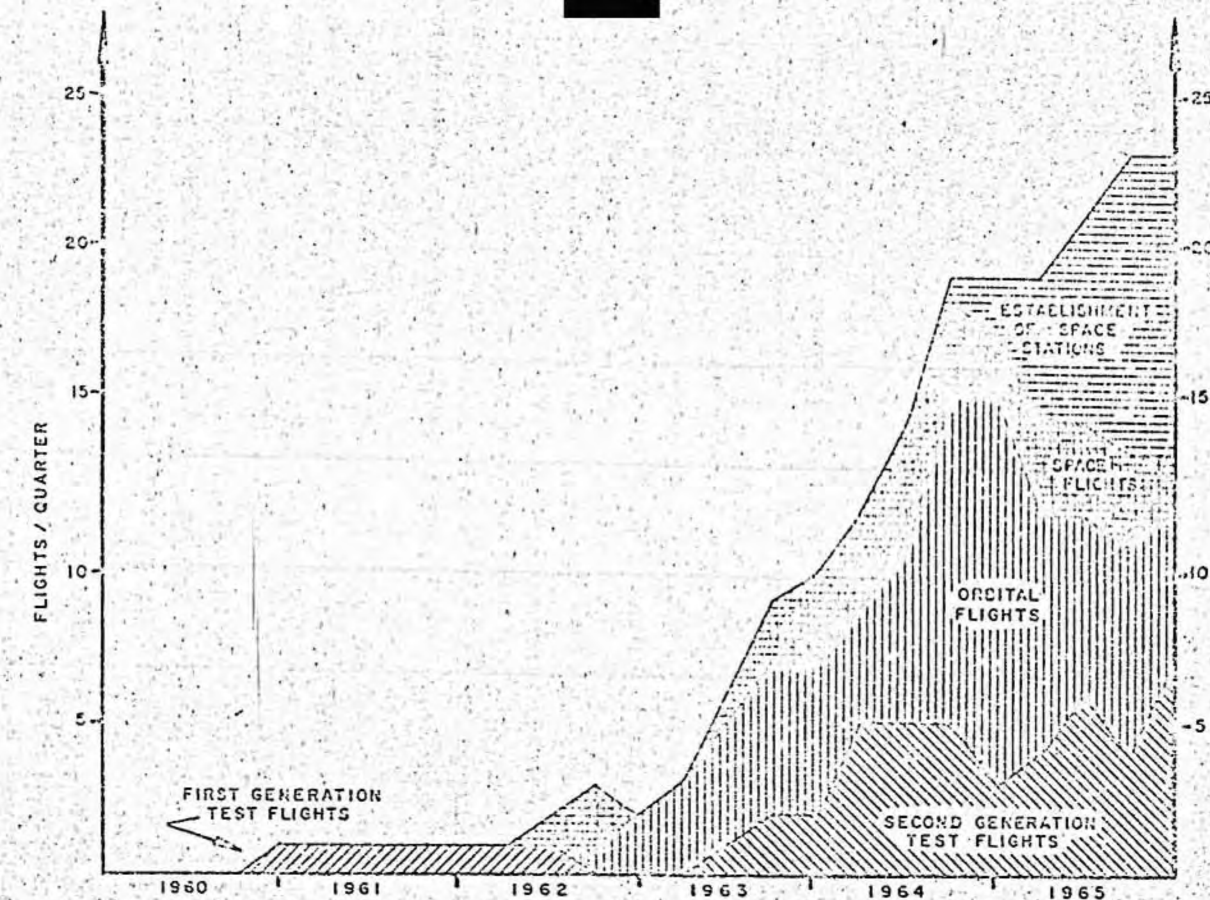

FIG. 20 TYPICAL EXPANSION OF JUNO V PROGRAM

[redacted]

The availability of each type of vehicle required to perform the missions indicated on Fig. 20 is considered to be well within the state-of-the-art. It is further considered that the development teams involved have the necessary development, testing, production, and firing capability.

