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A FEASIBLE APPROACH FOR
AN EARLY MANNED LUNAR LANDING (U)

PART I

SUMMARY REPORT OF AD HOC TASK GROUP STUDY (U)

JUNE 16, 1961

HEADQUARTERS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The effort of the Ad Hoc Task Group were supplemented very significantly by major contributions in each technical area from a large number of other staff members at the various NASA Centers and at NASA Headquarters. Although these added participants are too numerous to mention individually, their contributions are a vital part of the study results.

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INTRODUCTION*

PURPOSE AND STUDY APPROACH

This report, in two parts, presents a program development plan for attempting a first manned lunar landing in 1967. The two parts consist of a Summary Report and a Detailed Report representing the coordinated output of the ad hoc task group assigned to the study. The study was started in response to the request for such a study by the Associate Administrator in his memorandum of May 2, 1961 establishing the Ad Hoc Task Group.

The purpose of the study was to take a first cut at the tasks associated with the design, development and construction of the equipment and facilities as well as the development of the crews, and to show the time phasing of these tasks. Included are the space science, life science and advanced technology tasks whose data and results are needed for designing and developing the systems required in carrying out the mission.

The plan presented in the two reports does not presume to be a firm plan. Its basic purpose is, by choosing one feasible method, to size up the scope, schedule and cost of the job, discover the main problems, pacing items and major decisions and provide a threshold from which a firm and detailed project development plan can be jointly formulated by the various elements of NASA.

Parallel to this study a second NASA study has been carried out to examine other ways of accomplishing the manned lunar mission than the direct ascent method with chemical boosters. (A Survey of Various Vehicle Systems for the Manned Lunar Landing Mission, NASA, Lundin Committee Report, June 10, 1961.)

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*This introduction is included in both the Summary Report and the Detailed Report.

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The ultimate method chosen for the mission must still be decided and a firm plan defined. The 1967 target date for the first manned flight to the moon is a radical departure from the NASA Long Range Plan of January 1961. The latter was paced in accordance with a budget growth in space exploration aimed at performing the first flight in the post-1970 period whereas this report indicates how an early mission can be accomplished, and how much it will cost.

The study does not consider the nature of the activities on the lunar surface once the crew lands, nor how long they will stay there before returning to earth. It was believed that this was not of vital concern at this preliminary stage of the planning. However, it must certainly be given serious consideration in any further planning.

The study was directed by the headquarters staff but a number of field center personnel were brought in to participate as members of the task group. The many tasks involved in each phase of the program were defined and interrelated in time and sequence networks. These networks were machine processed by the Sequenced Milestone System, a variation of PERT, to discover slacks and overruns in program time. After several trials, compatible networks were derived which fitted the chosen starting date of July 1, 1961 and the mission target date of August 1967. A total of about 1800 discreet tasks were included in the ultimate composite networks of the complete program.

GROUND RULES AND GUIDELINES

The following ground rules and guidelines have governed the flexibility of the program development plan. Some were established by the Associate Administrator in his directive of May 2, 1961 initiating the study, others evolved in the early part of the study.

1. Manned lunar landing target date in 1967.

2. Direct ascent without rendezvous was the approach selected early in the study. However, rendezvous was considered to be an essential program in its own right. It was not included in the funding for the manned lunar landing program even though it may serve as a backup method for accomplishing the mission.

3. Intermediate major space missions such as manned circumlunar flight, unmanned soft lunar landing, etc., are desirable at the earliest possible date to aid in the development of the manned lunar landing system and to produce a series of accomplishments between now and 1967.

4. The use of Saturn C-2 for intermediate missions may be evaluated relative to an alternate launch vehicle having a higher thrust first stage and C-2 upper stage components.

5. Parallel development of liquid and solid propulsion leading to a Nova vehicle is to be assumed.

6. Nuclear powered launch vehicles shall not be considered in the first manned lunar landing mission. However, nuclear power generation source may be considered for the spacecraft if it appears feasible within the time limitations of the program schedule.

7. The flight test program is to be laid out with adequate launching to meet the needs of the program considering the reliabilities involved.

8. Alternate approaches should be provided in critical areas.

9. Booster recovery will be considered only secondarily, i.e., if it doesn't slow up the development program.

10. DOD help or facilities should be considered.

11. High reliability escape and abort capabilities will be stressed.

PROGRAM ELEMENTS

The tasks which comprise the total program are grouped into the following six major categories, each of which is programmed separately and treated separately in the detailed report.

1. The manned spacecraft, including its instrumentation, life support equipment, etc.

2. The launch vehicles (including alternative and/or backup approaches) and the spacecraft propulsion system for moon landing and take-off.

3. Ground support facilities, including those for hardware development, launch, tracking and data acquisition and advanced research.

4. Life sciences, including investigation of the effects of the space and lunar environment on man and his tolerance levels and the requirements for his protection and functioning.

5. Space science prerequisites, including probes and space vehicles for investigating the cislunar and moon surface environment.

6. Advanced technology programs to obtain knowledge needed in the design, development of vehicle systems and in the protection of man against reentry heating and radiation.

USE OF THE SEQUENCED MILESTONE SYSTEM

The NASA Sequenced Milestone System (SMS) was used as a planning aid to interrelate the program elements and to develop the master flight plan. The SMS is an adaptation of the well established Navy PERT system which has the following features:

a. A network of activities (tasks) and milestones placed in a dependent sequence.

b. The use of data processing equipment to determine critical paths (pacing items) and slack.

In the development of the master flight plan, the SMS was used to:

a. Assess relative merits of alternate approaches.

b. Identify key decision milestones and establish the latest allowable dates by when such decisions must be made.

c. Identify pacing items and test the effects of adding resources or considering parallel efforts.

d. Identify those tasks which must be started immediately.

e. Assist in determination of funding requirements and rate of funding build-up.

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PROGRAM FUNDING

Generally, the cost associated with a program is considered after the planning of the technical program and the time phasing have been completed. In this study, a different approach was used in that a range of budget figures was derived early in the effort and revised as the technical program and its schedule were refined. The entire budget is keyed to the Sequenced Milestone System (SMS), adjustments being made as the program schedule was changed for various elements in the SMS network. There have been three major reviews, each narrowing down the range of budget figures. The final "hard numbers" are presented in the summary report and elaborated on in the detailed report.

The budget presented is a "requirements budget" in that it is built from the bottom up. An arbitrary ceiling was not imposed on any of the groups working on the program. The budget has been composed from the bits and pieces comprising the time-phased technical tasks and constrained by the assumed rates with which NASA and industry can be geared up to do the job in the early part of the program. Hundreds of man-hours have been spent at NASA Headquarters and the field centers and data in great detail has been developed, reviewed and coordinated. As a result, a high degree of confidence can be placed in the FY 1962 and 1963 figures. The projected costs for FY 1964 and beyond are considered an order of magnitude better than those ordinarily developed for a comparable span of budgetary increments.

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PROGRAM PLAN

OBJECTIVES

The basic objectives of the manned lunar landing study are shown in figure 1. These objectives are to show the feasibility of the mission, the magnitude and scope of the effort, the various programs and development necessary to accomplish the mission, the time phasing and inter-relationships of the various elements of the program and supporting activities, the areas where effort must be initiated or accelerated to generate the required technological data and, finally, the major management decisions and actions necessary to implement the program. In addition to these objectives, the total program cost will be indicated with particular emphasis on FY 1962 and 1963 budget requirements.

The study has in it a degree of conservatism with regard to the feasibility of accomplishing the mission and the size of the program required. At the same time, however, the program has a degree of optimism in it with regard to the time required to complete the mission, since time for contingencies for unknown major technical difficulties has not been included. Thus should any major technical problems or set-backs occur during the course of the program, some slippage will obviously result in accomplishment of the mission.

WHAT THE STUDY SHOWS

- FEASIBILITY OF THE MISSION
- GENERAL MAGNITUDE, SCOPE AND COST OF MISSION
- PROGRAMS AND DEVELOPMENTS NECESSARY TO ACCOMPLISH MISSION
- TIME PHASING OF THE MISSION AND ITS SUPPORTING COMPONENTS
- AREAS WHERE EFFORT MUST BE INITIATED OR ACCELERATED TO GENERATE NEW TECHNOLOGICAL DATA
- MAJOR MANAGEMENT DECISIONS AND ACTIONS NECESSARY TO IMPLEMENT MISSION

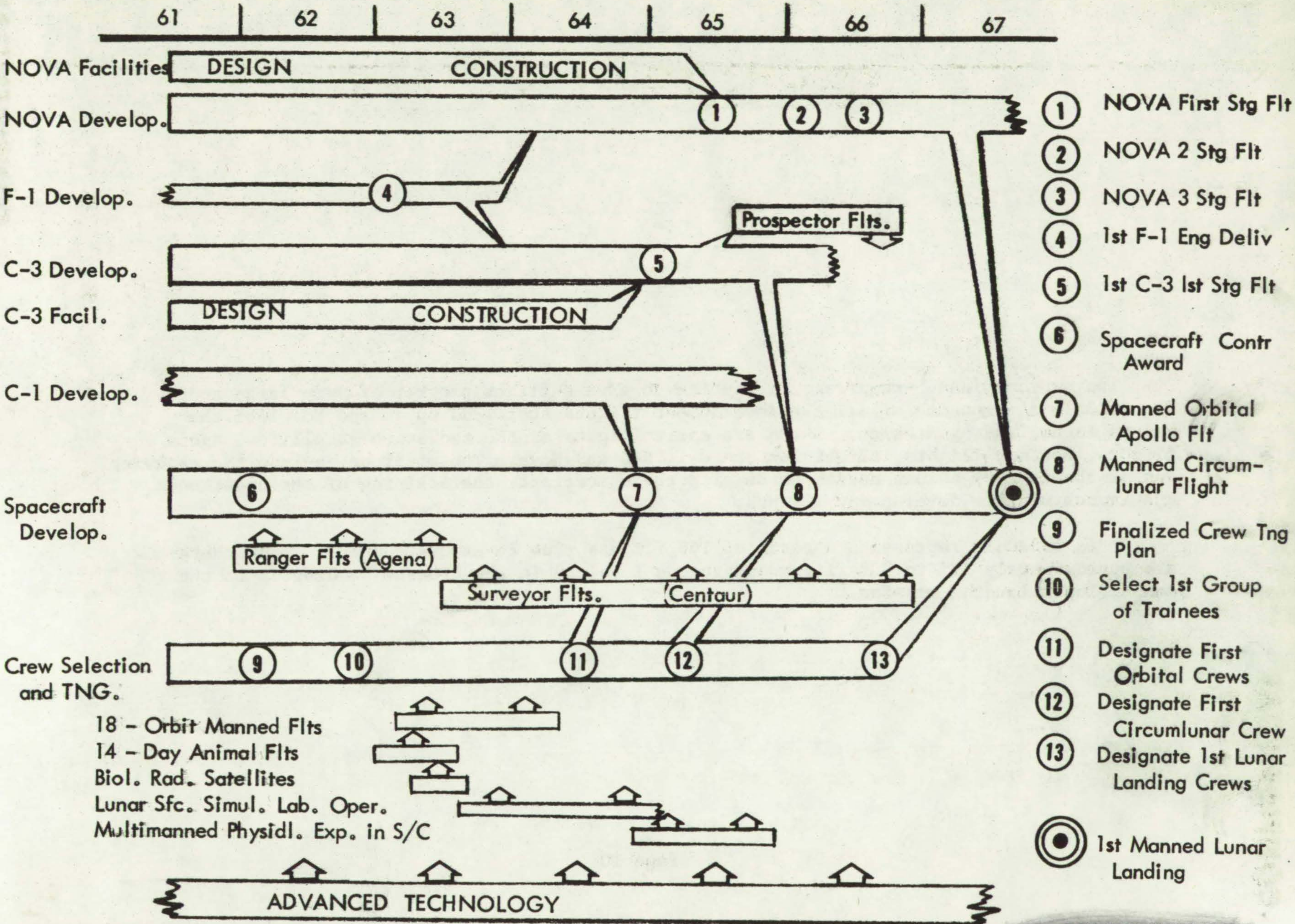
PROGRAM SCOPE

To give an impression of the over-all scope of the program, the inter-relationship of the major events are shown in figure 2. The principal portions of the program are the development of the Nova, the C-3, the spacecraft and the flight crew. Feeding into the Nova program are its development and launch facilities as well as the development of the F-1 engine. The F-1 engine is also important to the C-3 program. Similarly, the required facilities feed in to the C-3 development. The C-1 launch vehicle is shown being used in the spacecraft development with the manned orbital flight shown late in 1964. In early 1966, the C-3 is used in the spacecraft development program to launch the Apollo on its manned circumlunar flight.

Down below is shown the Ranger flights on Agena, the Surveyor flights on Centaur, both feeding information to the spacecraft design and development concerning lunar characteristics. Shown at the bottom of the chart are the 18 orbit manned flights, the animal flights, the various biological radiation flights, the lunar landing simulations, the multi-manned physiological experiments in the spacecraft and, finally, the advanced technology area, all of which continually feed information in to the development of the spacecraft and/or launch vehicles. The crew training program shows the crew being pahsed in to the initial flights of the spacecraft.

Ultimately, the spacecraft Nova and the flight crew are all ready to accomplish the first manned lunar landing in the third quarter of 1967.

INTERRELATIONSHIP OF MAJOR EVENTS



The various launch requirements combine to give a flight program of very large scope. Figure 3 is a composite of all the development flights that lead up to and complete the manned lunar landing mission. Shown are early flights of the radiation satellites, Agena flights, Centaur flights, flights on the C-1, C-3 and Nova. The missions include the carrying out of the investigations needed to develop the spacecraft, the training of the crews and the launch vehicle development flights.

This schedule represents a total of 167 flights plus 26 aircraft drops. Thus there are approximately 175 to 200 flight operations involved in the program leading up to the manned lunar landing mission.

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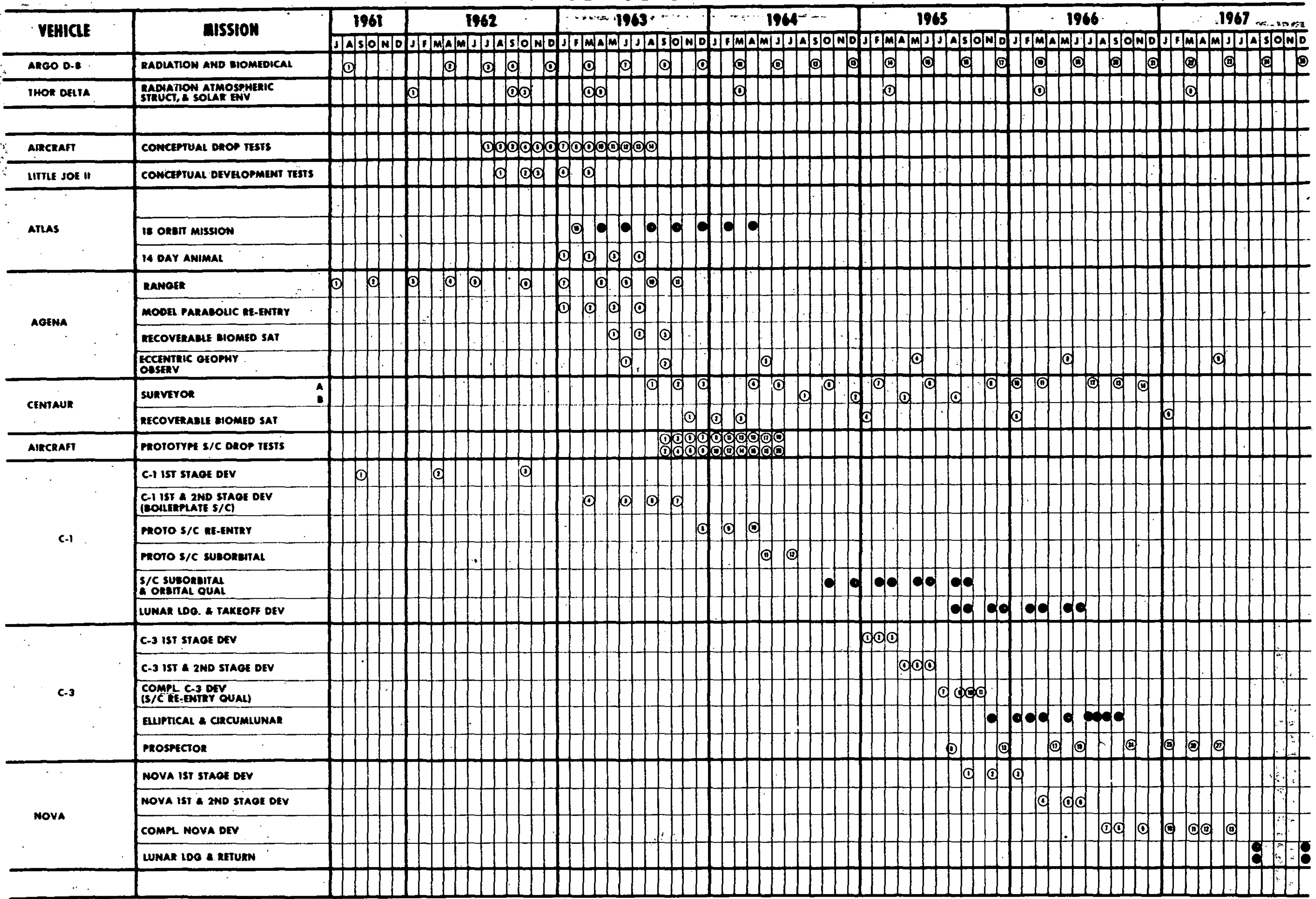
MASTER FLIGHT PLAN

