MANNED MARS MISSION HEALTH MAINTENANCE FACILITY

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ABSTRACT

This paper addresses the Health Maintenance Facility (HMF) requirements which enable/enhance manned Mars missions (MMMs). It does not attempt to resolve any issues that may affect the feasibility of any given element in the HMF. The paper makes reference to the current work being conducted in the design of the Space Station HMF. HMF requirements are discussed within the context of two distinctly different scenarios: (1) HMF as part of the Mars surface infrastructure, and (2) HMF as part of the nine months translation from low Earth orbit to Mars orbit. Requirements for an HMF are provided, and a concept of an HMF is shown.

PART 1: HMR AS PART OF THE MARS SURFACE INFRASTRUCTURE

Objective

To define the requirements for a module dedicated to crew medical support and medical research on the surface of Mars. The assumption is that four (4) individuals will remain on the surface for 60 - 90 days.

Background

The establishment of a permanently manned Mars Station creates an unprecedented state of crew isolation with neither immediate nor near-term return capability to Earth. The situation created is, in some ways, similar to Antartica expeditions in which the people live in a state of near isolation for a period of nine months at the South Pole. The Mars crew, however, will be substantially more dependent upon life support systems since atmospheric oxygen and probably water are not available on Mars. The crew will also be months or years from reaching Earth; this represents a significant extension of Antartica isolation.

Thus, it is clear that a crew of four people detailed to Mars will not have access to the full spectrum of health care support and the same standards of health care available on Earth. In other words, certain risks will have to be accepted by the program and the crew. The medical screening of the crew participating in such a mission will need to be far more extensive than any such screening previously conducted, possibly to include prophylactic appendectomies and cholecystectomies.

At least one of the four crewmembers will need to be a surgically trained medical generalist. Fortunately, the Antartica experience (as well as NASA'S own experience) has demonstrated that medical problems are relatively infrequent among properly screened individuals. There seems to occur two situations, the first being one in which the medical contingency is of such benign nature (e.g. colds in a crewmember who is relatively immunosuppressed) as to present no significant health hazard, and the second being of such catastrophic dimensions (usually secondary to accidental trauma) as to result in death even if it did have Earth-bound medical support.

Since actual medical events are so infrequent, a substantial portion of the resources in the HMF and of the time spent by the physician crewmember will be directed to the long term medical monitoring of the crew and the practice of preventive medicine in the form of exercise, education and entertainment.

The presence of one-third (1/3) gravity on the surface of Mars will facilitate the use of off-the-shelf medical hardware in the HMF. It will also simplify medical procedures such as surgery which would otherwise be very difficult to perform in microgravity. The crew will also have the possibility, with the adjunct of exercise, to remain in a much more well conditioned state than if exposed to microgravity for a similar length of time. In brief, the gravity of Mars is definitely a positive feature for both design of the infrastructure HMF and for the overall health of the crew.

Requirements and Design of the HMF

The therapeutic/diagnostic modalities of the HMF must be such that the following general requirements may be satisfied: (1) The Mission Surgeon and HMF can reasonably handle most minor common non-surgical medical problems, and (2) The Mission Surgeon and HMF can reasonably handle minor surgical problems and possess limited capability to deal with major surgical events.

The preventive modalities of the HMF should satisfy the following requirements: (1) The Mission Surgeon and the HMF can obtain a predefined (as well as unscheduled) array of medical data on the crewmembers in order to follow the effects of long term exposure on the surface of Mars, and (2) The Mission Surgeon and the HMF can provide a

scheduled conditioning program in order to maintain cardiovascular and musculoskeletal function at optimum levels while on the surface.

The JSC Task Force in charge of designing the Space Station HMF has subdivided its various components under prevention, diagnostic, and therapeutic classifications. The group has proceeded to identify state-of-the-art hardware which would make up the various components of the Space Station HMF. The dimensions of the Space Station (SS) HMF are estimated at 320 cubic feet in equipment and workspace (6' x 6' x 9') and 1500 pounds in weight or the approximate equivalent of four (4) single racks, Spacelab style. Figure 1 shows a schematic picture of the SS HMF valid as of May 1, 1985.

The manned Mars mission (MMM) HMF is envisioned as a larger facility in order to provide more supplies which will be needed for a much longer mission as well as increased capabilities to satisfy more extensively the requirements listed under preventive/diagnostic/therapeutic categories. The dimensions of the MMM HMF are estimated at least at 480 cubic feet in equipment and workspace (9' x 9' x 6') and 2000 pounds in weight. There are no schematics of the MMM HMF at this time.

A preliminary analysis of the various functional requirements for the HMF is shown and is identical to the currently planned Space Station HMF. It is felt that increased quantity of supplies and capabilities for more extensive procedures such as surgery will be definitely required for the MMM HMF.

