History of Rocketry and Astronautics

Proceedings of the Twenty-Sixth History Symposium of the International Academy of Astronautics

Washington, D.C., U.S.A., 1992

Philippe Jung, Volume Editor

Donald C. Elder, Series Editor

AAS History Series, Volume 21

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 13

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 1997

ISSN 0730-3564

ISBN 0-87703-439-7 (Hard Cover)
ISBN 0-87703-440-0 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198

Printed and Bound in the U.S.A.

Chapter 14

Early Lunar Base Concepts: The Lockheed Experience, Part I*

T. L. Stroup and R. D. Allen†

Finally, in a field where the United States and the Soviet Union have a special capacity—in the field of space—there is room for new cooperation, for further joint efforts in the regulation and exploration of space. I include among these possibilities a joint expedition to the moon. . . .

Why, therefore, should man's first flight to the moon be a matter of natural competition? Why should the United States and the Soviet Union, in preparing for such expeditions, become involved in immense duplication of research construction and expenditure? Surely we should explore whether the scientists and astronauts of our two countries—indeed of all the world—cannot work together in the conquest of space, sending some day in this decade to the moon, not the representatives of a single nation, but the representatives of all of our countries.

John F. Kennedy, at the United Nations, September 19, 1963

---

* Presented at the Twenty-Sixth History Symposium of the International Academy of Astronautics, Washington, D.C., U.S.A., 1992.

† Lockheed Missiles & Space Company (LMSC), Sunnyvale, California, U.S.A.

Introduction

Within a month following John F. Kennedy's historical address on May 25, 1961, committing the United States to landing a man on the Moon, Lockheed had initiated a series of internally funded feasibility studies to position the corporation favorably in the expected competition for NASA space exploration contracts. The wide ranging scope of these internally funded projects is truly breath-taking, hinting at the level of enthusiasm and optimism then current in the aerospace industry.

This optimism spilled out into many areas. Internal studies and proposals, completed in the thirty months ending in December 1963, ranged from space stations to the extraction of usable materials from lunar materials (Table 1). Many of these were multiple volume studies, and they included 3 different annotated bibliographies. Some of these reports were classified. Even so, the many that were unclassified have generally not been reported on in the open literature. Lockheed lunar base study activities, before President Kennedy's announcement, are covered in a companion paper.[1]

Table 1

SELECTED LOCKHEED LUNAR STUDIES AND PROPOSALS, 1961-1963

Saturn C2 Payload Capability For Manned Lunar Missions	Jun. 1961
Support of Life on Lunar Surface	Sept. 1961
Manned Lunar Roving Vehicle Concept	Nov. 1961
Annotated Bibliography of Lunar Properties, Geology, Vehicles and Bases	Dec. 1961
Lunar Landing and Return Vehicle Study	Mar. 1962
Lunar Surface Operations	Mar. 1962
Lunar Landing Operations Study	Mar. 1962
Lunar Excursion Module	Aug. 1962
Lunar Logistics Study	Dec. 1962
Advanced Lunar Transportation System Studies	Jan. 1963
Bioastronautics Research for Post Apollo Manned Missions	Jan. 1963
Soft Lunar Landings from Circular Orbits	Feb. 1963
Proposal for Study of the Extraction of H_2O, H_2, and O_2 from Lunar Materials	May 1963
Initial Concept for a Lunar Base	Jun. 1963
Extended Lunar Operations	Jul. 1963
Nuclear Power Plant for Manned Lunar Bases	Jul. 1963
Study of a Manned Lunar Base Environmental Control & Life-Support System	Aug. 1963
A Handbook for Lunar Basing (Unpublished)	Oct. 1963
Lunar and Interplanetary Trajectories for the Period Beyond 1963, Bibliography	Nov. 1963
Nuclear Lunar Logistics Study	Dec. 1963
Touchdown Phase of Lunar Landings, Bibliography	Dec. 1963

The core of these lunar projects, initiated by Lockheed, was a series of engineering studies under the title of Extended Lunar Operations (ELO), that focused on short duration and permanent manned Moon missions.[2-9] Involved in Air Force space projects and lunar base activities at Lockheed since 1958, George Honzik was chosen as the project leader for these studies and became the principal engineering innovator. As the rationale for these studies, Honzik determined that maintaining "a manned expedition of any reasonable scope and duration on the Moon, it will be necessary eventually, to provide a permanent base."[2]

This permanent base was designed to support 100 men in cylindrical modules in the late or post Apollo time period. Using the proposed Saturn C-5 rocket, it would be resupplied with food and pressurization gases every 30 days. A spherical, 2 man, lunar tractor would help with base construction and provide surface transportation to geologically interesting sites. A long distance "hopper," using rocket engines, would be available for visiting distant sites. A nuclear power plant was selected to supply electricity to the lunar base. Initially, a 1 MWe nuclear power plant—under study, in 1961, at Argonne National Laboratory—was projected to support the lunar base. Later, as Lockheed developed expertise in nuclear systems, it proposed nuclear units based on SNAP technology.