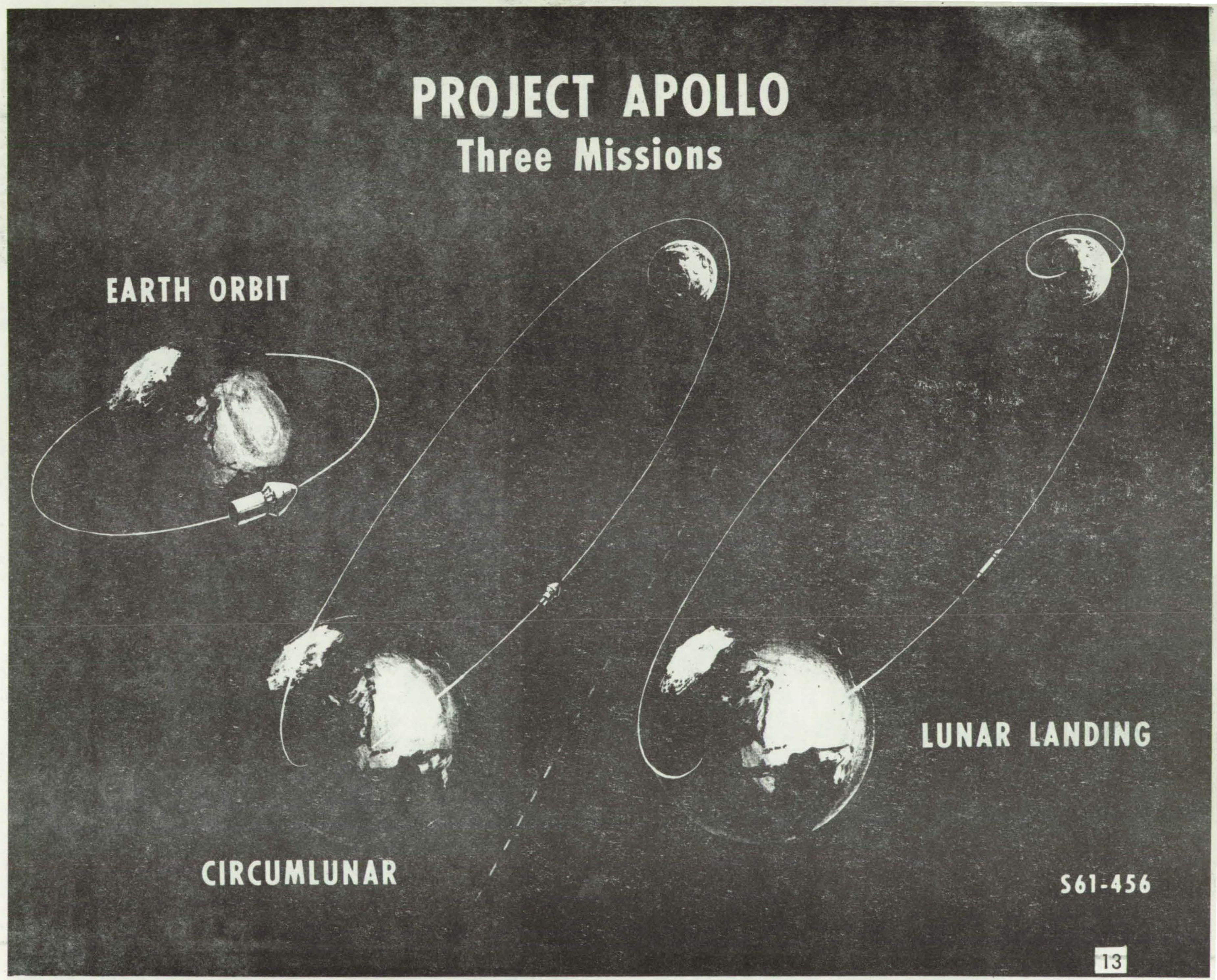
JUNE 9, 1961



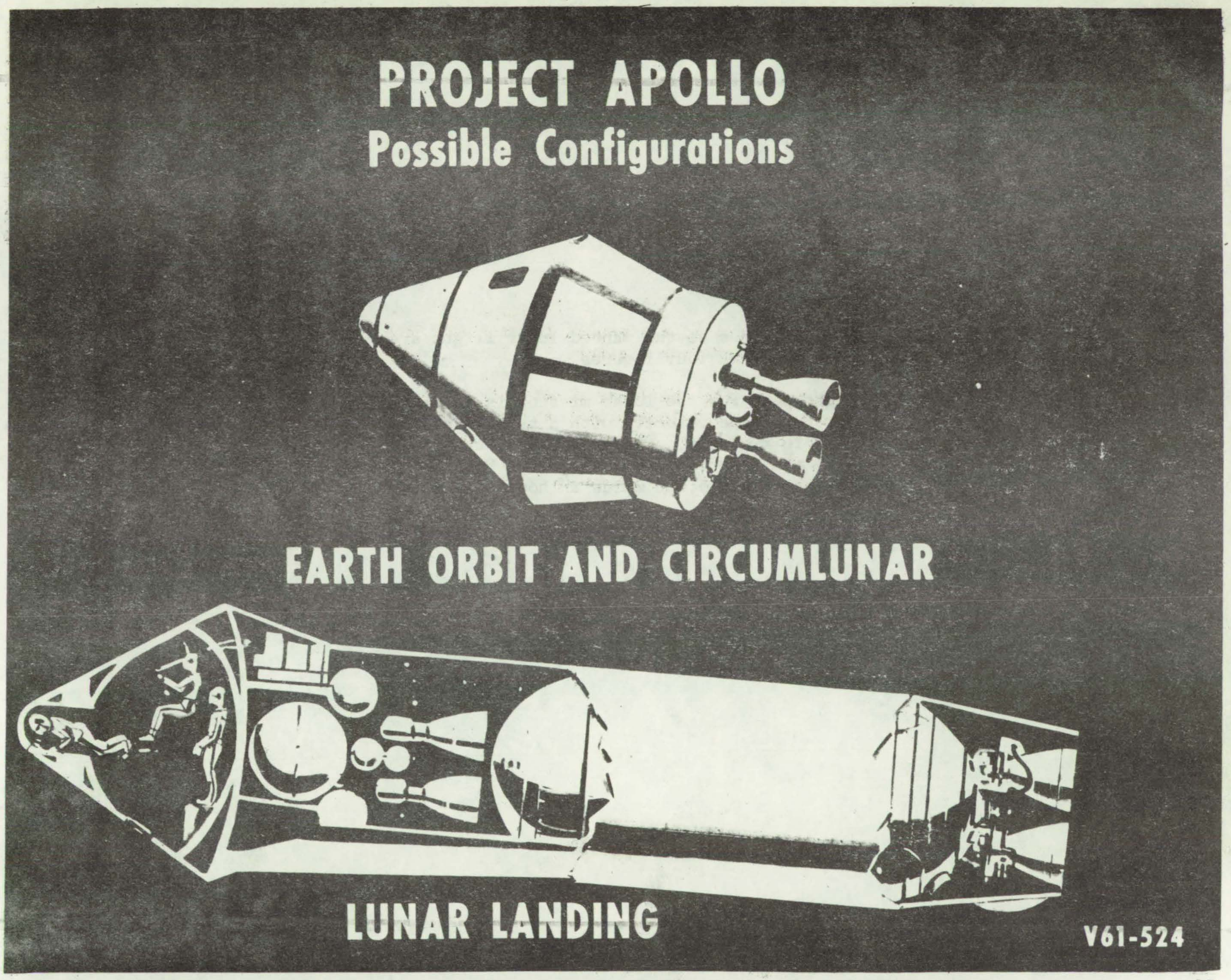
○ UNMANNED FLIGHTS ● MANNED FLIGHTS CONFIDENTIAL

MISSION APPROACH

There are two major types of flight missions which precede and lead up to the ultimate manned lunar landing mission as figure 4 illustrates. First are the manned earth orbital flights with three men in the capsule. These will be followed by elliptical and circumlunar flights. Both types must be performed successfully to assure system reliability and the compatibility of the spacecraft design and the crew.

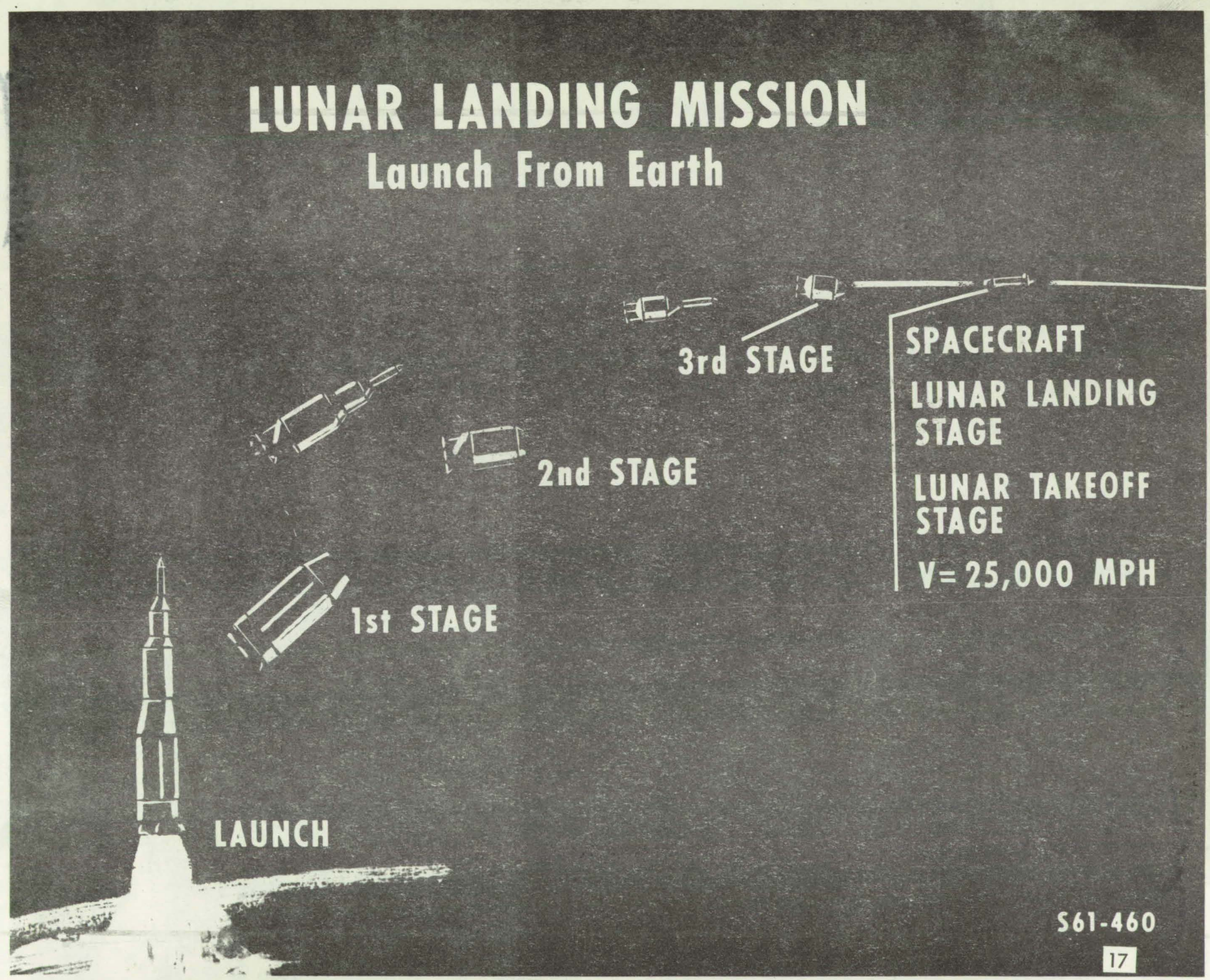

PROJECT APOLLO
Three Missions
EARTH ORBIT
CIRCUMLUNAR
LUNAR LANDING
S61-456

Spacecraft configurations that are proposed to accomplish earth orbital and circumlunar flights as well as lunar landing and takeoff are illustrated in figure 5. These configurations show one possible arrangement, with the three-manned capsule in the forward portion. The aft-portion of the earth orbit and circumlunar system is the lunar take-off stage. For all earth orbital missions it will be used as the abort system to provide more experience with it to insure high reliability. This stage would probably use storable propellants. The lunar landing stage is a hydrogen oxygen stage probably using two LR-115 engines.


PROJECT APOLLO
Possible Configurations
EARTH ORBIT AND CIRCUMLUNAR
LUNAR LANDING
V61-524

The various phases of the manned lunar flight are illustrated in the next four figures.

The flight plan for the lunar mission is to use a direct ascent to escape velocity with a three-stage boost as illustrated in figure 6. The spacecraft, the lunar landing stage, the lunar take-off stage are boosted to the escape velocity of 25,000 miles an hour.


LUNAR LANDING MISSION
Launch From Earth
3rd STAGE
SPACECRAFT
LUNAR LANDING STAGE
LUNAR TAKEOFF STAGE
V= 25,000 MPH
2nd STAGE
1st STAGE
LAUNCH
S61-460
17

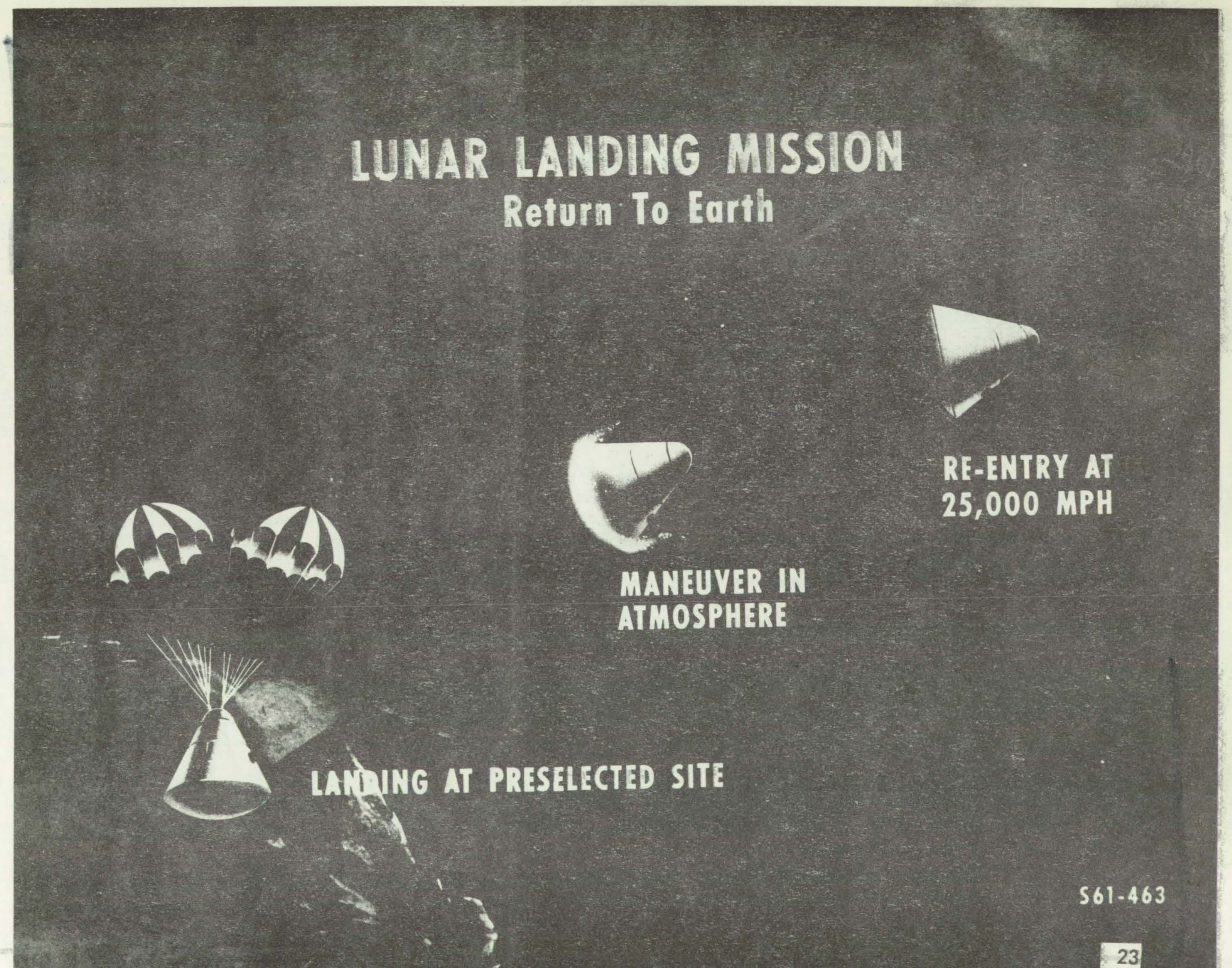
One method of landing on the moon is shown in figure 7. In this case the lunar landing would be accomplished by backing the vehicle in and landing it in the conventional aircraft attitude. Another approach would be to land the vehicle vertically on its tail.


LUNAR LANDING
S61-46T

Lunar take-off is illustrated in figure 8. The lunar landing stage is left behind as the lunar take-off stage launches the manned capsule on its return trip to earth.


LUNAR TAKEOFF

Finally, after separating from the lunar take-off stage, the capsule reenters the earth's atmosphere at 25,000 miles an hour, the heat shield preventing the capsule from burning up. Recovery is with parachutes in much the same way as the Mercury. Figure 9 illustrates the reentry and landing phase of the mission.


LUNAR LANDING MISSION
Return To Earth
RE-ENTRY AT
25,000 MPH
MANEUVER IN
ATMOSPHERE
LANDING AT PRESELECTED SITE
S61-463

SPACECRAFT REQUIREMENTS

Who?

The basic spacecraft components and their weights are shown in figure 10. Two columns of spacecraft weights are shown. The one headed "Studies" represents a conservative composite of the results obtained from the three Apollo Study Contractors. The "Allowed" column represents the spacecraft weights the study group feels are more realistic for a feasible program. In the Contractors' studies, the structure and heat protection, the power supply, the crew environment and control system, guidance and control, communications and instrumentation, added up to a total spacecraft weight of about 9,700 pounds. No radiation shielding as such was included.

In reviewing the weights, it was believed that those chosen for the supporting systems, power supply, the crew systems, guidance and communications were reasonable and realistic. However, it was believed that about 1,500 pounds should be added for structure and heat protection. About half of this is contingency in structural weight, which always has a tendency to grow in a system like this. The other half is contingency for the heat shield This is an area in which more information is needed in order to know exactly what the heat shield requirements are. To insure a feasible system, it was believed that the addition of this 1,500 pounds was quite necessary.

For radiation shielding, 1,250 pounds has been added. This shielding might well be principally water. In the orginal studies, the contractors relied on the structure and equipment in the spacecraft to protect the crew from solar radiation. Based on what we know today, we feel that this additional shielding might well protect the crew to the extent that solar radiation exposure would not exceed 25 rem except during giant solar flares. These giant solar flares occur on the order of once every one to four years. About seven giant flares have occurred in the last ten years.

With these added contingencies the total spacecraft weight amounts to 12,500 pounds.

[redacted]

SPACECRAFT WEIGHTS

	STUDIES	ALLOWED
STRUCTURE & HEAT PROTECTION	5100	6600
POWER SUPPLY	1000	1000
CREW & ENV. CONTROL SYSTEM	1700	1700
GUIDANCE AND CONTROL	1400	1400
COMMUNICATIONS AND INSTRUMENTATION	550	550
RADIATION SHIELDING	—	1250
	9700 LBS	12,500 LBS

[redacted]

Over-all system weights for two missions -- the circumlunar mission and the lunar landing mission are shown in figure 11. Of course, in each case, the spacecraft weight is the 12,500 pounds shown in figure 10. There are two propulsion systems, one for the lunar return, and one for abort. For the circumlunar case, the lunar return system will be used for abort propulsion. The size of the tanks and some of the structure will be reduced so that the empty weight will be about 2,500 pounds. With 10,000 pounds of storable propellants, a total of 25,000 pounds must be placed in an escape trajectory to accomplish the circumlunar mission.

For the lunar landing mission, it is necessary that the lunar return stage have a structure of about 5,000 pounds with 37,000 pounds of storable propellants. The lunar landing system requires 14,000 pounds of structure (including the landing gear) and 81,000 pounds of hydrogen and oxygen propellant. Thus, a total of 150,000 pounds must be put into an escape trajectory to accomplish the manned lunar landing mission. This payload establishes the launch vehicle capability requirement for the Nova type vehicle.

MISSION WEIGHTS

	CIRCUMLUNAR	LUNAR LANDING
SPACECRAFT	12,500 LBS	12,500 LBS
LUNAR RETURN AND ABORT PROPULSION SYSTEM		
EMPTY	2,500	5,000
PROPELLANTS (STOREABLE)	10,000	37,000
LUNAR LANDING PROPULSION SYSTEM		
EMPTY	—	14,000
PROPELLANTS (H_2-O_2)	—	81,500
TOTAL	25,000 LBS	150,000 LBS

The spacecraft development schedule is shown in figure 12. The three principal components are: the manned capsule or reentry vehicle, the lunar return and abort system and the lunar landing propulsion system. The solid vertical bars indicate the dates on which the contracts must be let in order to meet the 1967 flight date.

The reentry vehicle contract is scheduled to be let January 1, 1962. During the course of vehicle development, information regarding weightlessness will be derived from the 14-day animal flights. The Agena reentry flights will give information on heat shield design. Data from the biomedical and radiation satellites will check initial assumptions on radiation shielding. The spacecraft development will take about 2½ years at which time it will be ready for launching on the Saturn C-1.

Simultaneously, a contract should be let about mid-1962 to develop the lunar return and abort system. It will require about two years of development and will also phase into the Saturn C-1 orbital flights that begin near the end of 1964.

In the latter part of 1962, the contract for the lunar landing propulsion system development should be let. During the development of this system, data will be fed in to the spacecraft design from the Surveyor lunar landing missions on the characteristics of the lunar surface to guide in design of the landing gear system. The Saturn C-1 orbital flights will, in the latter part of 1965 or early 1966, phase in to the elliptical or circumlunar flights on the Saturn C-3 when it becomes available early in 1966. Likewise, as soon as the lunar landing propulsion system is developed, ballistic flights on the Saturn C-1 will be made to simulate the lunar landing. Early in 1967 the spacecraft system is expected to be ready to phase in to the Nova for the manned lunar landing mission.

It should be pointed out that very little study has gone into precisely what operations would take place on the moon or how they would be executed. Thus considerable thought and effort must be devoted to the areas of lunar landing systems, lunar surface exploration ~~be~~ BY the crew and techniques for checkout and launch of the return vehicle.

It should be notted that the spacecraft will be ready in 1967, whereas the lunar landing mission would, in all probability, not take place until about the third quarter of 1967. What this means is that the spacecraft does not appear to be the pacing item. Nevertheless, it is extremely important to start the various spacecraft components as early as possible to provide some time for contingencies. Furthermore, should the Nova vehicle development move along at a more promising rate than anticipated, it might be possible to use an earlier Nova for the manned lunar mission.

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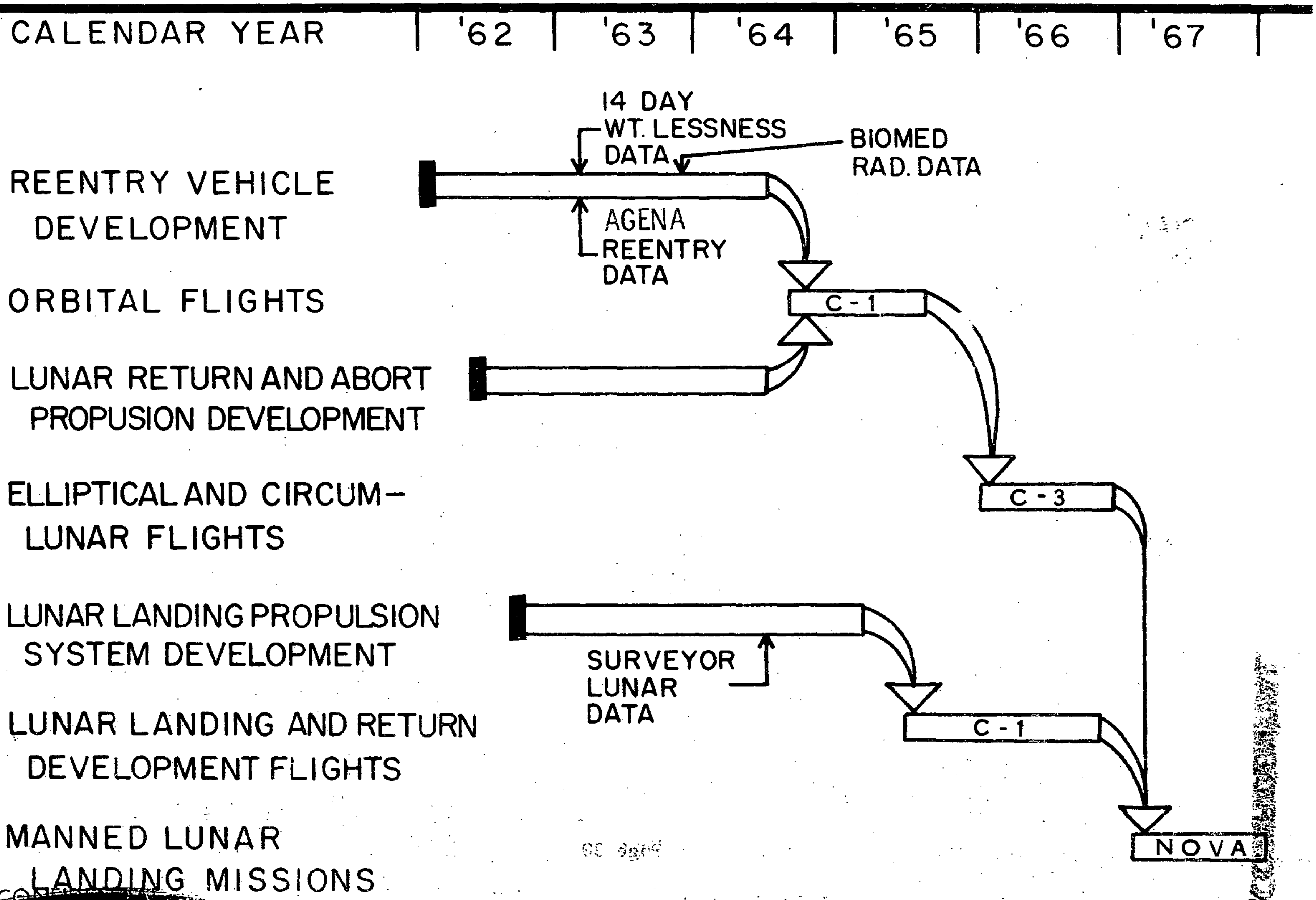
SPACECRAFT PHASING



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Closely tied in with the spacecraft development are the flight crews which are required on on the C-1 orbital, C-3 circumlunar and the Nova lunar landing flights.