PART 2: HMF AS PART OF THE TRANSLATION FROM LOW EARTH ORBIT TO MARS ORBIT

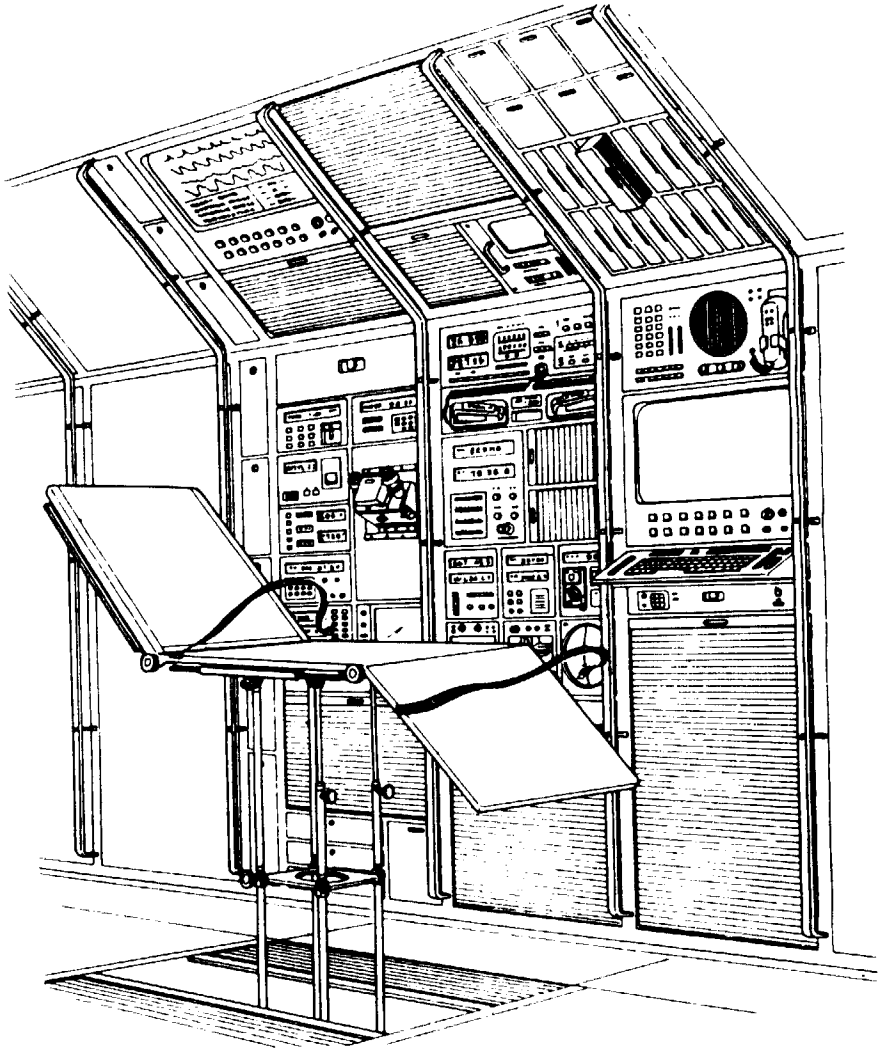
Objective

To define the requirements for a module dedicated to crew medical support and medical research during the transit from low Earth orbit to Mars orbit.

Background

The facts pertaining to a manned outpost on Mars apply equally to the crew during transit from Earth to Mars. A major environmental difference lies in the existence of a one-third gravitational field on the surface of Mars whereas none is present during translation.

Since many months exposure to microgravity is likely to result in severe deconditioning and, further, would require a prolonged adaptation



HEALTH MAINTENANCE FACILITY (HMF) FOR SPACE STATION. HMF FOR MARS MISSION WILL CONSIST OF A SIMILAR MODULAR ASSEMBLY OF VARIOUS UNITS FOR DIAGNOSIS AND TREATMENT. ADDITIONAL SPACE WILL BE REQUIRED FOR STORAGE OF SUPPLIES FOR A LONGER MISSION. ALSO, THE MARS MISSION HMF WILL REQUIRE A SUBSTANTIAL AMOUNT OF SPACE FOR EXERCISE EQUIPMENT NOT INCLUDED IN THE 3-RACK SYSTEM FOR SPACE STATION

FIGURE 1

of the crew landing on Mars, the case is made here for an artificial gravitational field of at least one-third (1/3) G during translation.

Requirements and Design of the HMF

Assuming that an artificial field of one-third (1/3) G is available during transit, all requirements and design elements proposed here remain identical to those previously described for the manned outpost on Mars.

If artificial gravity is not available, then the design elements for the HMF during transit should incorporate hardware and techniques which will function in microgravity. Such considerations are being taken for the design of the Space Station HMF.

TABLE I

FIRST LEVEL FUNCTION -

Establish Life Critical Systems

SECOND LEVEL FUNCTION -

Health Maintenance (MMM)

THIRD AND LOWER LEVEL FUNCTIONS -

COUNTERMEASURES:

1. Functional Requirements: To include aerobic/anerobic equipment, upper and lower body capability interactive with computer exercise protocols.
2. Hardware Recommendations: Treadmill, bicycle ergometer, nordic track, rowing device, hill climber.

