Union Calendar No. 852

86TH CONGRESS 2d Session } HOUSE OF REPRESENTATIVES { REPORT No. 1931

ARMY LUNAR CONSTRUCTION AND MAPPING PROGRAM

JUNE 22, 1960.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. BROOKS of Louisiana, from the Committee on Science and Astronautics, submitted the following

REPORT

ARMY LUNAR CONSTRUCTION AND MAPPING PROGRAM

INTRODUCTION

According to our best information, and in all probability, the Moon has undergone less modification during the last several billion years than have the Earth, Mars, and Venus. Violent processes have left their marks, creating shallow craters which many scientists believe were produced by collisions of objects with its surface. The Moon may be similar to other matter accumulated by the Earth during its own formation. There has been no erosion by running water on the Moon, and in this way it is quite different from the Earth and, if Mars and Venus had oceans at some time in the past, it may be quite different from these planets as well. We can, therefore, expect that the Moon has retained more of the history of approximately the last 4 billion years than is generally characteristic of the planets. From this point of view the Moon is a much more important object of investigation than are the planets.

Today the Moon has become space objective No. 1. Efforts are now being made to measure the face of the Moon with greater precision than many parts of the Earth. The result of this work should be very exact contour maps for the use of lunar explorers. However, such precision maps will not be used for exploration only. Every year new theories are advanced concerning the nature of the lunar surface, the origin of the craters, the shape of the Moon and its formation. These theories have an important potential because they cast light upon the origin of the solar system, and possibly upon the origin of life on the Earth. These theories, however, are generally based upon the casual inspection of lunar photographs rather than upon precise measurement of lunar structures. It would appear to be simple enough to draw adequate maps from reasonably good photographs. However, any photograph of the Moon taken from the Earth has various imperfections. The Earth's atmosphere is the greatest cause of trouble that gives rise to these imperfections. The dust of the atmosphere obscures the view and air turbulence produces variations in scale across the image of the Moon. Another source of error is change in the appearance of features on the Moon's surface. Due to the direction of the Sun's rays, gentle slopes may appear to be rugged craters and peaks. Good mapping techniques are essential for a well-planned scientific lunar expedition.

The Committee on Science and Astronautics has had a continuing interest in the lunar phase of the overall national astronautics program. Of primary interest is the first phase, lunar mapping, to be followed by successive phases leading to a manned observatory on the Moon. Previous witnesses before the committee, including witnesses from the NASA, the military services, industry, and educational institutions, have proposed long-range programs to reach the goal of the manned lunar observatory. The 10-year plan of NASA, although not extended to manned landings during this decade, is oriented toward this goal. The committee was familiar with the work the Army Corps of Engineers was doing and had planned along these lines. The objective of the hearing was to hear, firsthand, the Corps of Engineers plan from the Chief of Engineers, U.S. Army.

PROGRAM

The Chief of Engineers presented several phases of an overall program.

LUNAR MAPPING

In accordance with the Army's assigned responsibilities for mapping and geodesy in support of all agencies under the Joint Chiefs of Staff, the Corps of Engineers of the Department of the Army has proposed satellite systems specifically for both mapping and geodesy. These systems would enable the production of maps of areas otherwise inaccessible. They can also produce maps that are more economical, more accurate, and which would be available sooner than those made by conventional means.

Recognizing that lunar maps will be needed prior to unmanned as well as manned exploration of the Moon, the Army Map Service began studying methods of mapping the Moon in 1958. From these studies grew Project LAMP, which stands for lunar analysis and mapping program.

The Department of the Air Force is doing work in the field of lunar mapping which is complementary to that of the Corps of Engineers. The Department of the Air Force work is more in the nature of obtaining aerial photographs, whereas the Corps of Engineers utilizes the photographs to produce the final product, the map. There is close coordination to insure that there is no duplication and that each of the services is taking the maximum advantage of the capabilities of the other.[1]

PROJECT LAMP

In order to achieve any degree of success with a manned landing on the Moon, a multiphase program of preparation is needed. This includes not only lunar mapping and lunar analysis, but also a construction capability and environmental training. The Corps of Engineers of the Department of the Army has a comprehensive program currently underway, given the name of Project LAMP, mentioned above, which proposes to furnish the necessary data for precision maps and information on the structural formation of the Moon. In addition to this program, there are being studied development of lunar construction methods designed to withstand the peculiar environment of the Moon, and training facilities to provide, in simulated form, the exacting conditions of the hostile lunar environment.

[1] See appendix for review of the program of the Department of the Air Force.

The objectives of Project LAMP are these:

(1) To make a rapid and accurate (plus or minus 300 feet) three-dimensional survey of the entire lunar surface;

(2) To determine the characteristics of the surface of the Moon by multiple-frequency electromagnetic interrogation; and

(3) To produce topographic-terrain and surface-property maps to be used in selecting scientific landing sites on the Moon.

Project LAMP has four stages designed to provide a working program by the end of 1963.

In stage I of LAMP, the Army Map Service, with the U.S. Geological Survey, is using currently available photographs, radar reflection data and other material to prepare a map of 1: 5,000,000 scale of the visible side of the Moon. A map of this scale would represent the area of the United States in about 3 feet of width. The principal result of this effort would be the production of the horizontal control network on the Moon through the use of a large digital computer. The name selenodesy is applied to this lunar survey process. With this selenodetic grid there can be located on a map, more accurately than has been heretofore possible, the craters, maria and other known features of the lunar surface.

