093808

U. S. GENERAL ACCOUNTING OFFICE

STAFF STUDY

VIKING '75 PROJECT

National Aeronautics and Space Administration

FEBRUARY 1973

~~713075~~ 093808

Contents

ABBREVIATIONS

FAT	Flight Acceptance Tests
JPL	Jet Propulsion Laboratory
MMC	Martin Marietta Corporation
NASA	National Aeronautics and Space Administration
OMB	Office of Management and Budget
VPO	Viking Project Office

SUMMARY

VIKING PROJECT

SYSTEM DESCRIPTION AND STATUS

The Viking Project will launch two unmanned spacecraft to Mars in 1975. Each spacecraft will have a lander and an orbiter. The purpose of the project is to obtain atmospheric and surface information concerning Mars. The Viking Project Office (VPO) and overall management is at Langley Research Center, Hampton, Virginia.

COMING EVENTS

During 1973, the majority of VIKING's parts, components and subsystems will enter a critical design development testing phase.

COST

When presented to the Congress in March 1969, the project was estimated at $364 1 million. This was not a sound estimate because the project had not been clearly defined at that date. By August 1969, VPO had essentially completed negotiating one contract, obtained considerably more data and more clearly defined the project mission. The project was then estimated at $694.8 million. This included $64 million for inflation and $85 million for contingencies. A further increase of $102 2 million occurred following a decision in January 1970 to delay the project 2 years. Other cost increases, principally for scientific support, increased the estimate to $829.4 million in August 1972 These estimates exclude the cost of Titan III/Centaur launch vehicles which are currently estimated at about $86 million including shroud development and mission peculiar costs.

CONTRACT DATA

The lander is designed and constructed under a cost plus award fee/ incentive fee contract with Martin Marietta Corporation, Denver, Colorado. The orbiter is being designed and constructed by the Jet Propulsion Laboratory, Pasadena, California, under a cost reimbursable contract.

PERFORMANCE

There have been no significant deviations from the established performance requirements.

PROGRAM MILESTONES

The spacecraft were originally scheduled for launch in July and August 1973. Component delivery and testing schedules were established to meet these launch dates. However, in January 1970, the launches were rescheduled for 1975 due to budget constraints. A delay of two years was necessary because prime launch opportunities occur only at 25-month intervals. At the time of our review, no major delays in meeting these new dates were foreseen.

RELATIONSHIP TO OTHER SYSTEMS

Viking follows the Mariners in the series of NASA Mars exploration missions. Mariner IV, which flew by the planet in 1965, obtained the first close-up pictures of the Mars surface. Mariners VI and VII followed in 1969 and the latest flight, Mariner IX was in 1971.

TESTING PROCEDURES

The performance requirements and related testing procedures established by VPO are extensive. They are designed to produce parts, components, and subsystems that will endure conditions exceeding the worst environment known to confront the project. The extensive performance test requirements in instances "stretch" the state of the art. This, in turn, has increased the project cost to an undeterminable extent.

Only limited design development testing had been completed when we concluded our review. VPO has an extensive overview and reporting system to detect problems early. The actions taken to cope with problems indicate the system is adequate to identify technical problems and extensive performance test requirements and to permit reassessing the performance requirements in terms of cost to meet them and the risk of failing to meet the requirements within the prescribed time frame.

During 1973, the majority of Viking's parts, components, and subsystems will enter a critical design development testing phase. Particularly during this period, it will be essential that original judgments to set high performance/test requirements be constantly reassessed **in favor of alternatives which are consistent with the mission as problems are encountered.**

PROGRAM MANAGEMENT

The Project Manager has established a system of control which enables him to closely survey the project.

PROGRESS MEASUREMENT

Through the VPO system of progress measurement, the Viking Project Manager has a timely overview of overall project cost and progress towards achieving program milestones and performance requirements

MATTERS FOR CONSIDERATION

VPO gathers much of the same type data that the Congress requires from the Department of Defense on the status of major weapon systems However, NASA's data would probably have to be refined to facilitate reporting on program status in a format similar to that required of the Department of Defense.

Viking's costs are not recorded to separately distinguish design and testing costs from production costs. Because of the extensive testing prescribed by VPO, we believe it would be helpful if the cost of testing were separately recorded and reported to the Congress.

We believe that data on changes in costs, scheduled milestones, and performance characteristics--similar to the reports the Department of Defense submits on major weapon systems--would be useful to the Congress in evaluating the Viking Project. We are suggesting that NASA prepare such reports periodically for submission to the Congress, that these reports contain details on budgeted and actual cost of testing, and that significant information regarding the risk in meeting performance characteristics be reported.

AGENCY COMMENTS

A draft of this staff study was reviewed by NASA officials. In commenting on the draft, NASA expressed primary concern with (1) our proposal that the cost of testing be separately recorded and reported to the Congress, and (2) our chapter on testing procedures which NASA felt contained an inplication that its testing requirements are excessive

NASA also provided us with detailed comments which have been incorporated as appropriate As far as we know there are no residual differences in fact. A copy of NASA's reply dated March 2, 1973, is included as Appendix VIII

Our proposal that NASA separately distinguish design and testing costs from production costs was made primarily to provide NASA management and the Congress with visibility over the degree of new technology required in individual programs. In our opinion, such visibility would be useful in comparing the benefits to be derived from new high technology programs with the resources to be consumed.

It is not our intention to infer that NASA's testing requirements for the Viking are excessive. In fact we have recognized in this report the ability of NASA's reporting system to identify during testing those test or performance requirements which may not be needed so that adjustments to the testing program can be made where appropriate in order to conserve resources.

CHAPTER 1

INTRODUCTION

This is the first staff study of the Viking Project. It concerns changes to the program from the time of initial submission to the Congress through August 1972, test and evaluation procedures, and the method by which the program is managed and progress is measured

PROJECT DESCRIPTION AND OBJECTIVE

Viking is part of the National Aeronautics and Space Administration's (NASA) plans for the systematic investigation of space and the planets. Its objective is to significantly advance the knowledge of Mars by measurements in the atmosphere and on the surface and observing the planet during approach and from orbit. Particular emphasis will be placed on obtaining information about biological, chemical, and environmental factors relevant to the existence or potential existence of life on the planet.

Two spacecraft, each consisting of an orbiter and a lander, will be launched from Cape Kennedy between mid-August and mid-September 1975. They will provide for landings at different locations on Mars. They will be launched by Titan III/Centaur rockets.

The flight to Mars, 460 million miles, will require slightly less than 1 year In cruise, the orbiter will supply electric power, attitude control and propulsion for mid-course corrections.

While in Mars orbit, the spacecraft will transmit data on preselected landing sites. This may continue for 2 months, while the landing sites are confirmed or new sites are selected.

Pursuant to an international agreement, the lander will be sterilized and sealed in a capsule prior to launch. This capsule will be discarded in orbit prior to the landing.

Upon entering the Martian atmosphere, the lander will deploy a parachute. At 5,000 feet, the parachute will be jettisoned and retro-rockets fired, permitting a soft landing. During its descent, measurements will be made of Mars' atmospheric composition, pressure, temperature and density.

The orbiter will relay data from the lander. It will also obtain data concerning characteristics of the planet's surface and atmosphere.

The lander is designed to function for at least 90 days on the surface of Mars. It must withstand 150 to 200 mile winds and temperatures varying from 100°F to -180°F

Cameras aboard the lander will photograph the landing site and surrounding area Soil samples will be obtained by an extendable boom and analyzed aboard the lander.

Photographs of the spacecraft and mission sequence furnished by NASA are shown in Appendix I through V.

SYSTEM HISTORY

The Viking Project can be traced to the Voyager--an earlier more extensive project to explore the solar system with unmanned spacecraft. It initially included two missions to Mars in 1971. It was later revised to include two missions one to Mars in 1973, and one to either Mars or Venus in 1975 Two identical spacecraft were planned for each mission. Both the orbiter and lander were to survive 1 year. The weight of each 1973 spacecraft was to be 20,000 pounds The estimated cost of the program was $1.8 billion for the 1973 and 1975 spacecraft and $400 million for launch vehicles.

