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MILITARY LUNAR BASE PROGRAM (c)

or

S.R. 183 LUNAR OBSERVATORY STUDY (u)

VOLUME I

STUDY SUMMARY

and

PROGRAM PLAN

ARDC

PROJECT NO. 7987

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TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENT	i
BACKGROUND	iii
LIST OF ILLUSTRATIONS	v
STUDY SUMMARY	I-1
CONCLUSIONS	I-7
RECOMMENDATIONS	I-9
INTRODUCTION—VOLUME I	I-11
TRANSPORTATION ANALYSIS	I-13
Measures of Effectiveness	I-13
System Synthesis	I-14
Typical Systems	I-16
Systems Evaluation	I-17
Transportation Analysis Summary	I-19
LUNAR BASE PROGRAM PLAN	I-21
Lunar Base Philosophy	I-21
Milestones	I-21
Program Phases	I-22
Master Program Schedule	I-23
ENVIRONMENT	I-25
RELIABILITY AND SAFETY	I-27
PHASE I—LUNAR PROBES	I-31
PHASE II—LUNAR ORBITS	I-33
PHASE III—SOFT LUNAR LANDING	I-37
PHASE IV—LUNAR LANDING & RETURN	I-41
PHASE V—MANNED VEHICLE DEVELOPMENT	I-45
PHASE VI—LUNAR BASE DEVELOPMENT	I-49
COST ANALYSIS	I-53
SPACE MISSION ANALYSIS	I-59
ATTACHMENTS	I-69
1. Study Program Schedule	I-69
2. Study Requirement and Amendment #1	I-71
3. Work Statement and Amendment #1	I-77
4. Attendance Roster—Contractor Presentations	I-85
5. Evaluation Panels	I-87
6. Contractors Reports	I-89

LIST OF ILLUSTRATIONS

Chart Number	*Title*	*Page*
	MASTER PROGRAM SCHEDULE	I-23
	ANNUAL LUNAR BASE PROGRAM COSTS	I-57
	ANNUAL MANPOWER REQUIREMENTS	I-58

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STUDY SUMMARY

The purpose of this study was to "determine an economical and sound approach for establishing a manned intelligence observatory on the moon." Normally the end product of this type of study is an Evaluation Report. However, due to the importance of the study conclusions and the significance of time, it was decided to prepare a preliminary Program Plan, as part of the final Report.

The final report has been prepared in two volumes. Volume I includes this Study Summary and the Program Plan. Volume II consists of the Technical Requirements to support the Program Plan. The Technical Requirements are presented in "technical packages" that cover each of the major technical areas. Each package includes the characteristics and required development schedules for all known items within the specific technical area, as well as the development philosophy to be followed.

The "technical packages" have been prepared to assist the appropriate development agencies to initiate the required applied research and technical development programs. The complete Military Lunar Base Program Report is suitable for use by personnel in a Program Office to establish a Lunar Base Program, or to coordinate Air Force lunar requirements with the NASA.

Based on present knowledge, the study has concluded that it is technically feasible to establish a manned base on the moon. "Technically feasible" is not meant to imply that the equipments are available, or the techniques are completely known. Actually it means that the problems have been analyzed, and logical and reasonable extensions to the "state-of-the-art" should provide the desired techniques and equipments and this is comparable to the establishment of the original "design objectives" for the Ballistic Missile Programs in the year, 1954.

As the study progressed it became obvious that this is *not* a program "far off in the future." Actually the long lead development items should be started *immediately* if maximum military advantage is to be derived from a lunar program. If this is done the United States could send a man to the moon and return him to the earth during the last quarter of 1967.

The final decision concerning the types of strategic systems to be placed on the moon (such as a Lunar Based Earth Bombardment System) can be safely deferred for three to four years. However, the program to establish a lunar base must not be delayed and the initial base design must meet *military* requirements. For example, the base should be designed as a permanent installation, it should be underground, it should strive to be completely self-supporting, and it should provide suitable accommodations to support extended tours of duty. A companion study on Strategic Lunar Systems (SR-192) has shown that the lunar base is the most time-critical part of the system, so it is obvious that any delay in initiating the base development program will proportionally delay the final operational capability.

