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GEMINI SPACECRAFT ADVANCED MISSIONS (U)

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TABLE OF CONTENTS

LIST OF PAGES

This report consists of the following pages:

1. INTRODUCTION

Nine advanced missions, or experiments, for the Gemini Spacecraft are discussed in this report. In Section 2, a qualitative, narrative discussion of the following aspects of the missions is presented:

1. Title
2. Description
3. Technical or Scientific Benefit
4. Effects on U.S. Space Program
   - (a) Apollo
   - (b) AES and Advanced Missions in General
   - (c) DOD
5. Prestige Value
   - (a) Domestic
   - (b) International
6. Performance Feasibility
7. Cost Feasibility
8. Schedule Feasibility
9. Operations Feasibility
10. Impact on Gemini Program
11. Other Aspects

Additional technical detail on each of the missions is presented in Section 3. The missions are summarized, and cost and schedule information are presented in Section 4.

The information presented is more comprehensive for some missions than for others, reflecting differences in background information available and previous work performed in related areas at McDonnell. The cost and schedule information presented herein are for planning purposes only and apply to efforts associated directly with the experiments and spacecraft. Launch vehicle availability is assumed and the costs that might be incurred on launch vehicles are not included.

2. ADVANCED MISSIONS

2.1 Rendezvous with an Unmanned Satellite

2.1.1 Description - The objective of the flight is to rendezvous with a non-cooperative target, namely the Pegasus satellite, photograph the meteoroid puncture panels to corroborate telemetered data, and remove and return a piece of one of the panels by extravehicular activity, if possible.

The basic mission plan is to: (1) inject into a low orbit coplanar with the Pegasus orbit for gross catch-up, (2) transfer open loop, based on tracking data, to a slow catch-up orbit slightly lower than the Pegasus orbit, and (3) perform a closed loop rendezvous after contact is made. An alternate plan would be to first rendezvous with an Agena and then use the Agena propulsion for the open loop transfer to the slow catch-up orbit. The Agena would then be discarded and a second closed loop rendezvous performed with Pegasus. The alternate is operationally complicated and would not be considered unless more extensive analysis shows the basic plan unworkable or undesirable.

After rendezvous is completed, a slow pass is made to photograph the meteoroid puncture panels. After the photograph run is completed, the two craft are "docked" and a crewman secures the specimen of the panel by EVA.

2.1.2 Technical or Scientific Benefit - The greatest benefit of the mission is the accomplishment of rendezvous with a non-cooperative target, thus opening the possibility of obtaining additional data using spacecraft with this capability. The information returned from the Pegasus should provide, in addition to substantiating data received from it by telemetry, direct information of the effects of meteoroid impacts on structures for use in future designs.

2.1.3 Effect on U.S. Space Program - The experience obtained would be directly applicable in the areas of satellite data retrieval, resupply, maintenance, repair, and recovery. The knowledge of meteoroids and their impact with a spacecraft

2.1.3 (Continued)

should be considerably increased, which will benefit the Apollo and other future space programs.

The mission will provide information for DOD directly applicable in the areas of satellite interception, inspection, and surveillance.

2.1.4 Prestige Value - The return of a piece of a spacecraft from orbit, a feat which has yet to be accomplished, would demonstrate advanced space skills and carry implications of an ability to exercise access to any orbiting object at will.

2.1.5 Performance Feasibility - Preliminary analysis shows that if the OAMS is augmented by the addition of two sets of tanks and four 100 lb. thrusters, and if some of the additional ΔV capability is used to extend the GLV payload capability, rendezvous with Pegasus is possible. Analysis shows that 860 lbs. of the 1860 lbs. of propellant loaded in the OAMS at liftoff will be used to inject the Gemini into a 87-100 na. mi. orbit. The remaining 1000 lbs. of propellant should be sufficient to complete the mission. The weight change associated with the change in spacecraft configuration and propellant loading, and the use of eight rockets for retrograde from the Pegasus orbit, are considered in the analysis.

Extensive analysis of: (1) injection performance, (2) rendezvous with a spacecraft in an elliptic orbit, and (3) of retrograde and re-entry will be required to more definitely establish the ΔV capability of the spacecraft and the ΔV required for rendezvous and retrograde.

2.1.6 Cost Feasibility - The first unit cost is estimated to be $19.75 million with each additional unit costing $1.75 million, plus the cost of the spacecraft and launch vehicle. (See Section 4.)

2.1.7 Schedule Feasibility - It is estimated that a Gemini could be modified in approximately 20 months.

2.1.8 Operations Feasibility - The effect of the changes required, OAMS augmentation and possible computer program changes should make little difference in over-all ground operations. Flight operations are similar to those for Gemini and are expected to be straightforward.

Radiation hazard over the South Atlantic may require flight operations at the Pegasus altitudes to be performed when the orbit does not enter this zone, according to a radiation analysis conducted using two different radiation models.

2.1.9 Impact on Gemini Program - The impact of the Pegasus mission on the Gemini Program would be principally that of sustaining a fairly sizeable engineering effort to accomplish the propulsion system configuration changes and to insure the integrity of the associated structural changes. In addition, changes to checkout equipment and AGE would have to be made. The magnitude of these changes have not been ascertained to date.

Aside from the actual hardware changes, the suitability of: (1) the Gemini scheme of rendezvous when in elliptic orbit, (2) the re-entry control scheme when re-entering from high orbits, and (3) the launch guidance back-up for controlling an OAMS augmented injection will have to be established. If any of the three were to give unsatisfactory performance, a new scheme would have to be devised, programmed, and procedures revised.

2.2 One Man Gemini-Earth Surface Mapping

2.2.1 Description - Low latitude earth surface photography applicable to topographic mapping, geological reconnaissance, and to studies of oceanography, hydrology, and meteorology, can be accomplished with a GLV launched One Man Gemini. A camera system which can be mounted in the right hand side of the crew compartment can provide useful resolution and mapping accuracies. A mission duration of 7 days allows complete coverage at the equator with 50 percent overlap. Low resolution auxiliary color cameras provide for correlation between color tonal gradations and the higher resolution black and white pictures.

The Gemini is flown upside down and sideways, with the right-hand hatch door open to expose the thermally controlled, unpressurized camera system. Mapping camera system design is such that close tolerance attitude, attitude rate, or image motion compensation control are not needed. However, a horizon camera is included to obtain precisely the local vertical when imaging the nadir. An auxiliary horizon scanner for coarse pitch and roll reference is also included. Manual yaw sensing and control to the ground track is employed.

Gemini ground tracking network data are used in conjunction with post flight photogrammetric data reduction. The mission is considered to have high confidence of success since reliable, relatively simple, state-of-the-art hardware is used throughout.

2.2.2 Technical and Scientific Benefit - The mission would be of scientific and technical benefit, in terms of topographical mapping of underdeveloped areas, determination of oceanographic characteristics, better definition of Earth folliation outlines, and geological refinements.

2.2.3 Effects on U.S. Space Program - Advanced missions in general would be aided by the experience gained with orbital mapping techniques and interpretations.

2.2.4 Prestige Value - International prestige would be enhanced by the scientific and commercial contributions to be gained by the increased accuracy and detail of the large scale mapping.

2.2.5 Performance Feasibility - Since the estimated mission performance is based upon use of existing equipment and technology, feasibility is not considered to be in question. The payload requirements are within GLV capability.

2.2.6 Cost Feasibility - The first unit cost is estimated to be $10.3 million with each additional unit costing $1.35 million, plus the cost of the spacecraft and launch vehicle. (See Section 4.)

2.2.7 Schedule Feasibility - It is estimated that about 24 months would be needed to perform the necessary engineering and fabrication.

2.2.8 Operations Feasibility - Ground tracking and monitoring for orbital period control is obtainable with the existing ground network. One Man Gemini operations have been previously studied at McDonnell and are considered quite feasible.

2.2.9 Impact on Gemini Program - The 24 months acquisition time would result in a delay of a few months if the mission were scheduled for spacecraft number 12. If a refurbished spacecraft were utilized, the mission could be accomplished without interference to the Gemini program.

2.3 One-Man Gemini with Astronomical Telescope

2.3.1 Description - Two types of telescope installations for the one-man Gemini were examined: (1) a 16-inch diameter telescope located in the right-hand crewman's seat, and (2) a 26-inch diameter telescope mounted in the adapter with access to the telescope through a hatch in the heat shield. Both installations are discussed in Section 3.3. Although minimum change to Gemini is a ground rule for the missions presented in this report, it is felt that the adapter-mounted design offers sufficiently greater return, scientifically and technologically, to make it the preferred approach. The hatch in the heat shield should be a developed item by 1967 due to the Gemini B program. The adapter mounted telescope is discussed in this section.