In August 1967, NASA cancelled the Voyager Program because it anticipated that the Congress would not approve future funds for the program. At the time of cancellation, NASA had spent $32 million on preliminary studies

A project similar to Viking (the Titan/Mars) was first proposed in NASA's fiscal 1969 budget. The Titan/Mars was similar to Viking except that it provided for a rough landing on the surface of Mars. Congress did not fund the Titan/Mars program.

The Viking Project was first proposed in the fiscal 1970 budget and was approved

A NASA representative said about 50 percent of the Voyager's preliminary planning was directly applicable to Viking.

Initially, the Viking spacecraft were to be launched in 1973. This would have required the spacecraft to travel 310 million miles and would have taken about 6 to 7 months to reach Mars. Due to budget constraints, NASA rescheduled the launch dates from 1973 to 1975. The delay of about 2 years was necessary because prime launch opportunities occur only at 25-month intervals Since the planets will be in different positions in 1975, the spacecraft must travel 460 million miles

PROJECT RESPONSIBILITY

NASA's Office of Space Science and Application selected the Langley Research Center, Hampton, Virginia, as the Viking management center. It was given the overall management responsibility for the project, including the design, construction, and systems integration of the landers. Other NASA centers and their assigned responsibilities are shown below.

Center	Responsibility
Jet Propulsion Laboratory Pasadena, California	Responsible for the orbiter under a cost reimbursable contract. This includes the design and construction as well as the scientific payload for the orbiter. The laboratory is also responsible for the tracking and data systems for the Viking Project
Lewis Research Center Cleveland, Ohio	Responsible for the launch vehicle--Titan III/Centaur.
John F Kennedy Space Center, Florida	Responsible for launch and operations of the project.

The lander is being designed and constructed under a cost plus award fee/incentive fee contract with Martin Marietta Corporation (MMC), Denver, Colorado. MMC is also responsible for testing the lander and its systems, for its interface with the orbiter and the launch and flight operations system, and for assisting the VPO in integration of the project.

SCOPE OF REVIEW

Information on this program was obtained by reviewing plans, reports, correspondence and other records and by interviewing officials at contractors' plants and the Viking Project Office. We evaluated management policies and the procedures and controls related to the decision-making process, but we did not make detailed analyses or audits of the basic data supporting program documents. We made no attempt to (1) develop technological approaches or (2) involve ourselves in decisions while they were being made.

CHAPTER 2

PROGRAM STATUS

When proposed to the Congress in March 1969, the Viking Project estimate was $364.1 million based on a launch data in 1973. At that time, the NASA Project was not yet sufficiently defined to provide a sound basis for this initial estimate. About August 1969, when the project mission was more firmly defined, the estimate was increased by $330.7 million, including a provision for inflation. By July 1970 the cost was further increased by $135.2 million, of which $102.2 million resulted when the launch was delayed 2 years. Viking's estimate at August 1972 was $829.4 million. The Viking Project Manager stated he expects to complete the project within this cost. These estimates exclude the cost of Titan III/Centaur launch vehicles which are currently estimated at about $86 million including shroud development and mission peculiar costs.

The Viking Project is a difficult, complex undertaking--particularly because it requires working with unknowns and because NASA had set performance requirements that, at times, "stretch" the state of the art. It is therefore susceptible to changes in design, performance requirements, and timing that can cause significant cost changes. This is demonstrated by the early cost increases attributable to more fully defining the mission and the cost increases experienced by delaying the launch 2 years which required a renegotiation of the contract with MMC.

COST ESTIMATE CHANGES

NASA estimated the $364.1 million using a parametric cost estimating process. The principal factors used were the estimated weight of the lander and the expected orbiter similarity to the Mariner project. But, when that estimate was prepared the Viking mission and experiments to be performed had not been fully defined. Therefore, NASA relied on prior projects to arrive at the weights used to estimate the cost. This estimate, when proposed to the Congress in March 1969, did not include about $64 million NASA estimated it would experience due to inflation.

In February 1969, NASA contracted with a team of 41 scientists to study and more fully define the Viking's scientific mission. By August 1969, NASA had selected a contractor for the lander and had essentially completed contract negotiations. It had also obtained a revised estimate from JPL on the cost of the orbiter. In this period, more precise specifications were developed. Using this data, NASA revised the project estimate to $694.8 million, including $85 million for contingencies. We believe this estimate was reasonable and soundly supported in terms of a scheduled launch date in 1973.

In January 1970, the launch date was postponed 2 years due to budget contraints (see page 14). After this decision, VPO renegotiated its contract with MMC and increased the contract price by $50 million. The estimates for the orbiter and project management were increased $36.4 million, and $18 million respectively. Other adjustments, some offsetting, brought the project cost increase attributable to the launch delay to $102.2 million.

Additional cost increases of $45.9 million were also experienced--principally for increased scientific support and technical changes. These were offset by some estimated cost reductions making the total estimate at July 1970, $830 million.

In August 1972, VPO estimated the project at $829.4 million, a reduction of $600,000. This estimate included $67.7 million for contingency reserves--a decrease of $39.8 million from the funds held in reserve at July 1971. Of this $67.7 million, $18.7 million had been committed for possible subcontractor overruns and technical requirements.

If this rate of cost increase continues in 1973, when the project will be in a critical testing phase, the reserves available at August 1972 may be insufficient. However, the Viking Project Manager believes the project cost will not exceed $830 million.

Through July 1972, $492 million had been authorized, $259.4 million had been obligated, and $234.9 million had been expended on the Viking program.

As discussed in chapter 5, VPO requires its staff and contractors to prepare budgets, record costs, and report variances in great detail.

Although these reports provide extensive internal control and are adequate for progress measurement, they do not separately show costs of design, development and testing.

SCHEDULED MILESTONE CHANGES

The Viking spacecraft were originally scheduled for launch in July and August 1973. Component delivery and testing schedules were established to meet these launch dates. When the launch dates were slipped 25 months the corresponding delivery and testing dates were rescheduled.

Between September 30, 1969, and January 17, 1970, the Office of Management and Budget (OMB) reduced NASA's proposed 1971 budget three times. NASA absorbed the first two reductions--$800 and $200 million, respectively--by cancelling or delaying projects including Skylab, Saturn V launch vehicle, and Appllo. In early January 1971, OMB notified NASA it would have to reduce its budget by another $200 million. To absorb this reduction NASA decided to drastically reduce the level of funding from that previously planned in the fiscal 1971 budget. NASA officials stated that Viking was selected because it was the only remaining project available to absorb the reduction. In testimony before the House Committee on Science and Astronautics, a few months later, NASA estimated that the slippage would cost from $100 to $150 million.

As of August 1972, VPO reported no slippage in schedule milestones which would result in the failure to meet the 1975 launch.

PERFORMANCE CHARACTERISTICS

Postponing the launch date increased the distance the spacecraft must travel by 150 million miles, requiring an additional 5 to 6 months flight time. This condition required some changes in the performance capabilities of the spacecraft, but the overall mission requirements have not changed significantly.

NASA DATA AVAILABLE ON PROGRAM STATUS

VPO gathers much of the same type data that the Congress requires from the Department of Defense on the status of major weapon systems. However, NASA's data would probably have to be refined to facilitate reporting on program status in a format similar to that required of the Department of Defense

As discussed in chapter 5 VPO prepares a semiannual Program Operating Plan This is VPO's official means of reporting cost-to-complete and funding data to NASA Headquarters. In addition to a current project cost estimate, there are supporting analyses explaining variances from the preceding report Each report also shows the cumulative costs and obligations to date. In addition, a monthly financial report is prepared by VPO and sent to NASA Headquarters.

These reports do not relate the project's present status to the original plan approved by the Congress. Neither do they report on significant changes in design, performance characteristics and milestones. Such data is reported to NASA Headquarters as part of a monthly financial report. Therefore, this data is readily available and could be assembled in a form similar to that now furnished the Congress by the Department of Defense for its major acquisition programs.