The extension of the JUNO V program to include the number of vehicles shown and the type of missions indicated assumes the availability of an equatorial launching site in 1962. In order to exploit to the fullest extent the mission and payload capabilities of the JUNO V vehicle family an equatorial launching site is considered mandatory. As stated earlier, the expansion of the JUNO V program shown in Fig. 20 is only one possibility; the system study presently being accomplished will endeavor to optimize the overall JUNO V program and provide necessary information to determine the best possible extension with respect to reliability, economy, performance, and schedule.

C. Cost Trends

The purpose of this section is to indicate cost trends and criteria for the JUNO V space vehicle program rather than to present detailed facts and itemized funding breakdowns. In order, however, to present some cost information for planning purposes, preliminary estimates indicate that the average hardware cost for the first ten JUNO V vehicles described earlier would be \$6 million to \$9 million each. This does not include the necessary engineering, labor, testing, support, and facility cost. Long-range estimates of hardware costs for a complete JUNO V vehicle show that the unit cost could be less than \$5 million; and, if booster recovery is considered, the unit cost could possibly be reduced to less than \$4 million.

The JUNO V system study, mentioned earlier, will include an optimization investigation from the cost standpoint and will result in a detailed cost breakdown for the entire program. As indicated above, the hardware cost for the JUNO V vehicle is relatively large. To realize the maximum possible return from the hardware, it is imperative that the necessary engineering and testing be accomplished to insure the highest possible reliability. Since the value of the development program will be measured by successful flights, it becomes apparent that a division must be made as to what percentage of the available money should be devoted to the procurement of hardware and what percentage to increasing the reliability through more thorough engineering and testing. If the JUNO V vehicle family is going to provide space transportation for the next decade, as envisioned to date, it is considered mandatory that every effort be made to insure a comprehensive engineering and testing effort in the beginning rather than an all-out flight program of relatively unreliable vehicles.

There are several general areas in the JUNO V program that will have considerable effect on reducing the overall cost:

1. In the design and development of the JUNO V vehicle system, every effort has been made to utilize hardware already developed and components that have been proved reliable. This has not been done to the point of eliminating the possibility of utilizing advancements in the state of the art and hardware that will be developed and proved during the life span of the program. On the contrary, many components presently planned for the JUNO V vehicle are presently in the development stage and will be programmed into the system as soon as their reliability is demonstrated.

2. The smallest number of major components (stages) required to provide the capability and flexibility desired in the JUNO V family will be used. A total of six different stages will be used as building blocks for the first generation of vehicles. With these building blocks, all conceivable missions, for this class vehicle, can be accomplished: These missions range from surface-to-surface transportation to planetary soft landings.

3. A booster recovery system will be utilized in the JUNO V program making it possible to recover and reuse the most expensive component of the vehicle. Earlier studies (Ref. 3) indicate that approximately 50% of the booster cost can be saved by utilizing a booster recovery system.

D. Reliability

In considering the overall JUNO V space vehicle development program, reliability plays a major role. It has been stated earlier that the JUNO V vehicle is planned for manned space travel and thus requires a system reliability approaching that of present day aircraft. The possibility of obtaining this high degree is rather remote during the early development phases. However, a major expenditure of effort on increasing the vehicle reliability during the early design and testing phase is considered essential and would result in a greater overall net return from the program, even though a smaller amount of flight hardware is provided.

A comprehensive study on the reliability of each of the major components in the JUNO V vehicle family will constitute one phase of the JUNO V system study. Here again the vehicle reliability throughout the program will depend for the most part on the engineering effort expended. Preliminary estimates of the system reliability with respect to the number of vehicles launched are presented in Fig. 21. The reliability has been divided into three general areas:

1. Booster recovery reliability, which indicates the probability of recovering the booster, is shown to start at approximately 20%. It should