Initiation and Objectives

As mentioned in Honzik's first quarterly report, a June 29, 1961 Interdepartmental Communication from Bruno W. Augenstein to Sid H. Browne authorized the initiation of Lockheed's Extended Lunar Operations (ELO) studies.[10] Augenstein was a senior staff scientist at the RAND Corporation, from 1949-1958, prior to joining Lockheed as a consulting scientist. Browne had a doctorate in physics from Yale University and had worked in various research assignments, including a stint at RAND, prior to joining Lockheed in 1954, becoming Associate Director of Advanced Systems Research in 1958. The stated objectives—to determine the significant factors for conducting extended manned lunar operations, and thus to provide a basis for ascertaining LMSC market potential—were to be achieved by:

- Selecting the probable missions to be implemented on the lunar surface.
- Developing mission priorities, durations and schedules.
- Determining life support needs for these missions.
- Creating base and transportation concepts to support the missions.
- Determining operations and logistics needs, and associated costs.

The first step was to initiate a literature review, which ran to three volumes, two published in December 1961, and the third in February 1962.[11] Two concurrent studies were undertaken as the initial effort got underway. While Honzik focused on supporting life on the lunar surface, the other developed lunar lander concepts and return vehicles.[12] This paper will focus primarily on the lunar surface study, or Extended Lunar Operations, led by George Honzik.

Although Honzik's team had access to RAND Corporation studies, they were not privy to the U.S. Army's major lunar base study, Project HORIZON.[13] They essentially started from scratch, enumerating three possible reasons for a manned Lunar Base:

- To perform scientific investigations which could not be done from the Earth, including geological and astronomical observations.
- To conduct military operations which used unique lunar features.
- To obtain political and propaganda advantage.

For a schedule baseline they used the NASA Planning Time Table, given in testimony to the 87th U.S. Congress by Abraham Hyatt. This timetable ended with the manned lunar landings of Apollo in the late 1960s and early 1970s. These parameters drove all the other requirements and results from this study.

Transportation on the Moon

Two forms of surface transportation were conceived for reconnaissance and exploration missions: a Lunar Traversing Vehicle (LTV) and a ballistic type rocket powered vehicle.

In his March 1962 LTV invention disclosure, inventor George Honzik claimed novelty for his concept and suggested significant advantages over previous attempts: "Space-fiction abounds," he said, "with abortive attempts to describe lunar vehicles. All concepts are earth bound attempts that ignore the lunar environment. All anticipated and expected difficulties encountered in lunar operations are reduced to manageable levels or eliminated entirely [in the LTV concept]."

The difficulties expected to be encountered on the lunar surface, Honzik characterized in the following way in an attachment to his invention disclosure:

- High vacuum atmospheric conditions promote vacuum welding of similar materials when in close proximity.
- Terrain irregular to an unknown degree with unknown engineering properties.

- o Lunar environment vitally hostile to man and seriously hostile to most equipment and many materials.
- o High cost of transportation of materials, equipment, fuel, personnel and supplies between the Earth and the Moon.

The LTV (Figure 1) had two pairs of large diameter wheels, each independently driven, in either direction about a pair of stationary axles, by four electric powered gear trains, and controllable from a single point. Steering is achieved by controlling, differentially, the relative speeds of the wheels which, in conjunction with the freedom to swing in a horizontal plane incorporated in the axle support, produces a curving path in the motion of the vehicle. The interconnecting frame between the forward and rear axle retains the middle of the axles at a specific 'wheel base,' while performing the function of providing a means of obtaining a reaction to the driving torques, and, also allowing the axle to swing for steering, and for following the variations in vertical irregularities in the lunar surface.

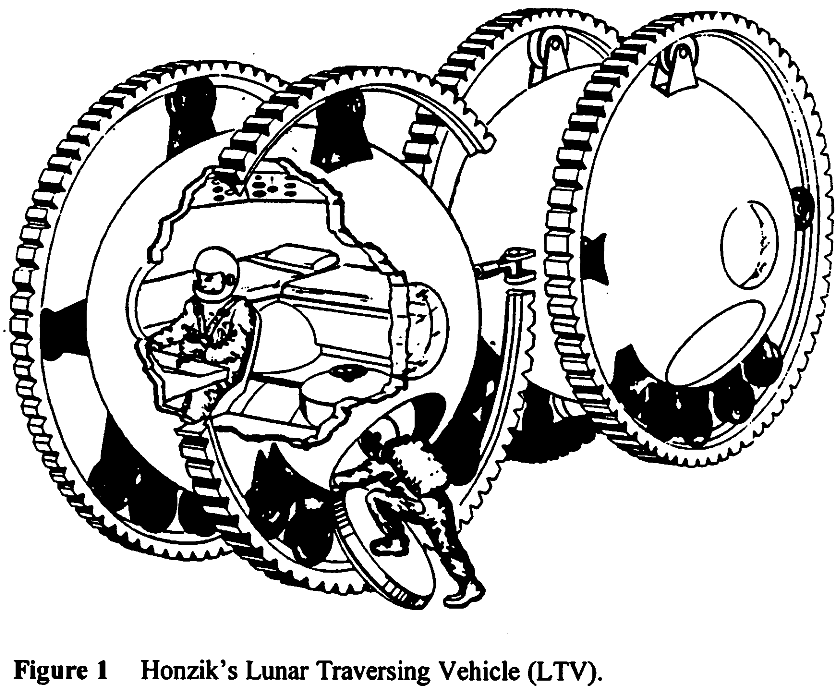

Figure 1 Honzik's Lunar Traversing Vehicle (LTV).