A one-man Gemini spacecraft with a 26-inch diameter, 560 pound, astronomical telescope in the adapter can be placed in a 200 na. mi. circular orbit by the Gemini launch vehicle in 1968. The two mission goals are: (1) to demonstrate the ability to make astronomical measurements with a pointing accuracy of 0.1 arc-seconds for periods over ten minutes, and (2) to obtain new astronomical data.

To provide a steady vehicle base for the telescope, the altitude and attitude are chosen to keep the external disturbance torques on the spacecraft low. A fine attitude control system is added to stabilize the spacecraft in the presence of the low disturbance torques. A heat shield hatch and tunnel are added to provide pressurized access to the telescope, and to provide room for experiments on the isolation of astronaut motions from the spacecraft and telescope. The spacecraft roll is used for roll pointing of the telescope, and the single-axis gimbal on the telescope is used for pointing in pitch. Measurements on any star can be made either by selecting launch time or by operating in the presence of a large gravity gradient torque.

2.3.2 Technical and Scientific Benefit - The one-man Gemini experiment could remove one of the major obstacles to the advancement of space astronomy by demonstrating a practical means for eliminating undesirable effects of astronaut motions on telescope pointing angle stability. Pointing angle stability is essential to the development of a capability for orbiting observations with telescope apertures over 100 inches, utilizing resolutions better than 0.04 arc seconds, for purposes such as seeing faint stars never before observed and for searching for planets associated with nearby stars.

The optical alignment and adjustments for such large observatories involves many tasks which are facilitated by manned operation. However, the astronaut disturbances must be kept small. Three techniques for keeping astronaut disturbances small are: (1) isolation of the telescope, (2) isolation of the astronaut in the observatory or in a separate spacecraft, and (3) compensation for the disturbances. The use of a separate spacecraft is not appealing due to time lost in transfer. Compensation for maximum likely disturbance torques caused by body or limb motions is difficult because the torques are large and change greatly in a short time interval. The isolation of the telescope from the spacecraft is difficult for the very large optics since the telescope is essentially part of the spacecraft.

The isolation of the astronaut from the spacecraft and telescope in a controlled floating or elastic support in the spacecraft offers a promising way of simplifying the problem of precise attitude control of the manned spacecraft. The astronaut could perform direct viewing, visual alignment, focusing, star acquisition, and other functions while mechanically, but not visually, isolated from the telescope. In the extreme, a controlled floating crewman support can be mechanically reaction balanced using drive signals from photo detectors which measure the support position with respect to the spacecraft. The use of an adapter mounted telescope and associated access tunnel permits testing crewman isolation techniques in the one-man

2.3.2 (Continued)

Gemini. In addition, techniques for compensation for disturbances can be evaluated.

The scientific benefits of the one-man Gemini include visual planetary observations and photographic plate and film data return.

2.3.3 Effect on U.S. Space Programs - The experiment provides a desirable foundation for manned orbiting observatories having large, greater than 100-inch, apertures.

2.3.4 Prestige Value - A "first" would considerably enhance prestige, particularly in the scientific community. Considerable additional prestige would accrue by publication of photographs hitherto unavailable, particularly if new astronomical phenomena were discovered.

2.3.5 Performance Feasibility - The 0.1 arc-second pointing angle stability for the telescope line of sight is considered to be a reasonable design goal. Payload requirements are within GLV capability.

2.3.6 Cost Feasibility - The first unit cost is estimated to be $53.3 million, with each additional unit costing $4.9 million, plus the cost of the spacecraft and the launch vehicle. (See Section 4.)

2.3.7 Schedule Feasibility - It is estimated that 30 months are required from go-ahead to delivery for the adapter mounted version.

2.3.8 Operations Feasibility - One-man operation of Gemini has been previously studied at McDonnell and appears to be quite feasible. The hatch in the heat shield will have been developed for Gemini B. Otherwise, operations are similar to those for Gemini.

2.4 Artificial Gravity Experiment

2.4.1 Description - Three methods of providing centrifugal force for artificial gravity with a Gemini spacecraft were investigated: (1) rotation of the Gemini directly connected to the burned-out Stage II of the GLV (Gemini Launch Vehicle), (2) rotation of the docked Gemini-Agena vehicle, and (3) rotation of a cable-connected Gemini and either the Agena or Stage II of the GLV.

The first method provides an eyeballs-out g force, unless the crewmen are repositioned, and the second method provides an eyeballs-in g force. Only the third method, by using the paraglider bridle, affords a means of providing a spinal g force. In addition, the cable-connected method provides a larger rotation radius which results in lower Coriolis effects. The cable system results, however, in increased weight, design, and operational complexity. The second method involves a rendezvous with an Agena. For each method, spin-up would be accomplished manually using the appropriate attitude control or maneuver thrusters.

In each concept, it will be of interest to consider several directions of spin. Because of Gemini cockpit confinement, spin about the various human body axes is accomplished by spinning the orbiting vehicle in various attitudes.

2.4.2 Technical Benefit - The test would provide data on the effects of in-space artificial gravity by rotation, increase the yield from data from subsequent investigations conducted on earth, and help substantiate or repudiate the need for, or amount of, artificial gravity provisions in future space station designs.

2.4.3 Effect on U.S. Space Program - Advanced manned missions, including Apollo Extension Systems and Manned Orbital Laboratories for extended periods of time, will derive the technical benefit cited. The Gemini test will provide data for making decisions concerning artificial gravity provisions at an earlier stage of development of advanced manned missions.

2.4.4 Prestige Value - Prestige would undoubtedly result from being first to produce artificial gravity in space and establish meaningful design criteria.

2.4.5 Performance Feasibility - The operational conditions studied indicate that methods using Gemini Orbit Attitude and Maneuver System (OAMS) thrusters are feasible if application to operations other than spin or despin are limited. It is anticipated that the maneuver thrusters will be used for both rendezvous and for artificial gravity. For non-rendezvous, methods any of the thrusters can be used for artificial gravity. A major portion of the design life of the lateral and vertical thrusters can be used for artificial gravity. The Agena attitude control system also could be used with additional storage of the cold gas propellant.

It is estimated that the experiment can be conducted within the GLV and Atlas-Agena payload capabilities.

2.4.6 Cost Feasibility - For the two methods involving direct coupling to either the GLV or Agena stages, the first unit cost is estimated to be $3.75 million with each additional unit costing $0.25 million. For the cable connected system, with either the Agena or GLV stage, the first unit cost is estimated to be $22 million with each additional unit costing $2.0 million. Costs of spacecraft and launch vehicles are to be added. (See Section 4.)

2.4.7 Schedule Feasibility - Flights with the directly-connected vehicle methods appear to be readily feasible early in the current Gemini program. The cable method is estimated to require a 15-month development period. However, with any one of the approaches, the experiment could be accomplished within the present Gemini schedule, assuming an immediate go-ahead.

2.4.8 Operational Feasibility - The directly connected vehicles result in an operationally simple method of producing centrifugal force for artificial gravity. The thrusters are used directly to obtain the angular velocity. Opera-

2.4.8 (Continued)

tions are similar to those involved in a normal rapid slew maneuver. Thus, the docked Gemini-Agena concept appears feasible and achievable at an early date. Rotation of the Gemini directly connected to Stage II of the GLV, with the crew members positioned to minimize adverse physiological effects, presents complications in viewing the required displays and in controlling the entire vehicle.

A relatively complex operation is required with the cable system. This operation includes cable attachment; cable reel-out to the extended position, re-orientation of the Gemini capsule, spin-up to the artificial gravity level while keeping cable slack from becoming excessive, and disconnecting the cable at the end of artificial gravity operation. However, previous McDonnell studies have shown this method to be completely feasible.

2.4.9 Impact on Gemini Program - The impact on the Gemini program should be minor, as discussed in Sections 2.4.6 and 2.4.7.

2.5 Simulation of LEM Rendezvous

2.5.1 Description - The rendezvous of the Lunar Excursion Module (LEM) of the Apollo spacecraft with the Command Module (CM) in lunar orbit is one of the essential elements of the return phase of the Apollo lunar mission. Therefore an early earth-orbit test of the LEM rendezvous equipment and technique would be highly desirable. However, the LEM does not possess a re-entry or launch vehicle escape capability so a manned launch would be extremely risky. Automating the LEM probably would not provide a very satisfactory simulation since in the actual Lunar Orbit Rendezvous (LOR) heavy reliance is made on manual methods and human capabilities. A Gemini spacecraft, with its inherent re-entry and escape capability, could be used as a test bed for early simulation of the LEM LOR technique. Such a test flight would involve outfitting a Gemini spacecraft with LEM equipment to perform computations and radar observations, or modifying Gemini equipment in order to simulate the LEM rendezvous operations. A rendezvous target with actual Apollo CM equipment or equivalent hardware would either be launched separately or carried into orbit aboard the Gemini.

