PAX PERMANENT MARTIAN BASE
Space Architecture for the First Human Habitation on Mars

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PAX PERMANENT MARTIAN BASE:
Space Architecture for the First Human Habitation on Mars

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ABSTRACT

America at the Threshold: Report of the Synthesis Group on America's Space Exploration Initiative (the "Synthesis Report," sometimes called the Stafford Report after its astronaut chair, published in 1991) recommended that NASA explore what it called four "architectures," i.e., four different scenarios for habitation on Mars. The Advanced Design Program in Space Architecture at the University of Wisconsin-Milwaukee supported this report and two of its scenarios--"Architecture 1" and "Architecture 4"--during the spring of 1992. This report investigates the implications of different mission scenarios, the Martian environment, supporting technologies, and especially human factors and environment-behavior considerations for the design of the first permanent Martian base. The report is comprised of sections on mission analysis, implications of the Martian atmosphere and geologic environment, development of habitability design requirements based on environment-behavior and human factors research, and a full design proposed (concept design and design development) for the first permanent Martian base and habitat. The design is presented in terms of a base site plan, master plan based on a Mars direct scenario phased through IOC, and design development details of a complete Martian habitat for 18 crew members including all laboratory, mission control, and crew support spaces.

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, 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.

4. *Genesis II: Advanced Lunar Outpost*, by Joseph P. Fieber, Janis Huebner-Moths & Kerry L. Paruleski (edited by Gary T. Moore). ISBN 0-938744-74-7, R91-2, 1991; pp. xvi + 72, illus.; $10.00.

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EXECUTIVE SUMMARY

America at the Threshold: Report of the Synthesis Group on America's Space Exploration Initiative (Stafford, 1991; called the "Synthesis Report") recommended that NASA explore what it called four "architectures," i.e., four different scenarios for habitation on Mars.

The Advanced Design Program in Space Architecture at the University of Wisconsin- Milwaukee supported this report and two of its scenarios--"Architecture 1" and "Architecture 4"--during the spring of 1992. This Space Architecture Design Group investigated the implications of different mission scenarios, the Martian environment, supporting technologies, and especially human factors and environment-behavior considerations for the design of the first permanent Martian base.

The following report is comprised of sections on mission analysis, implications of the Martian atmosphere and geologic environment, development of habitability design requirements based on environment-behavior and human factors research, and a full design (concept design and design development) for a first permanent Martian base and habitat. The design is presented in terms of a base site plan, master plan based on the Zubrin "Mars direct" scenario phased through IOC, and design development details of a complete Martian habitat for 18 crew members including all laboratory, mission control, and crew support spaces.

Our thinking, based on an integration of the Synthesis Report and a document from the Exploration Program Office (Wheeler, 1992), suggested the likelihood of the following four mission scenarios: (1) *precursor telerobotic missions* around 1998, (2) *expeditionary landings* around 2005 to 2014 on the order of 500 days total trip time with a stay of 30 to 100 days, (3) longer duration missions on the order of 1,000 days with a typical stay time of 500 to 600 days between 2007 and 2016 to establish *human-tended outposts*, and (4) long-duration missions to establish the initial operating configuration of the first *permanent base* (IOC) between 2009 and 2022. There are significant environment-behavior issues of habitation to be explored and solved in a long-duration permanent Martian base. The focus, therefore, of our current research and design work--and this report, the fifth in the Space Architecture Monograph Series--has been on the environment-behavior determinants of a long-duration *permanent* base.

Our work built off what the Synthesis Report referred to as the Mars "Waypoint" (by which is meant Mars planetary activities for human exploration of Mars and the Solar System, i.e., as a waypoint to later exploration into the Solar System). We accepted the Synthesis Report recommendations of a crew size of 6 crew members for the initial human-tended outpost and the ExPO recommendation of a crew size of 18 for the permanent IOC base. The base is designed assuming a mostly closed-loop life support system (closed except for food, which will be produced on an experimental basis in a pair of biotrons or Martian greenhouses) and remote automatic emplacement, checkout, and verification of the habitat and life support system.

The Mars waypoint assumes significant transfer of learning from orbital and lunar facilities including evaluation of lunar habitats. Our previous work in the USRA Advanced Design Program was instructive. An early phase of our Martian work was an analysis and critique of the five lunar habitats[1] designed by the Space Architecture Design Group since 1989--especially the two habitats taken into design development--for positive lessons to be transferred to the design of the first Martian habitat. Additional issues considered in this report include the following: mission scenario analysis; implications of the Martian atmosphere and geologic environment; changeability, replaceability, and expandability; supporting technologies; and especially human factors and environment-behavior considerations and design requirements for permanent Martian bases and habitats.