Although primarily conceived for use by human operators, the LTV could be adapted to remote control applications. The wheels were intended to be large enough to permit large compartments for housing crew personnel. These compartments would be pressurized and mainly, if not entirely, supported by the stationary axles. The virtually complete enclosure of the crew compartments by the wheel rims produced protective advantage from such known lunar hazards as meteoroids and radiation. Each compartment could be accessed through an outward facing port, incorporating an air lock and a viewing port for visual observation of the lunar terrain.

The ballistic type rocket powered vehicle was intended to provide a means of traversing from point to point on the lunar surface, permitting access to points of interest behind, or surrounded by, natural barriers to surface contact vehicles, with a drastic reduction in travel time (see Figure 2). Both a two-person and a four-person vehicle were developed, the former weighing 4,928 lbs. and the latter 7,912 lbs. In his Invention Disclosure, Honzik stated: "Advantageous use of ballistic vehicles is indicated for short trip operation, whereas the wheeled type vehicle is indicated as being a more economical expenditure of weight for missions requiring longer trips."

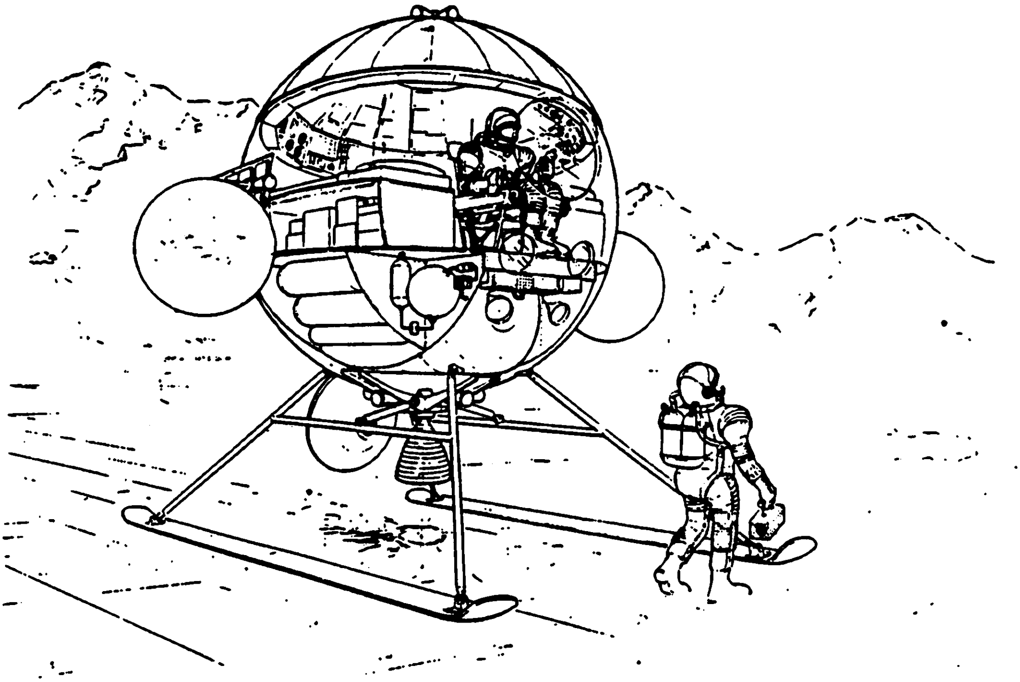

Figure 2 Honzik's Lunar Ballistic Vehicle.

Base Design

The Lunar Base was to be based on cylindrical modules that were to be completely constructed, outfitted, pressurized, and provisioned prior to leaving Earth. Once on the Moon's surface, they would be bolted together to form an interconnected structure. Two alternate concepts for the shelters were considered, horizontal or vertical modules (Figures 3 and 4). Both concepts were designed to deal with the structural stress of launch and landing, equipment distribution considering human factors, and compared weight and safety advantages. Subsurface base concepts were also considered, but rejected until more information on the Moon's composition was available for "serious design study." They did realize that the horizontal cylindrical concept was compatible with either surface or underground installation.