2.5.2 Technical Benefit - The guidance laws of LEM rendezvous have already been evaluated by digital computer simulations during the development of the rendezvous method. Also, detailed studies using statistical models of LEM hardware have been performed to predict the effects of hardware limitations on the lunar rendezvous. Human factors and other unpredicted variations could be discovered by an early test with man in the loop. The Gemini test flight would improve the technical understanding of LEM rendezvous by providing a test using actual hardware in a manned, space environment. The experiment would be of greatest technical importance if actual Apollo CM-LEM equipment is used. Without this hardware, the test would nevertheless be quite important since it would demonstrate the soundness of the LEM rendezvous laws.

2.5.3 Effects on U.S. Space Program - It is difficult to evaluate these effects without a detailed knowledge of the Apollo flight test program. A Gemini flight test would provide a very early indication of possible deficiencies, and would be an asset to the Apollo program. If deficiencies should be discovered, early diagnosis and design "fix" would be possible.

2.5.4 Prestige Value - A successful flight test would be a demonstration of the soundness of a key element for success in the United States lunar exploration program.

2.5.5 Performance Feasibility - The effect of the additional weight of LEM systems aboard the Gemini could, if necessary, be compensated by either off-loading maneuver propellant or shortening the mission, although it appears this would not be necessary. If LEM hardware is not used, there would not be a significant weight increase. The present Gemini orbit propulsion system would provide adequate propulsion performance for LEM rendezvous evaluation.

2.5.6 Cost Feasibility - It is estimated that the first unit cost would be $18.5 million with each additional unit costing $5.1 million if LEM equipment were used. If modified Gemini equipment were used, the first unit cost would be $7.5 million with each additional unit costing $3.1 million. Costs of spacecraft and launch vehicles are to be added. (See Section 4.)

2.5.7 Schedule Feasibility - Unknown if LEM equipment is used. A time from go-ahead of thirteen months seems reasonable with modified Gemini hardware, assuming the LEM guidance system description is firmly established at the time of go-ahead.

2.5.8 Operations Feasibility - With or without the utilization of LEM hardware, the proposed Gemini extension would be feasible from an operations viewpoint. Development of test requirements and procedures, data handling, and use of ETR and

2.5.8 (Continued)

the mission control center should be straightforward since the mission is a natural follow-on to planned Gemini Rendezvous missions.

2.5.9 <u>Impact on Gemini Program</u> - The test flight could be added as a piggy-back experiment to a Gemini flight in late 1966 or as the primary mission of an additional Gemini flight in early 1967. If the auxiliary computer tape memory unit is installed on later Gemini flights regardless of the LEM flight test requirements, the only cost increase would be in the development of a new flight tape to program the LEM system equations in the computer.

2.6 Structural Assembly in Orbit

2.6.1 Description - Man is capable of performing many useful extravehicular (EV) functions in space, such as assembly, maintenance, inspection and alignment of radiators, sensors, antennas, and propulsion systems, as well as serving as a back-up to automatic systems. Man's usefulness can be demonstrated by an experiment involving the structural assembly in orbit of a 40' diameter parabolic antenna, and the disassembly and recovery of a 100-lb. OAMS Thrust Chamber Assembly (TCA).

The antenna is folded and stowed on the nose of the Gemini for launch. An ascent fairing covers the entire assembly. One crewman leaves the Gemini with 30' extension umbilicals, and manually erects the antenna and extends the feed horn. Some structural modification to the Gemini nose to accommodate the increased launch loads is required. The surface of the antenna disk is an aluminum coated polyethylene mesh, irradiated, and formed in parabolic segments. Voids in the surface allow for passage of the crewman and afford clearer visibility for manual pointing. After erection, the antenna can be used for a variety of communication experiments.

The TCA is removed by the crewman and brought within the re-entry module. A special mounting to allow removal of the TCA is needed. Tube connectors are guillotined prior to egress, allowing time for cooling and dissipation of propellant downstream of the propellant isolation valves.

2.6.2 Technical or Scientific Benefit - Construction of the large communications antenna described would: (a) demonstrate the use of special design features to minimize assembly time, and (b) determine the effectiveness of this type of extravehicular operation.

The retrieval of the thrust chamber assembly simulates a type of repair activity which may be needed in future space operations. It would also establish the

2.6.2 (Continued)

feasibility of performing various tests of rocket motors and other equipment under orbital conditions, and returning the test specimen to earth for evaluation. These tests would be desirable in order to better establish the safety margin of thrusters or other spacecraft equipment.

2.6.3 Effect on U.S. Space Program - The demonstration that man can erect large structures in orbit is of significance for the planning of future missions.

Information derived from the proposed examination of the rocket specimens would be of advantage in designing propulsion systems for various space programs.

2.6.4 Prestige Value - The international and domestic prestige value of extravehicular activities has been demonstrated. U.S. prestige would be enhanced in this case since the experiments simulate operations of a practical nature.

2.6.5 Performance Feasibility - The experiment is considered to be feasible since advance in the state-of-the-art will not be required for the development of the erectable antenna. The payload is within the GLV capability.

2.6.6 Cost Feasibility - The first unit cost is estimated to be $16.75 million, with each additional unit costing $1.75 million, plus the cost of the spacecraft and launch vehicle. (See Section 4.)

2.6.7 Schedule Feasibility - It is estimated that it is feasible to have this mission ready for flight in approximately 16 months after go-ahead. The estimate allows for wind tunnel tests and structural proof tests.

2.6.8 Operations Feasibility - Considered entirely feasible since extravehicular capability should be proven prior to this mission.

2.6.9 Impact on Gemini Program - Re-design (beef-up) of nose section and increased emphasis on development of extravehicular capabilities of both the suit and re-entry module are needed.

2.6.10 Other Considerations - This mission can be logically combined with the Long Duration Gemini mission. The payload capability of the Agena allows for heavier and more complex (or more ambitious) structures than the antenna. Also, the erection of the tunnel/living quarters in the long duration mission constitutes a structural assembly in space experiment.

2.7 Propellant Transfer Tasks

2.7.1 Description - In-orbit transfer of storable propellants between tanks which do not utilize positive expulsion bladders can be accomplished with a minimally modified Gemini and Agena (Gemini Agena Target). The Gemini is of the rendezvous configuration. It is equipped with additional tankage to receive the propellant to be transferred from the Agena. These tanks, located in the adapter equipment section of the spacecraft, contain centrifugal separators which part the liquid from the vapor. The Agena is modified to accommodate the propellant supply tankage. These tanks have propellant collection or retention devices. The transfer lines are brought forward and connected by extravehicular (EVA) activity. Following transfer, the propellants are discarded with the adapter equipment section when it is jettisoned.

2.7.2 Technical or Scientific Benefit - The accomplishment of this task will provide the following technical benefits for future space missions:

A. Develop the EVA capability to accomplish the transfer line assembly and hook-up
B. Develop the capability to adapt to the use of special tools required for this assembly while in the EVA environment.
C. Evaluate the effectiveness of propellant separation devices (gas/fluid separator in receiving tank)
D. Evaluate the effectiveness of propellant retention devices (fluid retention in the supply tank).
E. Establish methods for quantity monitoring of fluid (propellant) remaining in the supply tanks and fluid accepted by the receiving tanks.

2.7.3 Effects on U.S. Space Programs - The technical benefits derived from this task which are applicable to future U.S. space programs are many. These include:

2.7.3 (Continued)

A. Early assessment of propellant transfer. Resupply will involve large quantities of propellants, thus necessitating the use of tanks without positive expulsion devices. The tanks used in this experiment are smaller than those which will be utilized in logistic resupply. However, they are sufficiently large to test and prove the basic techniques.

B. Early checkout of the Apollo LEM propellant quantity gauging system. System monitoring includes quantity monitoring of the supply tanks and the receiving tanks. The tanks used can be designed to the Apollo LEM diameter (12.5 in.) in order to utilize a prototype gauging system.

C. Assessment of man's capability to accomplish the assembly of transfer plumbing while in the EVA environment, including the handling of special tools and equipment.

2.7.4 Prestige Value - Accomplishment of the propellant transfer experiment will be viewed as a step in developing future space station and interplanetary capability.

2.7.5 Performance Feasibility - The feasibility of the mission is established by the use of scaled tanks to minimize weight, and by the use of existing gauging equipment. Modifications to the Gemini and Agena appear to be straightforward. Payload requirements are within the GLV and Agena capabilities. Because of the scale effect of the gauging devices, further analysis will be necessary to determine the exact test configuration.

