INTER-DEPARTMENT COMMUNICATION
THE MARTIN CO.

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TO D. J. Gaume

FROM G. M. Galmish MAIL NO. A-182 EXT. PHONE NO. 2297

SUBJECT Lunar Simulator MODEL

Enclosed are 5 copies of a summary report covering work done by Dept. 444/20 on the lunar structure. It will supplement the drawings previously given to you.

Procurement has obtained from F. J. Stokes Company a budget estimate of $25,000 for the vacuum pumping system required as outlined in our preliminary vacuum specification dated 20 August 1958. We are still investigating the vacuum pumping methods and the air conditioning equipment necessary inside the lunar base itself as well as in the simulator.

It is estimated that a final design and preparation of working drawings of the simulator including structural, mechanical and electrical work would require approximately 28 man months of engineering effort. This would not include any laboratory equipment installed in the building, nor would it include time for supporting structure design.

Very truly yours,

G. M. Galmish
Principal Engineer
AGBSD

GMG:mw

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SUMMARY REPORT OF WORK ACCOMPLISHED
TOWARD THE DESIGN OF THE LUNAR SIMULATOR.................
Dept. 444/20

23 September 1958

1.0 Scape - The problem was to develop the design criteria and provide a preliminary design for a lunar structure and for a simulator to be constructed on plant site to duplicate certain conditions under which the actual lunar structure must eventually operate.

2.0 Lunar Structures -

2.1 In the selection of suitable structures for lunar bases, three categories of problems have determining influence: lunar environmental conditions, purpose of structure, and available materials. Any investigation into these problems is limited by the fact that our present knowledge of the moon's surface is insufficient. For example, there are several contradictory hypotheses concerning the composition of lunar soil. For advance study purposes the most critical conditions from these assumptions should be considered in order to reduce hazards caused by structural failures. Extensive local research must be carried out on the moon before lunar rock can be safely utilized as building material for lunar bases. It follows then that originally all necessary materials for the construction of lunar bases must be transported by space ships, inducing minimum weight requirements for the selection of structural materials.

2.2 Lunar Environmental Conditions

2.2.1 Reduced gravity. This is not a serious problem. It means merely the reduction of all dead loads caused by moon gravitation to one-sixth their terrestrial values. The advantages of this reduction in weight are obvious. The structure will be lighter, more economical and correspondingly easier to handle. However, in the case where counterweight action is required, such as in crane design and retaining wall design, the reduced gravity offers no advantage. Dealing with extremely light structures a careful investigation of elastic stability, involving buckling, tilting, etc., is mandatory.

2.2.2 Lack of atmosphere. This creates more in the way of structural problems than reduced gravity because all buildings in which terrestrial conditions must be maintained will require pressurization. Consequently, a complete coverage with an airtight material is mandatory. This requirement leads to the almost exclusive utilization of three dimensional space structures which also afford other structural advantages. A satisfactory internal pressure range is considered to be 7-10 psi. The internal pressurization and the unknown soil conditions on the moon suggest self-contained structures which preclude need for heavy anchorage. Moreover, a self-contained structure reduces foundation problems if, as one hypothesis states, the surface of the moon is covered with light dust . The lack of atmosphere does not exclude structural connections by means of welding of aluminum alloys in a vacuum is entirely feasible. Some means must be provided, however, for cooling the welded surfaces by either a gas jet or water jet to reduce undesirable heat-stress concentration.

2.2.3 Temperature changes. Extremely high temperature changes and temperature differences within the different parts of the structure cause the greatest structural loads in many cases. One section of a structure exposed to direct sunlight may reach a temperature of + 140°C (+ 284°F), while another section of the same structure may be in the shade and have a temperature of -100°C (-148°F). The external building surface absorbing the direct sun rays will have a much higher temperature than the interior of the building where terrestrial room temperatures must be maintained. This problem may be partially solved by the use of heat reflecting materials on the exterior of the building. The extreme heat variation (approximately 400°F) may effect the physical properties of the material reducing acceptable ultimate stress values considerably. Poor heat-conducting material cannot be used in areas of high temperature differential between inside and outside surfaces since this uneven temperature change would dictate an unreasonably heavy structure. But in order to obtain even room temperatures, materials of good thermal insulation capacity are necessary. These adverse demands can be met by double-skin construction. Properly designed expansion joints between separate structural elements will help to reduce temperature stresses.