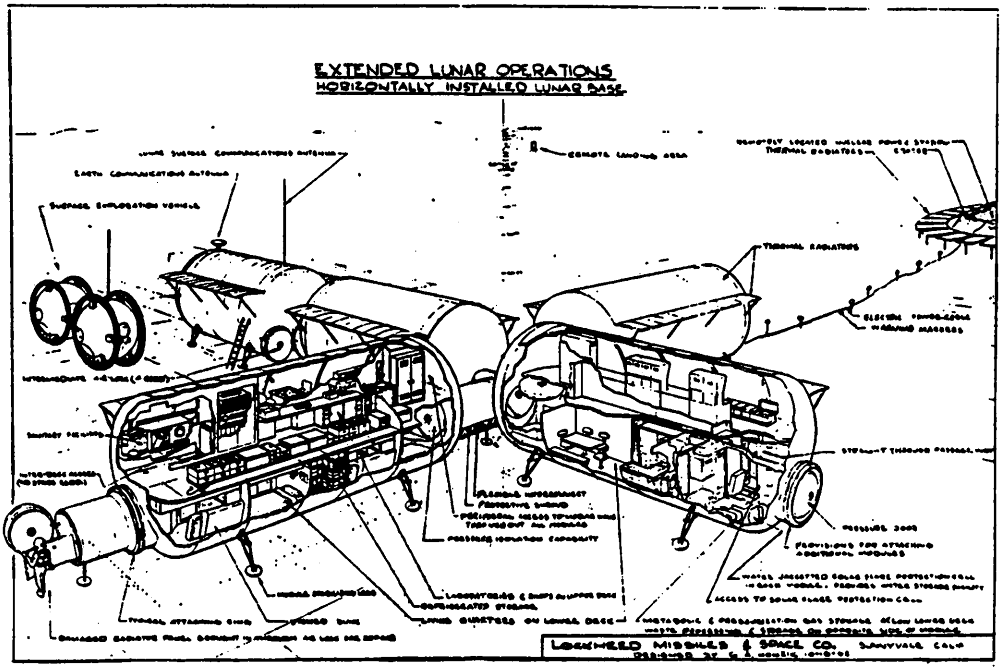

Figure 3 Honzik's Modular Horizontal Lunar Shelter.

Each module was 18 ft. in diameter, 42 ft. long, double-walled, environmentally self-sufficient, and it would support six astronauts. As many modules as needed would be joined by a flexible interconnect, which would permit misalignment of the modules and a minimum of lunar soil rearrangement under the module. Thermal radiator panels would be attached to the sides of the modules to dissipate excess heat. The double walled hull was filled with insulation, and it also served as a meteorite bumper and radiation shield. A solar flare radiation protection cell for all six of the crew in space suits was located below the lower deck, surrounded by water storage tanks.

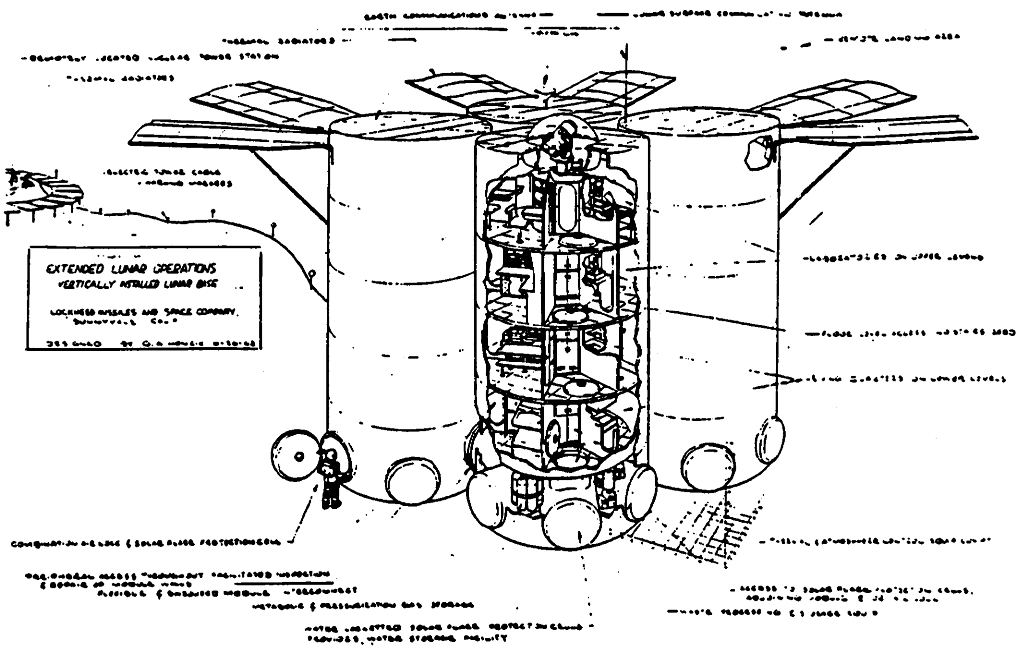

Figure 4 Honzik's Modular Vertical Lunar Shelter.

Module Emplacement

Since the shelter modules would arrive from Earth fully outfitted, careful handling and transport of them would be critical. The first payload to land on the Moon after the crew's arrival would be a cylinder containing two of the "multipurpose lunar surface operating vehicles," or LTVs. Attached to the first cylinder were two inflatable toroidal bumpers. The cylinder was designed to pivot off the landing rocket and fall to the surface, protected by the toroidal bumpers at each end (Figure 5). The cap would pop off, and the tractors would crawl out the end, ready to traverse the surface of the Moon. Two or more of the tractors would be linked together and used to lower the shelter modules off subsequent landing rockets, and into proper orientation on the Lunar surface (Figure 6).