2.7.6 Cost Feasibility - The first unit cost is estimated to be $20.5 million, with each additional unit costing $1.5 million, plus the cost of the spacecraft and launch vehicles.

2.7.7 Schedule Feasibility - It is estimated that approximately 24 months

2.7.7 (Continued)

will be needed to complete the modifications to the Gemini and Agena.

2.7.8 Operations Feasibility - The mission makes use of a standard Gemini/Agena rendezvous and docking. EVA will have been accomplished in previous Gemini flights. Therefore, new operational procedures, other than the actual manual coupling and subsequent propellant transfer, are not required.

2.7.9 Impact on Gemini Program - Since the acquisition time is estimated to be 24 months, delays would result if the experiment were incorporated on later Gemini flights. If a refurbished spacecraft were utilized, the mission could be accomplished without interference with the Gemini program.

2.8 Long Duration Mission

2.8.1 Description - The in-orbit configuration of the long duration (30-45 days) mission orbital spacecraft involves the addition of a "Mission Section" to the Agena and a combination "access tunnel/living quarters" segment which is used for transfer from the Gemini to the mission section. The mission section contains the food, water, personal gear, and emergency oxygen supplies. The section is 60 inches in diameter and 165 inches long. The access tunnel provides direct access to the mission section. It is inflatable and is erected by one man outside the spacecraft. The tunnel is composed of multi layers of dacron, polyurethane, and vinyl foam. The tunnel volume appears to be adequate for crew activities to be performed. The major modification to the Gemini consists of redesign to include another smaller hatch within the present right hand hatch.

2.8.2 Technical or Scientific Benefit - Possible benefits or a technical or scientific nature are:

A. Long duration weightlessness experiments (up to 45 days)

B. Extravehicular assembly and development of techniques for assembly in space outside a spacecraft or space station.

C. Expandable living quarters development and demonstration

2.8.3 Effects on U.S. Space Program

A. Apollo - Development and proof testing of Expandable Structures for temporary shelters on the moon for short periods of time, or for lunar instrumentation housings is obtained.

B. AES and Advanced Missions in General - The utility of expendable structures for space living quarters on long duration missions, and for use as

2.8.3 (Continued)

access tunnels or environmental hangers for advanced space stations, would be evaluated.

C. DOD - A tunnel of this type was considered for MOL crew transfer.

2.8.4 Prestige Value

A. Domestic - The mission would be an advancement in the state of the art in the development of equipment and techniques to be used in future space stations and lunar bases and exploration.

B. International - Extravehicular erection of a structure and the extended mission should enhance prestige.

2.8.5 Performance Feasibility - Over all performance appears to be feasible based on preliminary analysis of test requirements and existing hardware and technology. Preliminary estimates indicate the payload requirements to be within the capabilities of the GLV and the Atlas-Agena.

2.8.6 Cost Feasibility - The first unit cost is estimated to be $36 million, with each additional unit costing $6.0 million, plus the costs of the launch vehicles (see Section 4).

2.8.7 Schedule Feasibility - The development and qualification of the Access Tunnel/Living Quarters and associated equipment will take approximately 18 months.

2.8.8 Operations Feasibility - The present Gemini program will provide proof of the feasibility of extravehicular activity and a level of experience in free space action. Erection of the access tunnel and activation of the mission section appears to be an operationally feasible mode.

2.8.9 Impact on Gemini Program - Based on present schedule estimates, it appears the long duration mission could be fitted into the present Gemini program.

2.9 Land Landing

2.9.1 Description - Land landing is considered to be very desirable, and a parasail-landing rocket system for Gemini is currently under development by NASA. Tests of the parasail-landing rocket system are now in progress. The first full scale Gemini parasail drop test produced some unsatisfactory results: (1) the control motors apparently locked, which caused the spacecraft to turn while landing and probably caused the spacecraft to tumble; (2) the landing rockets fired, dislodged rocks of considerable size, and created a fairly large crater which may also have caused the spacecraft to tumble.

Consideration has been given to other methods for providing a land landing capability, should the present parasail landing system prove unacceptable. It is felt that major design changes to Gemini would not be acceptable and landing schemes involving minimum change to Gemini were considered. Two alternative approaches are:

A. The landing rockets for the parasail could be suspended from the parasail bridle.

B. The parasail-landing rocket configuration could be replaced with a cloverleaf parachute which would decrease the descent velocity to 13 fps prior to impact. Thirteen feet per second is the allowable impact velocity for the present Gemini structure.

Some other landing schemes considered, but which would require extensive change to Gemini, are:

A. Installation of Impact Bags between Heat Shield and large pressure bulkhead, plus the installation of a toroidal shape impact bag around the recovery section.

2.9.1 (Continued)

B. Installation of cable-spike arrangement in conjunction with an impact bag, an extendable heat shield, or vertical landing rockets and utilizing heat shield deformation for energy absorption.

C. Horizontal and vertical landing rockets.

D. Larger landing gear (increased stroke and strength).

2.9.2 Technical or Scientific Benefit - Land landing capability is desirable in the U.S. Space Program, particularly from a military standpoint since security would be more easily maintained. In addition, "dry" landings should reduce refurbishment required and is therefore desirable from a reusability standpoint.

A. Apollo - Future Apollo missions could benefit from addition of a land landing capability.

B. AES and Advanced Missions in General - Land landing techniques would be developed and available for possible application to future missions.

C. DOD - Land landing capability could be incorporated on the Gemini B.

2.9.4 Prestige Value - Domestic prestige should be increased by demonstrating this capability. Television could show the actual landing. Probably little international prestige can be gained since the Soviet Union presumably has a land landing capability.

2.9.5 Performance Feasibility - Weight estimates show that the clover leaf system could be incorporated within GLV payload capability by elimination of the rendezvous capability.

2.9.6 Cost Feasibility - For the parasail system employing landing rockets suspended from the risers, it is estimated that the first unit cost would be $4.6 million, with each additional unit costing $0.35 million. For the cloverleaf system, the first unit cost is estimated to be $15.2 million, with each additional unit costing $0.20 million. Spacecraft and launch vehicle costs are to be added.

2.9.7 Schedule Feasibility - It is estimated that cloverleaf system would require about 30 months to develop for Gemini. Qualification of a landing rocket suspended from the parasail risers would require about 24 months.

2.9.8 Operations Feasibility - Development of the cloverleaf chute appears to be well under way. Suspension of a landing rocket on the risers should be a relatively straightforward development.

2.9.9 Impact on Gemini Program - Land landing capability would be incorporated in conjunction with one or more other experiments.

2.9.10 Other Aspects - The installation of the present parasail system on Gemini (S/C #12) will incur a weight increase. The rendezvous system (radar, OAM's propellant tanks and pressurant, etc.) will be removed to provide for the additional weight of the parasail land landing system over the parachute water landing system. There are approximately 400 lbs. of experiments on S/C #12 which could be eliminated to permit retention of some rendezvous capability. It is doubtful that the rendezvous capability could be retained with a landing rocket stored in the rendezvous and recovery section, at least without extensive redesign.

The parasail land landing system has not been approved for installation on Gemini as of this date. However, McDonnell has submitted a work statement to NASA for approval.

3. SUPPORTING INFORMATION

3.1 Rendezvous with an Unmanned Satellite - The basic mission plan for rendezvous with the Pegasus is presented in Figure 3.1-1. The plan is to: (1) inject into a low orbit coplanar with the Pegasus orbit for gross catch-up, (2) transfer open loop, based on tracking data, to a slow catch-up orbit slightly lower than the Pegasus orbit, and (3) perform a closed-loop rendezvous after radar contact is made.

The amount of OAMS propellant remaining at injection of the Gemini into a 87-100 na. mi. orbit as a function of total OAMS propellant loaded at lift-off is shown in Figure 3.1-2.