Figure 13 shows the evolution of the flight crew selection, training and flight experience. It indicates that beginning immediately, there is a need to look at the crew requirements, what their composition will be, how they will be selected and, in general, what the training plan is going to look like. By the first quarter of 1962, these studies should be completed and the training plan defined so that screening of the flight crew candidates can begin.

Flight crew candidates should be ready on January 1, 1963 for a year and a half long training program. Upon completion of this program in mid-1964, they would then begin to phase in to the manned orbital flights on the C-1 and later, having had experience here, would phase in to the manned circumlunar flights and the lunar landing systems development flights. Actually the crews will have experience in both of these areas and by late 1966 will have had sufficient training to be ready to go on the manned lunar landing mission on Nova.

FLIGHT CREW SELECTION, TRAINING & FLIGHT EXPERIENCE

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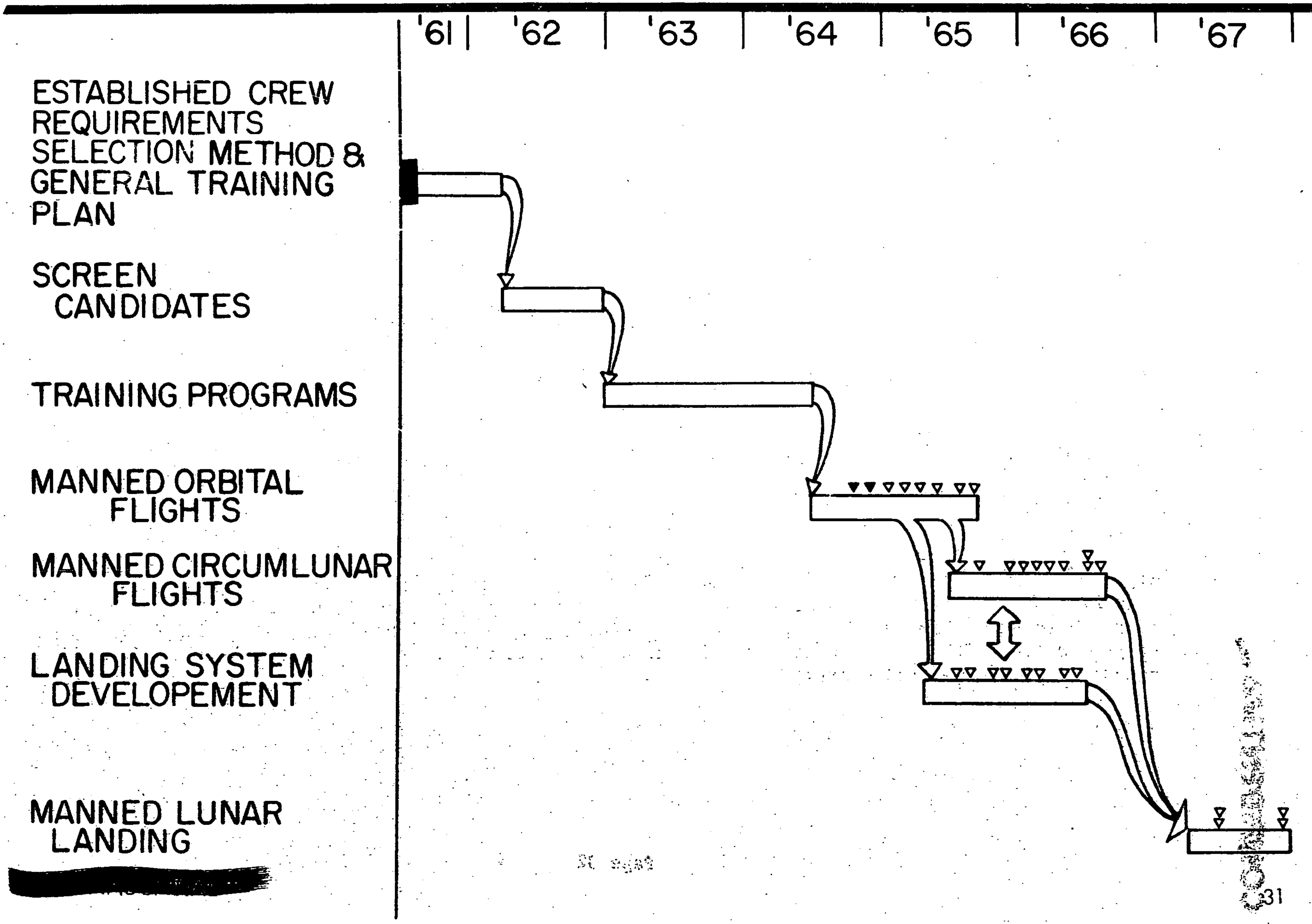

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LAUNCH VEHICLE DEVELOPMENT

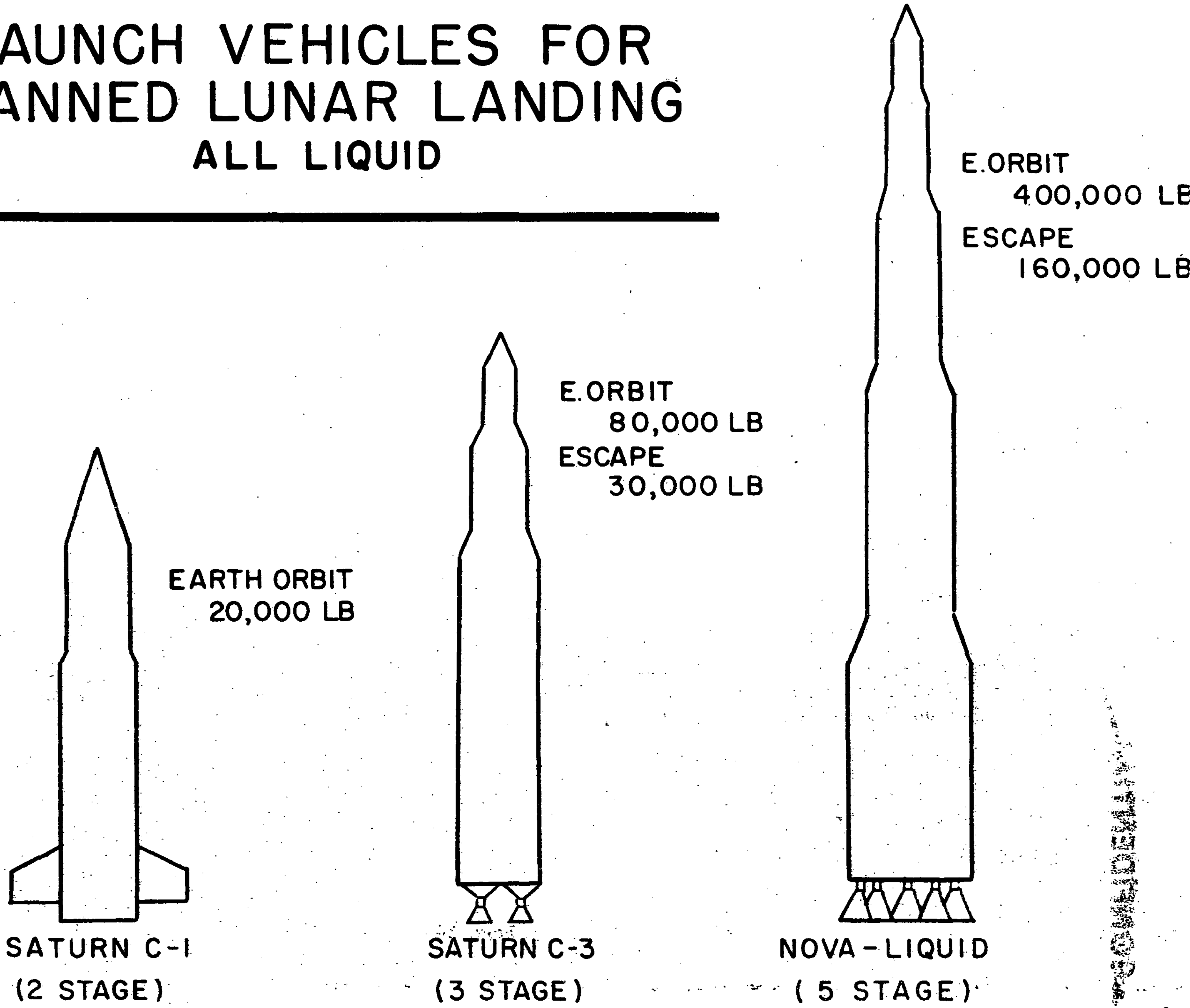
The weight requirements for the missions indicated previously determine the size of the launch vehicles that will be necessary to carry out the programs. These payload requirements lead to two launch vehicle families. One is a family of all liquid propulsion systems, the other is a family of vehicles which uses solid propulsion for the first stage or first and second stages. One of the basic ground rules of the study was that, initially, parallel developments of liquid and large solid rockets for the first stages of the C-3 and Nova vehicles would be carried out.

Figure 14 shows the family of all-liquid vehicles. The first vehicle in the family is the Saturn C-1. The first stage has 8 H-1 RP-Lox engines, and the upper stage has 6 LR-115 engines using liquid hydrogen-oxygen.

The second vehicle is the Saturn C-3. Note that the C-2 is missing from this family. It does not have sufficient capability to put the 25,000 pounds needed into a circumlunar trajectory. The Saturn C-3 has two F-1 engines in the first stage using RP-Lox and producing three million pounds of thrust. The second stage is a variation of the S-II stage with four J-2 engines. This vehicle provides an escape velocity payload weight of 30,000 pounds, easily taking care of the 25,000 pound spacecraft requirement. It also provides 80,000 pounds in earth orbit.

The third vehicle, the liquid Nova, has 8 F-1 engines in the first stage with total thrust of 12 million pounds. The second stage has 8 J-2 engines using hydrogen-oxygen and producing a little over a million and a half pounds of thrust. The third stage is a variation of the S-II stage, having anywhere from two to four J-2 engines. The fourth stage is the lunar landing stage and the fifth is the lunar take-off stage. This liquid propellant Nova will place 160,000 pounds in an escape trajectory.

LAUNCH VEHICLES FOR MANNED LUNAR LANDING
ALL LIQUID



The family of solid liquid boosters is shown in figure 15. Again, the C-1 is a part of this family.

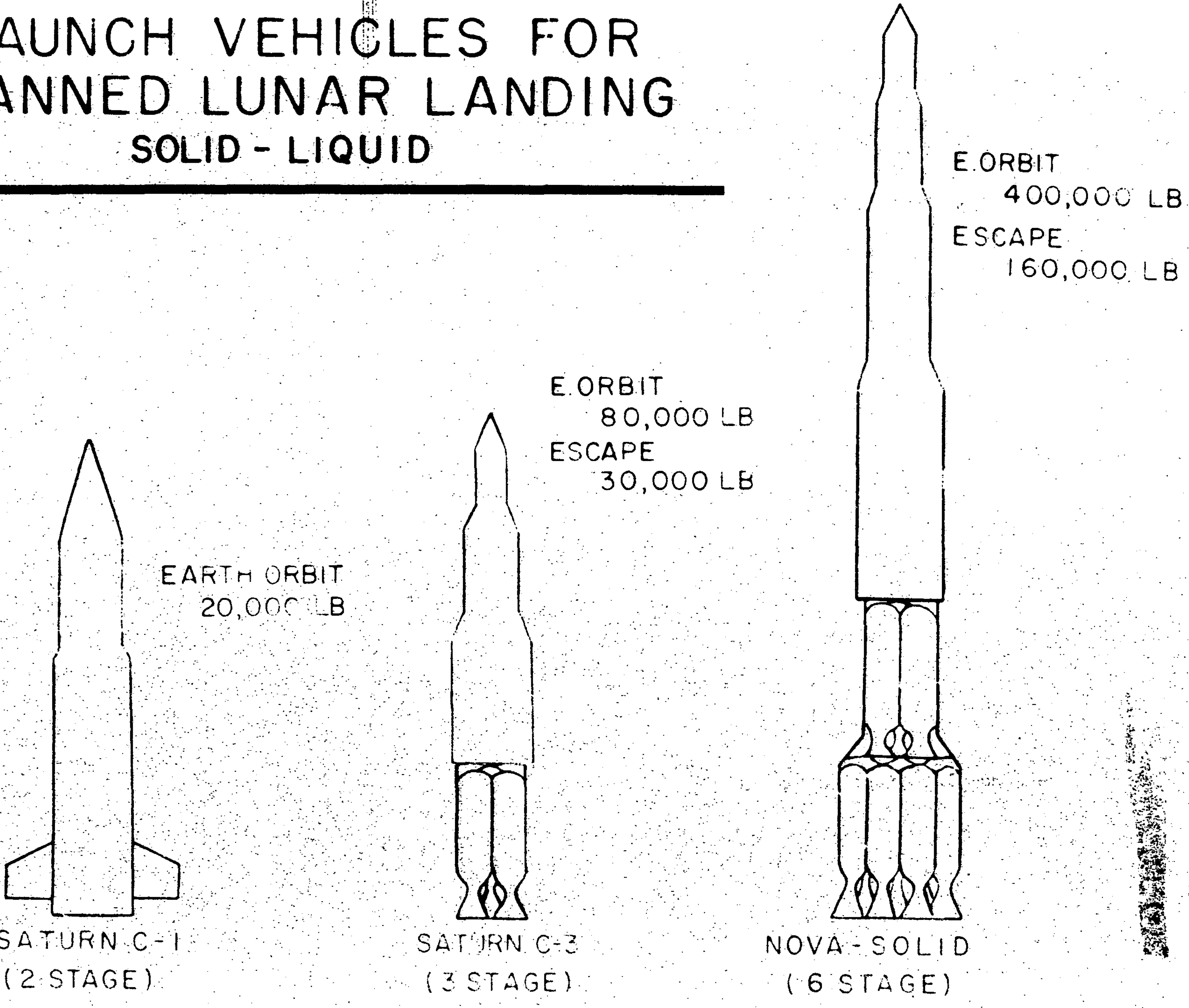
The C-3, in this case, has three solid propellant motors in the first stage, each having a thrust of a million and a half to two million pounds, giving a total of four and one-half to six million pounds thrust. The second and third stages of the solid C-3 are the same as those of the all-liquid version. This again gives the 30,000 pounds excape capability that is needed for the circumlunar mission.

For the solid-liquid Nova, it was found advantageous to use two solid stages in place of the first stage of the all-liquid version. The first stage consists of 7 three million pound thrust solid rocket chambers, giving a total thrust of twenty-one million pounds; the second stage consists of 3 solid rockets, each having two and one-half to three million pounds thrust, giving an eight to nine million pound thrust capability. The third stage is the 8J-2 hydrogen-oxygen stage followed by the S-II stage. This solid Nova also has a 160,000 pound excape payload capability.

These, then, are the launch vehicles selected to perform the missions associated with the manned lunar landing. Included in the launch vehicle development, but not covered on later development charts, is a parallel development of an 800,000 to 1,000,000 pound thrust hydrogen-oxygen rocket motor which might be used in the second stage as a backup. A contract for the development of this motor should follow along in parallel with the development of the J-2 and the development of the upper stages.

LAUNCH VEHICLES FOR MANNED LUNAR LANDING

SOLID - LIQUID



An examination of the development schedules of the C-3 and the Nova vehicles points out their time phasing and their most critical items and indicates points when a choice might be made between the liquid and the solid first stages for C-3 and Nova. The next several charts show these development schedules. Only the major components of the vehicles and their critical supporting items are shown.

Figure 16 shows the development schedule for the liquid C-3. Noted by the solid vertical bars, are the action or decision points that are important. One of the most important actions is the immediate acceleration of the funding of the F-1 engine production to insure that an adequate number of F-1 engines will be available by the end of 1962 to start assembly of the static test article.

It was found that the facilities are a critical item. In order to have the static test stand ready to begin static tests in the middle or third quarter of 1963, it is necessary to let a contract for the design and construction of the static test stand for the first stage of the C-3 in a minimum of time. This minimum time has been established as 12 weeks. The launch complex is also a critical item. A contractor must immediately be brought aboard to begin design of the launch complex for the liquid C-3 in order that it be available in the third quarter of 1962 for the first C-3 launch in January 1965. A contract for the development of the first stage is also necessary early in the schedule so that facility design criteria can be established by the end of this year for the static test stand and launch complex, the pacing items in the first stage development.

For the second stage, the J-2 acceptance stand is a critical item and funding should be accelerated so as to allow the J-2 contractor to immediately begin to build J-2 acceptance stands. With the arrival of these engines in late 1962, the static test article assembly can begin. The second stage should be complete by the end of 1964.

Three first stages with dummy upper stages will be launched beginning in early 1965. The following three flights in the second quarter of 1965 will be two-stage flights. With the third stage development completed by early 1965, the seventh flight of the C-3 in mid-1965 will be a complete three-stage flight.

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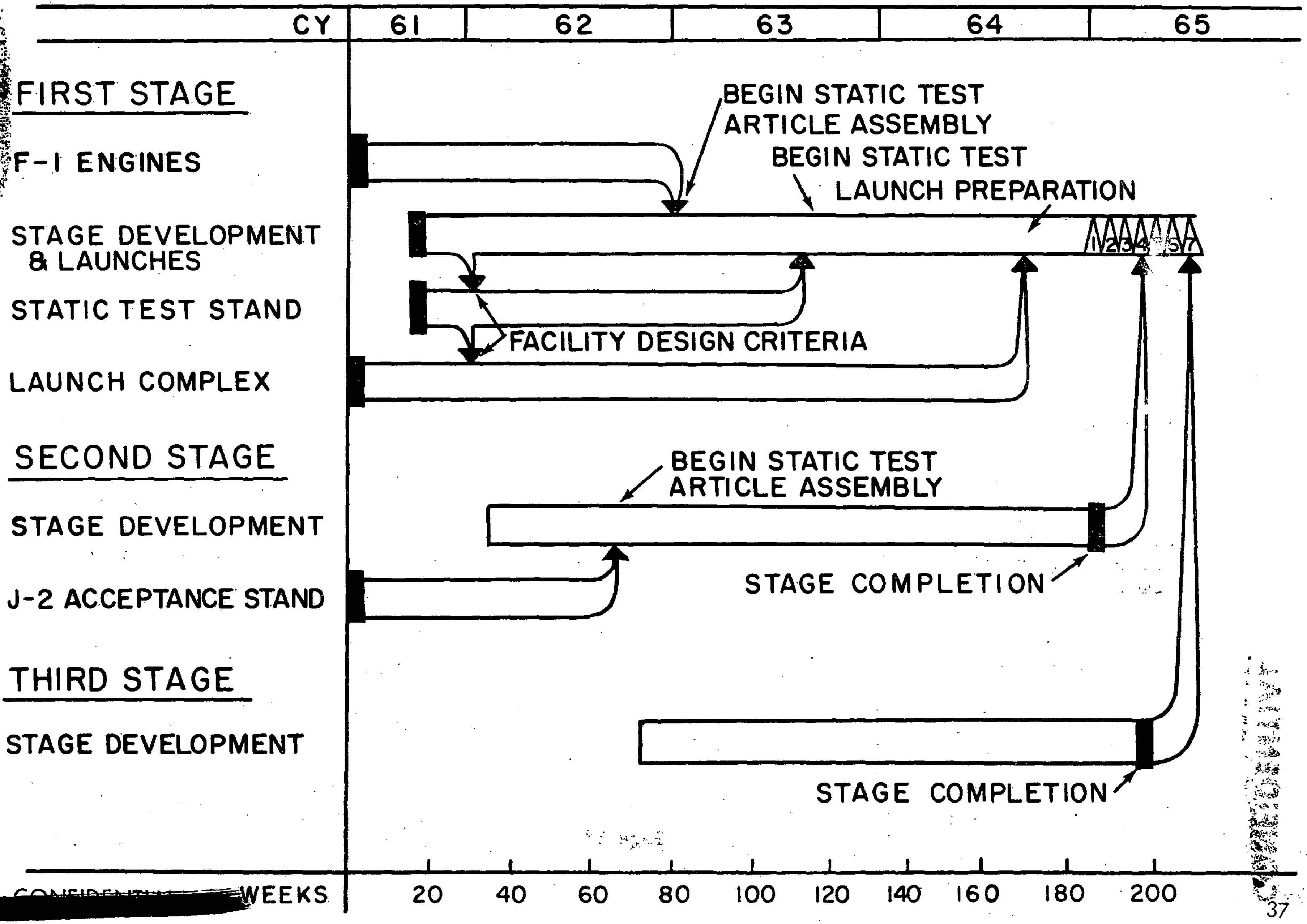
LIQUID C-3 VEHICLE DEVELOPMENT



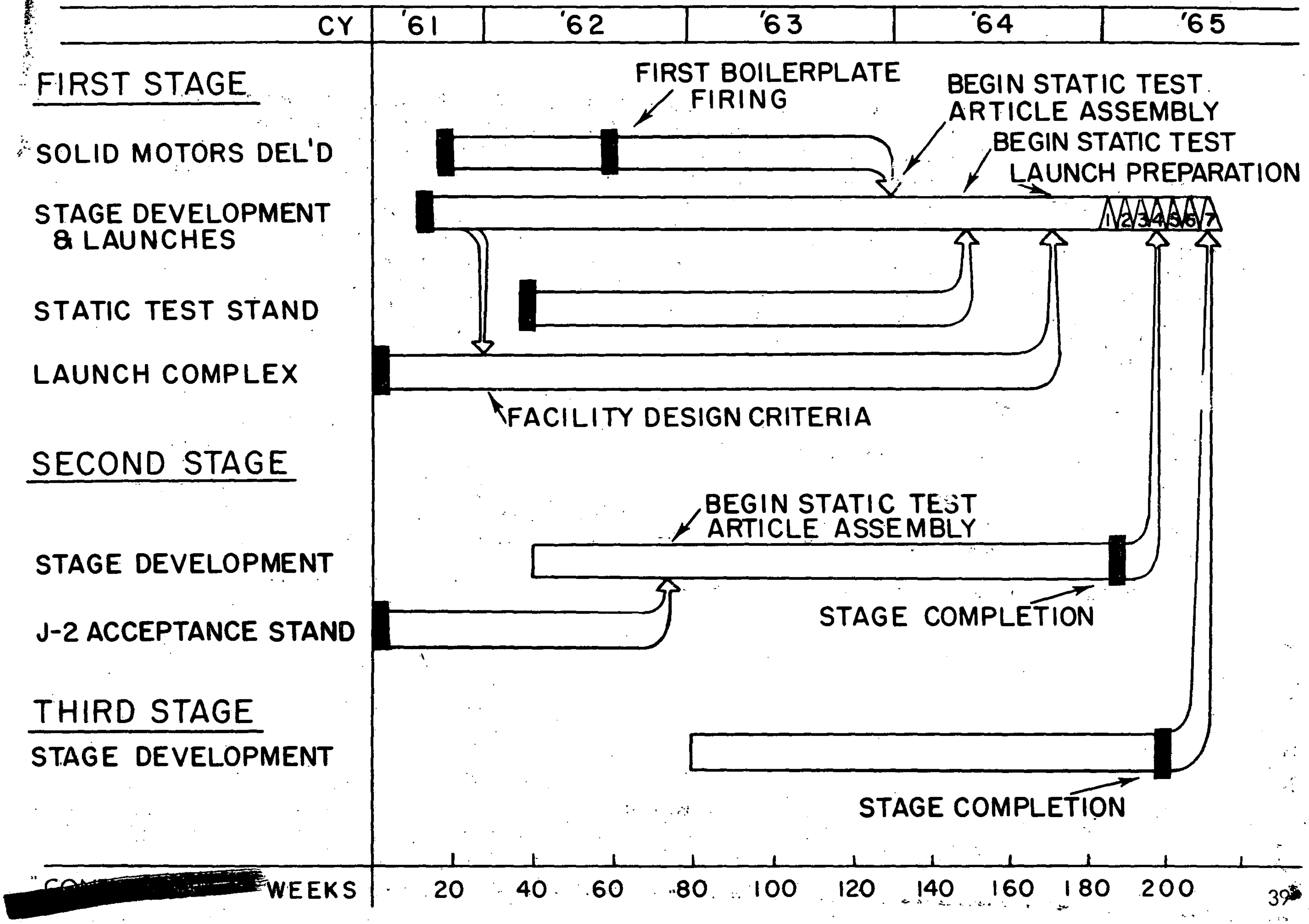
[redacted]

The solid C-3 development schedule shown in figure 17 is much the same as that of the liquid version.