2.2.4 Meteorite hazard. The design of a structure which would withstand the impact of large meteorites appears to be as unreasonable on the moon as it is on earth. Provision must be made, however, for the hazards produced by the puncturing effects of micro-meteorites which literally rain on the lunar surface. One of the most effective precautions against meteorite penetration is the double-skin construction concept, which, as has already been pointed out, affords the additional advantage of eliminating temperature stresses. The outer skin would act as a "meteorite bumper" and normally few particles would penetrate this barrier. The inner skin would provide the structural strength required and act as additional barrier for larger meteorites.

2.2.5 Solar Radiation. Within the next few years much more information on solor radiation at the moons surface will be available, and no work has been done to incorporate effective radiation sheilds in the proposed design.

2.2.6 Composition of the moon soil. There are three conflicting views quite generally promulgated which describe the moons surface. One envisions the surface as a hard rock surface of congealed lava; with little or no dust; another, envisions the surface as covered with varying depths of finely divided rock dust; the third, sees a layer of sand similar to our great deserts. All theories seem to be in agreement on the presence of igneous rock. The lunar structure will be supported on 4 structural legs which can be anchored to a rock surface either directly or by extension through a dust layer.

2.2.7 Seismic loads. As noted above (2.2.6), all theorys regarding the moon and its surface conditions agree on the presence of igneous racks, i.e. solidified magma. This magma shrinks upon cooling from its original molten state and the external surface layers which had been in equilibrium must collapse. Immediately before its transformation, all the seismic energy is stored as elastic-strain energy in the lunar racks. This strain accumulates slowly in the same manner as other geologic processes, consequently it is reasonable to assume that seismic motion will effect structures of a permanent nature. Larger permanent structures, therefore, should have incorporated in their design the ability to withstand seismic motion of unknown magnitude. For this purpose the three dimensional space structure qualifies better than any other type of structure.

2.3 Purpose of Structure

The purpose of the lunar structure, for the most part, should determine its size. Because of the limited stocks of air, food, water, etc., carried by a manned space ship, the establishment of a permanent lunar base with self-sufficient living quarters, workshops, and scientific laboratories must soon follow the initial moon landing. The construction materials for such a prefabricated structure would be transported by rocket ships. The prefabrication allows for erection without the necessity of extensive site preparation. Large permanent underground buildings would follow as a result of extensive research carried on from the temporary lunar base.

2.4 Materials

2.4.1 Certain aluminum alloys were selected which satisfy the requirements of high strength, low weight, good heat reflector, weldable, high temperature strength, good thermal conductivity. For transparent areas, Corning code 1722 glass has been tentatively selected (see 2.5).

2.5 Design

2.5.1 The shape of the structure selected is a true sphere of approximately 32 feet diameter. It will be supported by a center ring girder and four adjustable legs. An inner structure of three stories with central core stairwell & air lock will also be supported from the ring girder.

2.5.2 The skin of the structure in areas where transparency is not a requirement will consist of an inner shell, less than one quarter inch thick. The inner shell will be welded to form a pressure tight vessel. Bolted sections could be used but difficulties of sealing tend to eliminate this method. A layer of foamed insulation will cover the inner vessel. An outer skin about one thirty second inch thick provides the outside protection. This layer must have overlapping sections to ensure free expansion and contraction.

2.5.3 Transparent areas will have a minimum thickness of formed glass (Corning 1722). There is a good possibility that transparent dreds may not be required, and definite design must await elaborate testing and laboratory work.

2.5.4 An airlock will be required for access into the structure and as a safety chamber in the event of puncturing of the shell by gross meteorites.

3.0 Lunar Simulator

3.1 The shape of the lunar simulator is identical to that of the lunar structure (2.5.). The difference is in the materials used; structural steel, ordinary plate glass and sheet steel. A ribbed dome with transparent panels forms the upper half of the exterior, sheet steel forms the bottom half. The interior structure of three floors is suspended from the ring girder as it is the lunar structure. Inside design pressure was chosen at 7 psi with outside at either atmospheric or zero.

3.2 The exterior shell which will be erected at a later date to provide a vacuum chamber is a thin concrete envelope.

3.3 Reference is made to the following drawings SK-0000299, SK-0000726 sheets 1 thru 4.