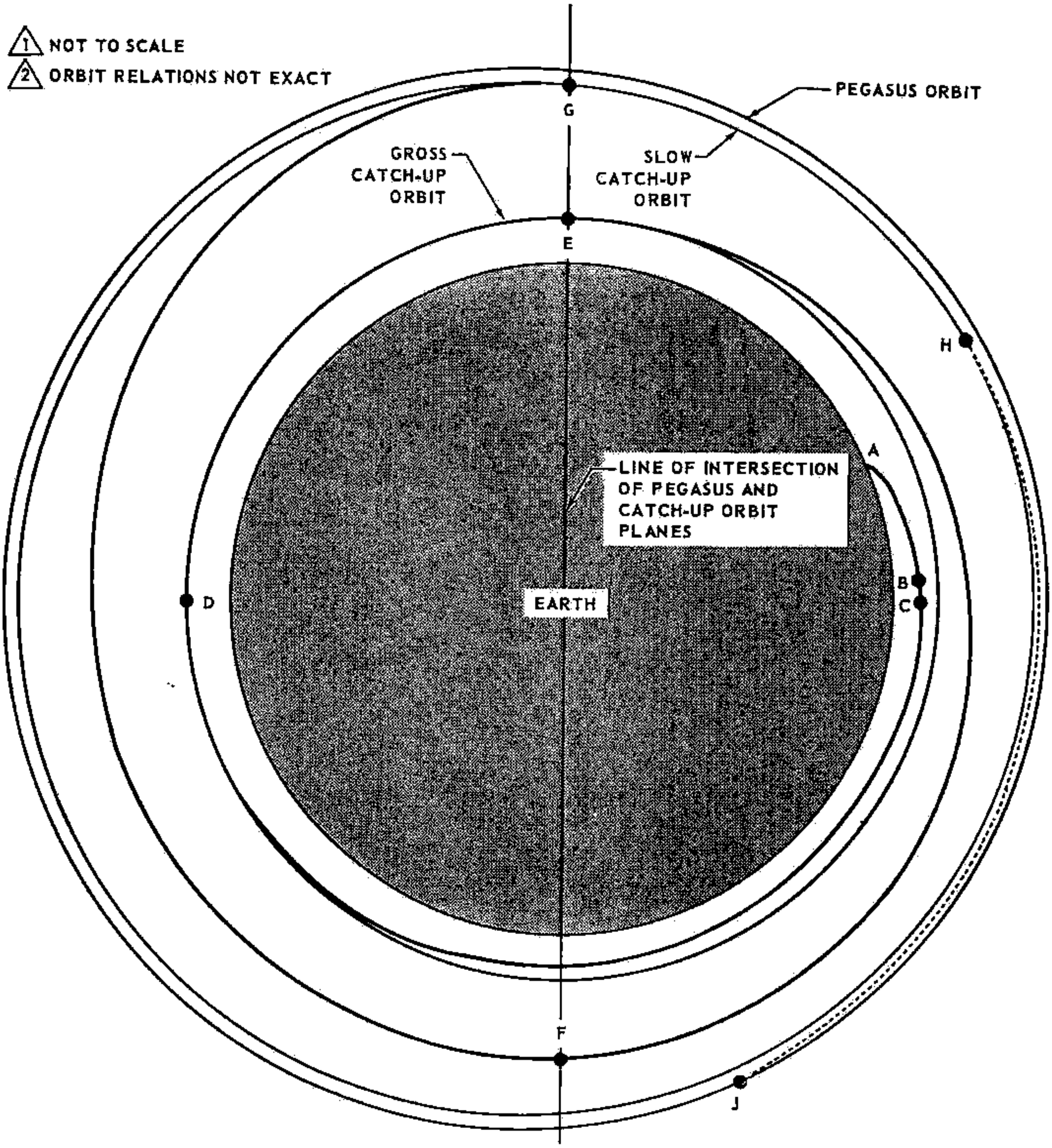
A preliminary estimate of the propellant required for the mission is shown in Table 3.1-1. This is also noted on Figure 3.1-2.

The weight data used in calculating the propellant required for rendezvous with Pegasus is given in Figure 3.1-3 as a function of OAMS propellant loaded. Current Gemini I_{sp} of 256 seconds was used in estimating propellant required for ΔV. An I_{sp} of 225 seconds (pulse mode) was used when estimating attitude control requirements.

Radiation dose rate estimates are summarized in Table 3.1-2. The mission dose depends on the detailed mission profile. The dose rates given allow the mission dose to be estimated when the time spent in each particular profile segment is known. As shown, the radiation dose is almost entirely received in the region south of the equator and between South America and Africa. Within this region, the dose received is dependent upon altitude, increasing rapidly with altitude.

For June 1966, a Lockheed radiation model (Reference 3.1-1) predicts that, for a 30^{o} inclination circular orbit at 325 nautical miles altitude, a man in a 1 lb/ft^2 space suit would receive 25 rads/day, with a range of uncertainty of

SCHEMATIC OF MISSION PROFILE



A. LAUNCH
B. AUGMENTED OAMS USED TO COMPLETE INJECTION
C. INJECTION INTO 87–100 N.M. ORBIT
D. CIRCULARIZE AT 100 N.M. FOR GROSS CATCH-UP
E. FIRST PULSE OF TRANSFER
F. SECOND PULSE OF TRANSFER
G. INJECTION INTO SLOW CATCH-UP ORBIT
H. START OF CLOSED LOOP RENDEZVOUS
J. COMPLETION OF RENDEZVOUS

FIGURE 3.1-1

OAMS PROPELLANT REMAINING AT INJECTION AS A FUNCTION OF OAMS PROPELLANT AT LIFTOFF

87–100 N.M. PARKING ORBIT

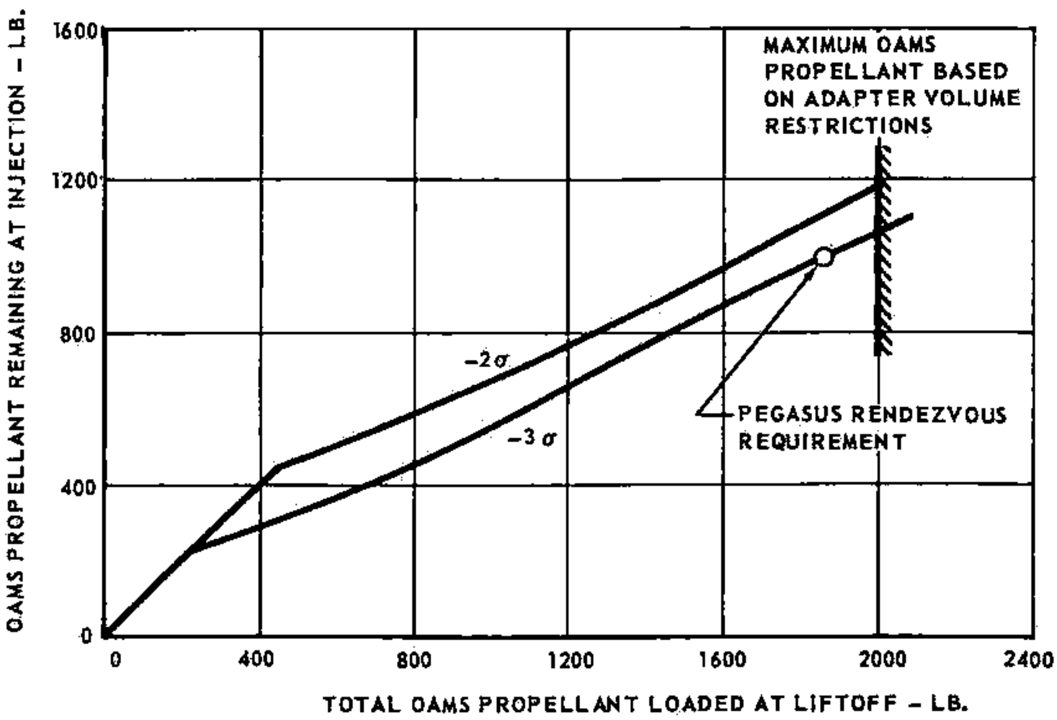


FIGURE 3.1-2

TABLE 3.1-1

ESTIMATED RENDEZVOUS ΔV

CIRCULARIZE @ 100 N.M.	23 FT./SEC.
TRANSFER TO SLOW CATCH-UP	790 FT./SEC.
CLOSED LOOP RENDEZVOUS (PERFECT)	17 FT./SEC.
GUIDANCE AND NAVIGATION ERRORS	50 FT./SEC.
DOCKING	50 FT./SEC.
TOTAL	930 FT./SEC.
OR IN POUNDS (8540 LB. INITIAL SPACECRAFT WEIGHT IN ORBIT)	920 LB.
ESTIMATED ATTITUDE CONTROL PROPELLANT (BASED ON .1 FT. c.g. ECCENTRICITY, 1 DEGREE THRUSTER ALIGNMENT AND 2.5 DEG./SEC. ORIENTATION RATES AND 20% MARGIN)	78 LB.
TOTAL WEIGHT	998 LB.