Viking's costs are not recorded to separately show costs for design and testing. Because of the extensive testing prescribed by VPO, we believe it would be helpful if the cost of testing were separately shown and reported to the Congress.

CONCLUSION AND RECOMMENDATION

We believe that data on changes in costs, scheduled milestones, and performance characteristics--similar to the reports the Department of Defense submits on major weapon systems--would be useful to the Congress in evaluating the Viking Project. Therefore, we suggest that NASA prepare such reports periodically for submission to the Congress. We suggest that these reports contain details on budgeted and actual cost of testing, and that significant information regarding the risk in meeting performance characteristics be reported.

CHAPTER 3

TESTING PROCEDURES

An effective test program should include formulation of an overall test plan and detailed test procedures, timely conduct of individual tests in accordance with the plan, and proper evaluation and reporting of test results. Provisions should also be made to reassess performance requirements in terms of the cost to meet them and the risk of failing to meet the requirements within the prescribed time frame.

The performance requirements and related testing procedures established by VPO are extensive. They are designed to produce parts, components, and subsystems that will endure conditions exceeding the worst environment known to confront the spacecraft. The extensive performance/test requirements in instances "stretch" the state of the art This in turn has increased the project cost to an undeterminable extent. VPO officials stated there were no firm criteria for setting the performance/test requirements, these were principally based on engineering judgment after evaluating the best data available. Mission success was an overriding consideration in setting high performance requirements and extensive testing procedures.

VPO officials have an extensive overview and reporting system to detect problems early. The Project Manager personally investigates and particiaptes in decisions on major problems as they are detected. Only limited design development testing (two components) had been completed when we concluded our review. The actions taken to cope with problems experienced with one component indicate the system is adequate to identify technical problems and nonessential performance/test requirements. The system permitted reassessing performance requirements in terms of the cost to meet them and the risk of failing to meet the requirements within the prescribed time frame.

During 1973, the majority of Viking's parts, components (units with two or more parts), and subsystems will enter a critical design development testing phase. Particularly during this period, it will be essential that original judgments to set high performance/test requirements be constantly reassessed in favor of alternatives which are consistent with the mission as problems are encountered.

NATURE OF TESTING

VPO prescribes and evaluates performance, endurance and reliability tests The tests are planned and done by prime contractors or subcontractors, but are monitored and evaluated by VPO representatives.

Tests are prescribed for each type material, part, component, and subsystem, and for the entire Viking package. At August 1972, a master test plan had been completed and approved for the lander. The test plan for the orbiter was being developed

Only materials approved by VPO may be used. Because international agreements prohibit contaminating planets, all materials for the lander must endure high temperatures to permit sterilization. The materials are also subjected to numerous reliability and endurance tests. For electronic parts, the Viking mission imposes more stringent standards than those applied to present military "high reliability" items, consequently testing has been expanded to provide the extra reliability. Each part is qualified by a two-step test process. The first subjects a part to tests designed to determine endurance in expected conditions. The second tests a part under conditions more severe than those known. A part must satisfactorily meet both tests to be accepted.

Similarly, components are subjected to extensive tests. Since the lander will contain about 130 and the orbiter about 240 components, testing is time-consuming and costly. Because there will be many tests, VPO requires more than one of each component. The number of each component fabricated will range from two to 28--with a norm of eight. The number to be fabricated was based on judgments as to anticipated problems and the critical nature of the item.

Components are subjected to one or more critical tests to measure performance and endurance under extreme conditions. They are first tested under conditions simulating the worst environment known. They are then tested for more severe conditions (qualification margins). For example, a component sensitive to acoustics will be subjected to twice the acoustic level expected.

The components will be tested alone and as part of a system. The following chart describes the various tests required

Purpose of component	Number fabricated	Component-level testing	System-level testing
Design development	1	Functional verification of design parameters prior to, during, and after exposure to --qualification margins, and --environments in excess of qualification margins to determine design limitations.	None
Design development	1	Flight Acceptance Testing (FAT)1/	Systems Test Bed-used to determine component interaction, verify computer software, and verify ground equipment interface.
Qualification	1	a. FAT b. Functional verification of design limitations prior to, during, and after exposure to qualification margins.	Spacecraft Test Lander-test integration with the Proof Test Orbiter, Tracking and Data System and Mission Control Center to verify functional interface compatibility.
Proof Test Capsule	1	FAT	a. FAT b. Functional verification of design limitations prior to, during, and after exposure to qualification margins. c. Integration with the Proof Test Orbiter to validate facilities, procedures, and launch vehicle interface at Cape Kennedy.
Flight articles	3	FAT	a. FAT b. Functional integration with Flight Orbiter and Launch Vehicle
Spare	1	FAT	None
Total	8		

1/ FAT-Functional verification of workmanship prior to, during, and after exposure to worst case environments in heat compatibility, vibration, and thermal vacuum.

STATUS OF TESTING

At the time of our review, very little design development testing had taken place in the Viking Project. Some problems have arisen, and requirements were reduced for one of the two components which received design development testing. A VPO spokesman said the project will be entering a critical phase in 1973 when the majority of the design development testing will occur. The project has reached a point, however, where only changes needed to make the component work will be allowed, unless the change will significantly reduce cost or weight.

Some design development testing of the Articulated Boom Assembly in the Surface Sampler Subsystem had been performed, and the design development testing of the Viking Standard Initiator had been completed. The boom subcontractor had difficulty meeting testing and specification requirements, and a reduction in requirements was permitted. The following describes the boom, problems in meeting initial requirements, and actions to overcome the problems.

MMC awarded a firm fixed-price subcontract to Celesco Industries on July 1, 1971 The subcontract was for $3,289,000 and covered design, development, fabrication, testing, delivery and support of the Articulated Boom Assembly. The subcontract included one boom for soil sampling and another for meteorology. Originally, VPO planned for both booms to be identical

The soil sampler boom is a 10-foot retractable arm that reaches out from the lander, collects soil, and then retracts. It must then circle and deposit the soil in the spacecraft It is flexible and winds itself for retraction and storage. The booms were required to undergo design development, qualification and flight acceptance tests, including tests for heat compatibility, vibration, and shock.

The original subcontract between MMC and Celesco required that the booms be tested to assure they could perform 1,000 extend-retract cycles. VPO personnel told us that the meteorology boom would be used more than the soil sampler boom. However, the number of boom test cycles was only a judgment since, when the contract was awarded, the number of cycles needed had not been determined.
By January 1972, Celesco had tried 10 different boom configurations but none would successfully complete an extend-retract test of more than 200 cycles.

VPO, by this time, had revised its mission requirements and decided that meteorology experiments could be conducted using an existing non-retracting boom. This enabled MMC to reduce the requirements for extend-retract tests. MMC then removed the subcontract requirement for the meteorology boom as well as the requirement for 1,000 extend-retract tests.

MMC, considering that the mission would require 30 to 45 extend-retract cycles, and that 51 such cycles would be required in testing the flight articles, felt a successful test at 200 to 250 cycles should be required VPO felt 500 should be required. A compromise of 350 cycles was reached.

As a result of this change, the subcontract price was reduced by $400,000 including about $50,000 for reduced testing. VPO personnel said the $50,000 was for testing the meteorology boom.

Problems also occurred with the motor assembly of the booms. Celesco had awarded a subcontract for three motors for each boom to Nash Controls, Incorporated Nash could not successfully supply the motors with the required mechanical torque limiters. It requested substitution of electronic torque limiters. In August 1972 Nash, Celesco, MMC and VPO agreed to eliminate the mechanical torque limiter requirement and use resistors to electrically control the torque An agreement was signed by the four organizations relaxing the performance requirements for the motor.

MMC has closely surveyed the operations of Celesco and Nash An MMC representative assigned to Celesco ratifies written test procedures and witnesses critical in-process operations, inspections and tests. He also witnesses selected acceptance, prototype, design development, qualification and flight acceptance tests.

CONCLUSION

From material through integrated testing, requirements are extremely demanding as demonstrated by the following.

Material--only approved material may be used unless prior VPO approval is obtained.

