1. OBJECTIVES

In 1991, the National Space Council published *America at the Threshold: Report of the Synthesis Group on America's Space Exploration Initiative* (Stafford, 1991; referred to as the "Synthesis Report"). That report recommended that NASA explore what it called four "architectures," four different scenarios for habitation on Mars based on lunar exploration and habitation.

For the spring of 1992, the Advanced Design Program in Space Architecture at UW-Milwaukee supported that report and its four scenarios, specifically "Architecture 1" and "Architecture 4." The purpose of this project was to research design, and offer a proposal to NASA for a first Martian permanent base and habitat.

Rather than responding to all the issues that ultimately would have to be considered in the design of a mature Martian base, and based on a self-critique of our last two years' work and very helpful suggestions from colleagues around the country, we decided to focus on human/environmental considerations of Martian base design. Three other sets of issues were investigated to less depth. The objectives, therefore, were to investigate and design in response to the following:

- Mars mission scenarios
- Mars environment
- human factors and environment-behavior considerations
- changeability, replaceability, and expandability

1.1 MARS MISSION SCENARIO

A Mars mission scenario outlines the activities that will occur in getting to Mars, and what will be done there. Scenarios are divided into four phases of development, beginning with precursors and continuing to a permanent Martian base. The objectives in this portion of the report will be to outline and then integrate different scenarios for getting to and staying on Mars.

1.2 MARS ENVIRONMENT

The Martian environment will have a great impact on the design of any habitat, its infrastructure, and the activities that occur in and around it. The "environment" includes factors such as atmospheric considerations, radiation, altitude, soil composition and temperature.

Key environmental issues that will determine the location and character of a Martian base include the presence of water, distance from the origin of dust storms, elevation, geologic features, and surface conditions. All of these will impact the safety of the base and crew and the possibilities of scientific gain from the mission.

1.3 HUMAN FACTORS AND ENVIRONMENT-BEHAVIOR CONSIDERATIONS

Until recently, human and environment-behavior considerations have not been viewed as significantly important elements for successful extraterrestrial exploration. Science and engineering were paramount in the eyes of 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 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 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 laboratories, 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, teleconferencing and meetings, hygiene facilities, and a health maintenance facility, as well as special places for privacy and psychological retreat.

Emphasis in our work and in this report is placed on human factors and environment-behavior (HF/EB) requirements that impact on habitability for long-duration habitation. A full range of issues will 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."

Though Martian bases have not been explored in any detail to date, a number of lunar base designs have appeared in technical publications (Alred, 1989; Capps & Moore, 1990; Graf, 1988; Lin, Senseney, Arp, & Lindbergh, 1988; Moore, Baschiera, Fieber, & Moths, 1990; Moore et al., 1991; Namba, Yoshida, Matsumoto, Sugihara, & Kai, 1988; Nowak, Sadeh, & Janakus, 1992; Richter, Drake, Kumar, & Anderson, 1990; Thangavelu, 1991; Vanderbilt, Criswell, & Sadeh, 1988). The vast majority of these have been driven by mass efficiency and cost containment, adaptation of current technology, or structural considerations, not by detailed analyses of human factors/environment-behavior considerations. Yet, as Clearwater and Harrison (1990; cited in Cohen & Brody, 1991) point out, the temptation to trade cost or structural efficiency for habitability would be a major mistake. Substantial concern has been expressed about the biological needs of astronauts, including radiation and reduced-gravitational exposure (e.g., Nicogossian & Parker, 1982). In contrast, relatively little research and design consideration has been given to psychological and social adjustment to space. It is becoming increasingly acknowledged, however, that psychological and social factors are important determinants of the success or failure of extraterrestrial missions (Connors, Harrison, & Akin, 1985).

Our research since 1989, and our continued approach as explored in the this project, has investigated the effect of elevating human factors and environment-behavior criteria in extraterrestrial habitat design (Moore, 1990; Moore et al., 1990, 1991; Moore & Huebner-Moths, 1991; Moore & Rebholz, 1992; Moore, Paruleski, Huebner-Moths, Rebholz, & Fieber, 1992).

A sizable amount of research has been published, conducted, or supported by NASA documenting important findings on habitability design from the human factors, psychological, sociological, and environment-behavior points of view (e.g., Connors et al., 1985; Clearwater, 1985, 1987; Clearwater & Harrison, 1990; M. Cohen, 1990; Cohen & Brody, 1991; Cordes & Moore, 1990; Harrison, Caldwell, & Struthers, 1988; Harrison, Sommer, Struthers, & Hoyt, 1988; Hewes, Spady, & Harris, 1966; Moore, 1990; Stuster, 1986). It is not the purpose of this report to present additional empirical findings, nor to review and criticize the literature to date. A primary purpose, however, is to begin the process of extracting design-relevant requirements from this literature and show their impact on Martian base design.

1.4 CHANGEABILITY, REPLACEABILITY, AND EXPANDABILITY

Changeability, modularity, replaceability, and expandability are crucial factors in the design of a Martian or any other extraterrestrial base. Modularity and replaceability not only allow ease of construction, but can contribute to the ability to easily adapt the base to changing functions over time. If the reorganization of spaces is make easy, expansion of the base becomes simpler. Allowing the crew to change the space around them will create an environment that is comfortable and may contribute to lessened stress and increased productivity. Including these factors in the design of any base and habitat will assure needed flexibility that will positively influence both the form and the function of the mission.