LAUNCH WEIGHT VS. PROPELLANT ON BOARD

8 RETROROCKETS
ESTIMATED RETROGRADE WT. – 5955 LB.
DESIGN RETROGRADE WT. – 6295 LB.

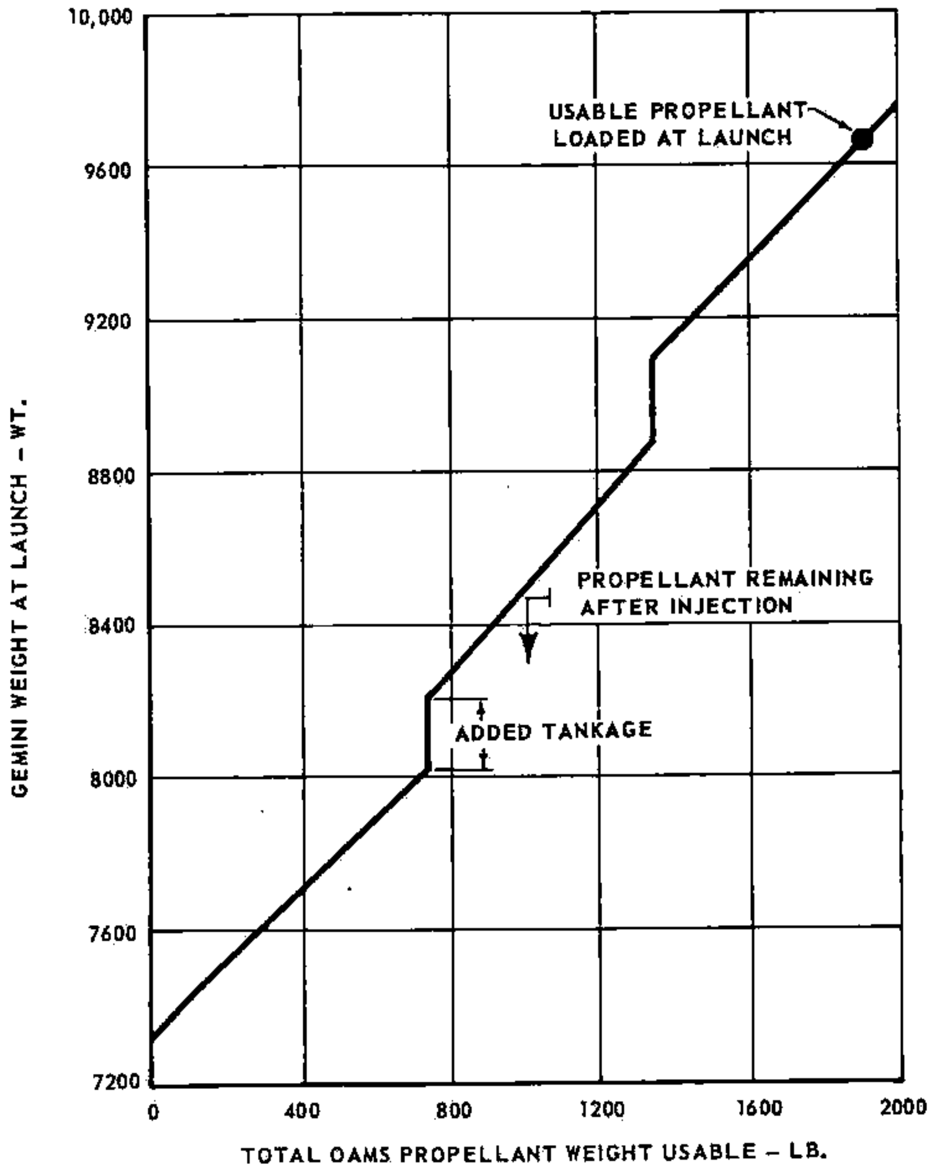


FIGURE 3.1–3

TABLE 3.1-2

RADIATION DOSE RATE ESTIMATES FOR
GEMINI-PEGASUS RENDEZVOUS MISSION

RADIATION ENVIRONMENT MODEL 30° ORBIT INCLINATION		EXTRAVEHICULAR OPERATIONS WITH 1 LB./FT.² SPACE SUIT				GEMINI			
		325 N.M. CIRCULAR	100 N.M. CIRCULAR	PERIGEE 270 N.M. OVER S. ATLANTIC	APOGEE 394 N.M. OVER S. ATLANTIC	325 N.M. CIRCULAR	100 N.M. CIRCULAR	PERIGEE 270 N.M. OVER S. ATLANTIC	APOGEE 394 N.M. OVER S. ATLANTIC
MCDONNELL AIRCRAFT CORPORATION	JANUARY 1966	16 6 TO 45	.3 .12 TO .9	10.2 3.75 TO 28.5	81 30 TO 225	5.2 2.1 TO 15	.12 .06 TO .3	3.3 1.3 TO 9.3	16.5 7 TO 48
	JUNE 1966	5.4 2 TO 15	.1 .04 TO .3	3.4 1.25 TO 9.5	27 10 TO 75	1.8 .7 TO 5	.04 .02 TO .1	1.1 .45 TO 3.1	5.5 2.3 TO 16
	JANUARY 1967	1.8 .7 TO 5	.03 .01 TO .1	1.1 .4 TO 3.1	9 3.3 TO 25	.6 .23 TO 1.7	.013 .01 TO .03	.4 .15 TO 1.1	1.8 .8 TO 5.3
LOCKHEED MISSILES AND SPACE COMPANY	JANUARY 1966	75 24 TO 240	.15 .06 TO 4.8	46.5 15 TO 150	375 120 TO 1200	25 8.1 TO 81	.6 .15 TO 1.5	15.6 5.1 TO 51	78 25.5 TO 255
	JUNE 1966	25 8 TO 80	.05 .02 TO 1.6	15.5 5 TO 50	125 40 TO 400	8.3 2.7 TO 27	.2 .05 TO .5	5.2 1.7 TO 17	26 8.5 TO 85
	JANUARY 1967	8.3 2.7 TO 27	.02 .007 TO .53	5.2 1.7 TO 17	41.7 13.3 TO 133	2.8 .9 TO 9	.07 .02 TO .2	1.7 .6 TO 6	8.7 2.8 TO 28

NOTE:

1. DOSE RATES ARE IN RAD/DAY. UPPER FIGURE IS THE BEST ESTIMATE. LOWER FIGURES ARE THE RANGE OF THE ESTIMATE.
2. LOCKHEED MODEL BASED ON REF. 3.1-1

3.1 (Continued)

from 8 rads/day to 80 rads/day. Inside the Gemini, the astronauts would receive about 30% of the dose.

For June 1966, a McDonnell radiation environment model predicts that, for the same orbit and altitude, a man in a 1 lb/ft^2 space suit would receive only 5.4 rads/day, with a range of uncertainty of from 2 rads/day to 15 rads/day. Inside the Gemini, the astronauts would receive about 30% of the above M.A.C. dose

Since both sets of values are predictions, based for the most part on the same or equivalent data, a choice as to the correctness of either model can not be made at this time. However, the M.A.C. model is less by a factor of nearly 5 than the Lockheed.

When the Gemini is in an elliptical orbit at an inclination of 30° and with a perigee of 290 nautical miles and apogee of 394 nautical miles, the dose to the astronauts will depend sharply on whether the apogee or the perigee is located south of the equator and between South America and Africa. With the perigee in this region, the dose figures above are divided by a factor of 1.6. With the apogee in this region, the dose figures are multiplied by a factor of 5. If the upper limit based on the Lockheed radiation model of 80 rads/day is correct, then an astronaut in a space suit would receive approximately 400 rads/day to his skin. This would cause erythema (skin burn) and would probably limit severely any future missions for the astronaut. Thus, one criterion for minimizing radiation dose in an elliptical orbit has been established; stay in the elliptical orbit only when the perigee is over the South Atlantic region, or when the orbit plane is outside that region.

The time spent in a 100 nautical mile circular orbit is of comparatively small consequence to the total mission dose, since the dose rates given for a

3.1 (Continued)

325 nautical mile circular orbit are less by about a factor of 50.

The mission dose will also depend on the month and year of the mission. For a January 1966 mission, the dose rates are a factor of 3 higher than the dose rates for June 1966. For a January 1967 mission, the dose rates are a factor of 3 lower than the dose rates for June 1966. This is primarily due to the slow decay of the Starfish artifical radiation zone.

The weight added to the Gemini is summarized in Table 3.1-3.