Stage I of the current study will carry the program through the year 1960. Stage II will expand the current effort to carry out the balloon photography and radio interrogation phase of the program. Also during stage II the requirements for the lunar orbiting system will be determined. This stage would require $800,000 and 12 to 18 months. Stages III and IV would carry the program to the point of readiness to launch a payload to orbit the Moon. In stage III the system would be designed, and in stage IV the hardware would be built and tested. Stage III would require $2 million and a total of 12 months for its programing. Stage IV would have a requirement of $5 million and a period of 12 months. Stages II, III, and IV are not yet funded.

The National Aeronautics and Space Administration has been briefed on Project LAMP, and the technical approach and progress of the program have been discussed with that organization. However, the program was not presented to NASA until early in February 1960. NASA was favorably impressed but stated that it was without funds to meet the requirements of stage II. The Corps of Engineers has been asked to coordinate with the Air Force and to integrate both programs. NASA proposes to review the integrated program some time in the future and to see what funding would be available to meet this requirement.

Project LAMP includes the use of three techniques for making a rapid and accurate three-dimensional survey of the entire lunar surface (including the "back" side). These are (1) radar, (2) television, and (3) camera. A prerequisite to the operational use of any of the proposed mapping schemes is the solution of propulsion, guidance, and control problems to satisfy the following specifications:

(*a*) The instrument system must be put into polar orbit of small eccentricity around the Moon at an altitude of between 50 and 100 miles above the lunar surface.

(*b*) The instrument package must be maintained in this orbit for as long as is necessary to cover the entire lunar surface. The time required ranges from one to several lunar days. (A lunar day is approximately 28 Earth days.)

(*c*) Direction and attitude stabilization must provide continuous three-axis control for the direction of the mapping.

The first of the three instrument systems is the one which could become operational at the earliest date. This is the radar system. It consists of a radar altimeter for continuously profiling the terrain beneath the Moon-orbiting vehicle, a multiple-frequency surface interrogator and passive distance-measuring devices. This system is more complex than the other two, but it has a potential weight advantage. As the space vehicle flies around the Moon, radar would record the profile of the surface directly beneath the flight path. After many such flights a record of the Moon's surface would be built up and stored in a computer. By plotting many profiles, a map could be produced if it were found desirable. This instrument system, however, is designed to establish a flight path for a manned space ship. For example, a computer in the vehicle would contain the radar information already obtained by the earlier unmanned mapping satellite. This space ship would measure the profile beneath it as before, and its computer would electronically compare these data with those stored in its memory file, automatically establishing the position and direction of the flight path.

The second system is the television. In addition to the components used in the radar system, television will be used for getting stereoscopic coverage of the Moon's surface as well as for obtaining star and Earth positional data in order to preserve the geometric relationship necessary for the stereophoto mapping. Basically, the television system would take pictures of the Moon and transmit them to the Earth. To orient these pictures, another TV camera in the satellite would take and transmit a picture of the stars at the same time in order to determine proper orientation. This would preserve the geometry necessary for correct mapping.

The third system is the camera system. This would combine the components of the radar system with a high resolution nadir camera and three horizon cameras. Stero coverage would be obtained by overlapping exposures taken with the nadir camera. The synchronized horizon cameras would provide simultaneous exposures from which the direction angles of the geometric nadir camera could be obtained. From the photogrammetric evaluation of the pictures and from altimeter measurement there could be derived a selenodetic coordinate system. In addition to the coordinates, there could also be established a lunar datum, a polar reference and the rotational rate. The camera system would provide not only a higher degree of accuracy than the other two systems, but also better resolution without jeopardizing the system's usefulness for mapping.

The radar system, which is quite light—on the order of 1,000 pounds payload—has as its main problem accuracy. The problems connected with the TV system are power for the telemetering and the transmitting band width. TV mapping schemes may become feasible, provided the booster is capable of placing a payload on the order of 10,000 pounds into lunar orbit. The primary difficulty with the camera system is the problem of physical recovery.

The results of the lunar-mapping mission will be completely useful only if they can be used by future lunar and circumlunar expeditions to locate themselves. For example, a spacecraft flying over a portion of the lunar surface previously mapped will have its sensors record the topographic profile along the flight path. As a result of the previous lunar mapping mission there will be available a digital terrain model which will reproduce the three-dimensional surface configuration of the overflight area. By matching the profiles sensed by the spacecraft with the digital terrain model, positional control of the vehicle and its flight path can be established.

LUNAR BASE CONCEPT

The establishment of a manned outpost in the lunar environment would demonstrate U.S. leadership in space. It could not only provide a base for exploration and operation on the Moon, but would support a capability for other operations in space. The Corps of Engineers has a design for a lunar base to accommodate a complement of 12 men engaged in scientific and technical investigation on the surface of the Moon. Although no radical construction techniques are incorporated in the design, nevertheless the facilities will require an extensive research and development program to develop and test the equipment and techniques involved. If such a program is begun immediately, it is considered that the lunar base could be available within the next decade so as to coincide with the availability date of the necessary transport system.