Parts--VPO believes parts must be tested more stringently than the presently available high reliability military items.

Components--components must successfully perform at a qualification margin up to twice the worst case environment expected.

The extensive performance/test requirements in instances "stretch" the state of the art. This in turn has increased the project cost to an undeterminable extent. VPO officials have established an extensive overview and reporting system to detect problems early Only limited design development testing (two components) had been completed when we concluded our review. However, the actions taken to cope with problems experienced with the booms indicate the system is adequate to identify technical problems and excessive performance/test requirements The system permitted reassessing performance requirements in terms of the cost to meet them and the risk of failing to meet the requirements within the prescribed time frame.

During 1973, the majority of Viking's parts, components, and subsystems will enter a critical design development testing phase. Particularly during this period, it will be essential that original judgments to set high performance/test requirements be constantly reassessed in favor of alternatives which are consistent with the mission as problems are encountered.

CHAPTER 4

PROGRAM MANAGEMENT

The capability of the NASA center, the Project Manager and his staff, as well as the authority granted the Project Manager, are important. The Project Manager has a system of control to closely survey the project both on a periodic and continuing basis. The following sections describe how the Project Manager controls the project. Organization charts of NASA and VPO are shown in appendixes VI and VII.

SELECTION OF CENTER

The Langley Research Center was selected as the VPO because

1. its technical and management capability was demonstrated in the Lunar Orbiter and Voyager programs, and
2. its research and development resources could support a new effort.

In other projects Langley reports to the Office of Aeronautics and Space Technology, however, on this project Langley reports to the Office Of Space Science.

SELECTION OF PROJECT MANAGER

The Project Manager was the Assistant Project Manager for the Lunar Orbiter Project and previously worked in space research in industry. He reports to the Director, Langley Research Center, but has been delegated authority to make all decisions concerning the project, subject to approval of the Director and/or NASA Headquarters.

Responsibility flows downward through six system managers at Langley or other locations. (See appendix VII)

MANAGEMENT SYSTEM

The Project Manager has established bases for measurement. Through a system of delegation of authority, monitoring, communication, and review, he is constantly aware of progress and problems.

Baselines

VPO was involved in preparing the cost budget for the project. It has approved changes to the budget and has established the format for detailed budgets at contractors' plants.

Definite parameters for testing and schedule delivery dates were established by VPO and incorporated into contracts and subcontracts. These data are in publications at VPO and many are shown on charts prominantly displayed in the Control Room at the VPO.

Selection of staff and contractor

The VPO staff was selected and the organization structure prepared under the direction of the Project Manager. Most top officials had experience with planetary or lunar exploration projects. In selecting MMC as the contractor for the lander, consideration was given to its staffing, facilities and prior experience in planetary exploration. JPL, the orbiter contractor, has been in this field for many years.

VPO personnel are permanently assigned to the contractors' plants and contractor personnel are assigned to some major subcontractors' plants Authority to take action has been delegated to these personnel.

Communication

With these levels of monitoring, problems can be reported quickly to higher management and to the Project Manager. In addition, staff meetings attended by division managers are held three times weekly. The 10 top problems are discussed at these meetings. Monthly the Viking Management Council, consisting of all senior staff, meet with the Project Manager. The Project Manager and division managers make frequent visits to the contractors' plants. Periodically top personnel from contractors, NASA and subcontractors discuss the entire project. The Project Manager also meets with the Executive Council, composed of the Directors of the Langley Research Center, JPL, Lewis Research Center, and MMC, to discuss problems. He also meets at the time of major design reviews with the Viking Review Advisory Panel, a group of NASA officials not associated with Viking, for an independent opinion on the programs' progress

Many reports are sent to VPO. Cost, schedule and technical performance reports are received monthly from JPL and MMC. Test results are reported periodically as phases of tests are completed. Project schedule reports are received monthly.

With information flowing in quickly from monitors or in reports the Project Manager may refer to baselines to evaluate the severity of problems Through meetings and visits he can obtain details and decide on alternative actions

Review

As data are received, the Project Manager has many options. At the various meetings problems are discussed and probable actions formulated. To obtain better data, the Project Manager or his staff may visit the contractor or subcontractor. Where required a review team may be established. For example, in July 1972 a financial review team was established to review all cost estimates at MMC and JPL.

Action

Because of the flow of information, the Project Manager is constantly aware of major problems He makes major decisions after reviewing alternatives available and talking with his staff or other responsible personnel. These decisions are communicated orally to his staff and monitors and formally through directives, contract revisions, etc.

CONCLUSION

We believe the Viking Project Manager has a system of control which enables him to closely survey the project both on a continuing and periodic basis.

CHAPTER 5

PROGRESS MEASUREMENT

Information in terms of cost, schedule and technical performance regularly reported to higher echelons should provide management with (1) a means to measure the progress of a systems through the acquisition process, and (2) an early warning of potential problems. The reporting system should provide the program manager with sufficient timely information to keep apprised of where the acquisition stands in relation to where it was expected to stand at a given point in time in terms of cost, schedule, and technical performance.

The VPO has a progress measurement system which provides a timely overview of total project cost and progress toward achieving program milestones and performance requirements The Project Manager is informed primarily through reports from contractors and subcontractors and personal interaction with key personnel of program participants.

We found that the contractors' work breakdown structures were properly integrated with their management control systems The integrated systems were structured to (1) define tasks to be performed, (2) provide for assignment of organizational responsibility at each level of the work breakdown structure, (3) establish time-phased cost and schedule baselines for authorized work, (4) provide for the accumulation of actual costs at a low level of effort and organizational structure; (5) allow for comparison of work accomplished with that planned; and (6) provide controls over changes to cost and schedule baselines. The contractors' work breakdown structures when combined with their systems for control of schedule and performance allowed for a comparison of the budgets for all work scheduled with the value of the work actually accomplished.

COST

The reporting systems of MMC and JPL provide for timely reporting, and compare actual costs with budgets. They also explain variances in enough detail so the Project Manager can recognize potential problems early

MMC reporting system

MMC budgets, records and reports cost using a four level work breakdown structure as follows.

Level 1 - Lander

Level 2 - A major function of the lander (there are 10 level 2 functions, each headed by a manager. These are closely related to the function of the six VPO system managers.)

Level 3 - Subfunctions of level 2 (For this level there are 64 items with a manager for each, some of whom manage more than one item These managers' responsibilities parallel those of VPO technical managers)

Level 4 - Basically a component level. (This level includes subcontracts, components, and functional type work for which MMC is responsible There are 132,level 4 items, each with a manager - some of whom may manage more than one item.)

MMC submits a detailed performance versus plan report to VPO monthly. Reestimation of the cost at completion is provided quarterly. Costs and budget data are summarized by labor (both dollars and man-months), overhead, travel and other direct charges, minor material, major contracts, critical subcontracts, reserve, and fee. Cost and budget data are also summarized by each level of responsibility showing the same breakout except for reserve and fee. No variance figures are shown in these summaries. However, in a separate narrative, MMC explains variances since the last quarterly report, and differences between the contract price and the current estimate at completion. In addition, MMC submits interim monthly reports showing the cost incurred.

MMC monitors its subcontractors' costs, progress, and technical performance with resident teams at most important subcontractors' plants. The teams review subcontractors' weekly reports which are forwarded to MMC. These data are incorporated into reports to VPO.

JPL reporting system

The JPL work breakdown structure classifies its cost at five levels. However, its level 2 corresponds to level 1 of MMC. The breakdown is as follows:

Level 1 - Viking Project

Level 2 - Orbiter

Level 3 - Six activities, each headed by a manager

Level 4 - Nineteen functional areas with a separate manager for each

Level 5 - A total of 270 subsystems or subfunctions.

The JPL budget is prepared and costs are recorded to the fifth level. The budget and actual costs for each subfunction are recorded on an internal monthly report. The budget cost for the year is matched with actual cost for the year to date on this report. While not being specifically identified, variances between budget and actual costs are made evident by this presentation.