TABLE 3.1-3

WEIGHT SUMMARY
RENDEZVOUS WITH UNMANNED SATELLITE (PEGASUS)

WEIGHT ADDED TO GEMINI ADAPTER		(2052)
PROPELLANT		1380
FUEL	622	
OXIDIZER	758	
TANKAGE		79
FUEL TANKS (4)	36	
OXIDIZER TANKS (4)	43	
PRESSURIZATION SYSTEM		82
HELIUM	8	
HELIUM TANKS (4)	74	
MOUNTING		130
THRUSTERS		51
100 LB. TCA (4)	37	
MOUNTING	9	
CIRCUITRY	5	
RETROGRADE SYSTEM		330
ROCKET MOTORS	270	
MOUNTING AND CIRCUITRY	60	

3.2 <u>One Man Gemini-Earth Surface Mapping</u> - Low altitude earth surface photography applicable to topographic mapping, geological reconnaissance, and to studies of oceanography, hydrology, and meteorology, can be accomplished with a One-Man Gemini. For illustration, from a 120 n.m. low inclination orbit, stereographic photographs can be obtained with nadir resolution of 22.5 ft. for 2:1 contrast and estimated mapping accuracies of better than 1000 feet. Film is provided for an area of 14.3 million square nautical miles. Complete coverage with 50% overlap at the equator, between $\pm$ 45° lateral swathwidths on successive days, can be completed in a seven day mission at the 120 n.m. orbital altitude and 35° inclination orbit.

3.2.1 <u>Experiment Equipment Description and Illustrative Performance</u> - The equipment complement, installed as shown in Figure 3.2-1, with the characteristics indicated in Table 3.2-1 consists of the following:

<u>Panoramic Mapping Cameras (2)</u> - Utilizing a 13 inch focal length, f/3.5, Petzval lens design by Itek (Figure 3.2-2) in a nodding lens pan design, a 100 lines per m.m. resolution is realizable at low contrast (2:1) on SO-206 thin base 70 m.m. film. A 10° x 90° scanning field is employed. The resolution at a 120 n.m. altitude and a contrast of 2:1 is 22.5 feet per cycle. A one millisecond or shorter exposure time is required with a sun altitude above 20°. The short exposure time coupled with the focal length permits loose image motion compensation, attitude rates, and attitude tolerances. Image motion compensation accuracy as poor as 15% of nadir V/h results in negligible resolution loss.

The cameras operate unpressurized, but are thermally controlled electrically to maintain alignment and focus. The included angle between the two cameras is 25° for stereoscopic viewing (map contouring). Fiducial marks and data annotation are included on each frame for correlation with post flight orbit data. With time

