GENESIS II
ADVANCED LUNAR OUTPOST

Space Architecture Monograph, Vol. 4

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GENESIS II: ADVANCED LUNAR OUTPOST

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ABSTRACT

This research and design study — the fourth in the Space Architecture Monograph Series — investigated advanced lunar habitats for astronauts and mission specialists on the Earth's moon. The work is based on design requirements and constrains set forth in previous monographs in this series (e.g., Cordes, 1989) and in research studies done especially for Genesis II, and supported by the development of the Genesis I Lunar Outpost (Hansmann & Moore, 1990). Design recommendations were based on environmental response to the lunar environment, human habitability (human factors and environment-behavior research), transportability (structural and materials systems with least mass), constructability (minimizing extravehicular time), construction dependability and resilience, and suitability for NASA lunar research missions in the early 21st century. The recommended design utilizes lunar lava tubes, with construction being a combination of Space Station Freedom-derived hard modules and light-weight Kevlar-laminate inflatable structures. The proposed habitat includes research laboratories and a biotron, crew quarters and crew support facility, mission control, health maintenance facility, maintenance work area and extravehicular chamber, storage and logistics facility, and special crew areas for psychological retreat, privacy, and contemplation. Furniture, specialized equipment, and lighting are included in the analysis and design. Drawings include base master plans, construction sequencing, overall architectural configuration, detailed floor plans, sections and axonometrics, interior perspectives, and construction details.

This study and report were supported by an Advanced Design Program grant from NASA/Universities Space Research Association (NASA/USRA) to the Regents of the University of Wisconsin System, University of Wisconsin-Milwaukee Center for Architecture and Urban Planning Research. USRA's Advanced Design Program operates under Grant NASW-4435 from the National Aeronautics and Space Administration.

OTHER MONOGRAPHS IN THE SPACE ARCHITECTURE MONOGRAPH SERIES

1. Space Architecture: Lunar Base Scenarios, by Anthony J. Schnarsky, Edwin G. Cordes, Thomas M. Crabb & Mark K. Jacobs (edited by Edwin G. Cordes, Gary T. Moore & Stephen J. Frahm). ISBN 0-938744-59-3, R88-1, 1988; pp. vi + 80, illus.; $10.00.

2. Genesis Lunar Outpost: Program/Requirements Document for an Early Stage Lunar Outpost, by Dino J. Baschiera & 12 others (edited by Edwin G. Cordes). ISBN 0-938744-61-5, R89-1, 1989; pp. xix + 89, illus.; $10.00.

3. Genesis Lunar Outpost: Criteria and Design, by Dino J. Baschiera, Joseph P. Fieber, Timothy L. Hansmann, Janis Huebner-Moths & Gary T. Moore (edited by Timothy L. Hansmann & Gary T. Moore). ISBN 0-938744-69-0, R90-1, 1990; pp. xii + 107, illus.; $10.00.

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EXECUTIVE SUMMARY

The University of Wisconsin-Milwaukee Space Architecture Design Group undertook a designed a second generation advanced lunar outpost, called Genesis II, during the 1990-91 academic year. The design was based on internal and external critiques of the first generation lunar outpost developed in 1989-90, two internships at NASA/Johnson Space Center designing a full-scale mock-up of a lunar inflatable spherical design, three independent study projects conducted during the fall semester of 1990, followed by an integrative design studio in the spring of 1991. A series of experts—scientists, engineers, and architects—from NASA/JSC, Wisconsin aeronautical industry, and area universities—gave technical input and offered critiques at design reviews throughout the process. Students from architecture and engineering were involved and together explored the potential of developing a second generation lunar research and habitation base utilizing lunar lava tubes and inflatable and hard module construction.

In the after shock of the space shuttle Challenger disaster in 1986, scientists, professionals, and citizens around the world have been rethinking the role humans can and should play in space. Current discussion and planning has moved away from "one shot scenarios" and space transportation systems into the arena of long duration missions and issues of possible extraterrestrial habitation. Plans for the near future in space development include a permanently inhabited space station, an inhabited lunar colony, and a possible joint United States/Soviet Union mission to Mars.

Space Architecture

For the first time it has been realized by NASA that the long duration of these planned events requires the involvement of architects, interior designers, industrial designers, planners, and other environmental design professionals in order to ensure environments suitable for human habitation and performance. To date, space design has been the almost exclusive province of the engineer and that profession's highly technical orientation. Long-range planning, systems integration, construction sequencing, and interiors environmentally suitable for humans are all areas in which the design professions have demonstrable expertise and in which they can exercise a positive and much needed influence. Acknowledging this, engineers involved in shaping our future in space have begun to collaborate with architects and other environmental designers in the design process. Thus has evolved space architecture, as the field is becoming known.