At least annually, the entire JPL budget is reviewed. A re-estimate is made down through level 5, considering internal reports and input from the level 4 managers. The budget is then revised as needed.

VPO receives the internal JPL reports monthly together with two monthly variance reports. One report explains the reason for any variances by month and by year. The other report shows actual and potential transfers from the reserve account each month.

VPO also receives a Program Operating Plan report. It is submitted semiannually at level 2. Any change in the budget will be reflected on the plan but no reference to the prior budget is given and no variances are shown

JPL requires its subcontractors to submit data on actual cost, progress and technical performance. For those subcontracts other than firm-fixed price type, detailed monthly and quarterly cost reports are required (monthly reports are submitted in less detail for the firm-fixed price subcontracts). The detailed monthly and quarterly reports compare actual and budgeted costs to date and the total cost budgeted and the current estimated cost at completion. These reports are monitored to identify problem areas and to determine the subcontract's progress. Other reports on schedule and performance are submitted to JPL for its use in reporting to VPO.

As part of its analysis, the JPL staff uses the Defense Contract Audit Agency and NASA audit teams when necessary to validate the data.

SCHEDULE AND PERFORMANCE

Included as a part of the MMC quarterly cost report is a "Risk Assessment" schedule which shows by selected lander component whether a component is in a high, medium or low-risk position regarding schedule and performance. Oral and written reports are submitted on components when problems arise. Monthly performance narrative reports are also submitted to VPO.

The primary method to measure and report the progress of achieving the desired performance characteristics is through the test and evaluation procedures. (Discussed in chapter 3.)

JPL uses 28 Program Evaluation and Review Technique (PERT) networks to measure and control the construction and delivery of the orbiter. Each network pertains to a system or subsystem in the orbiter. Within the overall PERT system, 25 major milestones have been established. All changes to the schedule are coordinated with the VPO.

The construction progress as reported in these PERT networks is analyzed by MMC, because it is responsible for integrating systems in the Viking Project. Delays and problems are identified and, along with analyses for the lander, are reported to the VPO for correction. JPL also submits monthly schedule and performance narrative reports to VPO.

During our review, JPL was preparing its master integrated test plan for the orbiter which will control and measure the performance characteristics of components and systems.

USE OF REPORTS

Cost reports received from MMC and JPL are different but, in each case, contain adequate data for analysis. VPO has a contract with the General Electric Company to assist in the analysis of the data. General Electric also reports on potential problems and visits contractors to review records and discuss problems.

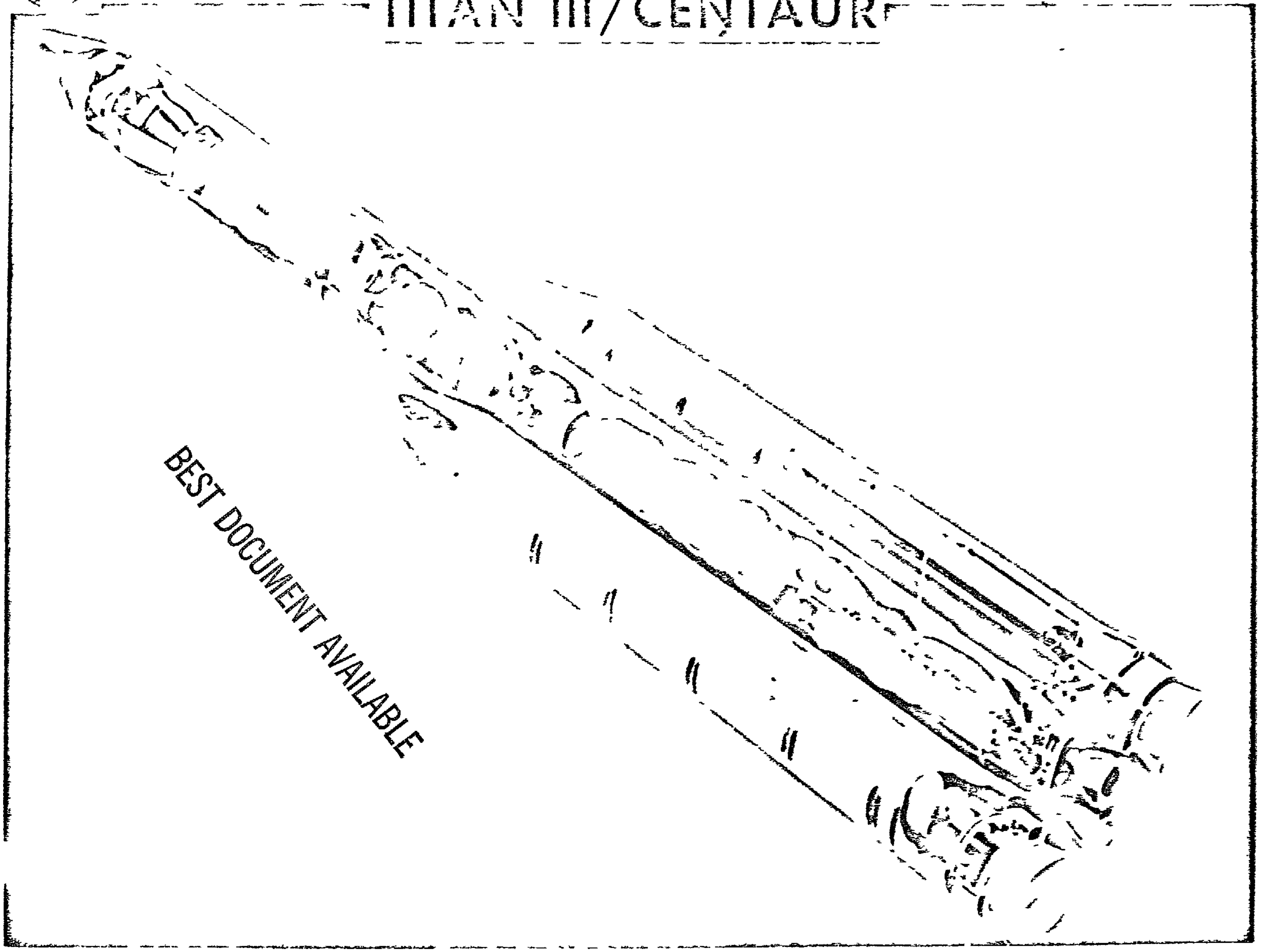
Schedule and performance reports are also analyzed and action is taken to correct problems as they arise.

As discussed in chapter 4, the project manager and his staff, through a system of monitoring, maintain close informal contact with Viking contractors and subcontractors. This provides for an additional means of progress measurement