The Air Force has indicated they can let a contract for solid motor development about September 1, 1961. This would give them a firing of the first boiler plate engines in the third quarter of 1962. This boiler plate engine will be a big heavy tank filled with propellant and having an orifice at oen end. The propellant grain will be ignited to demonstrate that the amount of propellant in a three million pound thrust rocket motor can be burned successfully. Thus, this is really not an engine but rather the burning of a tremendous grain of solid propellant. The engine development must be started at this point to feed in to the C-3 assembly at the end of 1964.

Again, the launch complex is a critical item requiring an early start of stage development to feed facility design criteria for the design of the static test stand. In this case, the requirement is not quite as critical as with the liquid C-3 since the solid propellant stand is less complicated as the liquid stand. Of course, the second and third stages of the solid C-3 are the same as for the liquid C-3. Thus, again, the critical item is the J-2 engine acceptance stand.

SOLID C-3 VEHICLE DEVELOPMENT

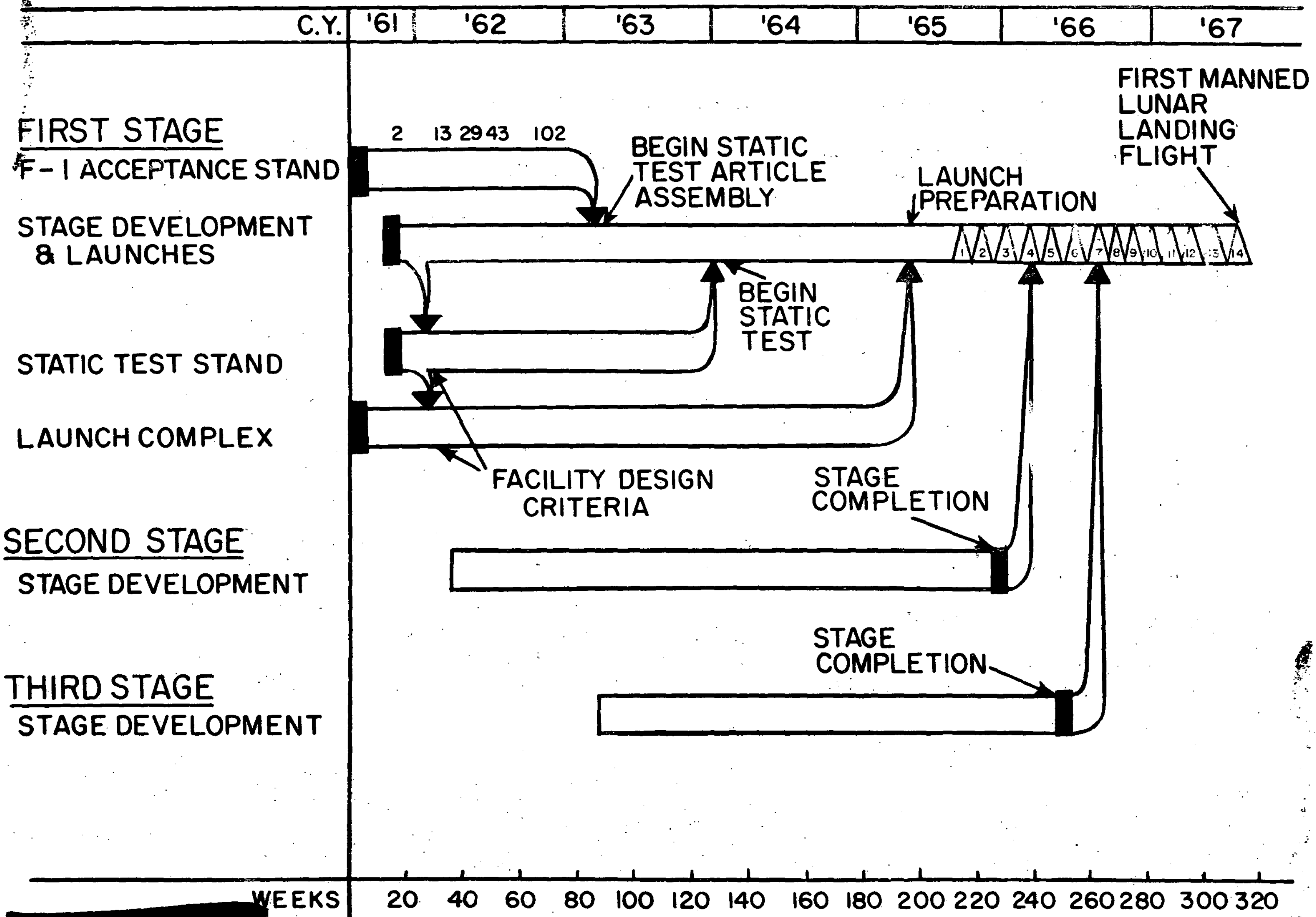


The liquid Nova development schedule is shown in figure 18. The story is much the same as for the C-3. The problem of the F-1 acceptance, initiation of the first stage development, provision of early facilities design criteria for the static test stand and launch complex, assembly of the Nova test article in early 1963, start of static test in early 1964, availability of the facility for the first Nova first stage launch in late 1965, are all interrelated in a very critical manner. The two-stage vehicle will be launched in early 1966 and the three-stage vehicle in late 1966. Three first-stage Novas, three two-stage Novas and seven three-stage development flights are scheduled before No. 14, which is the vehicle considered sufficiently reliable to handle the first manned lunar landing flight. As mentioned before, should the Nova development proceed smoother than anticipated, it is always possible that the first manned lunar flight can go on an earlier Nova. For example, the spacecraft might well be ready for Nova No. 11.

The small numbers on top of the "F-1 Acceptance Stand" bar are rather significant. These numbers represent the number of full duration F-1 engine firings that will be completed at various times during engine development. This is the complete engine with its pumps, valves, turbines, etc. Late in 1961 two F-1 firings will have been completed, followed by 13 firings by early 1962, nearly 40 by mid-1962 and, by the beginning of 1963 when assembly of the static test article begins, there will have been a hundred full duration firings of the F-1 engine. By that time, it should be well established whether or not the F-1 is going to work.

In the liquid Nova, as in the C-3, the pacing items are again the large facilities.

LIQUID NOVA VEHICLE DEVELOPMENT



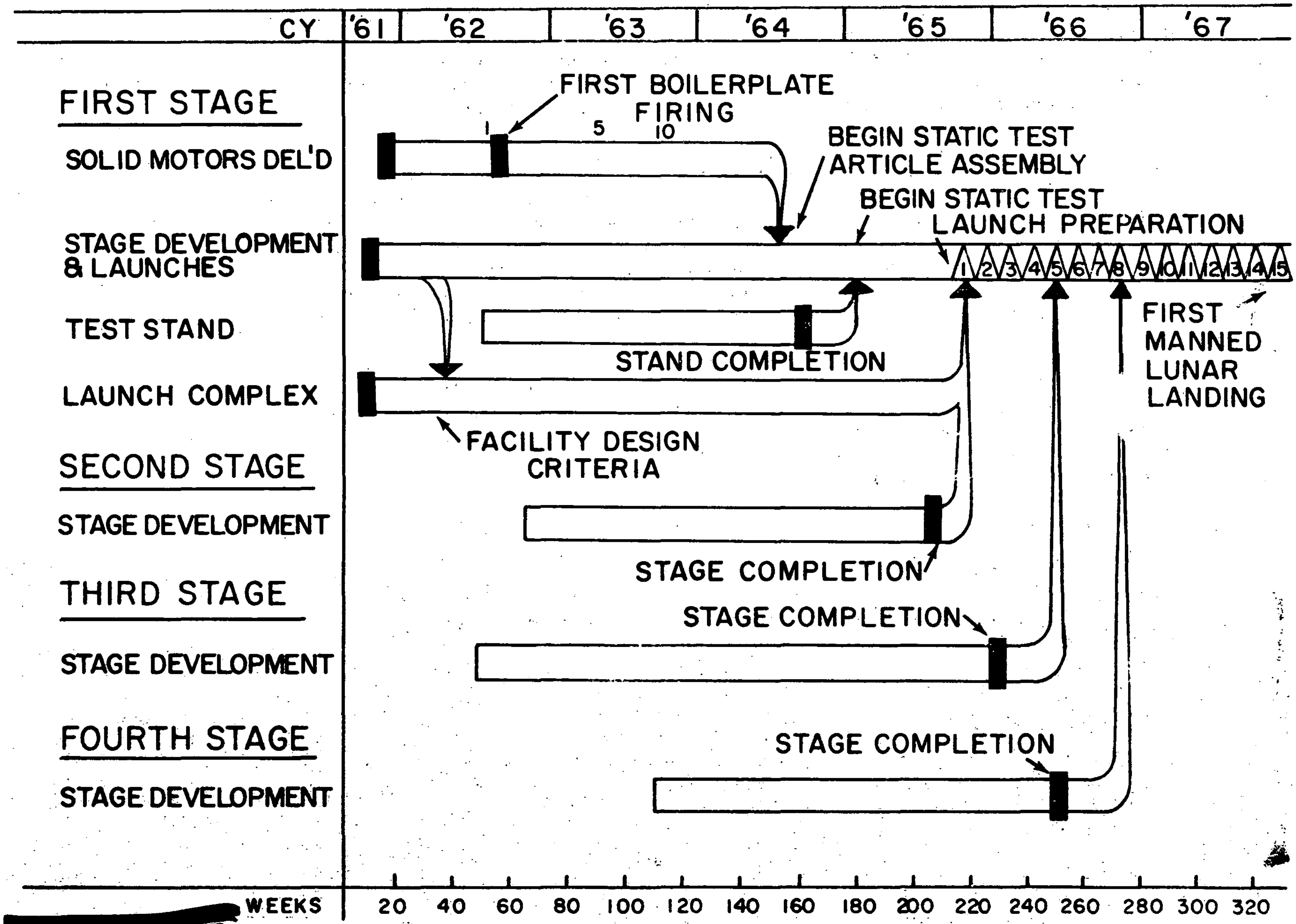
The solid-liquid Nova development schedule is shown in figure 19.

As before, development of solid engines starts early in the program. The solid rocket engine phases in to the assembly of the first stage in mid-1964. The launch complex and the test stands are again pacing items as in the other cases. Second stage development will come along with that of the first stage, making possible four launchings of the first and second solid stages together, beginning in late 1965. This will be followed with flights of the third and fourth stages, which are the same as the second and third stages of the liquid Nova. Three firings with the first three stages and seven more firings with all the stages gives a total of 14 development flights. Like the all-liquid Nova, the solid-liquid Nova scheduled for the first manned lunar flight, No. 15, will be ready in the third quarter of 1967.

As in the previous figure, the small numbers shown above the top bar indicate the number of engine firings. By the third quarter of 1962, the first boiler plate firing of a three million pound solid rocket chamber will take place. Before static test assembly starts, there will have been between ten to fifteen firings of a single three million pound thrust rocket, the last ones being prototype solid rocket engines. Once again, the facilities are pacing items.

An important point needs to be emphasized in connection with the development of the launch vehicles. There is need to start immediately an over-all system design analysis. The design of the stages comprising the vehicles cannot be started one at a time without serious consideration of the complete vehicle system. Rather they must be designed on the basis of a relatively extensive performance and structural analysis of the complete integrated vehicle and spacecraft so as to insure that the design specifications that are laid down for each stage are compatible will result ultimately in a feasible and reliable system.

SOLID NOVA VEHICLE DEVELOPMENT



The liquid and solid stage developments can now be compared in an effort to show when decisions can be made as to whether liquid or solid stages will be used for the ultimate manned lunar landing flight on Nova. Figure 20 repeats the contents of earlier charts for the first stage development of the liquid Nova and for the first and second stage development of the solid Nova. Various critical points are indicated. Note that the timing of the liquid and the solid Nova is about the same. The first launch of the first stage of Nova is going to come in early 1966 regardless of whether it is liquid or solid. Either one can be ready for a manned lunar landing flight in about the third quarter of 1967.

Looking at the over-all costs of the liquid and the solid Nova vehicles, and their supporting facilities, it is found that the cost comes out about the same, i.e., one can't really make a decision on the basis of cost. With regard to reliability, it would certainly be impossible to make any guesses because the program requirements stretch both the liquid and the solid motor well beyond the present demonstrated state of the art. What this means, then, is that a decision must be made at some point based on the successes, failures or troubles in the development of the liquid or the solid rocket motors. It is more than likely that an obvious decision point will not occur in which case the decision must be purely arbitrary.

The cutoff point or decision point might logically occur at the end of a fiscal year. At the end of the first year of the program (mid-1962 and end of FY 62) about 40 full duration F-1 runs will have been made. This should give a good indication as to whether the F-1s are either very good or very poor. By this time both the liquid and solid first stage design has begun but the first solid motor run has yet to be made. A decision at this point could in all probability only be arbitrary.

A year later (mid-1963), there will have been over 100 F-1 full duration runs and assembly of the liquid first stage static test article will have begun. In the solid case, about 5 full scale single motor runs will have been made and the first stage design will have progressed fairly well along towards fabrication of hardware. A decision might be made here if either the liquid or the solid looks either extremely good or extremely bad.

At the end of the third fiscal year (mid-1964), the liquid Nova static tests will have begun, giving a very good idea as to whether or not it will be successful. Also 10 to 15 solid motor development runs will have been completed and the fabrication of the solid stage will be well along. Certainly by this point a logical decision can be made. However, a decision at this time will be much too late, since most of the money for the large development and launch facilities will have been spent and such facilities will be either completed or approaching their completion.

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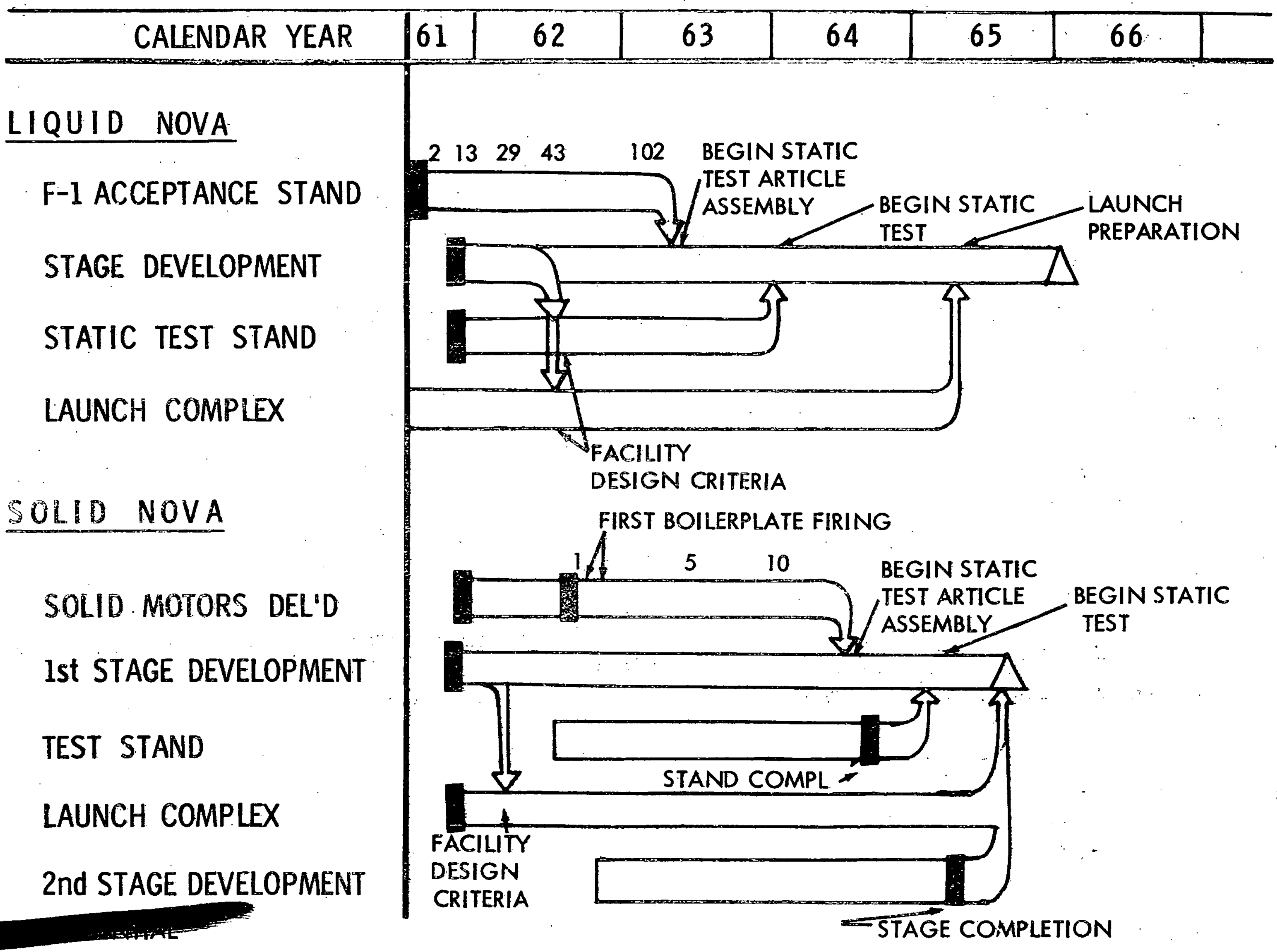
NOVA DECISION POINTS



[redacted]

While the parallel liquid and solid stage developments are being carried out, funds are pouring into static test stands and into launch complexes for both programs. What it means to delay this decision from year to year in terms of dollars is shown in figure 21.

The chart compares the liquid and solid Nova first stage development costs. The figures are cumulative costs in millions of dollars against the fiscal year points that have been mentioned above with the liquid and solid programs carried along together. These costs represent the costs of the liquid and solid stages and their development and launch facilities. Combined costs are represented by the solid curve. If a decision is made at the end of the first year to go liquid or solid, subsequent costs would go along the lowest dotted curve. Likewise, if the decision between liquids and solids were made at the end of the second fiscal year, the cost would proceed along the middle dotted curve and, finally, a third year decision would involve costs along the upper dotted curve.

The important point is that the difference in cost between the first and the second year of carrying along parallel developments will be about 400 million dollars; if the decision is delayed from the second year to the third year, it will cost an additional 550 million dollars. Thus parallel development of liquids and solids to mid-1964 will cost in excess of one billion dollars more than pursuing only a single approach from the start. Nevertheless, both approaches should be pursued at this time, although it would be less costly to select one as the primary system and carry the other along as a backup.