This report summarizes the major design criteria and concepts which lead to the evolutionary development of Genesis II, including issues related to health and safety, psychological and social responses to living and working in a confined, isolated environment, habitability, underground architecture, interior architecture, construction technology, near term high technology materials, structural analyses and structural systems, site planning, and long-range master planning.

History

In the spring of 1991, a group of students under the direction of the authors researched and designed this second generation advanced lunar outpost, Genesis II. Genesis II is planned to provide housing, research space, mission control space, and all amenities for 11 astronauts to live on the moon for durations up to 20 months with normal change-outs of 6 to 9 months. It will serve as an evolutionary, long-term testbed for all materials, processes, and development strategies to be employed in a mature lunar colony for the next 20 years, and as a research and construction technology testbed for all processes to be employed in the exploration and settlement of Mars. At the present time, it is expected that the first lift-off for such a lunar outpost would be around 2005, with IOC (initial operating configuration) achieved by 2015.

Mission Objectives

As currently envisioned, a lunar outpost should include base master planning and habitat design for a mission that could be focused on five experimental systems:

a. lunar mining and production analysis for lunar oxygen and helium3,
b. lunar construction technology testbed,
c. closed system ecological life support facility (biosphere),
d. lunar far-side observatory, and
e. human factors and environment-behavior research facility.

Methodology and Procedure

Development of the site plan and design for a second generation Genesis II focused on the central telerobotic command center running these mission operations, on the research facilities, on the crew support habitat, and on other ancillary spaces needed to assure quality of life.

Design issues considered included base master planning and phasing, human factors, psychological and social reactions to long-duration space missions, high-tech materials and construction technology, lighting, mechanical, and HVAC/ECLSS systems, energy systems, and overall design aesthetics.The design is based on a facility programming document produced by a group of undergraduate and graduate students in the fall of 1989 (Baschiera & others, 1989), a final design document produced in the spring of 1990 based on first year study results (Hansmann & Moore, 1990; Moore, Baschiera, Fieber & Moths, 1990), an intern report completed for NASA/JSC during the summer of 1990 (Connell, Fieber, Paruleski & Torres, 1990), and three independent study projects completed during the fall of 1990 (Fieber, 1990; Huebner-Moths, 1991; Paruleski, 1990).

Areas of detailed architectural and engineering (A/E) design investigation were conducted throughout the year as part of these reports and the final integrative design studio. These studies included, but were not limited to, the following: investigation of the implications of new, hi-tech, light-weight, high strength materials especially elastomers and thin films; character of the lunar environment; extraction of design relevant information from previous space experience, analogous situations, and simulations, e.g., Mir and Skylab, Antarctica and Navy submarines, and Tektite; and human factors analysis of the minimum space requirements for different lunar habitation and research functions in 1/6th gravity.

The final integrative design studio was conducted as a professional team project, with the faculty advisory directing the project, and the three teaching assistants and other advanced students assuming the role of team leaders for various specialized functions. The class worked as one team, producing one final project, but were subdivided into various teams with specific tasks and deadlines as the semester unfolded.

The final design was summarized in a series of 30"x40" drawings, produced both in black-and-white for this report and subsequent technical papers and in color for slide presentations and exhibits. A model showing the final design proposal situated above and in a lunar lava tube was constructed.

Highlights of the Proposed Design for the Genesis II Lunar Base

The proposed design is situated in a lunar lava tube near the former Apollo 15 site, located at 3 degrees East by 25 degrees North, alongside Hadley Rille at Palus Putredinis (Marsh of Decay).

The master site plan is zoned such that the launch and landing facility is approximately 3 km to the south, the nuclear power facility is 1 km to the north, the mining facility and industrial zone 1.25 km to the west, and the solar array field and heat-dissipation radiator field near the habitat. The habitat itself is over an opening—drilled and then sintered—to the safe confines of the lava tube (see Figure 3.3-1 ff. starting on p. 25 in the body of the report).

Following extensive telerobotic research and exploration, the base will be developed in three main stages spanning almost 10 years: (1) emplacement of an assembly facility and the erection of radiation protection truss-work with accompanying regolith covering; (2) integration phase during which the balance of base components are delivered, all surface facilities are constructed, the shaft to the lava tube is drilled, exploded, and sintered, and the structural truss-work and initial crew quarters are lowered through the opening and assembled on the base of the lava tube; and (3) final initial operation configuration during which two large, two-floor inflatables are lowered into the lava tube, inflated, and outfitted for expanded crew quarters and research space, with attendant reconfiguration of the rest of the base for the permanent 11-person base.