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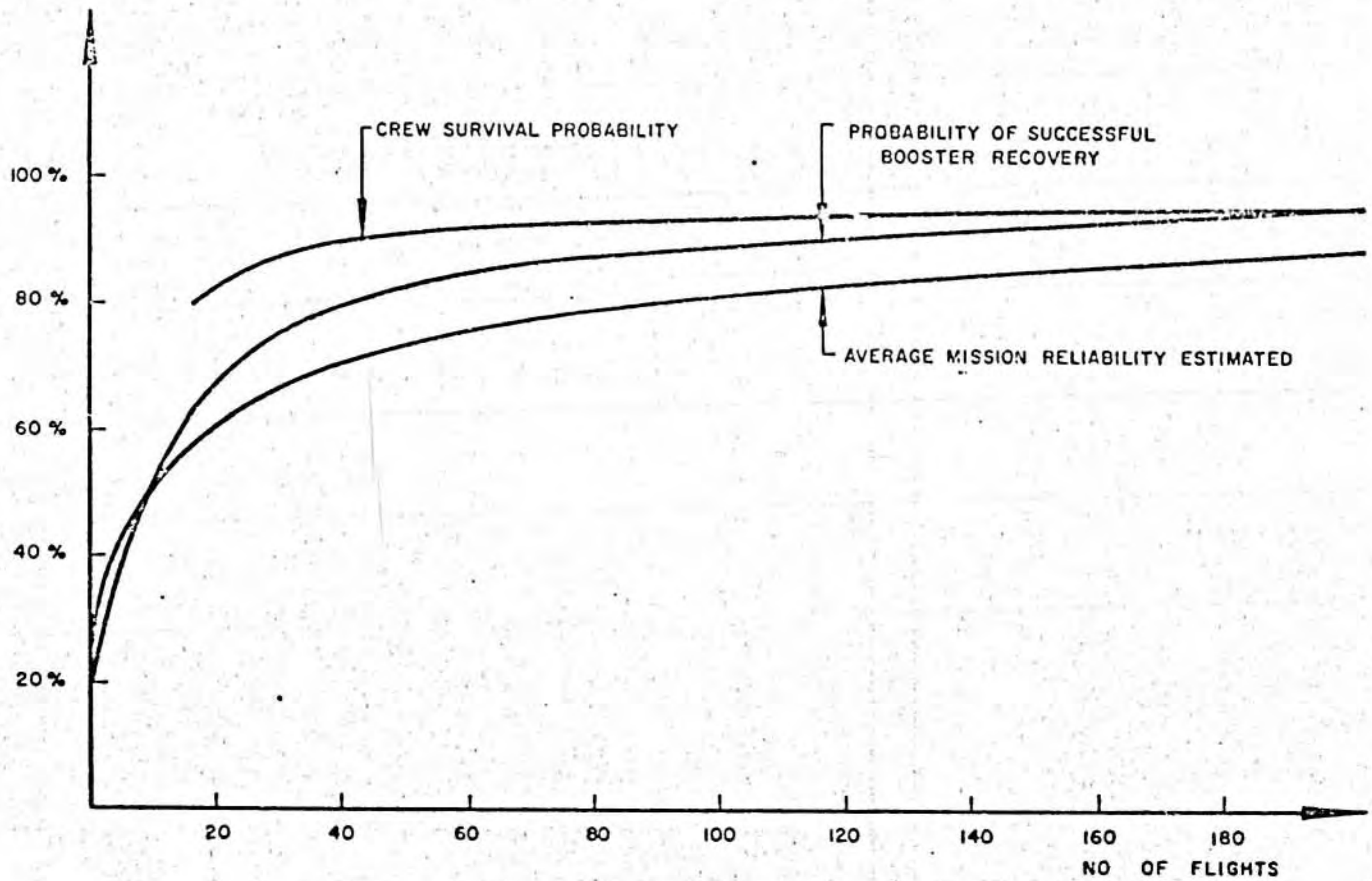

FIG. 21 JUNO V RELIABILITY

[redacted]

be understood, however, that the recovery system is expected to be approximately 80% reliable. The 20% is derived from the product of the vehicle reliability and the recovery reliability. As can be seen, the recovery reliability increases above the missile reliability. This is possible since the booster portion of the flight, including recovery, will become more reliable, although the upper stage reliability may still remain relatively low.