TOXICOLOGY:

1. Functional Requirements: Capability to measure O_2, N_2, CO, CO_2 and TBD compounds.
2. Hardware Recommendations: Mass Spectrometer, gas chromatograph, laser fingerprint I.D.

HYPERBARIC:

1. Functional Requirements: Two person hyperbaric treatment facility (HTF) capable of generating 6 atmosphere.
2. Hardware Recommendations: Modify airlock.

HEMATOLOGY/IMMUNOLOGY:

1. Functional Requirements: Complete blood count with differential, hematocrit, hemoglobin, platelet count, prothrombin time, partial thromboplastin time, fibrinogen, and C reactive protein.
2. Hardware Recommendations: QBC system, Flow cytometry, Digital microscopy.

CLINICAL CHEMISTRY:

1. Functional Requirements: Sodium, potassium, chloride, bicarbonate, CO_2, urea, calcium, phosphate creatinine, Glucose, triglycerides, cholesterol, ammonia, amylase, lipase, total and direct bilirubin, alkaline phosphatatase, SGPT, SGDT, GGPT, creatine phosphokinase and isoenzymes, albumin, total protein, alanine, valine, isolevcine, phenylalanine, tyrosine, 3-methyl-histidine, and tryptophan.

2. Hardware Recommendation: Dry chemistry, ectachem, reflotron, ion sensitive electrodes, ion sensitive field effect transducer.

MICROBIOLOGY:

1. Functional Requirements: Rapid identification and AB sensitivity of Medical/environmental pathogens.
2. Hardware Recommendations: Automated microbial system.

URINALYSIS:

1. Functional Requirements: Specific gravity, Ph, quantitative protein, glucose, ketones, cell count, sodium, potassium, chloride, bicarbonate, urea, 3-methylhistidine, calcium, phosphate, myglobin, creatinine.
2. Hardware Recommendations: Stand-alone vs piggy back with other systems.

IMAGING:

1. Functional Requirements: A low radiation digital diagnostic imaging system with Earth transmission capability.
2. Hardware Recommendations: Digital radiography, miniaturized CAT, computerized ultrasound.

PHYSICIAN'S EQUIPMENT:

1. Functional Requirements: Standard physical exam equipment including stethoscope, otoscope, ophthalmoscope, visual acuity apparatus, and measurement equipment for height, weight, and blood pressure.
2. Hardware Recommendations: Physician's "Black bag".

IV-HYPERAL:

1. Functional Requirements: A rehydratable intravenous administration system utilizing stanard physiologic intravenous solutions and peripheral hyperalimentation.
2. Hardware Recommendations: Purification system administration system (portable).

CARDIOVASCULAR/LIFE SUPPORT:

1. Functional Requirements: Capability to monitor systolic and diastolic blood pressure, heart rate, electrocardiogram with digital output for arrmythmia detection, cardiac output, ejection fraction, peripheral vascular integrity, peripheral PO_2, PCO_2, PH. A cardiac defibrillator is required. Capability to measure body surface temperature, core temperature, ambient temperature, and metabolic rate.

2. Hardware Recommendations: Modular unit for ADV. cardiac life support and critical care capability. Modular unit incorporating capnograph, breathing gas mixture with different CO_2 concentration for obtaining mixed venous PCO_2 to determine cardiac output non-invasively.

RESPIRATORY/VENTILATOR:

1. Functional Requirements: Capability for measuring respiratory pressures, flows, minute and alveolar ventilations, deadspace and tidal-ventilation, respiratory quotient, O_2 consumption, CO_2 produced, pulmonary capillary blood flow, and pulmonary function tests, capability to measure respiratory volume/flow relationship. A programmable positive pressure ventilation with positive and expiratory capability, blood gas analysis including Ph, PAO_2, $PaCO_2$, $A\text{-}VO_2$ difference, right atrial pressure.
2. Hardware Recommendations: Small programmable positive pressure entilation with peep capability. Small blood gas analyzer incorporating a minimum of blood handling procedures.

PHARMACY/SUPPLIES:

1. Functional Requirements: A supply of necessary pharmaceuticals, bandages, and splints to support the designated crew size and duration. Emergency medical supplies will be stored in the safe haven to allow for a 28 day self-contained survival period.
2. Hardware Recommendations: Pharmaceutical and supply modules in which constituent items are organized by function. Small contingency pharmacy and supply kit for safe haven.

SURGERY/ANESTHESIA:

1. Functional Requirements: Capabilities for surgery, local and regional anesthesia, and dental intervention.
2. Hardware Recommendations: Portable surgical module incorporating surgical supplies, restraint systems, lighting, electrocautery, medical surgical suction device, and dental kit.