EARTH SURFACE MAPPING CAMERA INSTALLATION
ONE-MAN GEMINI

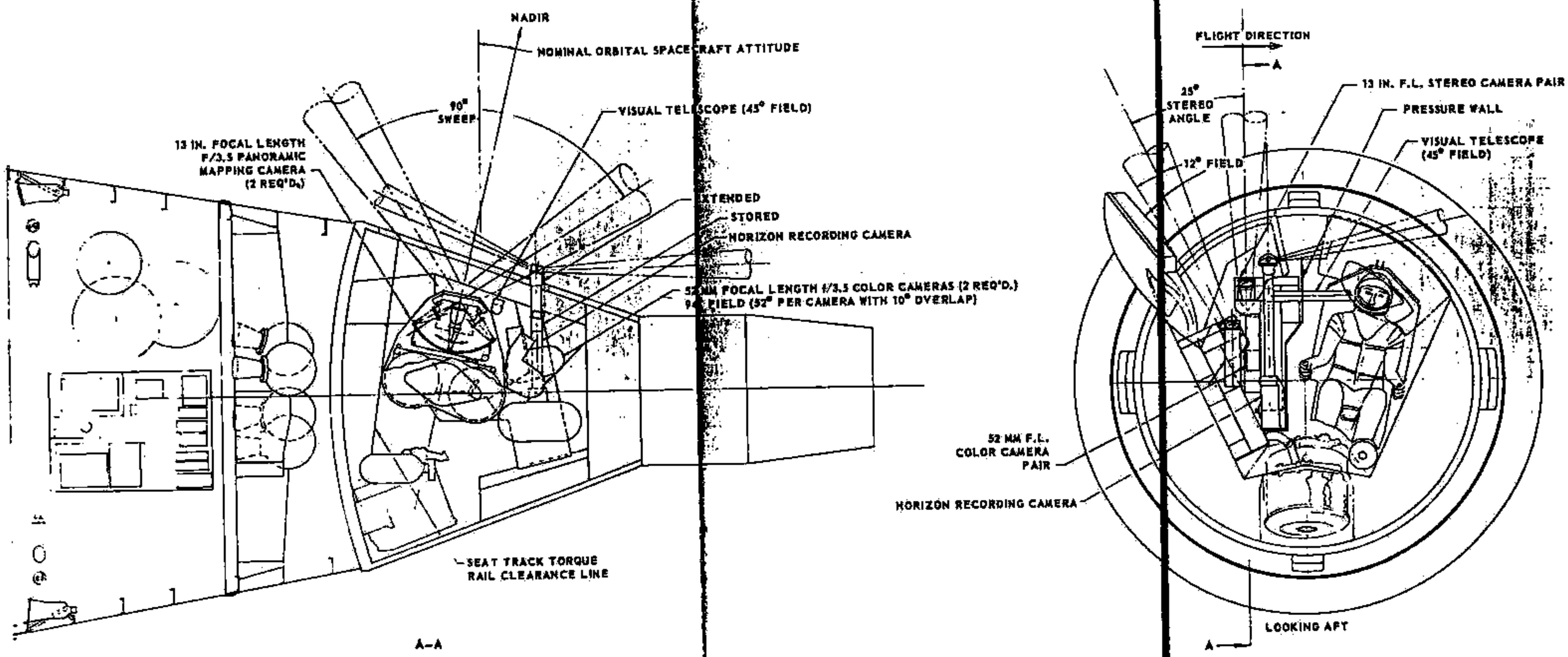


FIGURE 3.2-1

EARTH SURFACE MAPPING CAMERA INSTALLATION
ONE-MAN GEMINI

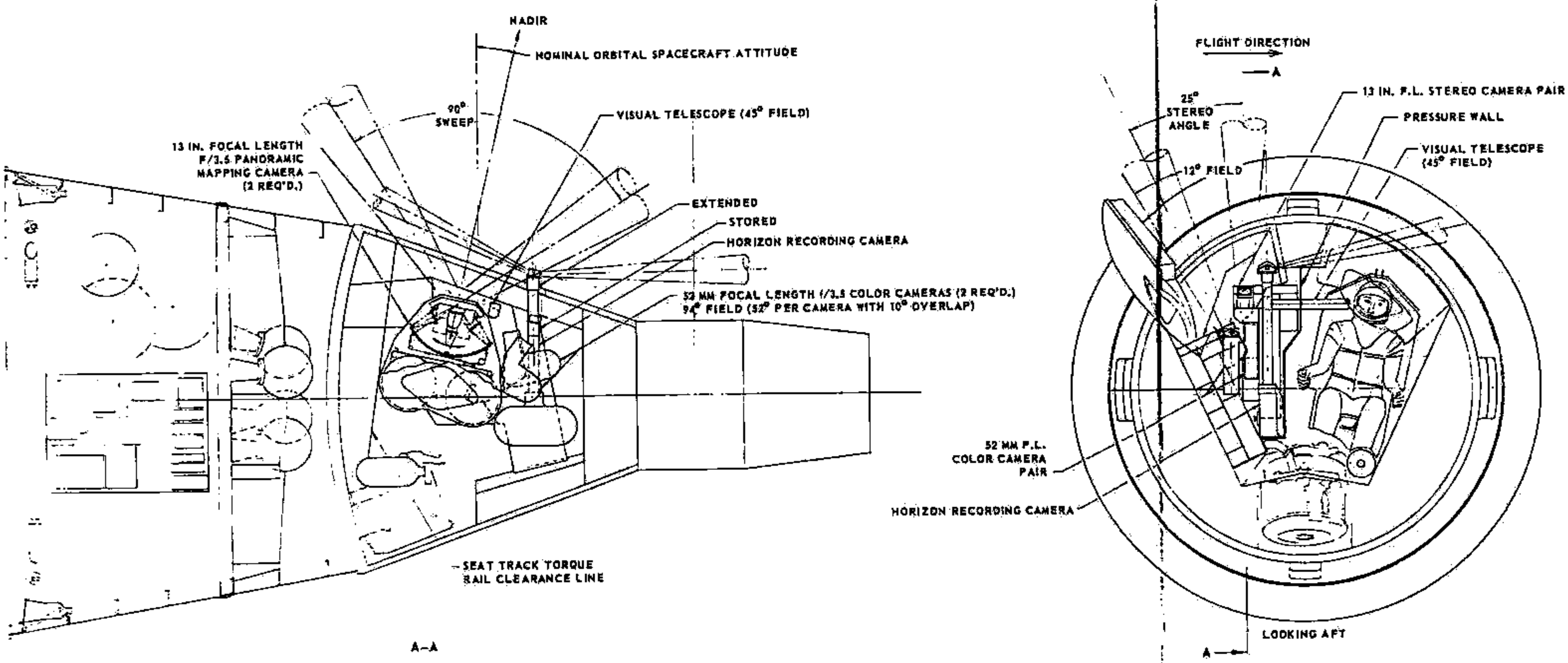


FIGURE 3.2–1

TABLE 3.2-1

MISSION EQUIPMENT CHARACTERISTICS
ONE-MAN GEMINI EARTH SURFACE MAPPING

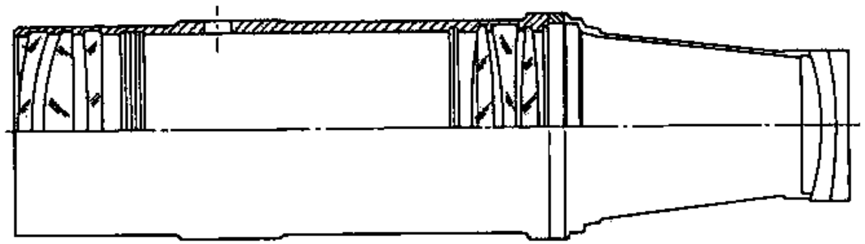
	QUANTITY	WEIGHT LB.-EACH	FIELD OF VIEW	FORMAT INCHES	PERFORMANCE @ 120 N.M.	FILM WT. LB.	MAPPING AREA 10% OVERLAP @ 120 N.M.	STEREO
PANORAMIC CAMERA – 13 IN f.l., f/3.5 PETZVAL FOLDED LENS, SO-206 FILM	2	75 W/O FILM 107.7 W/FILM	$10^\circ \times 90^\circ$	2.25 x 20.4	22.5 FT. RES. @2:1 CONTRAST	32.7 EA.	14.3×10^6 N.M. EACH CAMERA	YES 25° ANGLE
HORIZON CAMERA	1	20 W/O FILM 29 W/FILM	7°	2.25 x 2.25	<5 MIN.	9	COVER PAN PHOTOGRAPHY	–
COLOR CAMERA – 52MM f.l. f/3.5, FRAME	2	6 W/O FILM 9 W/FILM	52° EACH $+90^\circ$ CROSSTRACK BOTH	2.25 x 2.25	375 FT.	6	COVER PAN PHOTOGRAPHY	YES 55% O.L. FORWARD
VIEWFINDER – x 1.5 MAGNIFICATION YAW RETICLE	1	10	45° TRUE FIELD	–	–	–	–	–
HORIZON SENSOR	1	10	–	–	–	–	–	–

NOTE: SYSTEM POWER CONSUMPTION RUNNING IS 250 WATTS, WHEN SYSTEM ON STANDBY, THERMAL CONTROL CONSUMES 50 WATTS

Itek/TECHNICAL BULLETIN

13-inch, f/3.5 PETZVAL LENS

13-inch, f/3.5 PETZVAL LENS

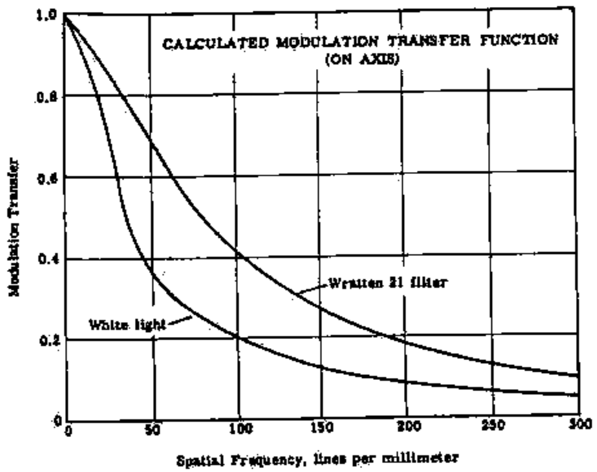


Itek's 13-inch, f/3.5 Petzval lens is an extremely high acuity lens that provides a high contrast AWAR of over 235 lines per millimeter. Low contrast AWAR is over 150 lines per millimeter. Performance is excellent in either white light or over more limited spectral regions.

Designed primarily for use in photographing distant objects, the lens uses a field flattened Petzval design of eight elements, and in a magnesium cell, weighs 6 pounds.

The size of the lens and the negligible distortion of the system make it suitable for frame, strip, or panoramic camera applications. It can also be produced in other focal lengths, and is available either in the straight configuration shown above, or folded for special applications.

Further information can be obtained by calling or writing: Government Systems Marketing, Itek Corporation.



CHARACTERISTICS

Lens type	Field flattened Petzval, 8 elements
Relative aperture	f/3.5, T/3.8
Field of view	±6°, 12° total
Image format	2½ × 2½ inches
Spectral range	0.52 to 0.70 μ
Equivalent focal length	13.0 inches
Back focal length	0.7 inch
Overall length	17.08 inches
Overall diameter	4.8 inches
Overall weight	6 pounds
Transmission	84 percent (axially)
Distortion	Less than 3 μ across the field

PERFORMANCE

Wratten 21 Spectral Range (0.52 to 0.70 μ)

Angle, degrees	Resolution* High Contrast Target (1,000:1)	Low Contrast Target (2:1)
0	250	160
2	250	160
4	250	155
6	180	125

* All resolution figures are given in lines per millimeter using Eastman Kodak 4404 film and MIL-STD ½" targets.

FIGURE 3.2-2

3.2.1 (Continued)

between camera frames and velocity accurately known, a baseline is established which in conjunction with a mechanically controlled camera convergence angle of 25° permits uncertainties in altitude (and scale) to be minimized by analysis of stereoscopic parallax between matching stereo photos. Coupled with a few arc-minutes error in local vertical from a horizon camera, mapping accuracies of 1000 feet are anticipated.

Film used is SO-206 thin base on 18 inch diameter reels. The reel diameter in the right hand crew compartment is the limiting factor rather than film weight. Sufficient film is carried to map 14.3 million square nautical miles in stereo from 120 n.m.

Horizon Camera (1) - A 70 m.m. frame camera which views the horizons is slaved to the pan cameras. Local vertical to a few minutes of arc is ascertained at the instant of each pan camera sweep center. A boresight center reticle is exposed on each horizon segment of the frame so that attitude excursions can be compensated in pan camera frame nadir point determinations.

The horizon camera head is retracted during launch, and is extended in orbit to provide a clear view of the horizon quadrants. Upon completion of the mission, the head may be either retracted or jettisoned to permit hatch closure.

Sufficient film is carried to correspond to complete exhaustion of the pan camera film (one frame/pan camera frame).

The design is similar to that of the horizon camera built by Wild of Heerbrugg.

70 m.m. Color Cameras (2) - Continuous color coverage is provided for the areas mapped by the pan cameras by the inclusion of two-52 m.m. focal length f/3.5, 70 m.m. color cameras. The cameras, each with a 52° field of view, look down and to the side with a slight nadir lateral overlap of about 5°, thus providing more than 90° lateral viewing using both cameras. Forward overlap of 55% is

3.2.1 (Continued)

is programmed so that stereoscopic color analysis can be performed. Sufficient film is carried to map the entire area mapped by the pan cameras. A resolution of slightly greater than 400 ft. from a 120 n.m. altitude is obtained.

Viewfinder (1) - The astronaut's viewfinder consists of a simple optical train using periscopic wide field optics. A real field of 40° at a magnification of 1.5 is employed to enable the astronaut to look down at part of the field to be mapped. The entire system is operated manually over areas of extensive cloud cover to conserve film. The viewfinder will include a yaw reference reticle for manual control of yaw attitude. The astronaut controls the spacecraft in yaw to within a few degrees of the nadir ground track.

Control Panel (1) - A simple control panel for astronaut operation consisting of on-off-warmup system positions as well as a display of film used is included. A clock display and up-date feature are essential to proper system operation, since operation is manually intiated and stopped. One control knob is used manually to insert ground supplied V/h for control of image motion compensation and the camera intervalometer.

3.2.2 Orbital Mapping Considerations - Selection of the orbit characteristics for the mapping mission is based on several overlapping factors which need to be evaluated to assure a practical and efficient mission. The following paragraphs discuss some of these considerations for a circular orbit with an altitude between 100 and 160 n.m. A sensor with a total lateral field of view of 90° with its line of sight pointed along the local vertical is assumed.

The orbit-to-orbit and the day-to-day shift of the spacecraft ground track with respect to a reference point on the earth is determined by the orbit period.