CONCLUSION

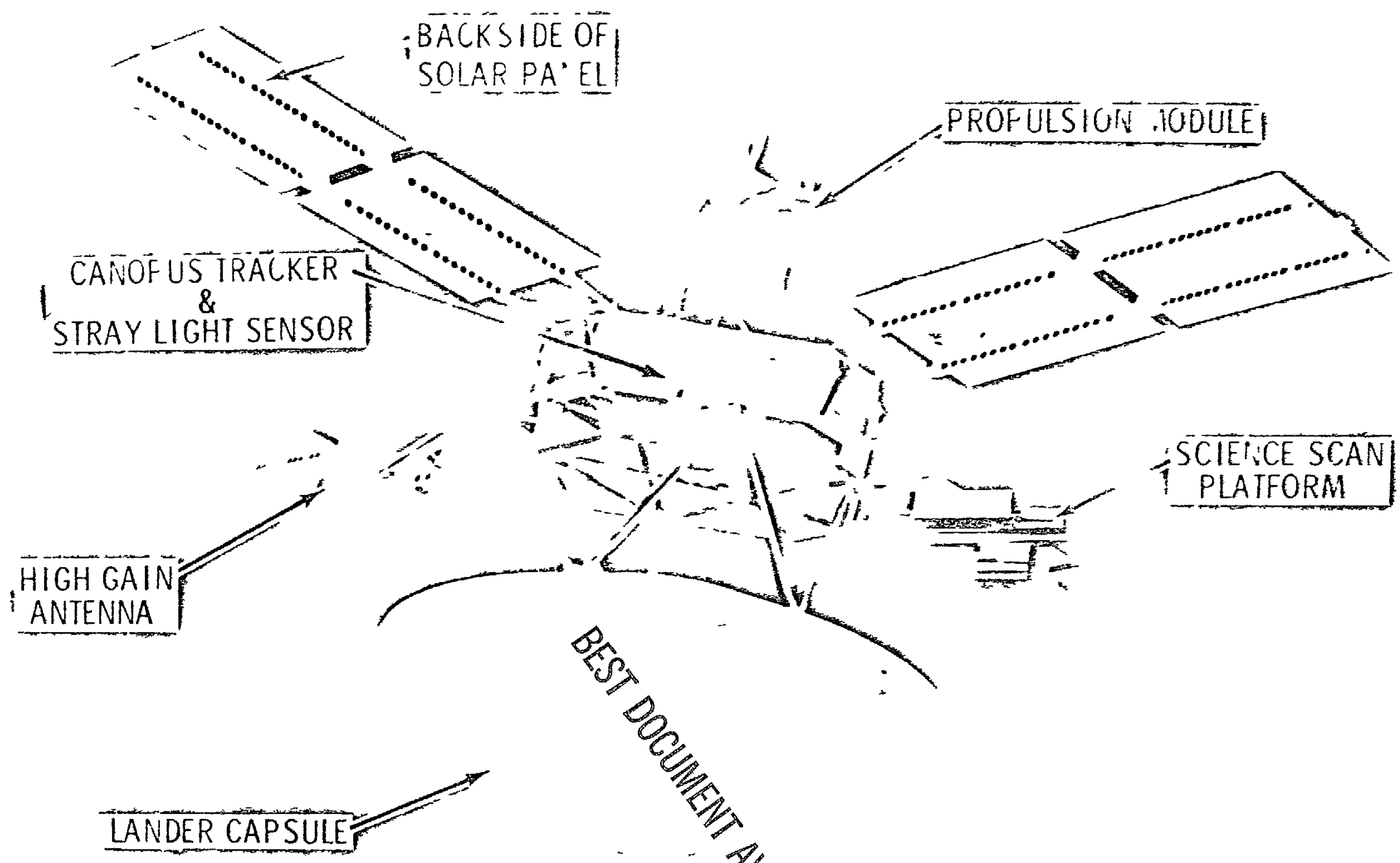
Through the VPO system of progress measurement, the Viking Project Manager has a timely overview of overall project cost and progress toward achieving program milestones and performance requirements.

VIKING LAUNCH VEHICLE
TITAN III/CENTAUR



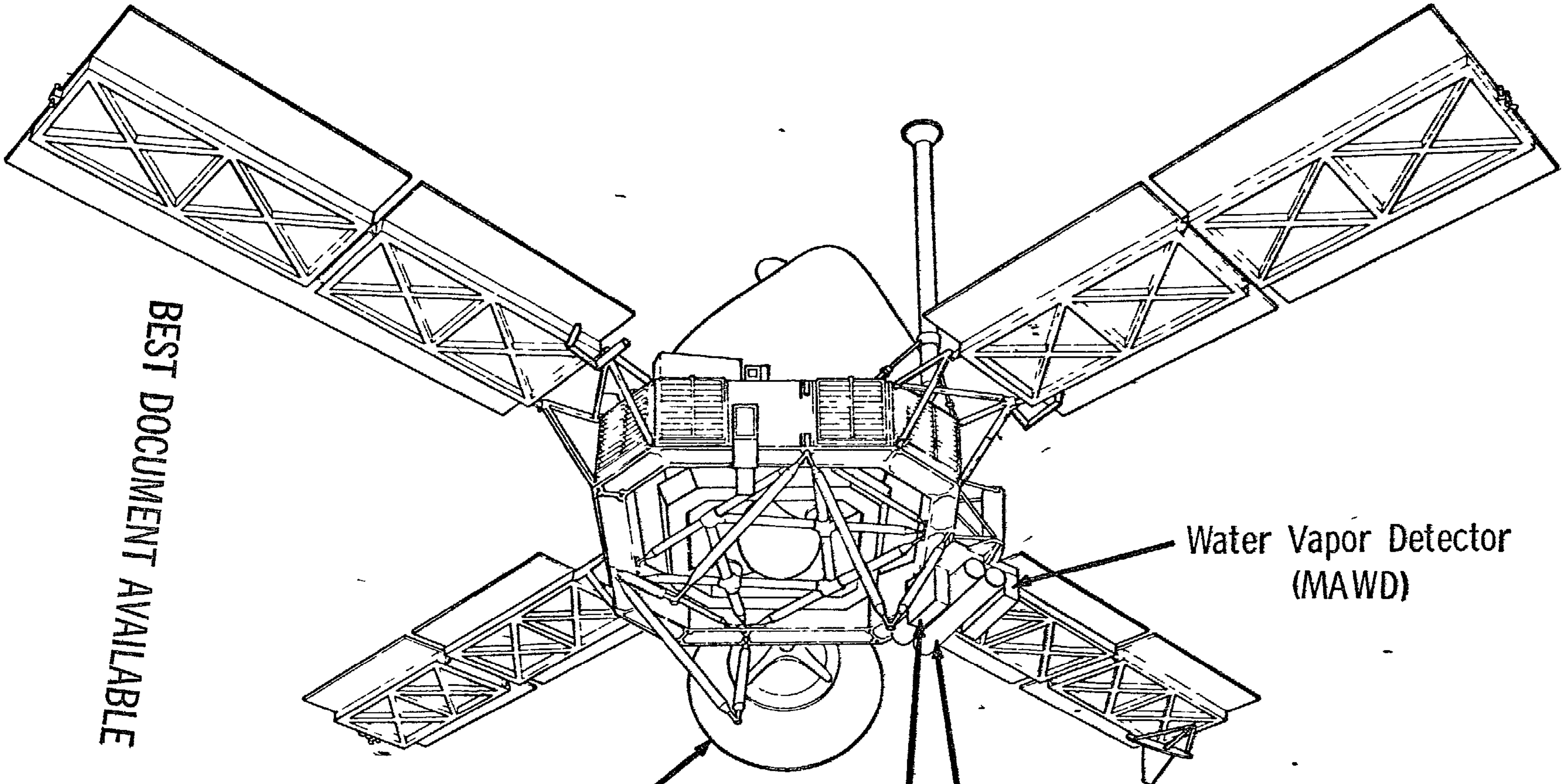
MODEL OF SPACECRAFT CONFIGURATION IN CRUISE MODE

VIE . OF SHADE SIDE OF ORBITER)