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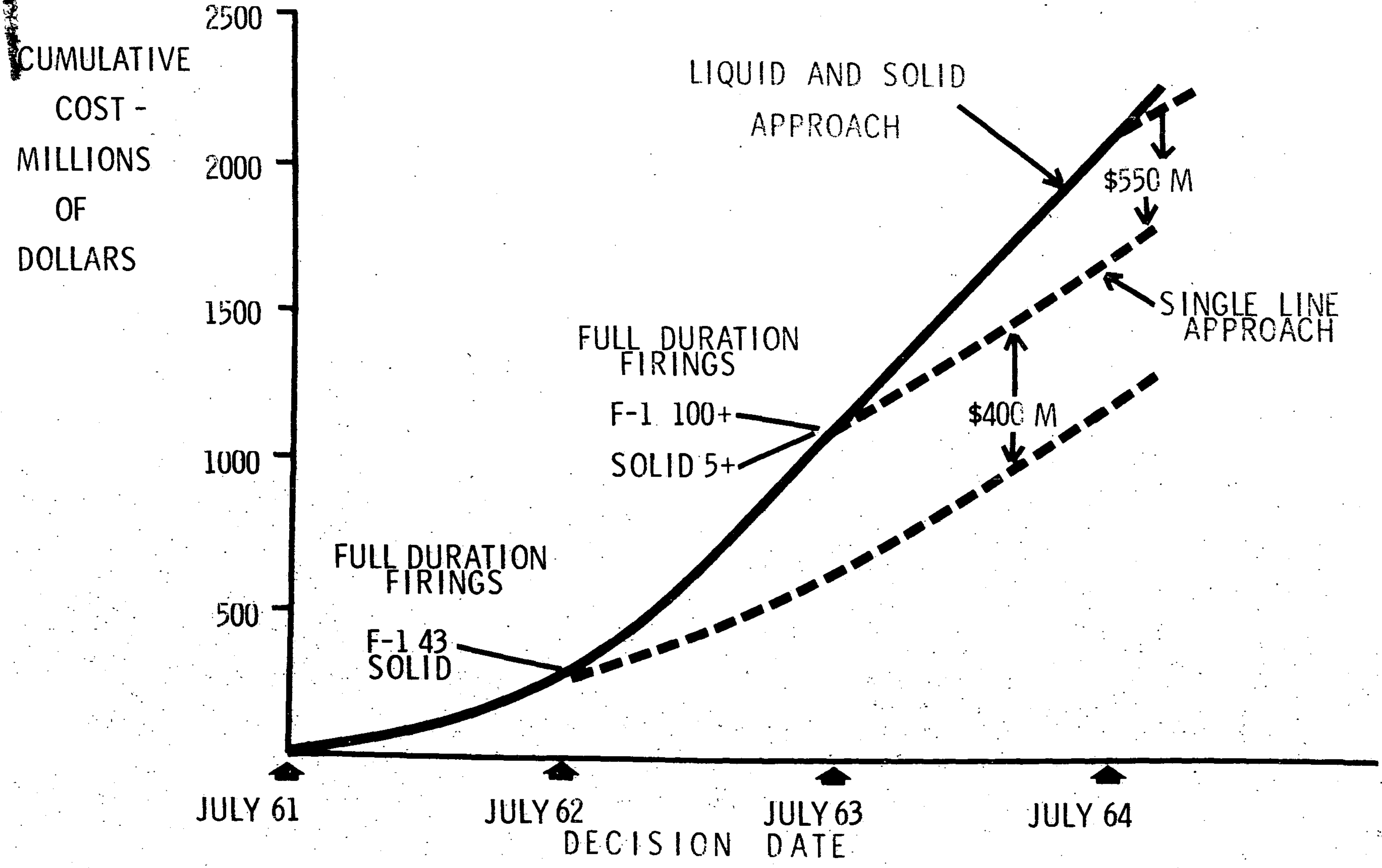
COMPARISON OF LIQUID AND SOLID NOVA FIRST STAGE DEVELOPMENT COSTS



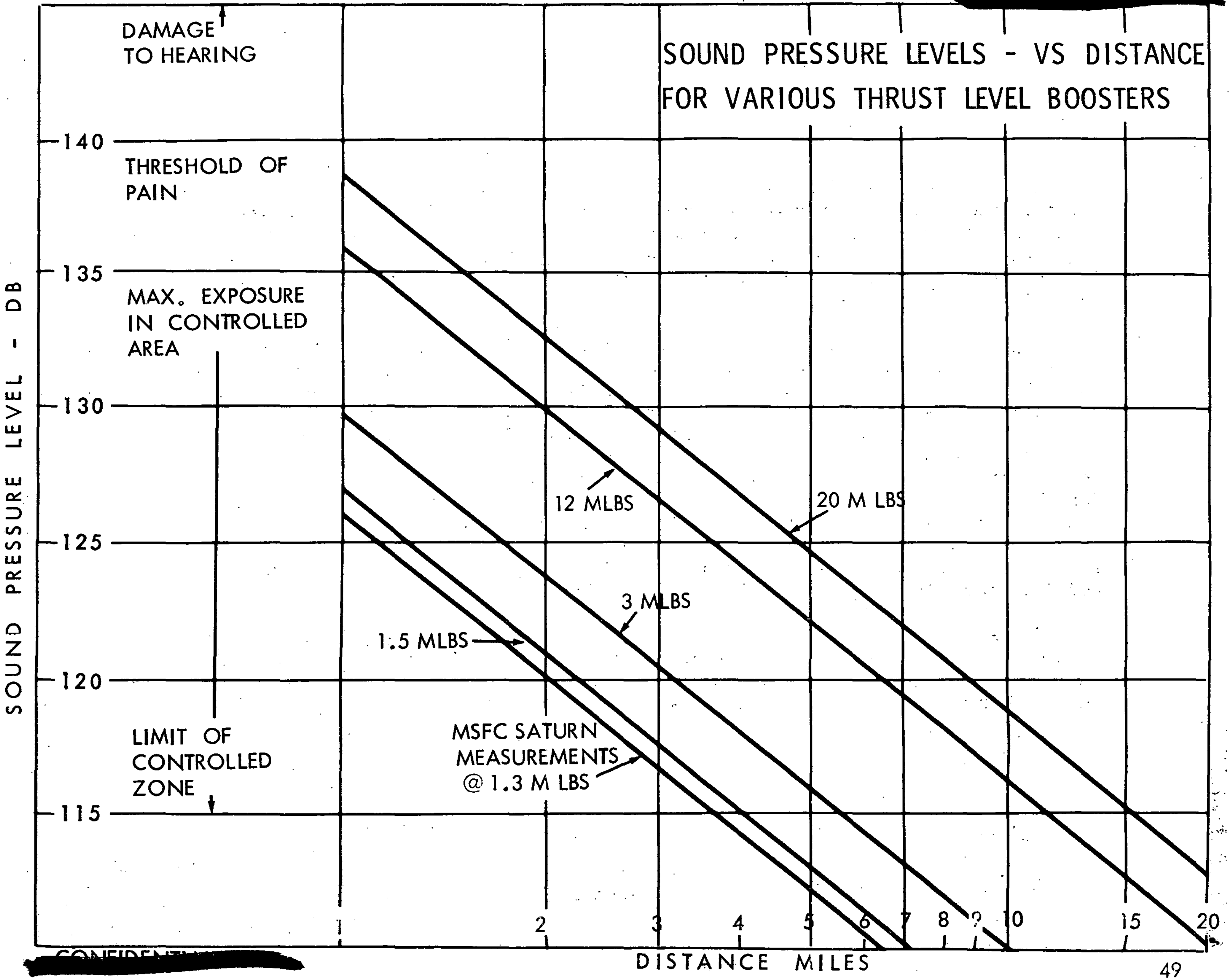
[redacted]

FACILITIES

The next several charts deal with the facilities which are required to support a program of this magnitude. There are many and varied kinds of facilities needed for launch, for development and for supporting programs. The detailed report treats the entire facilities requirements. This summary report will dwell on the launch facilities only. The launch facilities are really the major and the critical facilities and are the facilities in which there exist the greatest unknowns.

Perhaps the greatest problem associated with launch facilities for very large launch vehicles has to do with noise level. Figure 22 illustrates this problem. The sound pressure level in decibels is plotted against distance in miles on a logarithmic scale. The bottom line represents the sound pressure level versus distance as measured by MSFC for the Saturn operating at 1.3 million pounds thrust. Extrapolated from these data are curves for a million and a half pounds, three million, 12 million and 20 million pound thrusts. Twelve million pound thrust corresponds to the all-liquid Nova, the 20 million pound thrust corresponds approximately to the liquid-solid Nova. There is estimated to be about 3 decibel difference in sound level between the 12 and 20 million pound thrusts. The chart shows three important sound levels: above 140 db causes damage to hearing, 135 db is the threshold of pain, from 135 db down to 115 db is the maximum exposure area in a controlled zone.

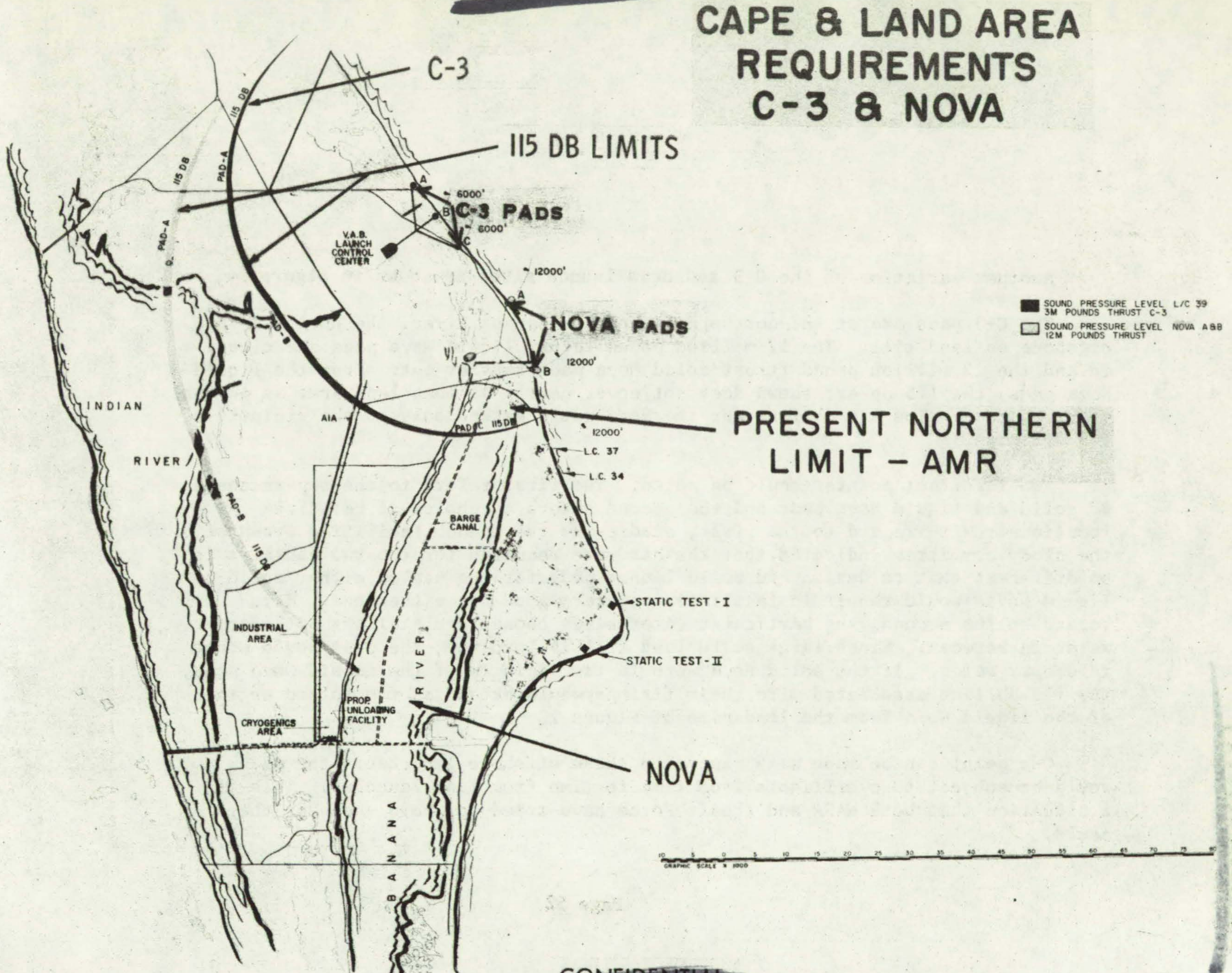
There are certain ground rules associated with noise which must be observed. One of the ground rules that the Air Force and NASA have jointly recommended is that the government will own or will have noise easements on all real estate where the noise level during launch will be 115 db or higher. This is the significance of the limit of the control zone. Between 115 and 120 db is an area where those people occupying the area will be warned of an event. They would use ear plugs but it would be safe for them to be out-of-doors. The noise level would be about equivalent to a freight train rushing by at very close proximity. From 120 to 135 db is the real control area where, during the launch, movement of personnel would have to be controlled and all personnel would have to be inside buildings. This does not mean that they would have to be inside of dugouts, etc., it just means inside of a building to cut the noise level down to below 120 db and perhaps 115 db or lower. The area above 135 db would be completely evacuated. In the case of the liquid Nova this would be an area in radius of about one mile; for the solid Nova it would be 1½ miles from the launch site. At 150 db, which is slightly off the top of the curve, structural damage starts, i.e., the brick and mortar begins to fall apart. However, 150 db occurs very close to the launch pad and anything designed or built in this area would be built to withstand these very high noise pressure levels.


SOUND PRESSURE LEVELS - VS DISTANCE
FOR VARIOUS THRUST LEVEL BOOSTERS
DAMAGE TO HEARING
THRESHOLD OF PAIN
MAX. EXPOSURE IN CONTROLLED AREA
LIMIT OF CONTROLLED ZONE
140
135
130
125
120
115
SOUND PRESSURE LEVEL - DB
20 M LBS
12 MLBS
3 MLBS
1.5 MLBS
MSFC SATURN MEASUREMENTS @ 1.3 M LBS
1
2
3
4
5
6
7
8
9
10
15
20
DISTANCE MILES

It is to be noted that there has been a system hazard analysis of large vehicle systems made by a board composed of members from AMR, from the AF Space Systems Division and from the NASA Launch Operations Directorate. This group has defined regulations for this control zone and made joint facility recommendations. Several launch sites based on the board's recommendations have been considered. These are shown in the following charts.

Figure 23 shows a map of AMR with possible launch sites for C-3 and Nova. The map shows the present northern limit of AMR real estate and the present AMR complex. Three C-3 launch pads could be established as shown near the top part of the map. Nova launch pads could be located a short distance below the C-3 pads. Shown on the figure are areas denoting the region of 115 db noise level. In accordance with current recommendations, the government would have to own the real estate or have noise easements within the outermost arc to launch Nova from AMR. The 120 db line for the Nova launch pad would cut mid-way across the Cape. This means that throughout the lower half of the AMR complex personnel can continue to work out-of-doors unhampered but probably using ear plugs. Over the northern half of the AMR complex, all of the personnel would have to be controlled, i.e., they have to be indoors but could continue to occupy the buildings in this area.

There are approximately one thousand property owners and a population of over a thousand in the area that would have to be acquired north and west of AMR. However, the Air Force and NASA personnel at AMR are beginning to look into the problems involved in procedures needed to acquire this land.

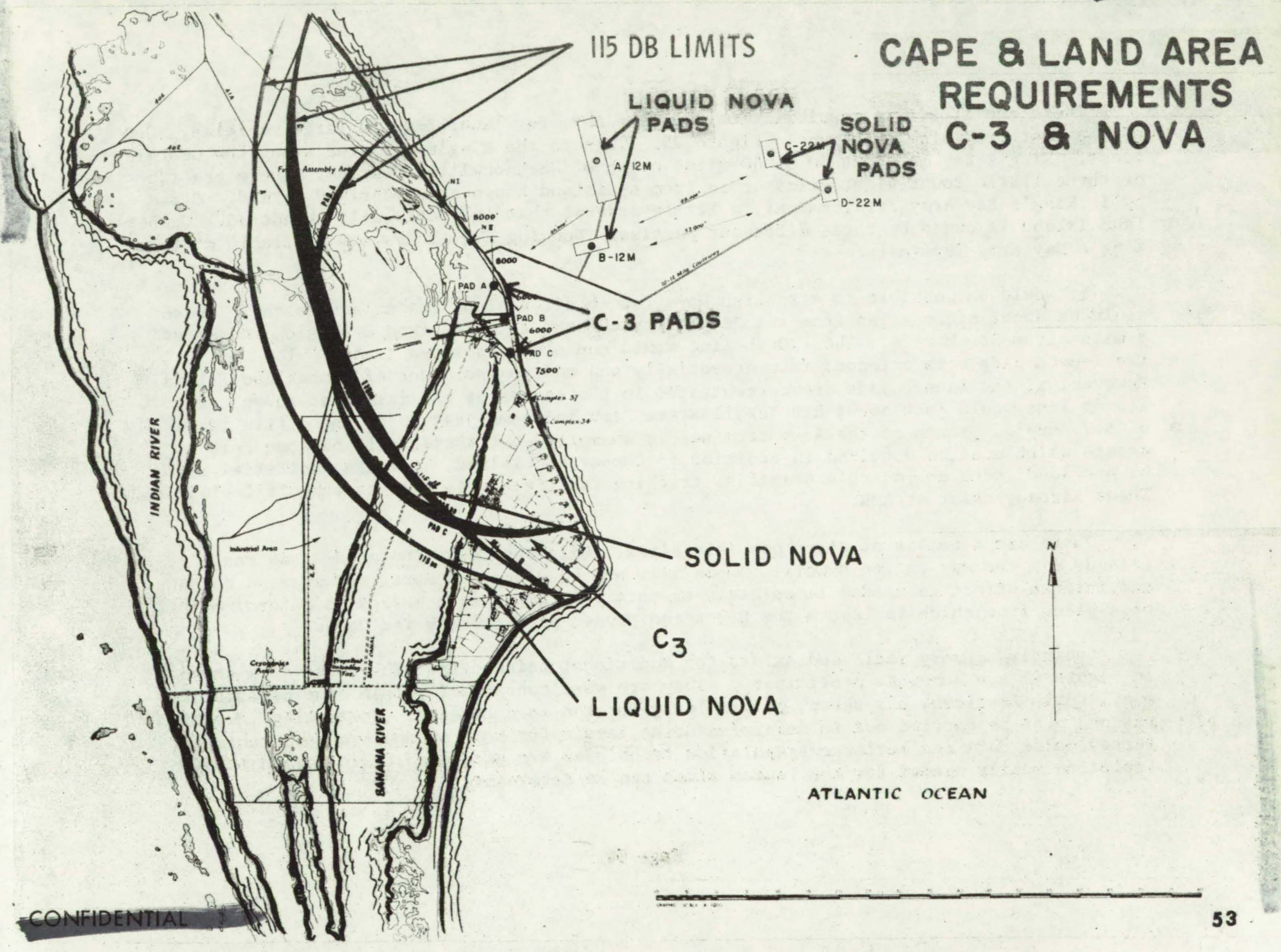

CAPE & LAND AREA REQUIREMENTS C-3 & NOVA
C-3
115 DB LIMITS
C-3 PADS
6000'
A
B
C
V.A.B. LAUNCH CONTROL CENTER
12000'
NOVA PADS
PRESENT NORTHERN LIMIT - AMR
PAD-A
PAD-B
PAD-C
115 DB
AIA
L.C. 37
L.C. 34
INDIAN
RIVER
BARGE CANAL
STATIC TEST - I
STATIC TEST - II
INDUSTRIAL AREA
CRYOGENICS AREA
PROP. UNLOADING FACILITY
RIVER
BANANA
NOVA
SOUND PRESSURE LEVEL L/C 39 3M POUNDS THRUST C-3
SOUND PRESSURE LEVEL NOVA A&B 12M POUNDS THRUST
GRAPHIC SCALE X 1000

Another variation of the C-3 and Nova launch sites is shown in figure 24.

The C-3 pads are at the northern tip of the Banana River, the Nova pads are offshore on land fill. The 12 million pound thrust liquid Nova pads are closer in and the 22 million pound thrust solid Nova pads further out. From the liquid Nova pads, the 115 db arc shown does not cover nearly as much land area as in the previous case. The 120 db line for the Nova would extend only to the vicinity of the C-3 pads.

Two important points should be noted. The first refers to the separateness of solid and liquid Nova pads and the second refers to choice of relative locations. With regard to the first, studies by the Launch Facilities Group of the study committee indicated that the hardware required for the two vehicles is so different that to design and build launch pads for the use of either solid or liquid Novas would result in facilities not very good for either one. With regard to the second, the particular water sites chosen are shallows with deeper water in between. Since large scale land fill is involved, the cost would mount in deeper water. If the solid Nova were in the vicinity of the liquid Nova pads, the 115 db line associated with their firings would extend as far inland as that of the liquid Nova from the land site of Figure 23.

One point can be made with regard to these offshore launches: the pads would be subject to overflights from time to time from land launches. This is a situation that both NASA and theAir Force have tried to avoid whenever they could.