The subject of establishing a military lunar base is extremely complex and includes almost every known technical discipline. For the technical portion of this report the technical problems have been categorized as Propulsion, Secondary Power, Guidance, Life Support, Communications and Data Handling, Sensors, Materials and Resources, Lunar Base Design, and Environment. However, the general subject can be simply described as searching for the answers to the following four questions.

1. HOW can a manned base be established on the moon?
2. WHEN can a manned base be established on the moon?
3. HOW MUCH will it cost to establish a manned lunar base?
4. WHY should a manned base be established on the moon?

A majority of the study effort was expended on the question of "How can a manned base be established on the moon?" The first step was to perform a Transportation Analysis and determine the most advantageous method of transporting men and materials to the moon and returning the men to earth. All conceivable chemical, nuclear and ion propulsion systems, using earth and lunar satellites, as well as "direct shot" trajectories, were considered. In addition, every reasonable technical perturbation was considered. *As a result of the analysis it was conclusively shown that the "direct shot" to the moon, using a five stage chemically propelled vehicle, is the most desirable.* This was not the expected conclusion since the establishment and use of a manned earth satellite-refueling station has been proposed for many years as the best way for man to travel to the moon. However, these original proposals did not have the benefit of a detailed analysis like the one performed in this study.

The analysis indicated the nuclear propulsion system could not be operational before 1970, so it was not advisable to rely on this system to establish the lunar base. However, if a nuclear system is available as expected in 1970, it could be used as indicated on the Master Program Schedule to logistically support the base.

With the "direct shot" determined to be the most desirable approach, it was possible to develop a vehicle concept. Based on technical and payload considerations, as well as the psychologists philosophy on "ideal crew size," it was concluded that a three-man aerodynamic re-entry vehicle would be the best method for transporting men to the moon and for returning them to the earth. This vehicle would weigh approximately 30,000 pounds as it enters the earth's atmosphere, and it would be capable of completely automatic-unmanned-10 day flights. The initial unmanned earth reentry flights will require a landing area of 10 x 20 miles. When man has been included in the system a more conventional landing strip will be useable, but to meet both of these requirements a facility like Edwards Air Force Base will be necessary.

The vehicle would be launched as the payload of a five stage system that has six million pounds of thrust in the first stage. All stages of the system would use liquid hydrogen and oxygen for propulsion, since this combination has about a 3 to 1 payload advantage over the more conventional liquid oxygen and RP-1 combination. It was determined that the proposed NOVA vehicles using liquid oxygen and RP-1 in the first stage would not be adequate for supporting manned lunar base operations. Therefore, it is desirable to go completely to the use of liquid hydrogen and oxygen as soon as possible.

The first four stages of this same system will provide the capability of soft landing a payload of 50,000 to 80,000 pounds at a preselected lunar site. This provides a configuration suitable for transporting large cargo payloads to the moon for use in constructing the permanent lunar base. Approximately one million pounds of cargo will need to be delivered to the lunar surface in order to construct and support the permanent base. Part of this cargo will consist of telescopic and sensing equipment for performing "surveillance and control" of cislunar space.

An analysis of the functions that are necessary to operate a lunar base has shown that a base complement of 21 personnel will be required. The tour of duty for space personnel is extremely critical, since "personnel transport" is one of the most important cost factors in a space program. Present studies show the maximum tour of duty on an orbiting space satellite is in the neighborhood of 30 days. However, it seems reasonable to expect tours of 7 to 9 months on a lunar base due to the possibility of better living conditions, availability of a natural gravity environment, and greater protection from natural hazards while in the underground base.

Once the decision was made to use a "direct shot" chemical system and a vehicle configuration was determined, it became possible to outline a program for developing equipments and a plan for establishing the lunar base. The program broke down into six logical phases with each phase designed to meet a specific secondary objective. These objectives all lead directly to the prime objective of establishing a manned military lunar base.