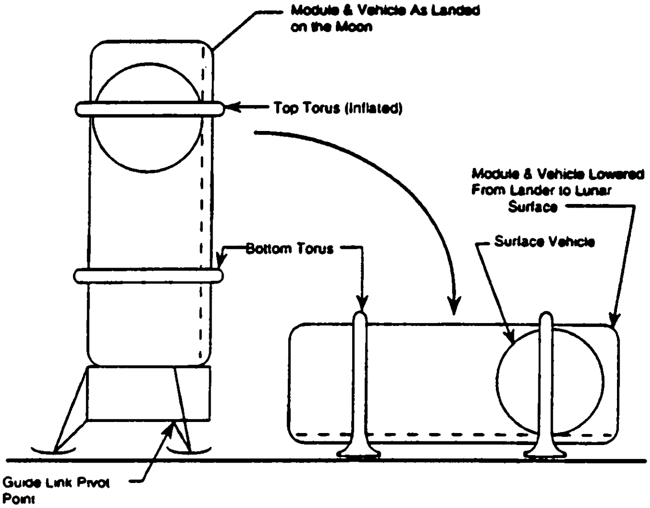

Figure 5 Redrawing of "Geometry of Lowering Service Module & Contents to Lunar Surface" from Reference 9.

Life Support

In designing the life support systems for the lunar base, the Lockheed engineers first had to establish the requirements that would control the design. They realized the complexity of reproducing an Earth like environment for the base, but they decided that building an Earth environment would be easier than adapting a human to an alien environment over long periods of time. So the atmosphere was set at 78% nitrogen, 21% oxygen, and the remainder water vapor and carbon dioxide. The thermal environment would be controlled to 78°F, 50% relative humidity, with an air velocity of 12-25 ft/min.

Honzik and his engineers realized the importance of regenerating and recycling water and oxygen after comparing five candidate life support systems. Ranging from a nearly open system, where everything is supplied (including atmosphere), to one where 80% of the metabolic mass is recycled, the five candidates only covered oxygen and water. All food was dehydrated, frozen, packaged, freeze dried and brought from Earth every 30 days. No mention was made of hydroponics or growing their own food on the Moon. They did consider the additional power requirements and weight penalties needed to regenerate oxygen and water.

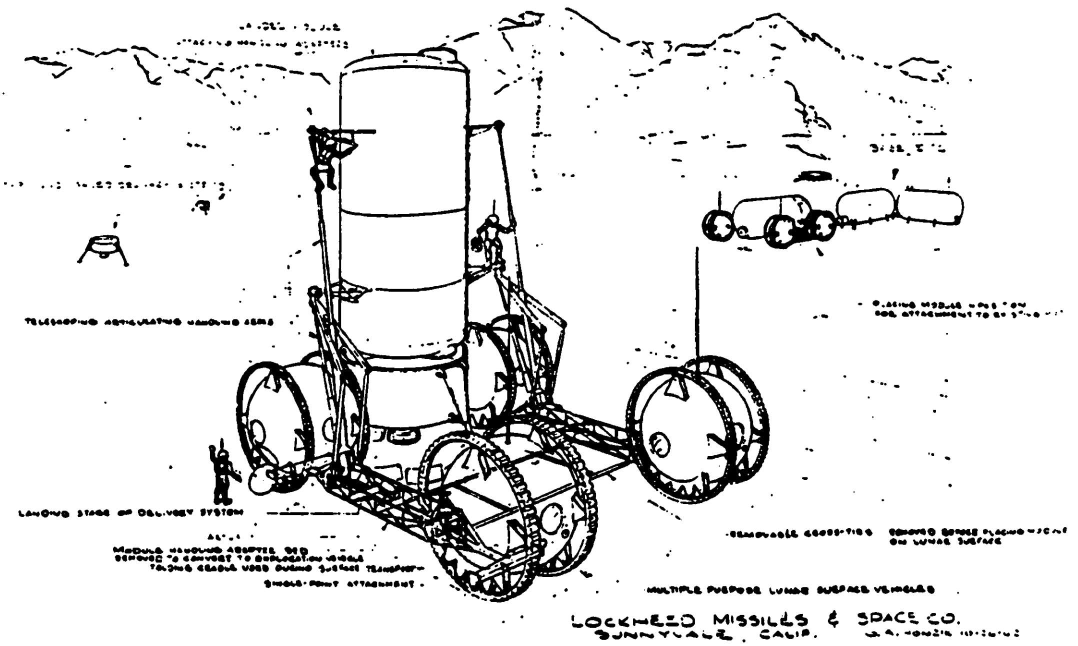

Figure 6 Module Handling on the Lunar Surface.