CAPE & LAND AREA REQUIREMENTS C-3 & NOVA
115 DB LIMITS
LIQUID NOVA PADS
SOLID NOVA PADS
A-12M
B-12M
C-22M
D-22M
PAD A
PAD B
PAD C
6000
7500'
8000'
C-3 PADS
Complex 37
Complex 34
SOLID NOVA
C3
LIQUID NOVA
INDIAN RIVER
BANANA RIVER
Industrial Area
N
ATLANTIC OCEAN

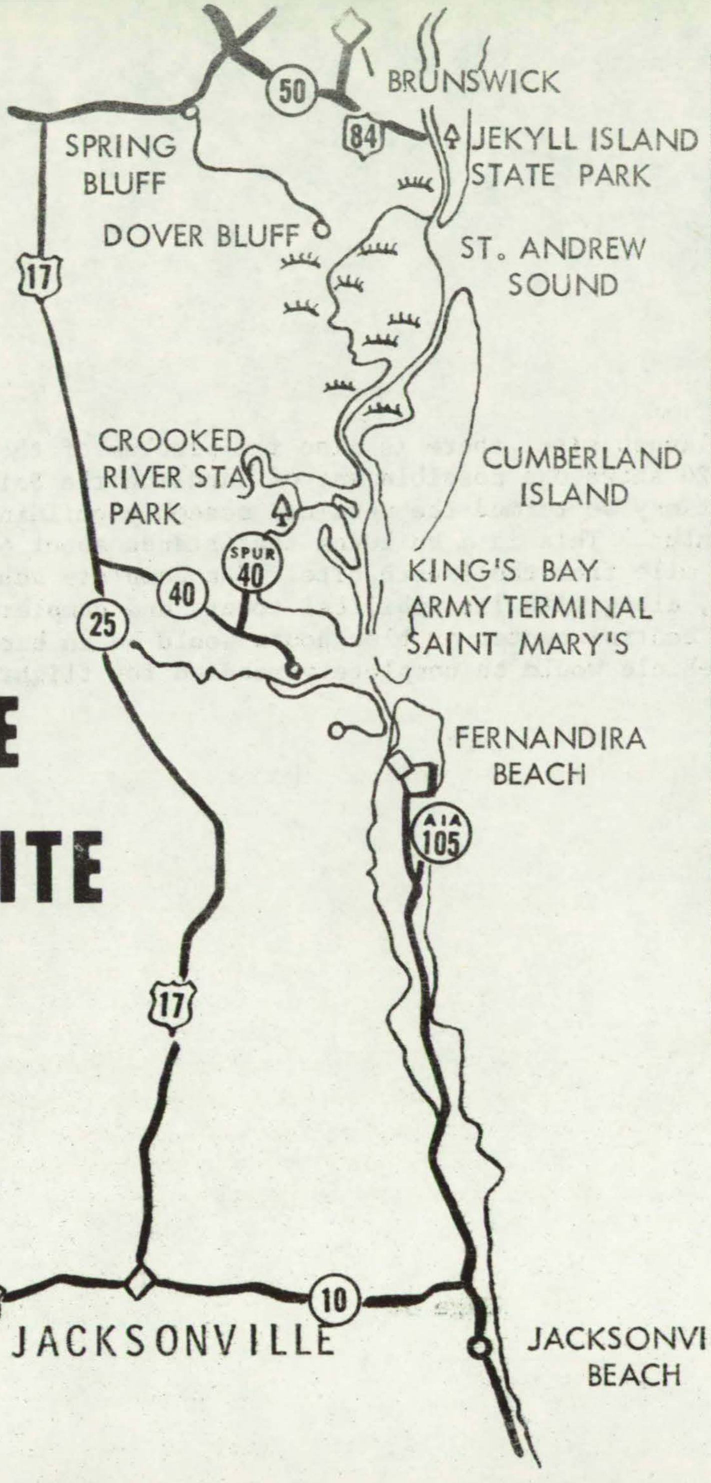
There are alternate possibilities, besides AMR, for launching the large vehicles. One of the most promising is shown in Figure 25. This is the King's Bay area along the Georgia coast. King's Bay is about 50 or 60 miles north of Jacksonville, Florida. There are two or three little towns eight miles or so from an island known as Cumberland Island. Close by is King's Bay Army Air Terminal, a little arsenal that is pretty well abandoned. Cumberland Island is owned by three different parties. Docking facilities are available at the King's Bay Army Terminal.

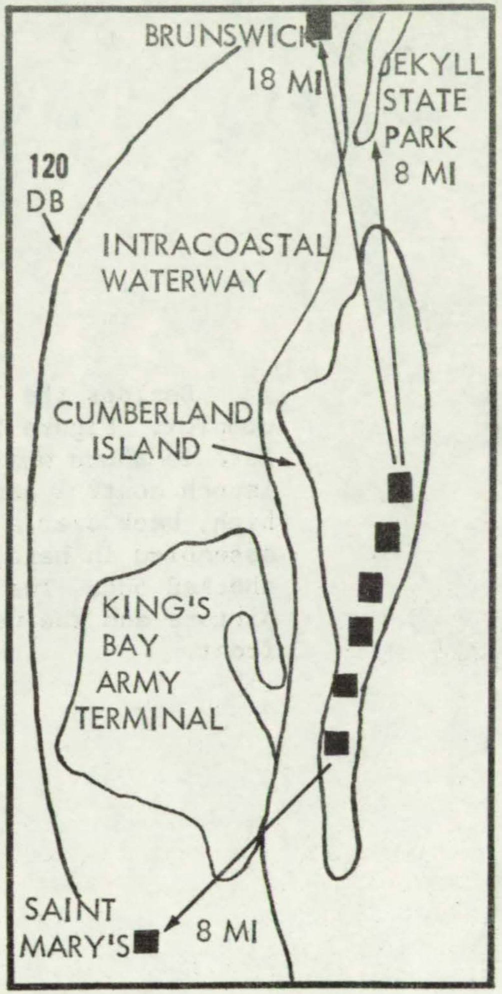
It would be possible to establish Nova launch sites along Cumberland Island. These would be about eight miles from the Jekyll State Park, 18 miles from Brunswick and about 8 miles from St. Mary's. The 120 db line would run along as shown in the "blow-up" if the launch pads were extended from essentially one end to the other of Cumberland Island. However, if the launch pads are concentrated in the center of the island as shown, the 115 db line would just about hit Jekyll State Park and come just up to the little town of St. Mary's. North of the Army terminal is swampland, but there would be some real estate which must be acquired in addition to Cumberland Island. Certain facilities must be provided, such as launch and initial tracking facilities, as well as support facilities. These already exist at AMR.

There are a number of other possible sites. Opinions regarding good sites range to islands all the way out to Hawaii. These will not be discussed here. However, a serious and intense effort is needed immediately on this problem of site survey to determine the best place from which to launch the C-3's and Novas, particularly the Novas.

Secondly, a very real need exists for additional noise data. The noise data shown in Figure 22 are somewhat preliminary. They are more conservative than some contractors, e.g., North American, has shown, particularly for the sold rockets. Continuing investigations must be carried out to determine noise levels for some of the big Nova vehicles. Better noise data and better extrapolation techniques are needed so that the amount of isolation really needed for the launch sites can be determined.

ALTERNATE LAUNCH SITE





POSSIBLE 12 M LB

LAUNCH SITES

Besides the launch site, there is also the problem of the launch complex. Figure 26 shows one possible way of handling the Saturn C-3. Here is shown what may be termed the vertical assembly building and launch control center. This is a building that stands about 400 feet high, back over a mile from the launch site. The complete vehicle is assembled in here, along with its umbilical tower, and completely checked out. The control center or blockhouse would be in back of the picture and the vehicle would be completely readied for flight in the front.

L.C. NO. 39
VERTICAL ASSEMBLY BUILDING & LAUNCH CONTROL CENTER

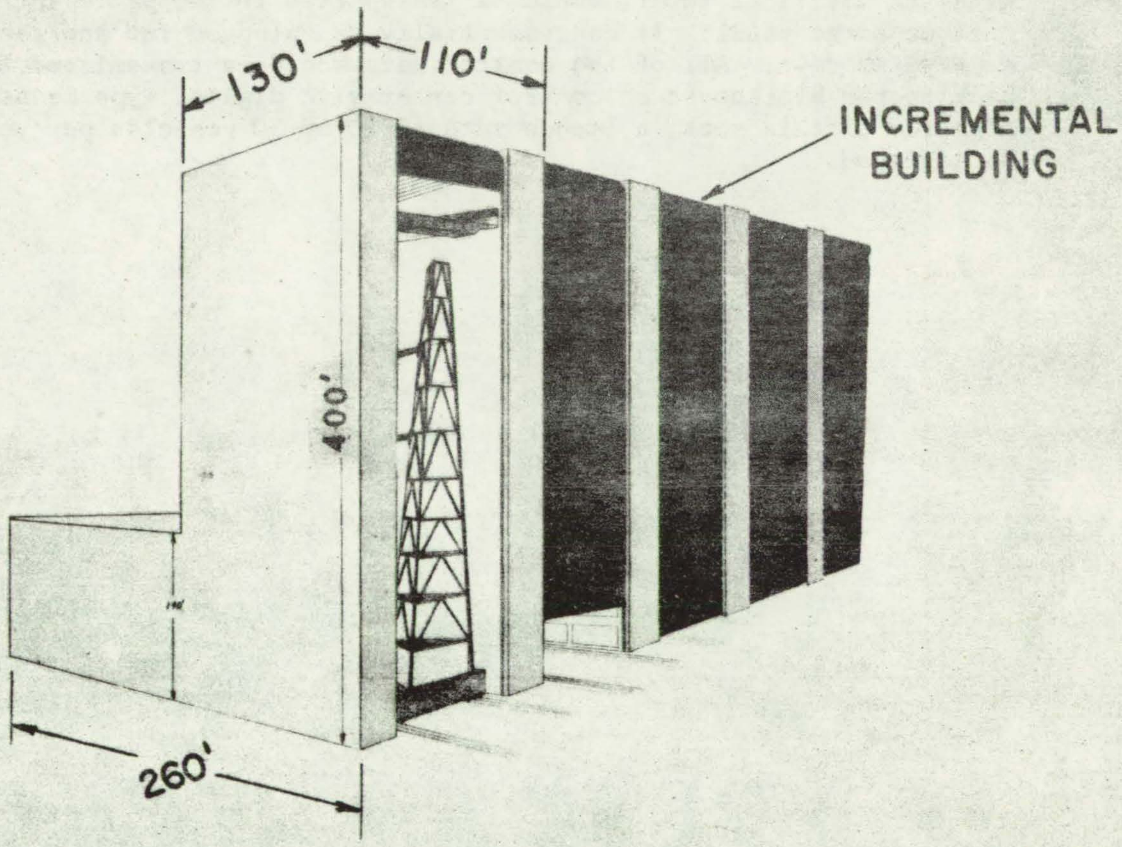
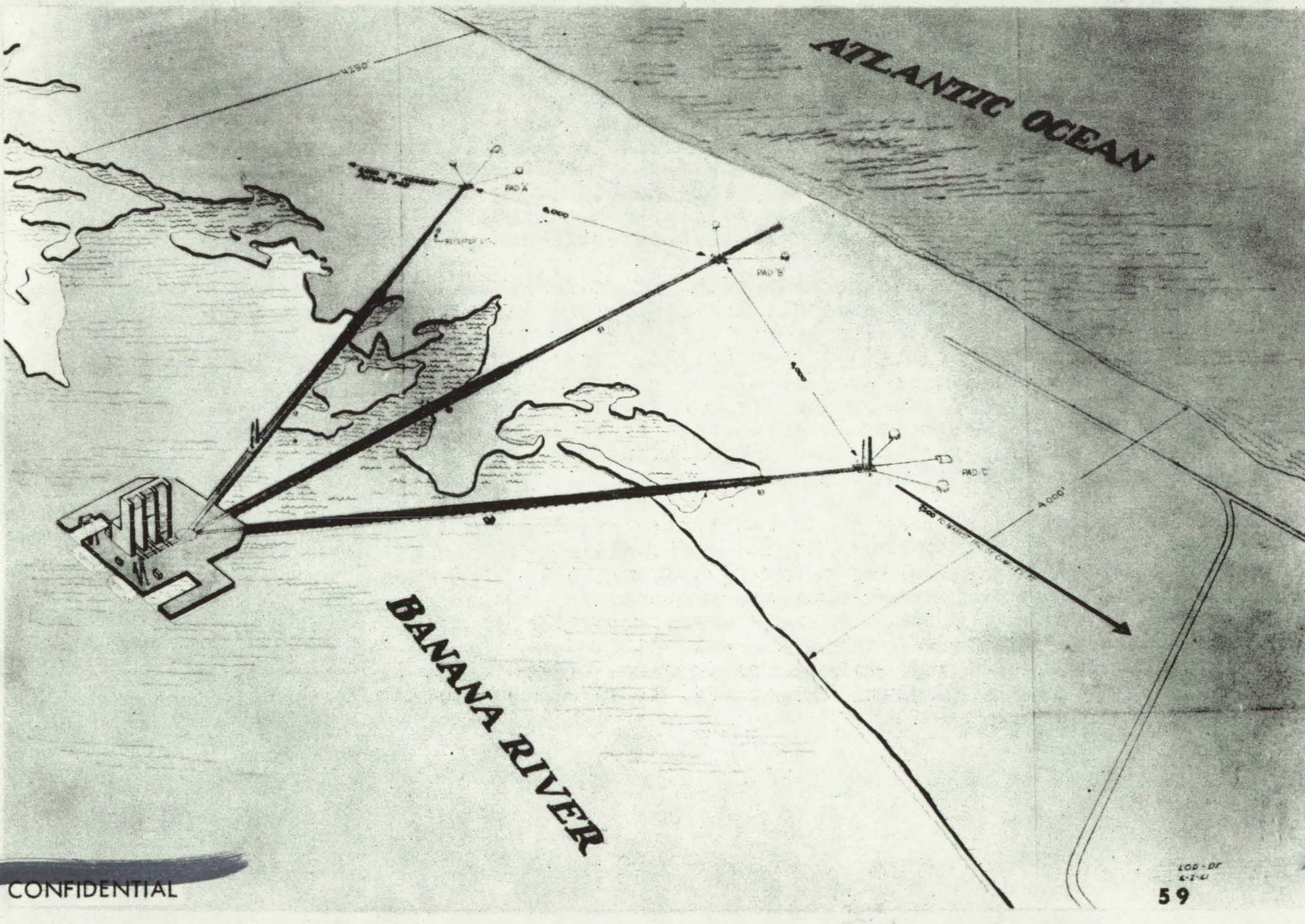


Figure 27 shows the complete layout of the C-3 complex. The building of the previous figure would be located on land fill in the Banana River as shown. There would then be required perhaps three relatively simple C-3 pads. The vehicle all checked out and in its vertical position, along with its umbilical tower, would be transported to the pad either along a rail or barge canal. It can essentially be "plugged in" and launched in a very few days. All of the control data would be transmitted from the pad back to the blockhouse or control center with digital type means. With a system of this sort, a launch rate of 20 or 30 vehicles per year could be achieved.

L.C. NO. 39
COMPLEX LAYOUT

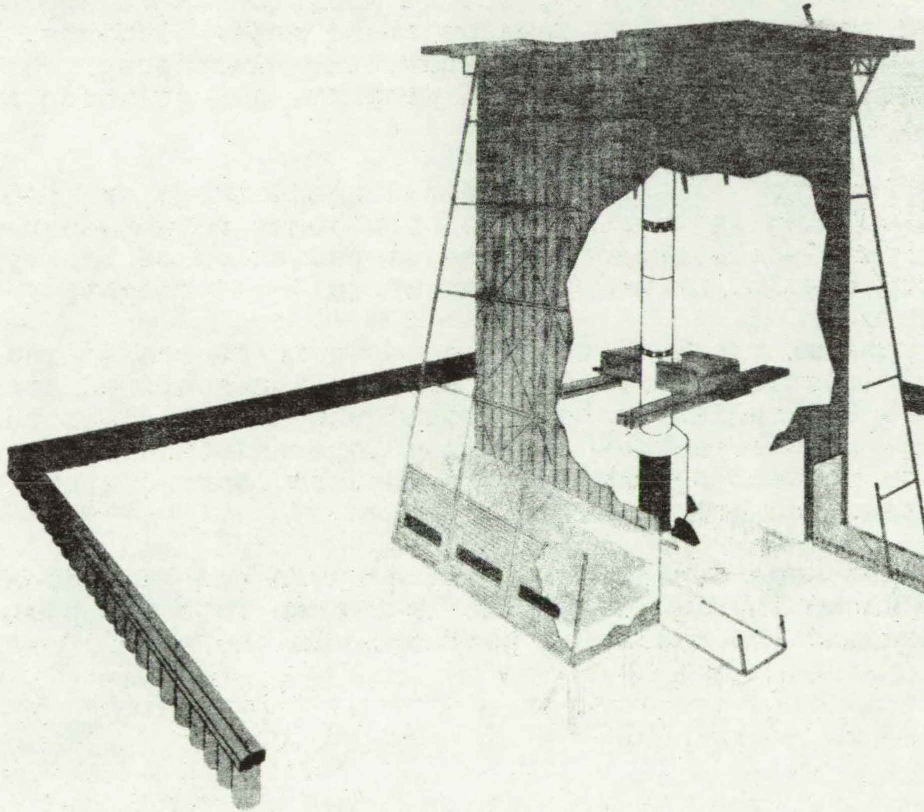


The Nova launch facility illustrated in Figure 28 can be an on-shore or off-shore facility. It looks most feasible and most realistic to assemble the vehicles on the stand. To build the vehicle in a remote site and move it to its stand, as is suggested for the C-3, would make operations very costly. The cost of the assembly building for the Nova type vehicle is more than the cost of the pads themselves. For a relatively low firing rate, say one every one to two months, it is cheaper to build the vehicles on the pad. Only for a more rapid firing rate of, say, once a week or once every two weeks, may it be cheaper to have the assembly building and not have to fund quite so many pads. For assembly on the pads, there is need for a large hurricane proof structure around the facility which, prior to launch, would break in half and each half move back about a thousand feet. For the off-shore case, where land fill is required, this means that a land fill with a minimum length on the order of a half mile is required to accommodate this equipment.

One other point can be made with regard to assembly on the stand versus assembly in the control assembly building. The liquid Nova launch vehicle may be assembled in a central assembly building, even though it would be extremely difficult because of the 350 feet height. There is currently some uncertainty as to whether it can be done at all by any practical means. In the case of the solid Nova, however, where the first and second stages are fully loaded with propellant, the weight is so great that it is impossible to build the whole thing up and transport it five or ten miles to the pad. The solid Novas would thus have to be built on the pads.

There are many other facilities required in the program. There are, as shown in earlier charts, engine and vehicle test and development facilities, e.g., deep space networks, recovery systems, etc. There are research and advanced technology facilities that are required to provide the data necessary to accomplish this program. In many areas these facilities are a pacing item as they were in the launch vehicle area. It is found that a number of these facilities should be started early in the program. They should be funded during the first year of the program. These will be discussed further in the sections on facility funding.

NOVA LAUNCH FACILITY ON SHORE OR OFFSHORE



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SUPPORTING RESEARCH

The spacecraft, the launch vehicle, the facilities, and the crew are the central elements of the program, but in addition there are many supporting items that are required to develop these major elements. These supporting items include the biomedical program, the lunar program, the radiation satellite program and the research program, all of which will be discussed briefly.

Biomedical Program - In the biomedical area, there are two real unknowns. The first unknown is the effect of prolonged weightlessness on human beings; the second is the effect on man of radiation of the type, duration and intensity that might be experienced in lunar flight.

There are several types of radiation. There is cosmic radiation which comes from solar disturbances. There are the types of radiation that will be encountered in the radiation belt around the earth. Then there are the heavy, high energy particles that come from intergalactic space and are extremely difficult to protect against. More must be learned about their effects on living tissue and on the human being.

To learn about some of these things, a human and biomedical program has been laid out as shown in Figure 29. It is broken into two portions, the weightlessness portion and the radiation portion. In the case of weightless-

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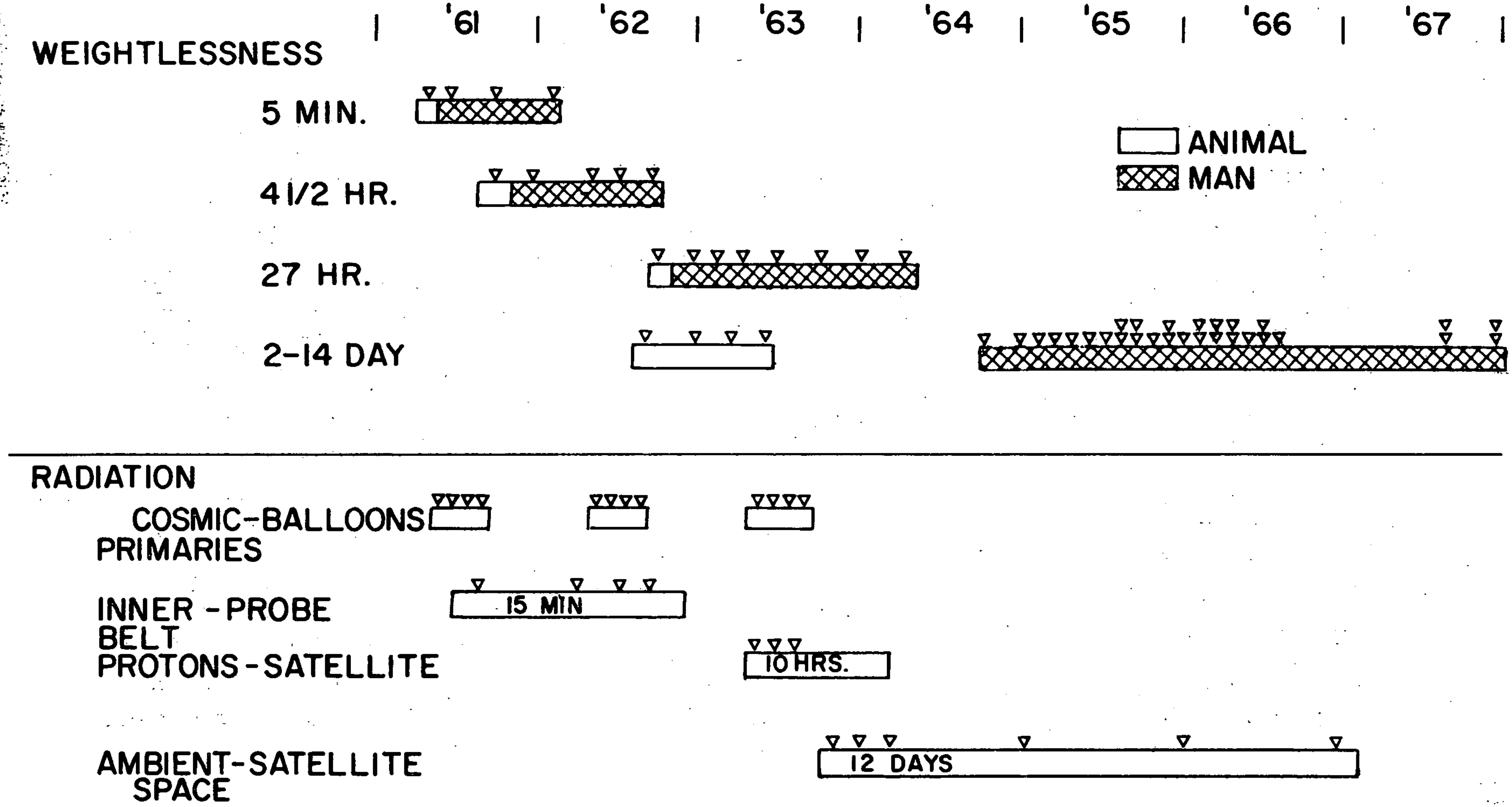
HUMAN AND BIOMED FLIGHTS



ness, there is indicated by year when data will be obtained for various durations. Of course, one flight of five minutes of weightlessness has already been made with the Mercury-Redstone and more are scheduled throughout the year. Beginning late this year, the first three-orbit animal flights are scheduled. Three-orbit ($4\frac{1}{2}$ hours) manned flights in Mercury extend through 1962. At the end of 1962, animal flights will be made, followed by manned flights for durations of 27 hours in a modified Mercury capsule. Thus, data will be available on the effects of weightlessness up to 27 hours. In late 1962 and 1963, with a modified Mercury capsule, animal flights will be made varying from two to fourteen days. Beginning late in 1964, manned flights with C-1's and later with C-3's in orbital and circumlunar missions will gather data on the effects of two to fourteen days of weightlessness on man before the actual Nova flights to the moon. This describes the general buildup of experience expected in the area of weightlessness.