Basic to each phase of the program is our present knowledge of the environment in space and on the moon. Therefore, as part of this study all existing space and lunar environment knowledge was surveyed, analyzed, summarized and applied to the program plan. The environmental data obtained from each phase of the program will add to this knowledge and assist in the design of equipments for the following phases.

Reliability and safety are of basic importance to each program phase. Reliability is equally essential to the unmanned as well as the manned flights. However, when man is placed in the vehicles safety becomes of prime importance. It was determined that the multi-engine vehicles should be capable of performing the mission even following the loss of one engine. Normally the loss in payload and efficiency to achieve an "engine out" capability is undesirable, but in this program where large quantities of hydrogen and oxygen are part of the regular payload to support the base, the corresponding loss in payload to provide extra fuel and oxidizer is not a disadvantage. Actually a "real" payload loss will only take place when a catastrophic engine failure occurs. In the cases of non-catastrophic failure, the mission will still be accomplished at reduced efficiency.

The following table presents the objectives and systems to be used in each of the six program phases:

PHASE	OBJECTIVE	BOOSTER	PAYLOAD (Pounds)	NO. OF SHOTS	METHOD
1. Lunar Probes	Obtain Lunar and Cislunar Environmental Data	ATLAS-ABLE	370	6	High Resolution Video System and Sensors.
2. Lunar Orbits	Map Complete Lunar Surface (10-15' Resolution)	ATLAS-CENTAUR	1,200	6	Solar energy and strip mapping.
3. Lunar Soft Landing	Soft Land on Moon and obtain environmental data	SATURN (4 stages)	2,000	9	Deceleration stage, terminal guidance alighting gear, core sampling devices.
		SATURN (5 stages)	4,500		
		NOVA-4 (5 stages)	25,000		
4. Lunar Landing and Return	Return First Payload from Moon (A core sample of the lunar surface)	SATURN (5 stages) NOVA-4 (5 stages)	1,400 10,000	6	Core drilling and analysis package, lunar launching-atmospheric drag and retro-rocket re-entry, earth terminal guidance.
5. Manned Vehicle Development	Develop a Three Man Space Vehicle for Aerodyanmic Earth Re-entry	NOVA-4 (5 stages) *ARAGO (5 stages)	30,000 (Hi alt & Lunar Pass) 30,000 (Lunar Landing & Return with Man)	13	Extend Dyna Soar Techniques to Re-entry velocities of 37,000 ft/sec, fully automatic flight of manned space vehicle to moon and return to earth.
6. Lunar Base Development	Construct an Operational Permanent Base on the moon and support a 21 man crew.	*ARAGO (5 stages)	30,000 (3-Man Space Vehicle) 57,000-80,000 (One Way Cargo Vehicle)	1/mo 1/mo	Construct temporary base, build underground permanent base, install operational surveillance equipment. Support of the completed base will require a total of 1 flight/month.

*ARAGO is the term used to describe the 6 million pound thrust, liquid hydrogen and oxygen, propulsion stage.

Many items of equipment will be required for the lunar base program and wherever existing or programmed equipments would meet the requirements of the lunar base program they were scheduled for use. Where the item did not presently exist and none is programmed, a development schedule was provided. In addition, all necessary items are scheduled for use in the program as early as possible. This will improve reliability by use and growth, and allow the equipments to be "man-rated" by the desired time.

The major-pacing hardware items that require development to start immediately are as follows:

1. A liquid hydrogen and oxygen rocket stage which develops six million pounds of thrust.
2. A 30,000 pound, three man, earth return vehicle.
3. A 100 KW nuclear power unit capable of operating on the lunar surface for two years.
4. A suit/capsule capable of protecting personnel in the lunar environment.
5. A closed ecological system for use in the permanent lunar base.
6. A high definition video strip mapping system to map the lunar surface.
7. Suitable biopacks for use in the first three phases of the program.
8. A fully throttable, 6,000 pound thrust, liquid hydrogen and oxygen propulsion system.
9. A hydrogen-oxygen fuel cell.
10. A horizon scanner and altitude control system for lunar terminal guidance.
11. A command link midcourse guidance system.
12. A communications and terminal guidance package to be dropped on the lunar surface from orbiting vehicles.