For life support systems at the lunar base, these reports concluded that, for nonregenerative systems, the total mission weight increases with mission time, whereas for regenerative systems, the reverse is true. This tends to indicate that, for a permanent base, the system with the least mission weight is a regenerable system designed for infinite mission length. Such a system would not require resupply, but it would have excessive weight for the initial launch.[9] Other life support components considered in the base design included waste disposal and sanitation, atmospheric contamination and control, dietary requirements, psychological factors, supply logistics, environmental sensors, leak rates, heat rejection, and a lunar space suit.

An interesting footnote concerns the regeneration of water from urine. In the unpublished *Lunar Handbook*, it was suggested that sweat and urine "will be regenerated in the case of the permanent bases." The technology of vacuum distillation, which would regenerate water from urine, is even described. But in three places in the draft version of the *Handbook*, including the above quote, the suggestion was lined out or modified. The conclusion drawn from these actions is, that the engineers knew that water regenerated from urine could be accomplished, but that just the thought of drinking water from urine would upset the astronauts or the people reading the report. Present day astronauts still have this aversion.

Lunar Power Plant Concepts

Honzik's team initially considered nuclear, geothermal, solar, and space sink power concepts. Nuclear concepts were relatively straightforward, with considerations of weight, shielding, and control requirements. Geothermal energy might be tapped into, following the detonation of a nuclear device on the lunar surface. Solar would use solar cells with batteries as storage devices. The space sink concept would be based on the feat of using a power source driven by the differential temperature between the lunar subsurface and deep space. Further mention of power plants in the Honzik studies is devoted strictly to nuclear power.

Initially, a nuclear power plant, developed at Argonne National Laboratory and reported in ANL 6261, was considered. The ANL plant was preassembled on Earth, and it was to be delivered to the Moon ready for operation. It had a design output of 1 MWe in continuous operation over a two year period. The total weight of the complete system was 22,000 lbs. The major components consisted of a fast reactor in a direct cycle with a mercury vapor turbine, a high frequency generator, a hydrogen compressor for the generator cooling system, a mercury circulation pump and condensate pump. Wing radiators were employed to condense the mercury and to cool the hydrogen.

Perhaps the best way to appreciate the development of nuclear power concepts for lunar bases at Lockheed is to refer to a proposal prepared in response to Department of Army request ENGMC-E, dated 20 June 1963.[14] There, two basic concepts were considered. In one of these the power plant is launched and delivered completely checked out and assembled with the heat rejection system integrated within the specified packaging limits. In the other concept, major components of the power plant would be packaged separately and stowed within the payload envelope for manual deployment on the lunar surface, potentially resulting in a plant of higher capacity, since the radiators could be stowed more compactly.

Either SNAP 8 or SNAP 50 technology—compact core epithermal reactors of the fast spectrum type using Rankine cycle conversion systems—could be applied in this concept. An extensive LMSC-funded study[15] of the SNAP 8 power plant in a similar cone-cylinder configuration indicated sufficient room within the constraining limits for radiating from a 100 KWe power plant.

On the basis of the then current development objectives, a power plant developing in excess of 1,000 KWe output (SNAP 50/SPUR) might be placed on the lunar surface with a single launch within the 25,000 pound limit.

The joint Army/NASA contract was awarded to Westinghouse Astronuclear Laboratory under Contract No. DA 49-129-ENG(NASA)-1A for a 100 KWe single 25,000-pound power plant module. The Westinghouse concept employed a mercury vapor cycle similar to that developed by the Argonne National Laboratory.

Missions

The Lockheed lunar base was designed with certain missions in mind. These mainly focus on exploration of the surface and science which could be done on the Moon. Military missions that they considered focused on using the lunar environs for military purposes or for denying their use to hostile governments. Possible military missions included weapons development and testing, detection and monitoring of nuclear weapons testing, and for propaganda and psychological effects.

But the science and exploration missions were what the base was primarily designed for. These missions were collected into two categories:

- o Increased knowledge.
- o Enhancement of life support capabilities.

Missions in the obtaining knowledge category included determining the origin and evolution of the Moon, helping to understand the origin and evolution of the solar system, searching for extraterrestrial (lunar) life, and studying the effects of the space environment on living systems. Missions that would enhance life support capabilities included locating natural shelters, finding water and oxygen sources, and developing space solar and nuclear power systems. Detailed outlines of these missions were developed, especially for geologic research.

The Lockheed team developed a Lunar Base Development Program that progressed from unmanned lunar probes through the Apollo landings through a 10 man Lunar base to a 100 manned base, all using the Saturn C-5 as their launch vehicle. They planned 4 man, 28 day scientific excursion missions, which left the base in the Lunar Traversing Vehicle. Eventually they even envisioned optical and radio telescopes on the Moon.