The lunar environment differs radically from that of the Earth. Many new concepts and techniques will be required to overcome the hostile environment of the Moon. Some of these lunar characteristics are a lack of atmosphere, large temperature variations, solar and cosmic radiation, meteorite bombardment, and reduced gravity. Lunar atmosphere may exist but if there approaches a near vacuum requiring special radiators to dissipate unwanted heat, an Earthlike atmosphere will have to be provided within the living facilities.

Protection must be provided for personnel against solar and cosmic radiation. Also there will be found an accumulation of electrostatic charges on metals due to the photoelectric effect, requiring structures, vehicles and personnel to be grounded. It is likewise anticipated that the scientific team on the Moon must be protected from an accidental look at the Sun, since such a look will result in instantaneous, permanent, and total blindness.

The velocity of particles striking the Moon will not be reduced by atmospheric drag, and consequently there must be provided adequate protection against these particles. The reduced lunar gravity will result in both advantages and disadvantages. The gravity is approximately one-sixth that of the Earth, and the reduced gravity would aid the exploring team in performing manual labor but it will require that vehicles and construction equipment (fig. 1) be redesigned to maintain an efficient power-to-traction ratio. Also, the reduced lunar gravity will make the use of surveying instruments that contain spirit levels much less practicable.

FIGURE 1

In determining the location of a lunar outpost, there should be taken into consideration not only safe landing areas but feasibility of construction of the site. The following points of interest must be evaluated:

(1) Landing and launching sites positioned so as to require minimum-energy trajectories;

(2) Location near areas of special scientific significance;

(3) Surface areas capable of supporting structures and vehicles;

(4) Ease with which site may be excavated to bury facilities; and

(5) Location to facilitate expansion of the base.

The first and foremost requirement for a lunar outpost (fig. 2) is the establishment of an environment in which man can live and work. This involves providing an earthlike atmosphere with means of replacing oxygen and nitrogen, removal of carbon dioxide, proper temperature, humidity, and pressure control. It is considered feasible that in the early base concept liquid oxygen and nitrogen could be transported from the Earth and used in both base compartment and space suit pressurization. Carbon dioxide would have to be removed by chemical and physical means, moisture would be removed by dehumidifiers and reused for washing. Food and, initially, drinking water would be transported from the Earth. The interior of the base would be heated and lighted electrically. The basic power supply would be provided by several small nuclear reactors. These reactors would be located in holes blasted in the surface several hundred feet from the main structures, each utilizing radiators and meteorite shielding. Transmission cables from the reactors would be buried. The basic structure would be cylindrical, the external dimensions of which are consistent with those of the transport rocket cargo section. Each structure would form one module of the base, and prior to launching it would be prefitted with equipment and facilities insofar as practicable, so that it could be readily assembled into a habitable structure on the Moon. The base would be buried several feet below the surface (fig. 3) of the lunar crust for thermal insulation and meteorite protection. Each module would have a double shield of titanium alloy separated by vacuum space achieved by venting to the outside.

To accomplish the necessary excavation backfill, module assembly, heavy-cargo handling and other mechanical functions, a multipurpose construction vehicle is envisioned. This vehicle would have metal wheels and a removable, pressurized cab, and would operate on electric power from fuel cells. It would have a bulldozer blade, crane boom, winch, fork lift arms and other attachments, and will be designed so that it could be operated remotely by wire or radio. It, of course, must be specifically designed to operate effectively in lunar gravity. This concept envisions a design capable of easy transportation and construction, with a high degree of reliability and safety.

Every task and every operation to be accomplished on the Moon must be thoroughly planned and rehearsed in advance on the Earth. The best way to accomplish this is by the use of a large-scale environmental simulation chamber which will provide research and training in this respect.