In the case of radiation, considering cosmic particles, there is currently an on-going program of about four balloon launches per year from Ft. Churchill. There is also an on-going program which is expected to continue probing the inner belt protons; this is the extension of the NERV program with recoverable emulsions. Also, a satellite is proposed to be built which can orbit in the inner belt for periods of up to ten hours and be recovered. It is also designed to spend up to twelve days in an elliptical orbit which will take it out to an apogee of some 50 to 60 thousand miles. This spacecraft would be in the order of 2,500 to 3,000 pounds. It might possibly be a variation of the Mercury capsule.

If this appears unfeasible a new capsule will have to be designed. The Office of Life Sciences Programs is currently looking into the possibility of launching a Discoverer experiment in cooperation with the Air Force before mid-1962. This experiment will be launched to an apogee of 2,000 miles with mice and other small life specimens aboard to get some information on the inner belt protons. These data could then be fed into the spacecraft development at an early date.

It is very urgent that these programs be implemented, particularly in the radiation area which is a real unknown. This will verify at the earliest possible date the assumptions that are being made in terms of the protection required in the spacecraft for the crews going on the lunar missions.

It is necessary, likewise, to continue gathering data on weightlessness to make certain that, if artificial gravity is needed, the spacecraft design can be so altered at the earliest possible date.

Solar and Radiation Satellites - Figure 30 shows the program for geophysical and solar observations which are necessary to support the primary mission. The program is divided into three principal areas: Radiation belt satellites, the solar observatories, and the sounding rockets. The flights indicated in the figure are additions to the present programs which are believed to be inadequate. In essence, the flights that are indicated for the radiation belt satellites and the solar observatories approximately double the flight effort in these two areas to insure that an operating radiation satellite and an operating solar observatory are orbiting at all times.

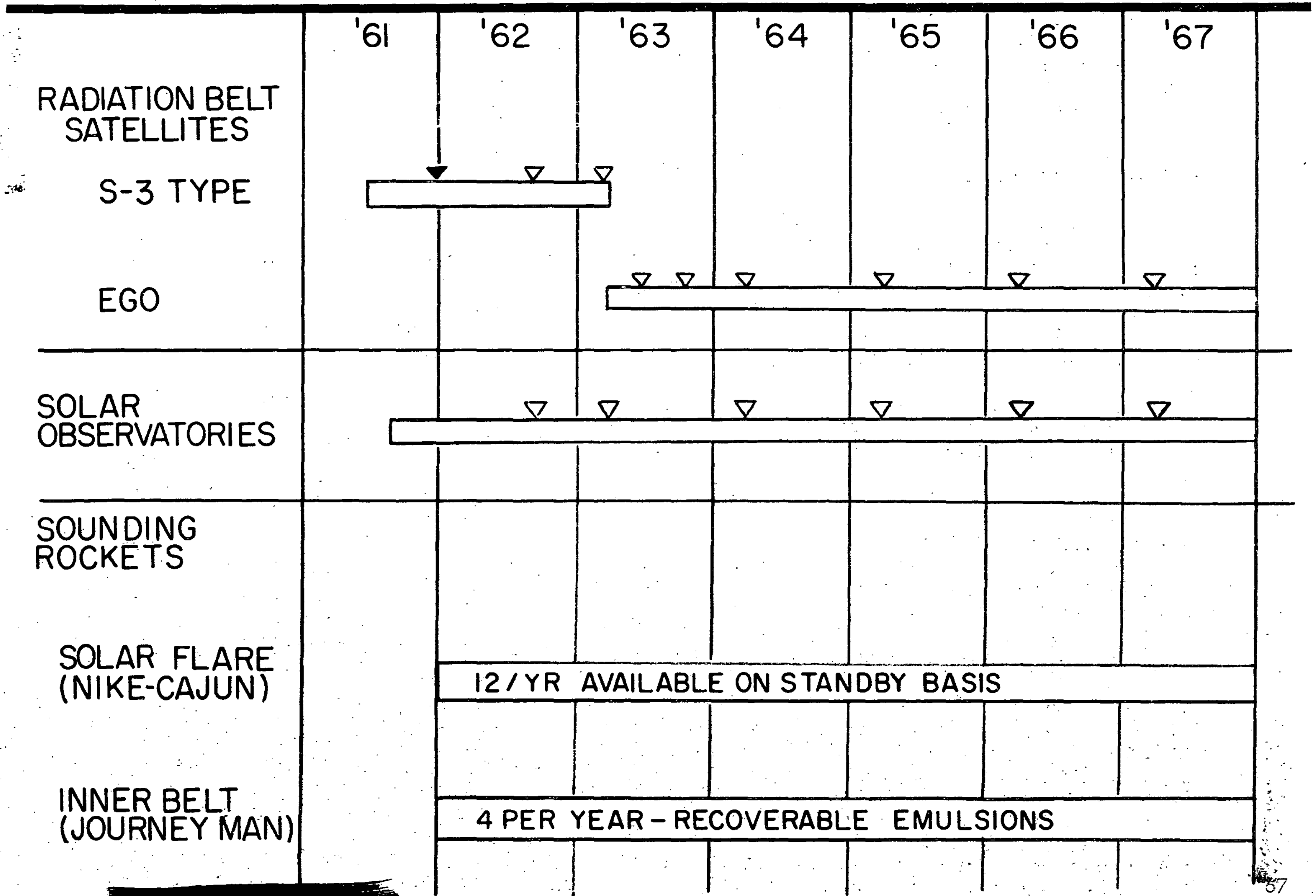
The S-3 type satellites start off the radiation experiments followed by the eccentric geophysical observatories (EGO). The latter will be larger and carry even more experiments. The purpose of these radiation satellites is to detect continually what is happening in the radiation belts. So far, the radiation belt has not changed much since it was discovered, but that is not to say that it will remain constant during the next few years.

There is a continuing program of solar observatories. These satellites gather data on solar activity which will be useful in predicting solar flares and in correlations with the radiation satellite data to indicate the relationship between solar activity and the observed radiation level.

The sounding rocket program consists of the Nike-Cajun solar flare sounding rocket on an approximately twelve per year available basis should a solar flare occur. These will obtain solar flare data with recoverable emulsions. The radiation belt satellites, due to the eccentricity and the inclination of their orbits, do not always pass through the radiation belt. To get to the heart of the radiation belt, the Journeyman sounding rockets will be used at the rate of about four per year with recoverable emulsions.

All of these are important supporting programs that require emphasis and acceleration.

GEOPHYSICAL AND SOLAR OBSERVATIONS



[redacted]

Unmanned Lunar Program - The unmanned lunar program has four parts, as shown in Figure 31. These are: the radiation environment in space, unmanned lunar exploration giving preliminary information about the moon, lunar landing site surveys and, finally, actual operational support of the manned mission with the lunar spacecraft. The program thus consists of Rangers I and II, followed by the Mariners. The gap in the Mariner program is filled by two more proposed Ranger I and II flights. The purpose of these flights is to provide radiation data in deep space out well beyond the earth's magnetic field to indicate the radiation environment in the entire cislunar space.

For initial unmanned lunar exploration, the Ranger capsules are used. These are followed later in 1963 by the Surveyor soft lander and, in mid-1964, by the Surveyor lunar orbiters. The orbiters will survey in more detail the landing sites. A current requirement for the landing site is an area of ten miles by 300 miles that is free from any vertical obstructions higher than 50 feet. With the Surveyor lander and orbiter, some of the smooth spots on the moon can be surveyed in an attempt to lay out these sites.

The Prospector is considered to be a large bus which can be used to transport anything from instruments to equipment to support the manned flight to the moon. The Prospector would be launched by the C-3 and transport a useful payload of between 3,000 and 4,000 pounds to the moon. It is proposed that the Prospector flights begin in mid-1965. Of course, the early flights would really be for developing the Prospector spacecraft. Since they would be launched well before any men would be on the moon, their payload would consist of scientific instruments and instruments to aid in further laying out the lunar landing site. It is difficult to determine at this time what the equipment should be. This really has to be defined and it is something which must be done soon. Prospector is an important part of the program because by mid-1967 it will be used to transport items to the moon which will support manned exploration. It is very likely that, if not in the first flight, at least in later flights the men are going to need some kind of ground transportation -- small machines which will give them a limited range of action on the surface of the moon. They are going to need additional oxygen as well as other life support equipment. They may well want structures that they can bolt together easily and live a little more comfortably than they can live in the capsule if they are to extend their stay on the moon. Thus, the Prospector is an important part of the program, and even though the Nova can be used for transportation, it appears to be much too large to transport the types of things needed for life support. The real justification, then, for Prospector is that it can be used to support an operating manned mission on the moon.

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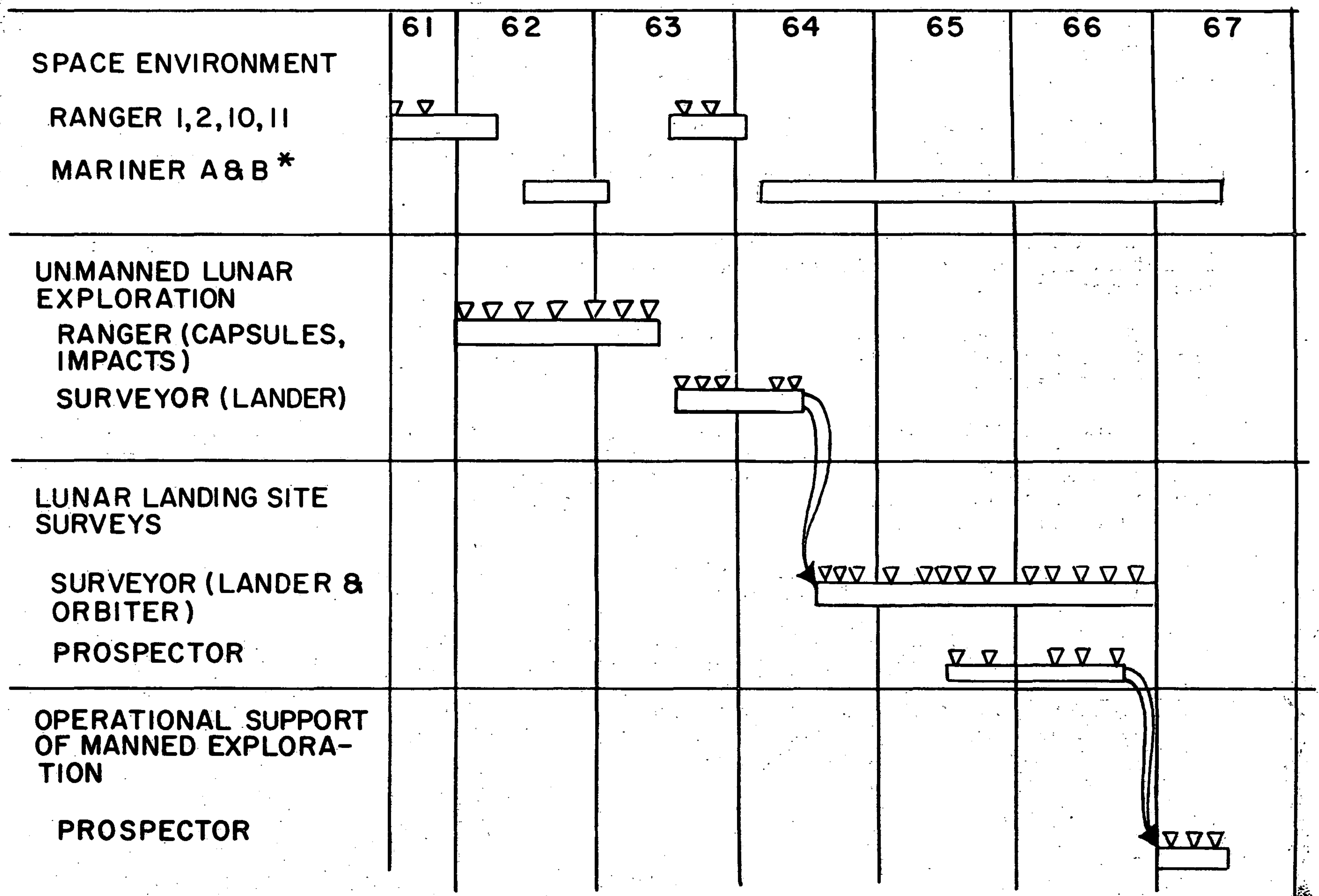
UNMANNED LUNAR FLIGHT PROGRAM



* PART OF PLANETARY PROGRAM, FUNDED SEPARATELY

[redacted]

Advanced Research - The advanced research and technology effort is geared to develop the information needed in designing the spacecraft and launch vehicles. Some of these critical areas are itemized in Figure 32.

The reentry heating, structures, materials and aerodynamics research will give a broad base on which to establish the design of the vehicles and spacecraft.

Secondly, navigation, guidance and control research will aid in developing improved accuracy and improved reliability. Injection guidance is well developed but much better definition of the system adequacy and the instrumentation is needed for midcourse control.

Radiation and shielding is associated with the effects of radiation on inorganic materials, on electronic equipment, the characteristics of materials making up the structure, etc.

The next item listed, lunar landing techniques, propulsion, guidance (including the piloting problems), is a wide open field. There is a real need to define some of the problems in this area.

Launch vehicle design and structural dynamics and control involve consideration of windshear problems, in-flight loads, system dynamics, launching and in-flight forces, stage separation, etc. Basic and fundamental data and design rules are needed to allow design of complete systems with much higher reliability and certainty of successful operation.

With regard to noise and explosion hazards, data are really meager in the very high noise energy levels of the sort generated by large vehicles.

The importance of the work in these areas cannot be overemphasized. New programs must be established and current programs accelerated in order to develop the necessary information in a timely and useful manner. There are, of course, many other research and technological problems of a lesser nature which must also be pursued on an accelerated basis in order to provide the early information needed to perform the basic mission successfully.

ADVANCED TECHNOLOGY
CRITICAL AREAS

- REENTRY HEATING, STRUCTURES AND MATERIALS, AERODYNAMICS
- NAVIGATION, GUIDANCE, AND CONTROL
- RADIATION AND SHIELDING
- LUNAR LANDING TECHNIQUES, PROPULSION, GUIDANCE (INCLUDING PILOTING PROBLEMS)
- LAUNCH VEHICLE DESIGN, STRUCTURAL DYNAMICS, AND CONTROL
- NOISE AND EXPLOSION HAZARDS

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EARLY MANAGEMENT ACTIONS REQUIRED

A vast and complicated program such as this has a large number of interacting components. It also has a very large number of unknown areas that must be explored. It is going to require a very large, well coordinated and energetic effort to get the job done successfully in the shortest possible time. In order to implement the program at the earliest possible date, there are a number of important management actions anddecisions that must be made during the first six months of the program. Figure 33 summarizes these in an effortto help point the way to getting the program started.

The first action is an obvious one: NASA must assign program management and system responsibility.

With regard to the spacecraft, several actions are necessary: Atlas Agena-B vehicles must be contracted for to conduct reentry tests to obtain reentry heating data for spacecraft heat shield design, an A&E contract must be initiated for a space flight center and its accompanying spacecraft test and development equipment, a contract for a new tracking station in South America must be let for the 18 orbit flights, the Apollo contract must be let, and the crew selection and training plan must be established.

Regarding the launch vehicle, the following actions are needed. First, complete preliminary overall systems design and integration studies must be made. This is the point made previously: that studies directed toward complete system design are needed which will lay down the design specifications and the design criteria for the individual stages. Second, accelerate the F-1 engine funding. Third, contract for the C-3 first stage development. This involves the first stage development for both the liquid and the solid C-3. Fourth, contract for the development of the liquid and solid Nova first stages. Even though the first Nova flight is about one year behind the first C-3 flight, it requires that additional year for design and development. Fifth and finally, contract for the Nova solid motor development. Since this development has been assigned as an Air Force responsibility, contract will be let by the Air Force.

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[redacted]

MAJOR MANAGEMENT DECISIONS AND ACTIONS REQUIRED DURING FIRST 6 MONTHS OF PROGRAM

PROGRAM

- ASSIGN PROGRAM MANAGEMENT AND SYSTEM RESPONSIBILITY.

SPACECRAFT

- CONTRACT FOR ATLAS AGENA-B MODEL REENTRY TESTS.
- INITIATE A&E CONTRACT FOR SPACE FLIGHT CENTER AND EQUIPMENT.
- CONTRACT FOR 18 ORBIT TRACKING STATION.
- LET APOLLO CONTRACT.
- ESTABLISH FLIGHT CREW MAKE-UP, SELECTION TECHNIQUES AND GENERAL TRAINING PLAN.

LAUNCH VEHICLES

- COMPLETE PRELIMINARY OVER-ALL SYSTEMS DESIGN AND INTEGRATION STUDIES.
- ACCELERATE F-1 ENGINE FUNDING.
- LET CONTRACT FOR C-3 FIRST STAGE DEVELOPMENT (LIQUID AND SOLID).
- LET CONTRACT FOR NOVA FIRST STAGE DEVELOPMENT (LIQUID & SOLID STAGES).
- LET CONTRACT FOR NOVA SOLID MOTOR DEVELOPMENT.

[redacted]

With regard to facilities, there are many separate actions to be taken. Basically, management must examine the needs carefully and initiate the support and construction necessary on an urgent basis to provide schedule implementation of this pacing element of the program.

In the area of supporting technology, there are six important actions needed in the first six months. First, the biomedical satellite program must be initiated. This is the 2,500 to 3,000 pound satellite that will go into the inner and outer radiation belts and be recoverable. Second, the 18 orbit Mercury flights must be funded. Third, contract for spacecraft modifications for the fourteen day animal flight must be let. Fourth, go-ahead on the development of Prospector must be given. This is not the funding, there is considerable in-house planning required before money need be assigned to the system. Fifth, accelerate the funding for the radiation satellite program. Sixth and finally, to provide timely technological support the advanced research programs must be accelerated.

The accomplishment of the manned lunar landing mission in this decade is going to be a tremendous technological monument of our time. It is going to require the utmost care in selecting the proper course of action to insure its successful completion in the shortest length of time.

MAJOR MANAGEMENT DECISIONS AND ACTIONS REQUIRED DURING FIRST 6 MONTHS OF PROGRAM

(CONTINUED)

FACILITIES

- INITIATE FACILITIES TO SUPPORT PROGRAM.

SUPPORTING TECHNOLOGY

- INITIATE BIOMEDICAL SATELLITE PROGRAM.
- FUND 18 ORBIT MERCURY FLIGHTS.
- LET SPACECRAFT MODIFICATION CONTRACT FOR 14-DAY ANIMAL FLIGHTS.
- GIVE GO-AHEAD ON DEVELOPMENT OF PROSPECTOR PROGRAM.
- ACCELERATE FUNDING FOR RADIATION SATELLITE PROGRAMS.
- INITIATE AND ACCELERATE SUPPORTING RESEARCH PROGRAMS.

PROGRAM FUNDING

The last nine figures present the cost aspects of the program. Figure 35 shows the elements of the NASA program associated with the manned lunar landing mission. This list comprises the "budget package" considered in the program cost. It includes the unmanned lunar program in toto, that is, the Ranger, Surveyor and Prospector. Additional radiation satellites and sounding rockets over and above what had normally been planned are included. The entire Saturn C-1 program, the C-3 and the liquid Nova, with all their supporting facilities and launch pads, are in the package. The total F-1, J-2 and the Y-1 engine (the new 800,000 to one million pound thrust liquid hydrogen engine) development are included. The Y-1 is in the program primarily as a backup but it will be needed probably for future launch vehicles as well. The Mercury follow-on, that is, the 18 orbit and 14 day animal program, the total Apollo program, most of the Life Sciences program, are all in the "budget package." The latter includes the new recoverable bio-satellite which is as yet undefined; it may be a new spacecraft or a modification of an existing capsule, such as Mercury. The new manned space flight center and accelerated advanced technology programs are included. This last does not include all of the NASA advanced technology but that accelerated portion needed in the early part of the decade to accomplish manned lunar landing.

The "budget package" presented does not include solid rocket engine and stage development, support or facilities although these have been priced. It does include launch site A&E for vehicle configurations using solid booster stages. It does not include orbital rendezvous which is considered a necessary but separate program. It does not include in-house S&E and Support of Plant. It does not include new Atlas launch pads which may be found necessary for the Agena and Centaur program presented earlier.

SPECIAL STUDY TASK

MANNED LUNAR PROGRAM BUDGET PACKAGE

INCLUDES

- UNMANNED LUNAR PROGRAM
- NEW RADIATION SATELLITES AND ROCKETS
- SATURN C-1, SATURN C-3, NOVA II
- F-1, J-2 AND Y-1 ENGINES
- MERCURY FOLLOW-ON
- APOLLO
- LIFE SCIENCES - BIOSATELLITE
- NEW MANNED SPACE FLIGHT CENTER
- ACCELERATED ADVANCED TECHNOLOGY

DOES NOT INCLUDE

- SOLID ROCKET ENGINE, STAGES AND SUPPORT
- ORBITAL RENDEZVOUS
- IN-HOUSE S&E AND SUPPORT OF PLANT
- ATLAS LAUNCH PADS

Figure 36 shows the budget guidelines or assumptions under which the budget was drawn up.

The first assumption is that a strong management group will be formed which has adequate authority to make the proper decisions and move fast in implementing the program.

Secondly, with regard to procedures, Armed Services Procurement Regulations (ASPR) have been used throughout. This means there is no assumption of any change in our regular business procedure. However, there is freer use of letter contracts than in the past.

Third, manufacturing and much of the design, etc., will be done "out-of-house." The in-house facilities and laboratories and centers will be used to provide specifications, contract monitoring and some system integration, etc.