The second major question concerning the establishment of a manned base on the moon is, "When can this be accomplished?" The Master Program Schedule for establishing a manned lunar base was obtained by scheduling the development of every known technical item and then integrating these individual schedules to determine when the base could become a reality. The Master Program Schedule for establishing a manned lunar base is included as Chart Number I-1 on page —.

Five major milestones worthy of special mention are:

1. First lunar sample returned to earth	November 1964
2. First manned lunar landing and return	August 1967
3. Temporary lunar base initiated (This temporary base will be on the lunar surface and it will provide facilities while the permanent underground base is under construction.)	November 1967
4. Permanent lunar base completed (The permanent base will support a complement of 21 men).	December 1968
5. Operational Lunar Base (Equipment will be installed to perform surveillance of earth-lunar space.)	June 1969

The third major question is, "How much will it cost to establish a manned lunar base?" A detailed breakdown is included in the section on Cost Analysis, page —. These cost figures were prepared by the Air Force. After the technical program plan was completed, the Cost Analysis Panel "coated" the program using the best Air Force information available from present ballistic missile and aircraft programs.

The important cost figures are summarized below:

Total Cost—Permanent Lunar Base	$7,726 million
Total Cost—10 Year Program (Includes installation of the permanent base and 6 months of operations.)	8,146 million
Annual Operating Cost	631 million

These costs are based on the following assumptions:

1. The major development engineering costs on the Saturn B and the NOVA 4 boosters has been assumed to be provided under independently funded programs. However, the actual cost of the boosters has been included and it was assumed that the first vehicle would be made available to the lunar program. If this is not the case, due to the "learning curve" it is expected that the vehicle costs would be decreased.

2. The costs include all shots in the program except the nuclear shots shown in the last half of 1970. The development costs for the nuclear system were not included because the lunar base program is not dependent upon the nuclear system. However, if the nuclear system is available and more economical it would be used to support the operational base.

3. Costs of all items normally considered as part of a weapon system (such as, launch pads and ground facilities) have been included.

4. It was assumed that adequate earth based tracking facilities will be available as the result of other programs. If they are not available the costs could increase by 300-600 million dollars in the later phases of the program.

When the average annual cost ($814 million) of the proposed program is compared to other Air Force efforts, it becomes apparent that this program is approximately equal to the output of just one of the major airframe companies normally supported by the Air Force. As a matter of information, the *annual* cost of the U. S. Farm Subsidy Program is approximately the same as the 9½ year program required to install the permanent lunar base.

One point worthy of particular mention when considering costs, is the development of lunar resources. Analysis has shown that the development of lunar resources could decrease the cost of Strategic Lunar Operations by as much as 25 per cent. This is based on the fact that the moon's surface probably consists of many types of silicates. Since hydrogen and oxygen are used as propellants in the transport vehicles, as essential elements in the secondary power systems, as an element for personnel breathing, and when combined as water for life support, the value of obtaining these two elements on the moon is obvious. Should oxygen and hydrogen be obtainable on the lunar surface they would be literally worth more than their weight in gold. This study has shown that it may be very possible to process lunar silicates to obtain water and then, by dissociation, the elements oxygen and hydrogen. It seemed very worthwhile to pursue this objective so a program schedule has been presented in the Environment section of Volume II. A glance at the lunar resource program schedule shows that the sample "core" of the lunar surface to be obtained in Phase IV, is critical to this effort. Although the process will require large quantities of power, solar energy is available in unlimited supply and nuclear power has been programmed for use on the lunar base.