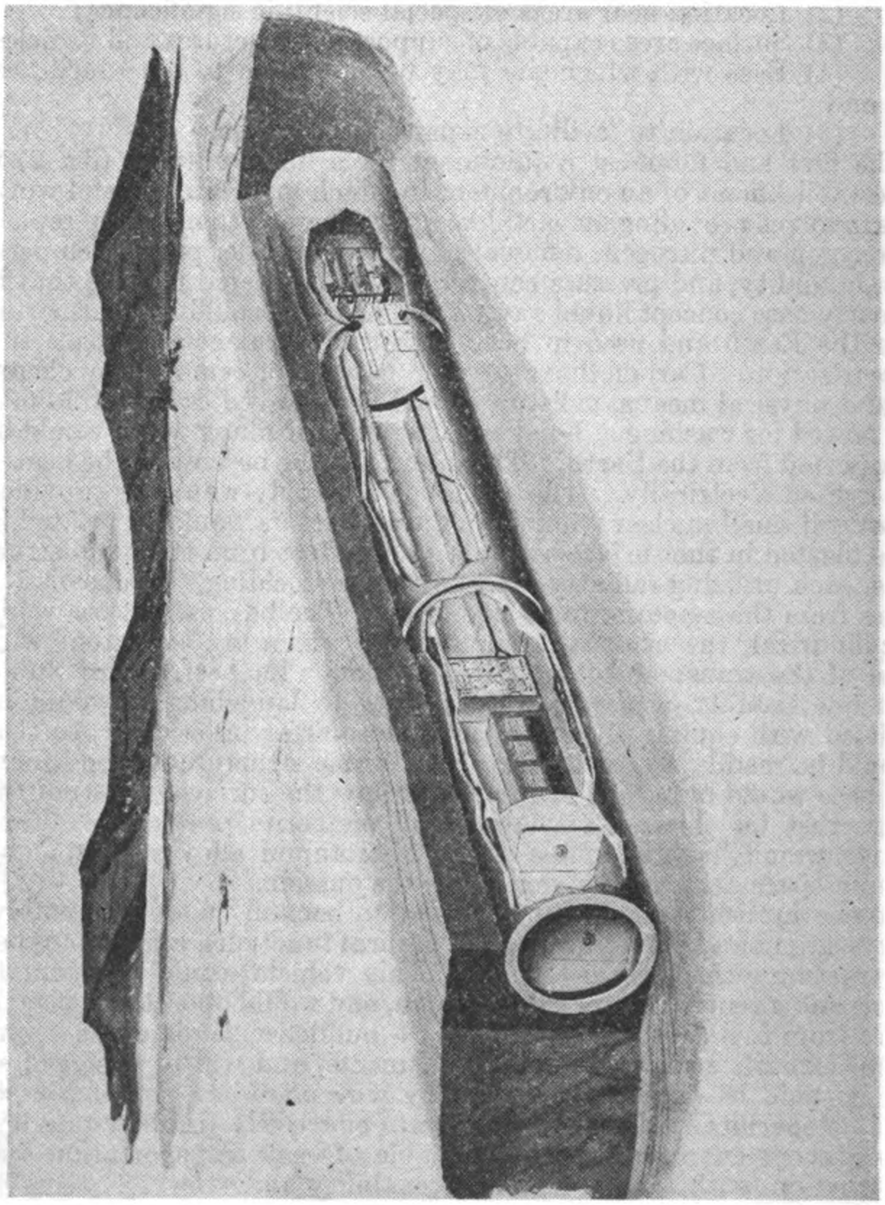

FIGURE 2

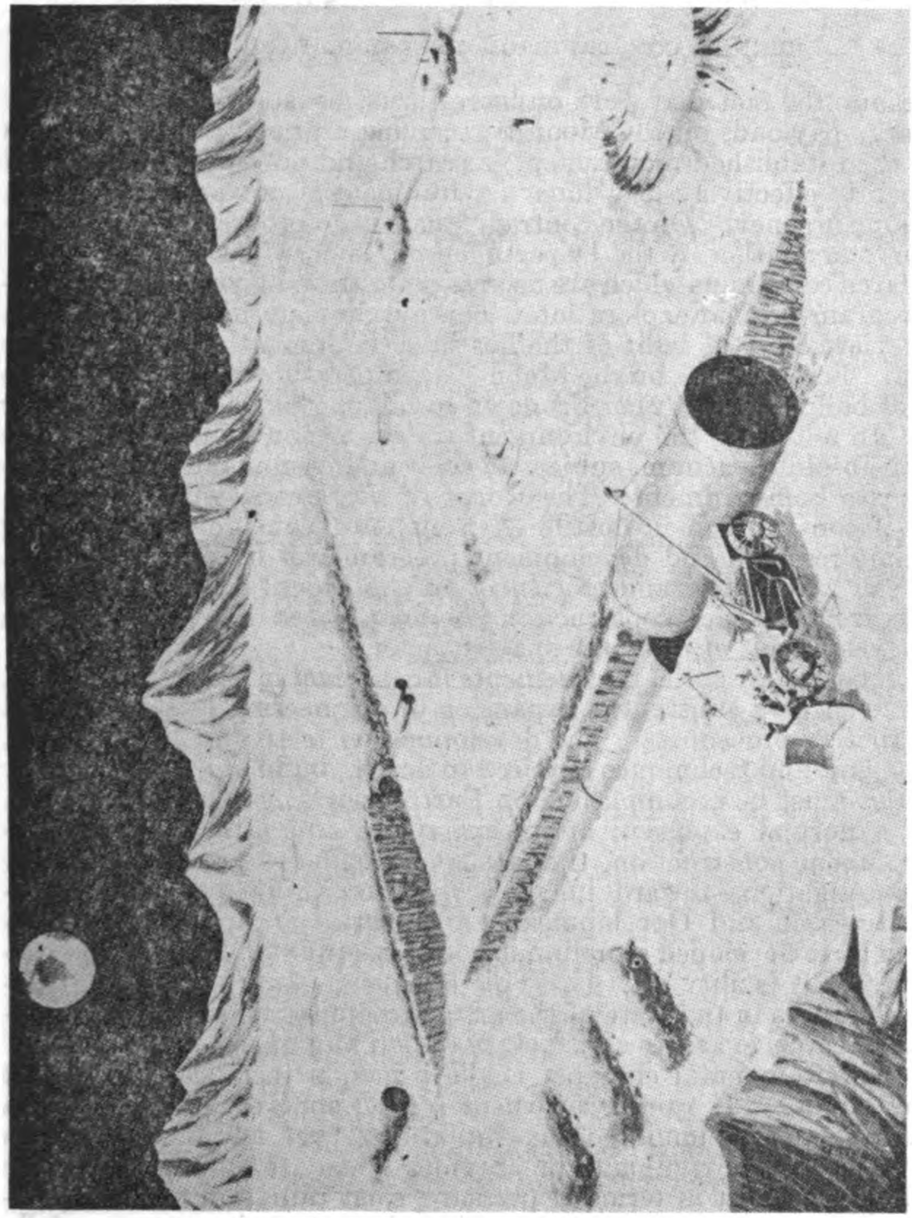

FIGURE 3

This concept for a lunar base may change many times during the research and development period leading up to the actual launching. Information gained within the next few years may have radical effects on opinions concerning the Moon. This concept is an example of the contribution of the Corps of Engineers for lunar construction that could lend assistance in achieving a great objective of the national space program.