Fourth, with regard to contractor selection, the ground rule was established that R&D contracts would take a minimum of twelve weeks to let. This minimum time must include the competition, evaluation and contractor selection phases. This is admittedly fast; some abbreviation or overlapping of the procedures may be required in certain cases.

As to construction of facilities, a minimum of 38 to 40 weeks is assumed for developing design criteria, A&E design and award of the construction contract. One of the most important assumptions made is that of incremental C of F funding, that is, funding as money is needed for the various phases of facilities development. This was found to be a necessary ground rule since the facilities turn out to present a much more accelerated requirement than had been anticipated; it would increase the FY 1962 and 1963 budget requirements out of all proportion if incremental C of F funding were not used.

Finally, all Saturn C-3 and Nova vehicles are budgeted under the launch vehicle item. All other vehicles which are operational, e.g., Agenas, Centaurs, and C-1's are budgeted by the mission. This is in keeping with the way it has been done in the past. This last ground rule is not to establish a policy; rather it was used as a budget guideline to expedite the budgeting process in this exercise so that money will not have to be transferred from pocket to pocket.

SPECIAL STUDY TASK

BUDGET GUIDELINES

- STRONG MANAGEMENT GROUP
- ASPR PROCEDURES THROUGHOUT
- PRIMARILY OUT-OF-HOUSE
- ACCELERATED CONTRACTOR SELECTION
  - R&D - 12 WKS MIN TO CONTRACT
  - C OF F - 38-40 WKS TO CONSTRUCTION CONTRACT
- INCREMENTAL C OF F FUNDING
- ALL SATURN C-3 AND NOVA VEHICLES BUDGETED BY LAUNCH VEHICLES

Figure 37 presents a total funding picture. While an arbitrary start date of July 1, 1961 was chosen, actually the budget picture can be broken up into a year-by-year basis. Thus, the start date can be adjusted backwards or forwards as required. It is seen that the first year, or first twelve months from the start date, requires 846 million dollars for R&D and 272 million-dollars for C of F. It is seen that the buildup in R&D occurs, as might be expected, about midway in the program. However, C of F buildup occurs much earlier than might have been anticipated. Large expenditures are required for C of F the first year; the second year is the peak year and its requirements are much larger even than for the first year. The total program money requirements are slightly less than 12 billion dollars.

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TOTAL FUNDING REQUIREMEMENTS

SPECIAL STUDY TASK

(IN MILLIONS OF $) YEAR

	1 st	2 nd	3 rd	4 th	5 th	6 th	TOTALS
R&D	846	1755	2795	2728	1541	813	10,478
C of F	272	546	316	70	1	-	1,205
TOTALS	1118	2301	3111	2798	1542	813	11,683

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Figure 38 shows the funding requirements broken down into categories. The spacecraft item includes the Apollo, lunar landing and takeoff stages, the 18 orbit and the 14 day animal programs, the biomedical satellite itself, exclusive of its instruments, and procurement of all the operational launch vehicles through Saturn C-1 to support these programs.

In launch vehicles and operations, the entire C-1, C-3 and Nova development programs are included.

The lunar and space sciences item includes the total unmanned lunar program as well as the EGO's, radiation satellites and others considered as necessary additions for the manned lunar program.

Life Sciences has already been explained. It includes all the associated satellite specimens and instrumentation as well as the accelerated medical program and the selection and training of astronauts.

The range and tracking instrumentation requirements occur earlier than expected.

The advanced technology builds up at a fast rate and phases out about half way through the program because the information is required early.

On a percentage basis, the spacecraft is about 33 percent of the total, the launch vehicle is about 50 percent of the total, supporting science and technology, that is, the lunar and space sciences, life sciences, and advanced technology taken together come to about 15 percent and range and tracking instrumentation about 2 percent of the total.

TOTAL FUNDING

SPECIAL STUDY TASK

R&D AND C of F

(IN MILLIONS OF $)

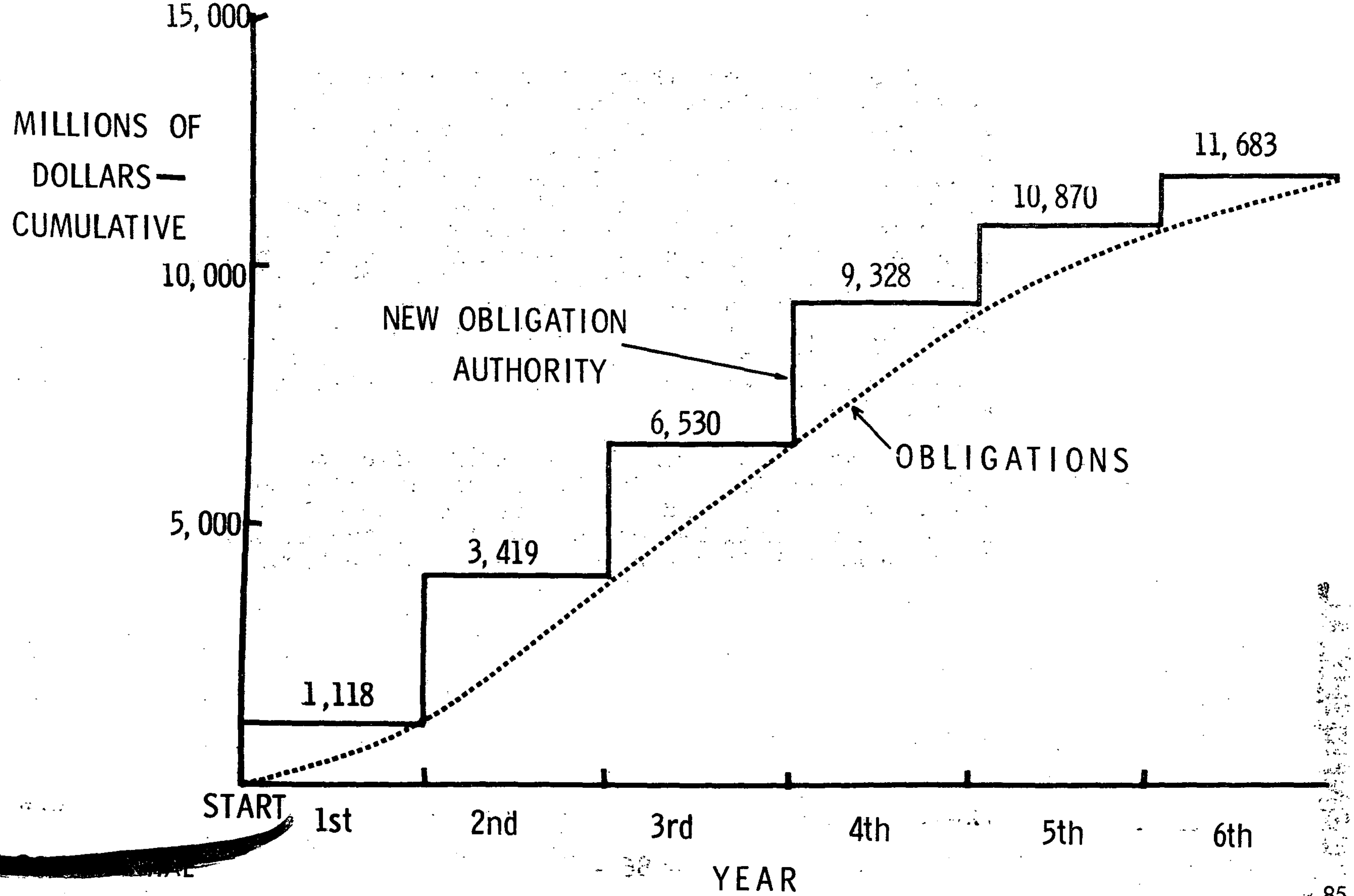
	YEAR						
	1 st	2 nd	3 rd	4 th	5 th	6 th	TOTALS
SPACECRAFT	225	586	1,045	1,176	570	255	3,857
LAUNCH VEHICLES & OPERATIONS	660	1,279	1,597	1,224	644	278	5,682
LUNAR AND SPACE SCIENCES	140	236	317	312	295	269	1,569
LIFE SCIENCES	30	49	47	46	33	11	216
RANGE & TRACKING INSTR	31	98	89	40	-	-	258
ADVANCED TECHNOLOGY	32	53	16	-	-	-	101
TOTAL	1,118	2,301	3,111	2,798	1,542	813	11,683

Figure 39 shows cost by year. The total cost is shown as 11.683 billion dollars.

[redacted]

SPECIAL STUDY TASK

CUMULATIVE FISCAL REQUIREMENTS



[redacted]

Figure 40 shows those elements of the program already included in the current 1962 budget. In launch vehicles, it is seen that Saturn, Nova propulsion technology, propulsion facilities, Nova launch facilities and all Saturn facilities are extracted. In the spacecraft, the Apollo program and the manned space flight center are extracted. In range and tracking station instrumentation, the total lunar program plus the additional scientific satellite flights identified with this program are extracted. Practically all of the life sciences program, the advanced technology program and some facilities that were associated with advanced facility design are also included.

In the current Fiscal Year 1962 budget then, 668 million dollars of R&D funds, and 191 million dollars of C of F funds for a total of 859 million dollars are available for application to the manned lunar program budget package under consideration.

SPECIAL STUDY TASK

[redacted]

NASA FY 62 BUDGET CREDIT

(IN MILLIONS OF $)

	R&D ITEM	R&D TOTAL	C OF F ITEM	C OF F TOTAL
LAUNCH VEHICLES		358		121
SATURN	224			
NOVA	48			
PROPULSION TECH	86			
PROPULSION FACILITIES			31	
NOVA LAUNCH FACILITY			28	
SATURN FACILITIES			62	
SPACECRAFT		160		60
APOLLO	160			
MANNED SPACE FLIGHT CENTER			60	
RANGE AND TRACKING INSTR.			5	5
LUNAR AND SPACE SCIENCES		131		
LUNAR PROGRAMS	120			
SCIENTIFIC SATELLITES	11			
LIFE SCIENCES	19	19		
ADVANCED TECHNOLOGY				5
ADVANCED FACILITY DESIGN			5	
	R&D	668		191
	C of F	191		
		859		

[redacted]

Figure 41 compares the present NASA manned lunar program budget of 859 million dollars for 1962 and the preliminary manned lunar budget of 2.5 billion dollars for 1963 with the funding requirements developed in this study for the same years. It should be kept in mind that the latter need not be specifically identified with particular fiscal years.

The totals for the two years combined are relatively close -- 3.359 billion versus 3.419 billion. Costs for the first year, however, are considerably different -- 1.118 billion versus 859 million. This latter discrepancy can be corrected by choosing a later start date to give an expenditure for FY 1962 corresponding to the present budget.

[redacted]

MANNED LUNAR LANDING

FUNDING COMPARISON

(IN MILLIONS OF $)

	FY 62	FY 63	TOTAL
NASA BUDGET	859	2500	3359
	1st yr	2nd yr	TOTAL
STUDY TASK	1118	2301	3419

WHAT START DATE CORRESPONDS TO NASA FY 62 BUDGET?

[redacted]

It was mentioned earlier that the start date chosen (July 1, 1961) was arbitrary and there could therefore be some sliding around of the schedule. This flexibility was utilized in matching the FY 1962 requirements with the present budget. The total time span in the program of about six years and the total program cost of 11.683 billion dollars were kept constant. Figure 42 shows the results of this for FY 1962 and 1963. It was found that a start date of August 15, 1962 (a six week re-orientation in start date) would make the cost match the present FY 1962 budget figures. Because of the usual parabolic buildup of cost curves, the second year's (FY 1963) requirements were such that the two year totals matched to within three percent.

When the R&D and C of F funding obligation rates were considered it was found that the FY 1962 NASA budget totals for R&D and C of F each appear adequate.

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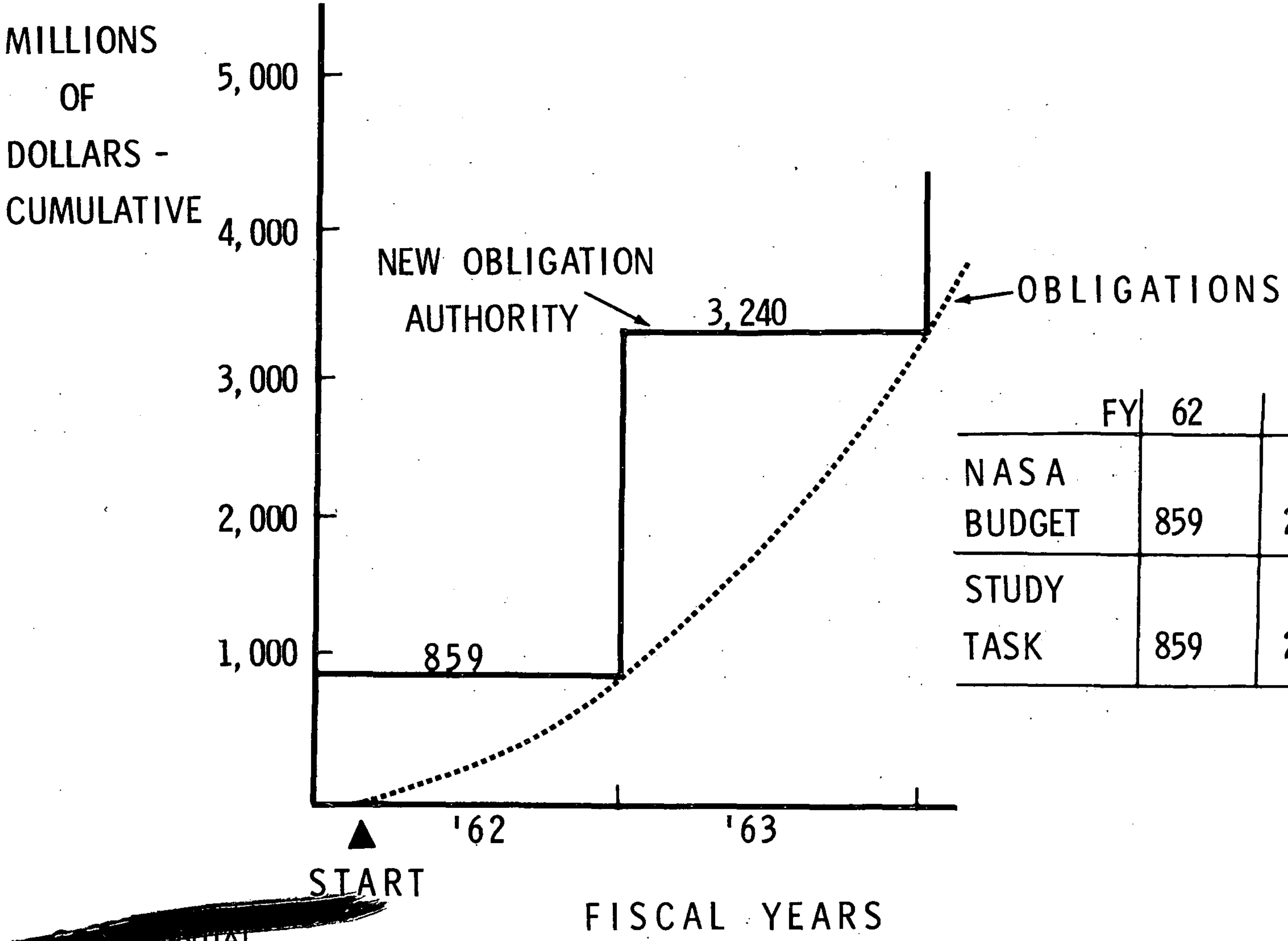
SPECIAL STUDY TASK

CUMULATIVE FY 62 AND FY 63 REQUIREMENTS
START AUGUST 15, 1961



FY	62	63	TOTAL
NASA BUDGET	859	2,500	3,359
STUDY TASK	859	2,381	3,240

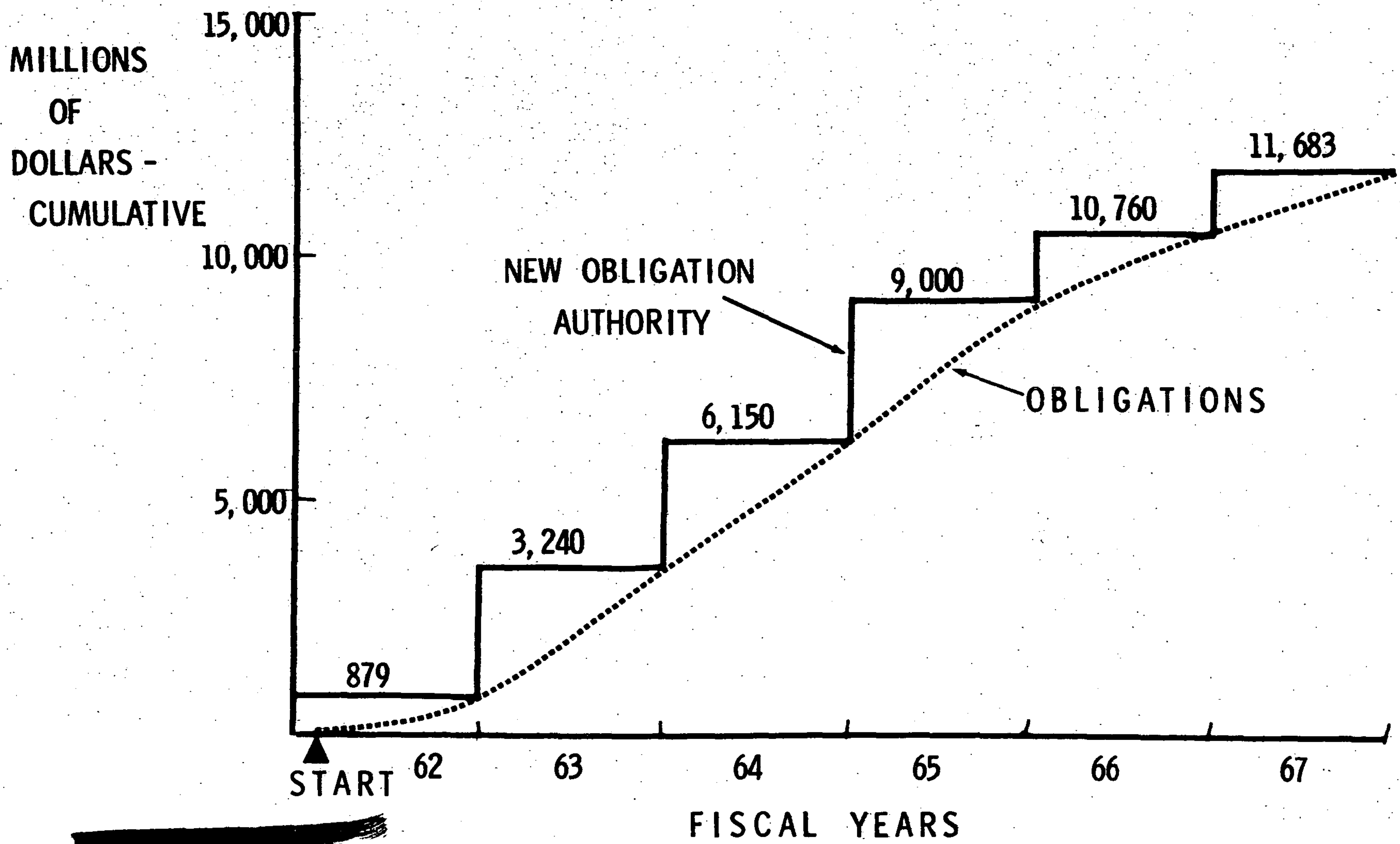
[redacted]

Figure 43 shows the total program adjusted again to the new start date of August 15. It should be emphasized again that this funding is necessary to get a crew safely on the moon and back again. There are, of course, other programs being carried out at the same time, e.g., the manned lunar station, etc., which would add to the costs presented. Only the manned lunar landing program "package" is considered here.

It is believed that the total amount and the year-by-year requirements are within reasonable limits even assuming some unforeseen circumstances. The FY 1962 total budget as well as the separate R&D and C of F funding totals appear adequate for a reasonable start date -- August 15. Facilities have always required special care in scheduling and funding and will become even more critical this program because of their pacing nature. Thus, one recommendation resulting from this budget analysis is that more flexibility is needed in C of F funding.

SPECIAL STUDY TASK

CUMULATIVE FISCAL REQUIREMENTS
START AUGUST, 15, 1961



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CONCLUSIONS

1. The study has indicated that a manned lunar landing and return mission is feasible approximately six years after program initiation, thus putting it in the 1967 time period.

2. A number of major management decisions and actions are required during the first six months of the program. Because these decisions and options encompass all aspects of the program, nearly simultaneous action is required in all program areas to insure integration and time phasing in a manner conducive to accomplishment of the manned lunar landing mission in the shortest time and at the least total cost.

3. It is estimated that the total program cost, within the funding guidelines of the study, will amount to nearly twelve billion dollars extending over a six year period. Unforeseen technical difficulties or an extension of the time required to complete the program will increase the total cost accordingly.

4. A strong management organization is required to direct the program. This organization should have broad authority in controlling and coordinating the various aspects of the program. This item is extremely urgent, as such an organization must be established before many of the key decisions can be made and important actions can be taken that are essential to timely and effective initiation and implementation of the program.

5. There are two areas in which information is vitally needed to support design of the spacecraft and its lunar landing system. These areas are: 1) the amount of solar radiation protection required for the crew and 2) lunar surface characteristics.

6. Facility construction and letting of the first stage development contracts are pacing items in the area of launch vehicle development. Pacing facility items are the first stage test stands and launch facilities for both the Saturn C-3 and the Nova. Both Nova and the C-3 must be started simultaneously to insure proper time phasing of the program.

7. Because construction of major supporting facilities must be started during the first two years of the program, increased flexibility of facility funding, i.e., incremental funding, etc., will be required in order to avoid an excessive fiscal impact during the early years of the program.

8. Parallel development of liquid and solid first stage boosters for the Saturn C-3 and Nova will be extremely costly. However, it will be virtually impossible to select either one in preference to the other solely on the basis of their relative performance and reliability until two to three years after start of the program, because of the lack of operating experience with large solid rockets.

9. The several areas of advanced research that support the program should be expanded or accelerated to provide the basic information needed in a timely manner.

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