Until recently, human and environment-behavior considerations were not viewed as significantly important elements for successful extraterrestrial exploration. Instead, science and engineering were paramount in the eyes of the designers. "There is now an increased awareness on the part of planners that design does affect behavior" (Fisher, Bell, & Baum, 1978). By studying the effects of human

[1] This critique was presented at the American Institute for Aeronautics and Astronautics Aerospace Design Conference, Irvine, California, February 1992 (Moore & Rebholz, 1992) and at the Environmental Design Research Association 22nd Annual Conference, Boulder, Colorado (by the student TAs). A set of resulting design requirements for human habitation of extraterrestrial planets was presented at the American Society of Civil Engineers' Space 92 Conference, Denver, Colorado, May 1992, and published in their proceedings (Moore, Paruleski, Huebner-Moths, Fieber, & Rebholz, 1992).

behavior in isolated and confined environments and then creating design requirements, it is expected that human factors can have a profound impact on the success of extraterrestrial space exploration.

A permanent Martian base will provide for a multi-national, multi-racial, mixed-gender crew for stay times as long as two years. The base will include mission related facilities such as research labs, mission operations workstations, airlock and dust-off chamber, storage for logistics, and life-support system. It will also contain crew-support facilities such as crew quarters, individual and group passive recreation areas, an active exercise facility, wardroom for eating or teleconferencing and meetings, hygiene facilities, health maintenance facility, as well as special places for privacy and psychological retreat.

Emphasis in our work and in this report is placed, therefore, on human factors and environment-behavior requirements that impact on habitability for long-duration habitation. A full range of issues must be investigated, from pragmatic issues of productivity and functionality to more abstract issues of imagery and symbolism. Considerations included but were not limited to anthropometric effects of 1/3rd gravity, safety, astronaut satisfaction and productivity, minimizing or alleviating stress, social interaction and privacy, orientation and wayfinding, perceptual variety, efficiency, functional convenience, and place and identity--the quality of "home."

A modular space frame construction system will provide the protective shelter for the habitat itself, called Pax (for the international Peace Settlement, opposite of the Latin name of the planet, Mars, the God of War), situated at the middle of a north-south axis to the base as a whole. This framing system will combine open square and triangular geometries to produce a roof and column support system. The proposed frame system is a kit of components, redundant in size and shape, that will allow the astronauts relative ease of construction. The system will consist of a structural space frame, column support system, textile regolith containment and radiation shielding system, and Martian regolith.

The habitat, or central portion of Pax, will be constructed in several stages. Construction can commence when two rigid modules and six crew members are on site, and their equipment, rovers, and logistics are in place. Additional modules and their crew will arrive, bringing the full compliment of rigid modules to four, and the number of crew members to twelve.

It is proposed that the final habitat, at IOC, will be comprised of five operational modules, each two floors in height: a 9-m hard-module entry module for dust-off, suit stowage and maintenance, and full recreation and exercise center in the lower level; two 12-m inflatable modules, one for laboratories and mission command and the other for crew quarters and the crew support facility; and two additional 9-m hard modules serving as two Martian greenhouses. The last hard module, part of the initial deployment, will be transferred elsewhere on the Martian surface as a hazardous laboratory.

Design development of all the interior habitat spaces--laboratories, mission control spaces, greenhouses, and all crew quarters and support spaces--makes up the majority of this report.

In conclusion, several critical design features of Pax are summarized, together with major strengths and limitations of this design and directions for future research and design development.

PREFACE AND ACKNOWLEDGEMENTS

Faculty and students of the University of Wisconsin-Milwaukee School of Architecture and Urban Planning (UW-Milwaukee) 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, a worldwide 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 of 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 through the 8th Annual Summer Conferences of the Universities Space Research Association 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, please see Appendix B). We have subsequently been awarded a minimum three-year sustaining grant from USRA for the 1992-95 period.

A selected group of 29 environment-behavior and human factors issues formed the basis for the Martian base design for 1991-1992. The issues selected have their origins in previous design work and research of lunar bases completed by the Space Architecture Design Group. This report summarizes those issues, discusses the design criteria, and presents a design proposal, named *Pax*, based upon accumulated research and design trade studies.

The Space Architecture Design Group would like to express appreciation for the continued support, encouragement, and opportunities the Advanced Design Program (ADP) has provided. We thank NASA and USRA for sponsoring the project, and Vicki Johnson, ADP Director, Barbara Rumbaugh, ADP Administrator, and their staff, for their continued support, and our growing array of Mentors and colleagues at NASA Johnson Space Center, including John Connolly, Kriss Kennedy, Wendell Mendell, Deborah Neubek, and Michael Roberts, for their advise and insights. Our thanks also to Brent Hellickson, Mark Galertner, and Cheri Morrow of the University of Colorado, Michael Pogue of Johnson Engineering, and Marc Cohen of NASA-Ames Research Center, whose critiques of our lunar work very much influenced the current work. We would like to thank the following for critical feedback and suggestions during the project:

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