ORBITER SCIENCE INVESTIGATIONS

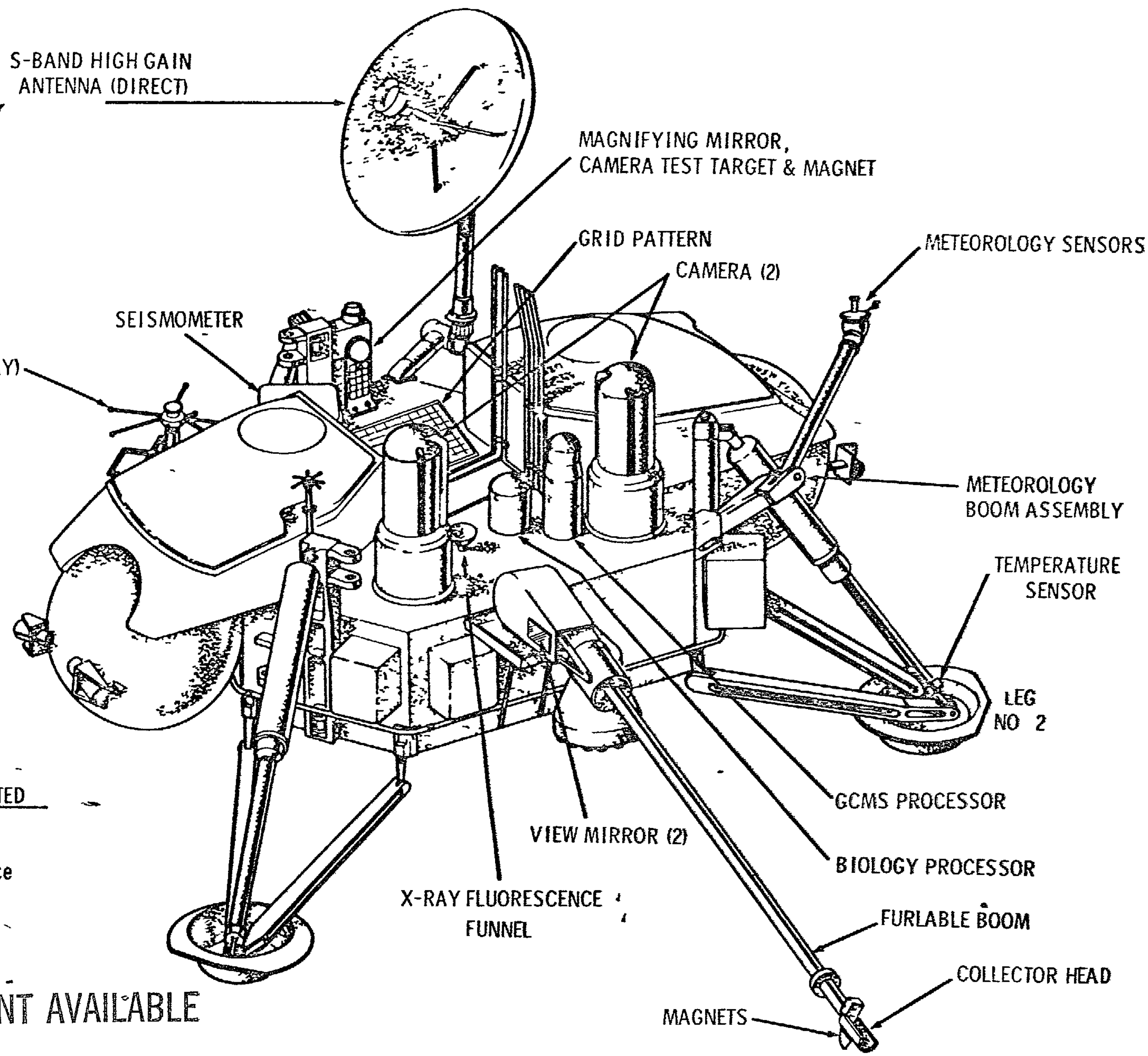
D1B2
6/72



APPENDIX III

VIKING LANDED SCIENCE CONFIGURATION

D6A
6/72



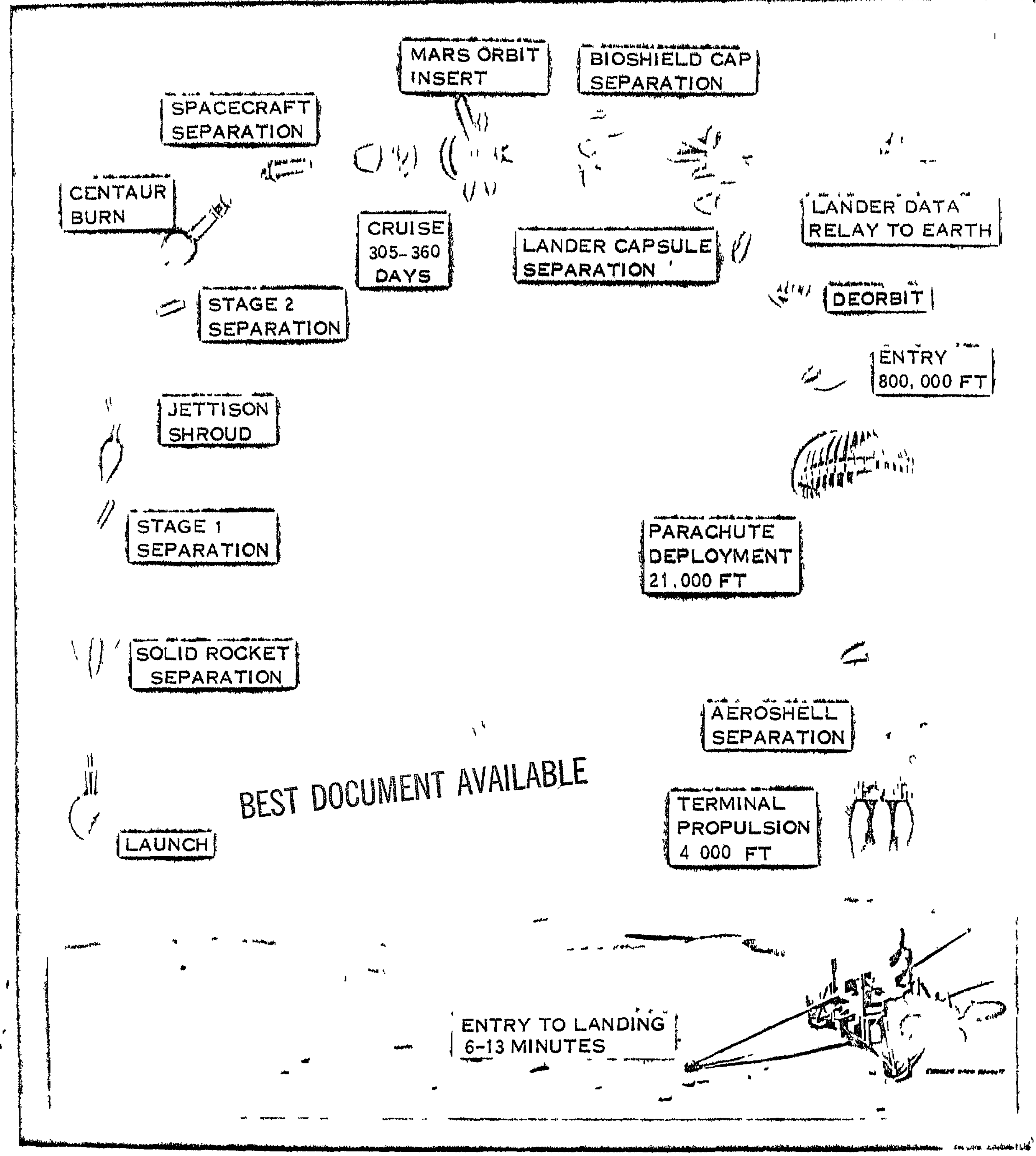
INTERNALLY MOUNTED
- Biology
- GCMS
- X-Ray Fluorescence
- Pressure Sensor