2. Vehicle reliability is shown to start at approximately 25% for vehicle No. 1 and increase to above 85%. It should be understood that the vehicle reliability shown is the product of the individual stage reliabilities which are difficult to predict at this early date.

3. Crew survival is based on the development of an escape system with an initial reliability of at least 80% and an increasing reliability to at least 95%. In determining the crew survival probability, the following equation should be used: crew survival = vehicle reliability + (1 - vehicle reliability) x crew escape system reliability.

The accuracy of the information presented in Fig. 21 is based on the effort or money devoted to the program to increase reliability. No fixed value can be placed on this effort at present; however, the curves are considered to be typical of the reliability that can be expected for a properly funded program.

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VII. CONCLUSIONS AND RECOMMENDATIONS (S)

A. Conclusions

As a result of additional study on the JUNO V space vehicle development program, the following conclusions can be drawn:

1. Schedule requirements, cost limitations, and engineering considerations favor the selection of an NAA engine cluster with a nominal thrust of 8 x 188K for the propulsion system combined with a parallel tankage arrangement. This design approach appears to be near optimum as seen today and makes maximum use of existing production and test facilities.

2. The presently anticipated 72 million dollar (four-vehicle) program is adequate to demonstrate the usefulness of a 1.5 million-lb thrust booster for the launching of large orbital payloads. It should not, however, be considered as an R&D program designed to fully exploit the potentialities of such a development, nor can it produce the required final reliability. There is a danger of schedule slippage early in the program if there is a delay in the allotment of funds, which are considered extremely scarce.

3. The anticipated firing schedule, which includes the launching of two 2-stage vehicles with orbital capabilities, requires a decision within 3 months on the second stage to be used. Funds up to $5.96 million of FY 1959 and 1960 money will be required, depending on the type of second stage selected.

4. If an uninterrupted continuation of the flight test program is desired after the present four-vehicle program, additional funding of a small amount will be required in FY 1960 and of a larger amount in FY 1961 for long lead-time items. The amount of funding required will result from the JUNO V systems study which is expected to be completed by March 1959.

5. The modification of the test tower and construction of the proposed interim launching site will have to be initiated without delay if the desired free flight firing schedule is to be met.

6. A booster recovery program, beginning with a simple parachute system, is considered mandatory to improve overall system reliability and reduce long-term total funding requirements for the JUNO V space vehicle.

7. The 3-stage JUNO V vehicle will provide the first U. S. capability for launching a satellite in the 20,000 to 30,000-lb class in 1962 and could provide the first manned lunar circumnavigation by 1964 if an all-out program could be initiated in 1959.

B. Recommendations

On the basis of the above conclusions the following recommendations are made:

1. Expand presently envisioned feasibility demonstration program covering four vehicles into an all-out R&D program not later than summer 1959 to keep abreast with, or possibly surpass, the RUSSIAN capabilities in this area. In this respect action should be taken in the near future to make additional funds available for the procurement of long lead-time items for the program, beyond the four approved vehicles, to insure an uninterrupted flight test program in 1962 and 1963.

[illegible] vehicle should be assigned a re-entry test payload for assisting development of payload and capsule recovery. Payload as well as second stage must be funded separately.

3. Initiate steps for construction of operational equatorial launching site to be available by summer 1962.

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Juno V
Satellite vehicles--Development

This report is the second in a series of reports on the Juno V Space Vehicle Development Program and indicates the present status of the overall program. The objective of the overall program is to provide a reliable, economical, and flexible carrier vehicle with relatively large payload capability for orbital and space missions at the earliest possible date. The report also gives the design philosophy as well as a description of the booster and possible vehicle configurations. In addition, a preliminary weight breakdown and preliminary performance characteristics are presented.