LUNAR CONSTRUCTION RESEARCH FACILITY

Despite the fact that work on large-thrust boosters capable of placing large payloads on the Moon is receiving a priority commensurate with the established requirement, research and development required to operate effectively in a lunar environment is not proceeding with the same urgency. On the contrary, there is no program being undertaken today, either by the Department of Defense or NASA, to study simulated conditions which are necessary for training prior to a successful program of lunar exploration. This requirement becomes apparent when viewed in the light of the hostile environment expected on the Moon. For example, on the Moon the temperature varies from above that of boiling water (212° F.) down to minus 270° F. within a lunar day. In addition, the environment on the Moon will place man in a near-absolute vacuum, subject to solar and cosmic radiation and to meteorite bombardment. The Corps of Engineers, with an experience of construction in hostile environments, concludes that a long leadtime research and development program will be required before man can exist safely and efficiently on the Moon. Such a program of research in space construction should proceed concurrently with the development of the large space booster.

To meet the essential requirements for survival in this environment, there must be a substantial expansion of engineering technology and construction procedures. The developmental testing of the material, equipment, and techniques required to design, build and operate lunar facilities must be accomplished on Earth prior to going to the Moon.

As a normal extension of its experience and interest in hostile-environment construction, the Corps of Engineers has now directed its investigations toward lunar-construction problems. The Engineer Research and Development Laboratories of the Corps of Engineers have developed a preliminary design study of a lunar construction research facility (fig. 4). This facility exploits the recent technical advances in the state of the art and requires no significant additional research to assure satisfactory design and operation.

The environmental chamber is the principal technical component of the facility. It would consist of a steel sphere equipped with a vacuum system, a simulated solar radiation source, and liquid nitrogen heat sinks. This combination provides adequate simulation of the lunar environment in terms of pressure, solar radiation and temperature. The chamber size and operating characteristics were carefully selected to achieve minimum size and cost, and yet offer maximum benefits to the Nation's space research programs during the life of the facility, which is estimated to be 20 years. While intended principally for the support of engineering research, the chamber will be capable of performing important tests on packaged assemblies, including the anticipated basic payload capsule of the Saturn vehicle.