The Demise of ELO

Beginning in late 1962, Lockheed started to brief NASA on its internally funded Lunar Base studies. Representatives from Langley Research Center and NASA's Office of Advanced Research and Technology visited Lockheed and were briefed on the ongoing studies. On March 6, 1963, a contingent from Lockheed visited NASA's Manned Spaceflight Center in Houston, to acquaint them with the Lockheed lunar base effort and to obtain the latest Apollo design information.[16]

Meanwhile, Honzik had filed three Disclosure of Invention patent forms with Lockheed's legal department for the Multiple Purpose Lunar Surface Vehicle, the Ballistic Type Vehicle For Lunar Surface Operation, and the Modular Concept For Horizontally Installed Lunar Base. They complemented his April 1962 filing for the Lunar Traversing Vehicle. Though the legal department did not proceed with any patent action with the U.S. government, the level of activity surrounding the lunar base studies was high.

In mid-March 1963, plans for continued study of ELO were made, including a cost analysis and an outline of a study for the second quarter study. Both were derailed upon news of an upcoming NASA request for proposals for a Lunar Base Study. This was the first of a series of studies for Lunar Exploration Systems for Apollo (LESA). The bidders conference was held in Washington, D.C., on May 13, and Lockheed submitted its proposal, full of data, analysis and pictures developed under the ELO study, on June 3, along with the rest of the industry.[18] The study contract was awarded to Boeing in July.

Because of the NASA Lunar Base Study and other proposals during April, May and June, very little work was completed on ELO by the end of July. The last published ELO report, the Lunar Base Technical Summary Report,[8] was dated July 30, 1963. It focused on the initial compilation of a Lunar Base Handbook and the continued development of a lunar base equipment data base. The Handbook was to be a synthesis and distillation of all the previous quarterly reports, a tool to provide Lockheed with a suitable technical background for developing lunar base operations systems concepts. Only three people were left putting time in on the project, Honzik, Lander, and Mills. And they had been involved since the beginning. In fact, in the first two quarters of 1963, the studies used only 70% of their authorized man hours for the first half of the year.

All work on the project did not stop at the end of July 1963. Work on the Handbook continued. Then, in August, another proposal, which essentially consisted of technical data from ELO, was submitted to NASA, focusing on life support for a lunar base.[19] On September 10 and 11, Honzik and two others visited Marshall Space Flight Center and the Manned Spacecraft Center to acquaint the centers with Lockheed's capabilities. But, by the end of the month, R. A. Post stated in an activity report to H. A. Zwemer that "the lunar handbook is lying fallow at present."[20] Work on ELO continued sporadically thereafter, with a study on the feasibility of inflatable lunar shelter modules and work on the Handbook. Plans were even made for 1964 to study Lunar Base Shelters, Lunar Base Surface Operating Vehicles, and a Lunar Base Concept Study and Evaluation in anticipation of NASA RFQs.

But the spark was gone. In an interview with the authors, George Honzik confided that, with the assassination of President John F. Kennedy on November 22, 1963, he felt that the Moon Program was dead, that it wouldn't survive a new president.[22] Within a few months, Honzik had left the program to work on "bread and butter" missiles and space projects, primarily military in nature. The *Lunar Handbook* was never finished. Fortunately, Honzik saved his draft copy of the *Lunar Handbook* and presented it to us for our research.

Even with the departure of Honzik, Lockheed wasn't finished with Extended Lunar Operations. LMSC was awarded a piece of LESA, essentially based on previous ELO work. The six-month study, "Deployment Procedures for Lunar Exploration Systems for Apollo (LESA)," elaborated the previous ELO studies, but with the focus on the required base elements developed by Boeing.[22] And on September 20, 1964, the San Jose (California) *Mercury-News* ran a color magazine section cover article on ELO, featuring the scene of module handling on the lunar surface (Figure 6). Unfortunately, none of the Lockheed engineers interviewed for the article had actually worked in primary roles on the project.

Relevance to Today

Even though much of the technology in ELO is outdated, today's lunar base designing engineers can learn a lot from it. For example, one of the major lessons Honzik learned was that it is best to have as little base set-up as possible done by the astronauts, since it is very hard to work in a space suit, something current Space Station *Freedom* engineers are rediscovering right now. Many unique ideas and concepts were developed by engineers of that time, since they had so few preconceived notions of how things should be. These concepts can be reexamined by today's engineers for ideas useful in the planning of tomorrow's lunar bases.

Acknowledgments

The authors are deeply indebted to George Honzik, retired LMSC engineer, for documents, materials and knowledge, without which the record of this endeavor might have been lost. The authors are most grateful for the invaluable assistance and materials given to them by Andy Saparito and Bill Collopy of LMSC's art department, both of whom painted the original scenes, based on Honzik's drawings. Librarians from both the Palo Alto and Sunnyvale branches of the LMSC Technical Information Center were most helpful in searching for historical documents and making copies available, with special mention going to Bernie Donegan, Sue Stanek and Doris Robinson. The authors also wish to thank Rodger Alleman of LMSC Patents/Licensing and his able assistant Bette Coulson for locating and providing copies of Honzik's invention disclosure documentation.

References

[1]R. D. Allen, "Early Lunar Base Concepts of the U.S. Air Force," IAA-92-0189, presented at the World Space Congress, Washington, D.C., September 1 (1992).