The fourth major question, "Why should a manned base be established on the moon?", was not answered as a part of this SR-183 study. SR-192, the Strategic Lunar System Study was initiated on 29 August 1958 for the specific purpose of looking at this question. However, to provide a complete picture on the lunar base it seems necessary to consider the question in this report. Since the

TRANSPORTATION

final results of SR 192 are not yet available, the mid-term conclusions have been utilized. The Space Mission Analysis portion of this final SR 183 report briefly discusses these conclusions. The essential factors can be stated as follows:

1. The lunar base possesses strategic value for the U. S. by providing a site where future military deterrent forces could be located.

2. The decision on the types of military forces to be installed at the lunar base can be safely deferred for 3 to 4 years *provided a military lunar base program is initiated immediately.*

3. A lunar based earth bombardment system could have a CEP of two to five nautical miles.

4. The development of lunar resources could enhance the potential for strategic space operations in the cis-lunar volume.

CONCLUSIONS

The most important conclusions of this study can be summarized by the following statements:

1. It is technically feasible to establish a lunar base by logical extension of present techniques.

2. Earliest lunar operations may be attained through the use of a direct shot chemically powered booster.

3. A 6 million pound thrust LOX/LH_2 propulsion capability must be developed for the three-manned vehicle for lunar landing and return missions.

4. Investigation indicates that the payload penalty for using earth re-entry retro rockets is so great that the only logical re-entry approach is by means of aerodynamic braking. Therefore, the present Dyna Soar program is essential to provide re-entry vehicle design data.

5. A multi-phased program is essential to establish an operational lunar base. The Program Plan presented in this report includes the following six phases:

Phase I	Lunar Probes
Phase II	Lunar Orbits
Phase III	Soft Lunar Landing
Phase IV	Lunar Landing and Return
Phase V	Manned Vehicle Development
Phase VI	Lunar Base Development

6. Based on the above program the following milestones have been established as reasonable objectives.

a. First Lunar Sample Returned to Earth	November 1964
b. Manned Lunar Landing and Return	August 1967
c. Temporary Lunar Base Initiated	November 1967
d. Permanent Lunar Base Completed	December 1968
e. Operational Lunar Base	June 1969

7. The initial phases of the program can be undertaken for an investment which averages approximately 800 million dollars per year during the initial buildup phase. After the establishment of the base the annual costs will decrease to about 600 million dollars per year. This may be still further reduced when nuclear propulsion becomes available and as lunar resources are developed to provide oxygen and hydrogen to support space operations.

8. A lunar base is the initial and essential step in the attainment of a military capability in the lunar volume.

9. A military lunar system has potential to increase our deterrent capability by insuring positive retaliation.

10. The decisions regarding the type of military operations to be conducted in lunar and cislunar space can be safely deferred for several years provided a military lunar base is established which can be readily expanded to support lunar operations.

11. From a national viewpoint it is desirable that a lunar base be established as soon as possible. This conclusion is based on the strategic potential as well as the psychological, political and scientific implications.

TRANSPORTATION

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RECOMMENDATIONS

The following actions are recommended as a result of this study.

1. The program for establishing a military lunar base be recognized as an Air Force requirement.

2. Immediate action be taken to implement the early phases of the program.

3. Immediate action be taken to start the development of the critical long lead items listed below:

   a. Six million pound thrust LOX/LH_2 propulsion system.

   b. Three-man space vehicle which can re-enter earth's atmosphere.

   c. There are smaller items that should be started before the end of 1960. These are listed in the separate technical areas.

4. A program office be established within ARDC to coordinate with NASA, all activities directed toward the establishment of the lunar base.

5. The military requirements and NASA's requirements be integrated into one national lunar program.

6. Responsibilities be assigned for the various phases of the integrated lunar program.

7. The establishment of the base be considered a military expedition.

8. The Air Force develop space operational know-how by being intimately involved in all phases of the lunar program. This is in keeping with the philosophy of concurrency and is necessary to shorten the development cycle.

9. Further study be initiated as explained in each section of the technical report. The follow-on SR-183 study will tie all of these together into a comprehensive systems study.