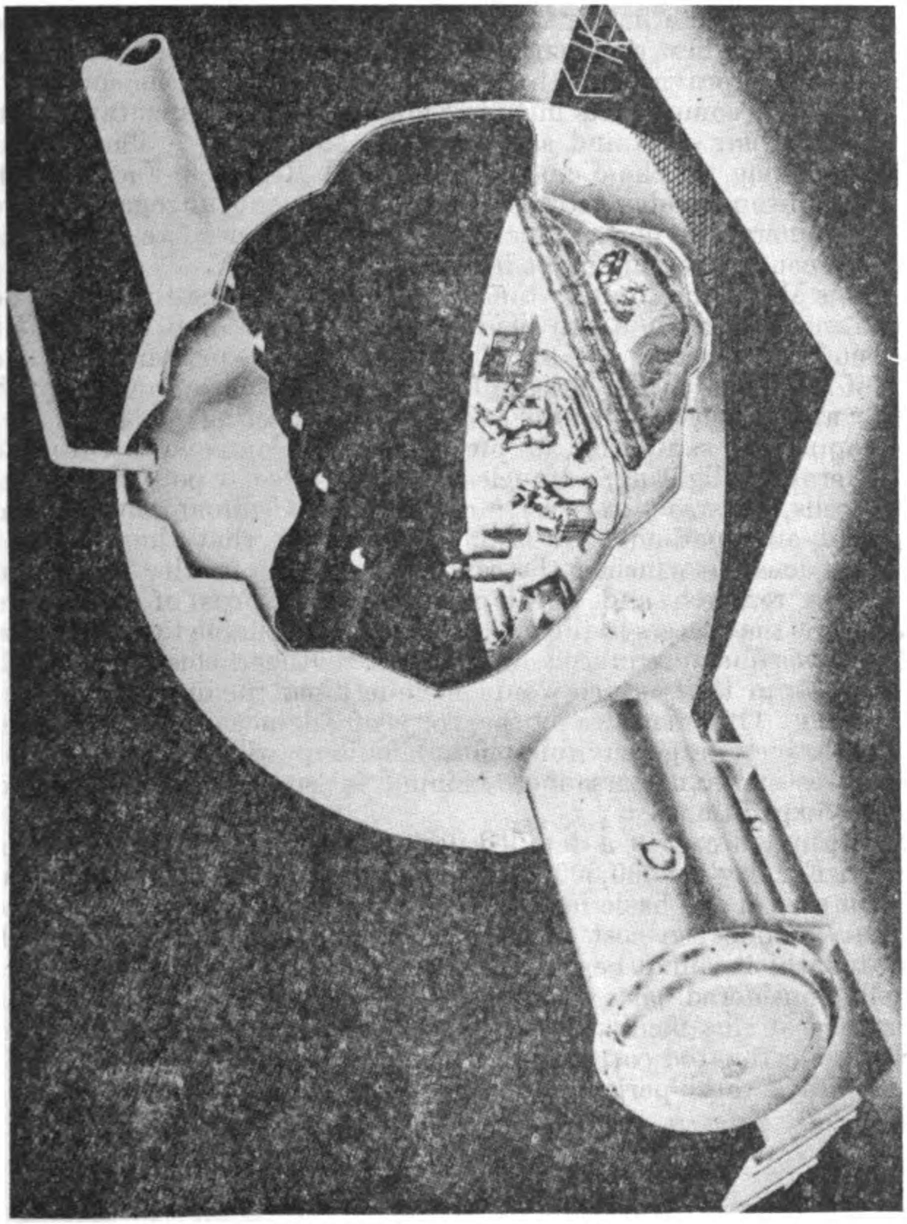

FIGURE 4

This lunar environment simulator will be an inhabited research facility. Provision has been made for occupancy by research teams of up to four men at a time. Successful operation of this simulator will not only permit the conduct of essential engineering research and development but will also dramatically demonstrate both the problems and their subsequent solutions concerning protection and utilization of men and machinery in construction on the lunar surface. To conserve operating time in the lunar simulator and to support studies better performed first on a smaller scale, required specialized laboratories are to be provided in the same building housing the simulator (fig. 5). Other components include controls and instrumentation, an instrument repair shop and a special first aid facility. The second building making up the Lunar Construction Research Facility will house the 75-ton-per-day nitrogen liquefaction plant, nitrogen storage tanks, an emergency power generator, central power switching facilities and a central heating plant for the entire facility.

There is almost no limit to the engineering problems that must be defined and solved on Earth before man can work and live on the lunar surface. Among the broad problem areas considered by the Corps of Engineers in the design of the Lunar Construction Research Facility are (*a*) environmental effects on engineering materials, (*b*) water supply and sanitation, (*c*) production and control of breathable atmospheres, (*d*) lighting, (*e*) nuclear power, (*f*) solar power systems, (*g*) fuel cells, (*h*) structural design criteria, and (*i*) lunar construction equipment and methods. It is noted, however, that the Corps of Engineers does not consider the capabilities of the facility limited to engineering research and development. The Corps of Engineers recommends that access to the facility be made available to all agencies of the Government requiring its services. Other fields of research benefiting from this service would include lunar medicine and communications. Other studies by the Corps of Engineers have indicated that a relatively large environmental simulator will be required for systems testing and personnel training in support of lunar and planetary expeditions.

The estimated cost of a detailed design of the Lunar Construction Research Facility is $500,000. The preliminary estimate of the construction cost of the basic facility is $6 million. This latter estimate does not include the cost of special instrumentation and research apparatus which cannot be defined in detail at this time and which are normally considered parts of specific research tasks. Considering the importance of this facility in developing required engineering capabilities, the estimated costs are quite modest. It is estimated that it will require a total period of 3 years to design and construct the facility.