BEST DOCUMENT AVAILABLE

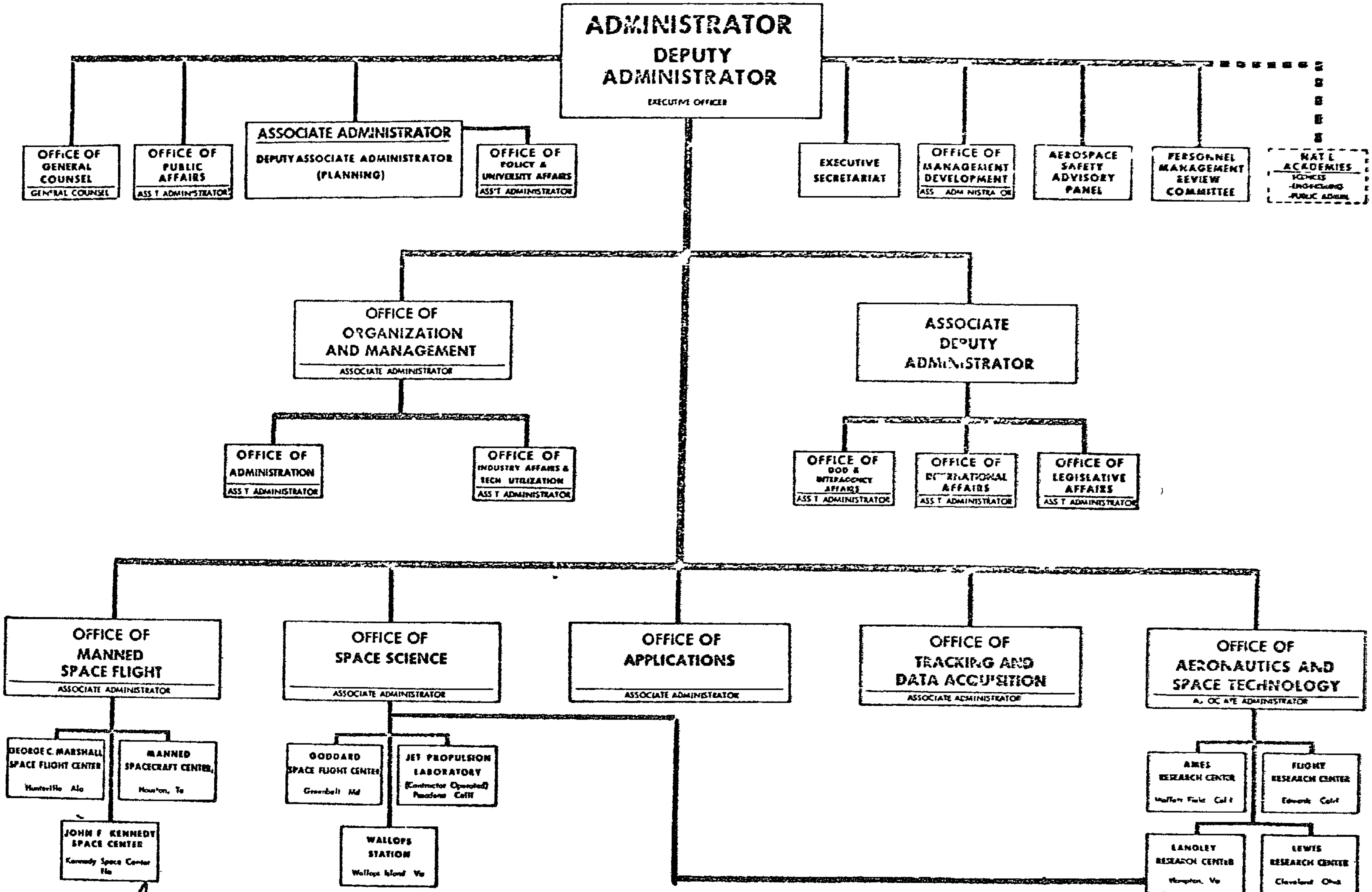
APPENDIX IV

E2
6/72

MISSION SEQUENCE



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



APPROVED [signature: James C. Fletcher]

EFFECTIVE January 14, 1972

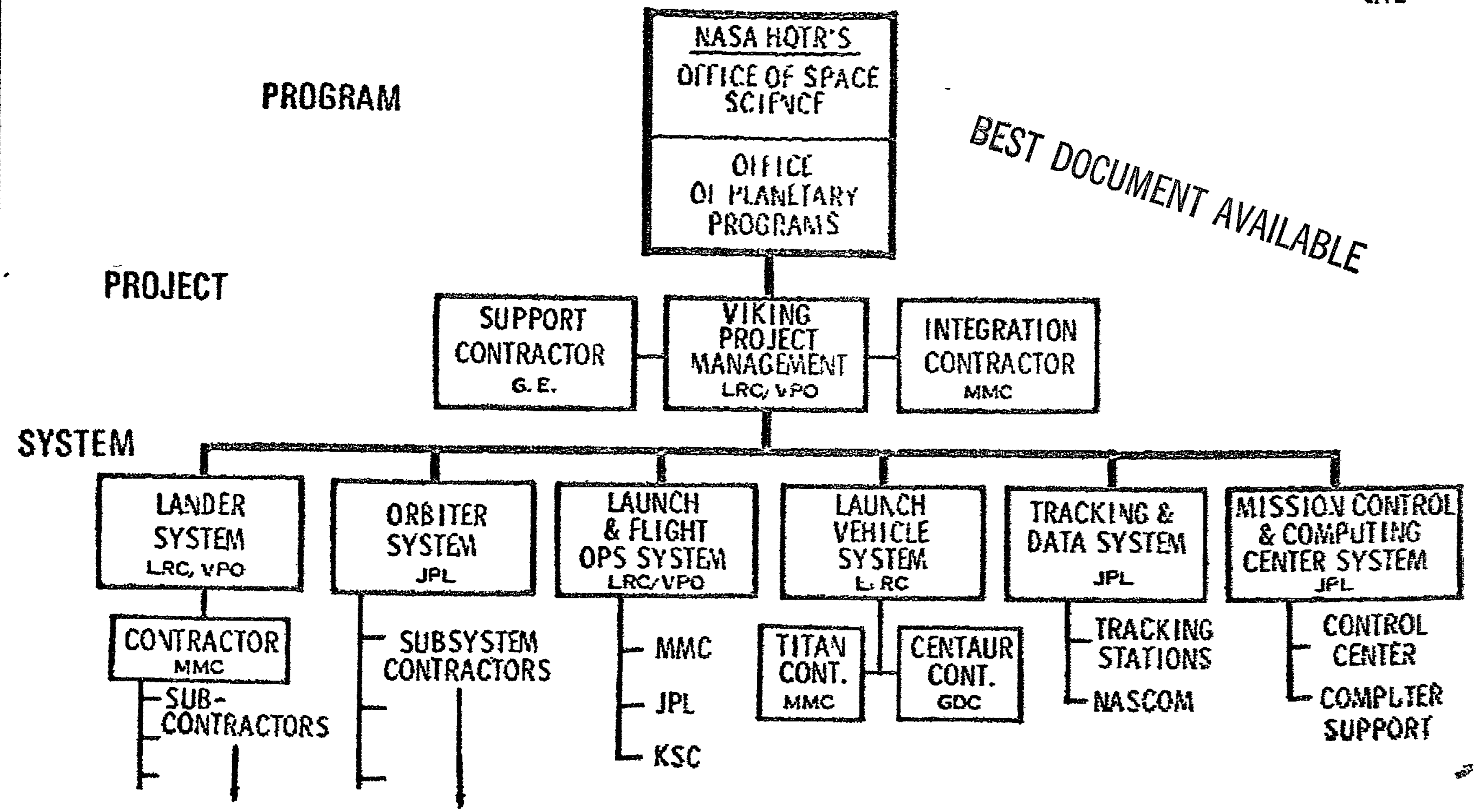
Supersedes Chart Effective December 3, 1971

BEST DOCUMENT AVAILABLE

VIKING PROJECT ORGANIZATION

CI
6/72

BEST DOCUMENT AVAILABLE



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D C 20546

REPLY TO
ATTN OF SP

MAR 2 1973

Mr. Hyman S. Baras
Assistant Director
Procurement and Systems
Acquisition Division
U. S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Baras:

Thank you for the opportunity to review the GAO staff study on the Viking Project which was forwarded by your letter dated February 9, 1973.

The comments of the Office of Space Science on the staff study are attached. Our primary concerns with the staff study are related to material in the Summary and in Chapter Three regarding Testing. The report (page 4) proposes that the cost of testing be separately recorded and reported to Congress. There is also an apparent implication that our testing requirements are excessive.

Aside from the difficulty and expense involved in segregating and recording testing costs, we do not believe that this level of detail would be useful either to NASA general management or to the Congress. Nor do we believe that our testing requirements are excessive for the missions we perform.

In the case of Viking, the spacecraft must function in an extremely hostile environment over a long period of time. The amount of money invested in the project requires that we make a major effort to achieve a sufficient reliability to assure a high probability of mission success. These circumstances are quite different from those affecting most

DOD weapons systems, where production quantities are involved. In NASA missions, only one or two spacecraft are involved. Either they work, or the mission fails.

We will be glad to discuss NASA's comments with you or members of your staff if you desire additional information.

Sincerely,

Bernard Moritz

for Richard C. McCurdy
Associate Administrator for
Organization and Management

Attachment: as stated