The design proposed to NASA is thus based on the use of Space Station Freedom-type hard modules, light-weight structural truss systems, and thin film elastomer inflatables. The habitat and research areas are situated in the safety of the lava tube, away from radiation, sharp temperature fluctuations, and deadly solar flares. Storage and vertical circulation to and from the surface occurs in a Shuttle-C type hard module installed in the sintered opening between the lava tube and the surface. Only logistics modules and the EVA chamber (for extra-vehicular activities) remain on the surface, thought protected by truss-work covered with a minimum of 0.5 m of lunar regolith. The basic configuration—a giant H on its side—can be seen in Figure 3.8.1-2 on p. 32 in the body of the report. Details—shown in a series of plans and axonometric drawings—of the two-story habitation and laboratory inflatables in the midst of the lava tube, the crew support module with mission operations and health maintenance facilities on the bottom of the lava tube, and the logistics and EVA modules on the lunar surface can be seen in Figures 3.8.1-3 ff. starting on p. 31 and are described in detail in the report.As considerable attention was placed on the quality of life, and the contribution which the designed environment can make to the overall quality of life, especially in confined quarters, more detailed designs are shown in larger scale drawings for individual spaces within the crew habitat areas (e.g., the wardroom/dining room, a game room, the exercise facility, several arrangements of the crew quarters, the personal hygiene facility, a small library, and several reading rooms and a conservatory providing places for retreat and renewal. Detailed designs were also developed, and are shown, for typical mission operations workstations, the operating theater of the health maintenance facility, and special furniture designs for 1/6th gravity body positions.

Technical engineering details are shown for wall sections, hatch connectors, the lighting system, and the structural space frame truss work.

Finally, as this second generation advanced lunar outpost may need to expand into a more mature lunar colony, expansion plans are shown in Figure 3.9-1 on p. 48 for expansion beyond IOC to accommodate increments of 5-6 additional astronauts and mission specialists up to the limit of the size of the cavern of the initially selected sub-surface lunar lava tube.

PREFACE AND ACKNOWLEDGEMENTS

This report presents the architectural requirements and design for an advanced lunar base habitat and research facility. This advanced lunar outpost, a second generation outpost, is planned for 11 astronauts and mission specialists at the former Apollo 15 site, located at 3 degrees East by 25 degrees North, alongside Hadley Rille at Palus Putredinis (Marsh of Decay). Construction would commence in 2005 with IOC (initial operating configuration) achieved by 2015. Design and construction will be led by a team of astronauts, scientists, architects, and engineers working together to build a permanently occupied habitat on the Moon.

Faculty and students of the University of Wisconsin-Milwaukee School of Architecture and Urban Planning (UW-Milwaukee/SARUP) have been actively involved in the research, analysis, and design of extraterrestrial environments since 1987. In 1987 the School began working with the Astronautics Corporation of America's, a world-wide aeronautics and aerospace company headquartered in Milwaukee, to define space design issues and criteria. In the fall of 1987, the Department of Architecture offered its first studio in "Space Architecture: Lunar Base Scenarios." The studio resulted in the first in our Space Architecture Monograph Series (Schnarsky, Cordes, Crabb & Jacobs, 1988). The School's Center for Architecture and Urban Planning Research (CAUPR) hosted a series of lectures and workshops by leading members of the aerospace industry and nationally recognized experts, made slide and video presentations at national meetings including the 3rd, 4th, and 5th Annual Summer Conferences of the Universities Space Research Association (e.g., Cordes, Moore & Hansmann, 1989), and wrote a series of articles about space research and design (e.g., Schnarsky, 1988).

In 1989 CAUPR was awarded a $115,000, three-year grant from NASA/Universities Space Research Association (NASA/USRA) to conduct an Advanced Design Program in Space Architecture. Created as a result of that grant, the Space Architecture Design Group has been responsible for research and technical papers, lectures, talks, and exhibits at local, state, and national conferences, and has received six research and design awards (for a complete listing of available publications, exhibits, and awards, please see Appendix C).

Following on the results of our work in 1990-91 to develop an initial lunar base (Hansmann & Moore, 1990; Moore, Baschiera, Fieber & Moths, 1990), the current report summarizes the main performance requirements for a second generation lunar base, discusses the design criteria and issues, and presents a design proposal — called Genesis II — based on accumulated research and design trade studies.

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