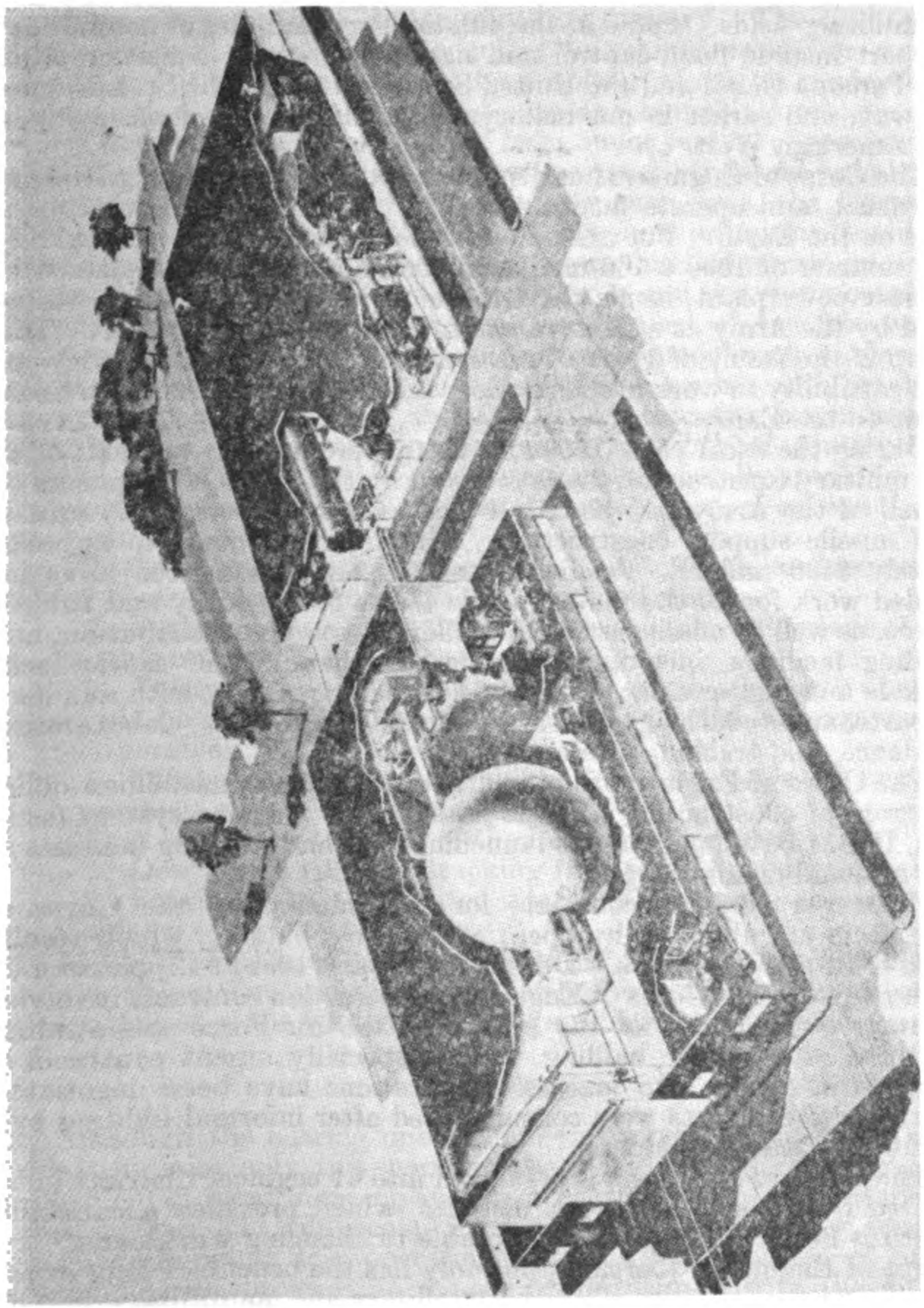

FIGURE 5

CONSTRUCTION EXPERIENCE

The background of the Corps of Engineers of the Department of the Army shows an experience of support not only of Department of Defense space systems but for the entire national space effort as well. The Corps of Engineers has rendered support in both military and nonmilitary fields. Some of the outstanding examples of nonmilitary support include flood-control and navigation works, construction of the Panama Canal and the United States portion of the St. Lawrence Seaway, and earlier in our history, the exploration and surveying of the American West.

The Corps of Engineers has demonstrated a unique ability to design, construct, and operate facilities under the extremes of environment here on the Earth. For example, the Corps of Engineers will build in the summer of 1960 a 100-man, semipermanent camp, complete with nuclear powerplant, inside the Greenland icecap. This camp will be used by the Army as a polar research and development center. This camp is the result of years of research and development to arrive at this capability to work in the Arctic, which is the most hostile environment on the Earth.

During the fiscal years 1959 and 1960 approximately one-half of all the military construction funds received by the Corps of Engineers on behalf of the Army and the Air Force have been devoted to missile and missile support construction. This figure amounts to approximately $400 million. Facilities designed and constructed have included work for all the major missile teams of the Army and the Air Force, as well as missile assembly buildings, storage, distribution, and loading facilities, including those for the handling of exotic fuels, rockets and high-pressure gases, and launching stands, with auxiliary appurtenances such as service towers, blockhouses, laboratories, guidance, and tracking stations.

The Corps of Engineers is presently engaged in a multibillion-dollar program of constructing ballistic missile early warning system facilities, ICBM bases, and missile launching, test and tracking facilities at the national missile ranges.

Whenever possible, contracts for construction by the Corps of Engineers are obtained by open, competitive bidding, which results in a fixed-price contract. During fiscal year 1959, 94.1 percent by dollar value, of all Corps of Engineers construction contracts involving military construction for the Army and the Air Force was awarded by open, competitive bidding. Only especially urgent contracts or projects in remote and inaccessible locations have been negotiated. Even those contracts were consummated after informal bidding by a number of selected bidders.

The Corps of Engineers is organized into 41 engineer districts in the United States and 8 oversea districts, which provides a capability which is flexible and quickly adaptable to changing workloads. The Corps of Engineers, therefore, not only has the benefit of long experience in construction programs, both military and nonmilitary, but has an organizational capability to accomplish the tasks required by extreme environmental conditions.

Equatorial Launch Site

It is anticipated that the Corps of Engineers, in support of the national missile program, may be called upon in the very near future to construct expanded launching facilities beyond those now available. It is anticipated that for the large boosters (Saturn and larger), a launching site near the Equator may be necessary. The equatorial launch site will reduce energy required to achieve orbital or escape velocity and it will also simplify the problems of orbital rendezvous. Nuclear stages, when incorporated into the launching vehicle, will require that launch sites be removed from major centers of population, and the equatorial sites appear in this respect to be the most promising. Recognizing the potential requirement for such sites, the Corps of Engineers has conducted studies to select the most promising localities. These studies have been aided by the topographic and terrain information available through the Army Map Service and the many cooperative mapping agreements in existence with most of the free world community of nations. These studies were made with a view to fulfilling the requirements not only of the space age but with practical engineering considerations as well; that is, soil capacity, water supply, power sources, access routes, economic availability of construction material and labor, and other considerations. Generally speaking, the following considerations should govern the selection of an equatorial launch site:

1. Open water should extend to about 1,500 miles downrange for booster recovery or impact of a second stage.
2. Eastward launchings should be used to take advantage of the Earth's rotation.
3. Thirty degrees of azimuth traverse, north and south of east, should be possible to allow daily launchings. Polar firings would be desirable.
4. Future expansion of the site is desirable; potential nuclear launchings should be considered.
5. A location within 2½° of the Equator is required.
6. Downrange sites for tracking facilities should be available.
7. Proximity to the United States is desirable, to ease the problems of logistic support.