[2]G. A. Honzik, Support of Life on Lunar Surface Technical Summary Report, Third Quarter 1961, Lockheed Missiles & Space Company, Inc., LMSC-5-14-61-S, *WO/WA 50-1416-5501*, September 20 (1961).

[3]G. A. Honzik, Extended Lunar Operations, Feasibility Study, Progress Report, Fourth Quarter 1961, Lockheed Missiles & Space Company, Inc., *WO/WA 50-5311-1001*, November 28 (1961).

[4]G. A. Honzik, Lunar Surface Operations Technical Summary Report, First Quarter 1962, Lockheed Missiles & Space Company, Inc., LMSC A012 684, *WO/WA 50-5339-0080*, March 19 (1962).

[5]G. A. Honzik, Extended Lunar Operations, Lunar Surface, 2nd Quarter, 1962, Lockheed Missiles & Space Company, Inc., LMSC-A013 250, *WO/WA 50-5365-0080*, June 29 (1962).

[6]G. A. Honzik, Extended Lunar Operations, Lunar Surface, Technical Summary Report, Third Quarter 1962, Lockheed Missiles & Space Company, Inc., LMSC-A013 981, *WO/WA 50-5365-0080*, October 3 (1962).

[7]G. A. Honzik, Extended Lunar Operations, Lunar Surface, Technical Summary Report, Fourth Quarter 1962, Lockheed Missiles & Space Company, Inc., LMSC A014 292, *WO/WA 50-5365-0800*, January 18 (1963).

[8]G. A. Honzik, Lunar Base Technical Summary Report, First & Second Quarters, 1963, Lockheed Missiles & Space Company, Inc., LMSC 657852, *WO/WA 50-5365-0800*, July 30 (1963).

[9]George Honzik, A Handbook for Lunar Basing—Draft Report (Unpublished), Lockheed Missiles & Space Company, Inc., October (1963).

[10]B. W. Augustein to S. H. Browne *et al.*, Lockheed Interdepartmental Communication, "IDC—Third Quarter Feasibility Studies," June 29 (1961).

[11]A. A. Beltran, J. B. Goldman, & E. E. Graziano, Annotated Bibliography of Lunar Properties, Geology, Vehicles, and Bases, Lockheed Missiles & Space Company, Inc., LMSC 5-53-61-2, LMSC SB-61-67, Part I—Known & Conjectured Properties; Part II—Vehicles, Trajectories, and Landings, December (1961), Part III—Lunar and Arctic Exploration and Habitation, February (1962); Supplement 1, LMSC 5-53-62-7, LMSC SB-62-11, September (1962).

[12]Lunar Landing and Return Vehicle Study, Technical Summary Report, Third Quarter 1961, Lockheed Missiles & Space Company, Inc., LMSC-5-14-61-3, LMSC-895 131, September (1961).

[13]F. I. Ordway, III, M. R. Sharpe, and R. C. Wakeford, "Project Horizon: An Early Study of a Lunar Outpost," Paper IAA-87-659 presented at the 38th Congress of the International Astronautical Federation, Brighton, U.K., 10-17 October 1987. Published in *Acta Astronautica*, Vol. 17, No. 10, p. 1105-1121, 1988. Also published in *History of Rocketry and Astronautics*, Paper AAS 92-331, ed. L. H. Cornett, Jr., *AAS History Series*, Vol. 15, 1993, pp. 79-105.

[14]Nuclear Power Plant for Manned Lunar Bases (Proposal in response to Department of Army request ENGMC-E, dated 20 June 1963), Lockheed Aircraft Corporation, LAC-ETP-405, July (1963).

[15]SNAP 8 Spacecraft Configuration and Mission Studies, Lockheed Missiles & Space Company, Inc., LMSC-A320665, May (1963).

[16]W. E. Frye and R. B. Gangstad to S. H. Browne and H. A. Zwemer, Lockheed Interdepartmental Communication, Report on Visit to NASA-MSC, Houston, Texas, March 12 (1963).

[17]NASA Headquarters Request for Proposal No. 10-1132, "Initial Concept for a Lunar Base."

[18]Initial Concept for a Lunar Base; Vol. I—Technical Proposal; Vol. II—Business Management Proposal, Lockheed Missiles & Space Company, Inc., LMSC 895 670, June 3 (1963).

[19]Study of a Manned Lunar Base Environmental Control & Life-Support System, Vol. 1—Technical Proposal; Vol. 2—Cost Proposal, Lockheed Missiles & Space Company, Inc., LMSC 895 862, August 23 (1963).

[20]R. A. Post to H. A. Zwemer, Lockheed Interdepartmental Communication, Activity Report, September 30 (1963).

[21]Interview with George Honzik, at his home in California, by T. L. Stroup and R. D. Allen, June 20 (1992).

[22]"Study of Deployment Procedures for Lunar Exploration Systems for Apollo (LESA), Phase I Interim Report, Volume I & II," Lockheed Missiles & Space Company, Inc., LMSC-A302 272—Phase I—Vol. 1 & 2, Contract DA-49-129-ENG-534, September (1964).