It has been concluded that an equatorial launch site is feasible in one or more locations and that such a facility would materially enhance the capabilities of the United States for space-flight operations.

Conclusions

1. Although the hearing upon which this report is based was of a one-day duration only, this should not be considered an indication that the problem of lunar mapping and lunar construction is without major interest. This field will become increasingly important as the time of large space boosters near operational stage. The program of lunar mapping should progress at a pace commensurate with the development of the large booster. The ability to place a manned vehicle on the Moon will prove only as successful as the capability of doing lunar scientific exploration. Therefore, lunar environmental studies should keep pace with both large boosters and lunar mapping programs.

2. Although a number of agencies are involved in studies of lunar mapping, there appears to be no overlapping of effort. Failure of the present cooperative effort to continue, however, could lead to unified control, with one agency being given complete authority in this area.

3. At present there is no known requirement from a military standpoint to establish a base on the Moon. It does appear, however, desirable from a scientific standpoint to establish such a base.

4. Preliminary lunar mapping is a prime requisite to the establishment of a base on the Moon. Project LAMP is worthy of consideration by the National Aeronautics and Space Administration to further its program of manned and unmanned exploration of the Moon.

5. The background of the Corps of Engineers of the Department of the Army, together with its years of experience and its flexible organization, indicates that its talents should be used in planning, programing and executing lunar construction.

6. The Corps of Engineers is to be complimented on the high percentage of its construction contracts which are awarded under competitive bidding.

APPENDIX

The Air Force has had two basic contracts in the area of lunar mapping and charting since 1958. The first is with the University of Manchester (principal investigator, Dr. Z. Kopal). Dr. Kopal developed a method for measuring vertical heights on the Moon, utilizing photographs of the shadows cast by lunar surface features. This method has the capability of providing measurements of the relative height of lunar features above a given point on the Moon with an accuracy of 100 to 200 feet. This accuracy is an order of magnitude better than the stereopair technique which is normally used. Dr. Kopal and his people perform all their observational work at Pic-du-Midi Observatory in France, which is noted for its excellent astronomical "seeing" conditions.

The purpose of this contract is to provide topographic information of the lunar surface that will permit the production of accurate lunar maps. The data provided by Dr. Kopal are transmitted to the Air Force Aeronautical Chart and Information Center (ACIC) for reduction. These data are then available for the manufacturing of accurate charts. Lunar charts are produced, first, to satisfy our own intelligence requirements and, second, to provide charts for the national space effort led by the National Aeronautics and Space Administration. The initial contract with the University of Manchester was for the period of November 1, 1958, to April 30, 1960 (AF 61(052)–168), and was for the sum of $21,509. This contract was increased on August 4, 1959, by $2,000 to include exploratory spectroscopic observations of the Moon.

A new contract was executed effective May 1, 1960, to run through October 31, 1960 (AF 61(052)–380), for the sum of $10,000. To date, the Air Force has spent $33,509 in the area of lunar mapping with the University of Manchester at an average rate of $16,754.50 per year. This relatively small contract has produced topographic information on one-fourth of the visible surface of the Moon. In addition to this direct contract with the University of Manchester, the Air Force has provided $40,000 to provide a 40-inch reflector telescope for the Pic-du-Midi Observatory. This small sum will provide a tremendously increased capability at this observatory for this type of research and takes advantage of an astronomical site that is widely recognized as one of the best in the world.

The second contract in this area has been with the Yerkes Observatory of the University of Chicago (principal investigator, Dr. G. Kuiper). The purpose of this project was to produce a new lunar photographic atlas. In the last 50 years, although telescopes have been improved, and many more and better photographs of the Moon have become available, no attempt has been made to produce a useful compilation of these photographs. At the suggestion of Dr. Kuiper, a recognized authority in the field, the Air Force agreed to finance

Yerkes Observatory in its collection and reduction of the best photographs available from the files of five of the leading observatories in the world. The observatories from which photographs were selected were Yerkes, Lick, Mount Wilson, Pic-du-Midi, and McDonald. Dr. Kuiper originally selected 1,200 photographs from which 280 were chosen on the basis of clarity to go into the atlas. The Moon's visible surface was divided into 44 areas and each area is represented by at least 4 photographs under different lighting conditions. This atlas is now complete and is being distributed on a need basis to Government agencies such as NASA.

It should be noted that one of the main reasons that the Air Force agreed to sponsor Dr. Kuiper in this work is that it was convinced at the time (prior to the formation of NASA) that the Nation would have a need for such an atlas in the future. This has been borne out by the response to the release of this atlas. The initial contract with Dr. Kuiper (AF 19(604)–3873) was for the sum of $61,000 for the period April 1, 1958, through March 31, 1959. This contract was extended on February 25, 1959, to September 3, 1959, with an increase of funds of $52,500. It was further extended on November 18, 1959, to April 30, 1960, with no increase in funds. The total contract expenditure over a 2-year period therefore has been $113,500.

The Air Force programs in this area have been fully coordinated with all interested agencies. This coordination has been achieved through the mechanism of the NASA–DOD Space Science Committee which contains members from the Army, Navy, Air Force, NSF, and NASA. In addition, NASA was completely briefed on the Air Force program and the results of this program offered for use by NASA.

O