History of the Health Maintenance Facility for Space Station Freedom

Mark R. Campbell

The concept of Space Station Freedom (SSF) was first announced by President Reagan in 1984, although the actual name of "Freedom" did not become official until 1988. It was to be a large, permanently manned space station powered by large solar panels and constructed and serviced intermittently by the Space Shuttle (six times per year, but with up to 45 d with no Shuttle docked at the station). There was to be a crew of eight with nominal individual stay times of 90 d, but possible extensions for up to 180 d. There were to be two laboratory modules and two habitation modules with Canadian, European, and Japanese involvement. First element launch was scheduled for 1994 as early as 1986, but this was delayed by the subsequent underfunding because of the Challenger disaster. Limited hardware fabrication began in 1988. More detailed design plans were produced with the announcement of the Space Exploration Initiative in 1990.[19] In 1993 the project was over budget, underpowered, 23% too heavy, behind schedule, and requiring too much extravehicular activity (EVA) time for construction. Congressional support collapsed, but negotiations with Russia morphed the SSF and plans for the Russian Mir-2 into the International Space Station.

The Health Maintenance Facility (HMF) was a concept developed by NASA Medical Operations beginning in 1986 to provide for medical care onboard the SSF.[14–16] The goals of the HMF were prevention of illness, diagnosis, medical and surgical treatment, stabilization of critical events [capable of full advanced cardiac life support (ACLS) and advanced trauma life support (ATLS)], and medical transport. The emphasis was on maintaining crewmember health to prevent mission impacts due to medical conditions and to prevent unnecessary medical evacuations. It was urged that for the HMF to achieve its full potential, every crew would need to have at least one M.D. on board.[11] There was at this time no Assured Crew Return Vehicle present in the SSF design and as there would be 45 d between Shuttle dockings, there would be no option during this time for medical evacuation. The 45 d to definitive medical care drove the enormous capabilities of the HMF.[1,9,11,18] The HMF was divided into several subsystems:

- Anesthesia (oral, local, regional, IV)
- Dental
- Fluid therapy (IV pump, generation of sterile IV fluids from the SSF pure water generation system)
- Imaging (digital X-ray)
- Medical analytical laboratory (blood, urine, microbiology analysis)
- Health Maintenance Facility Information System (medical record computer)
- Medical life support (defibrillator, monitor)
- Pharmacy/central supply
- Physician instruments
- Respiratory support (ventilator, oxygen supply)
- Surgery (waist level OR table, OR task lighting, cautery, full surgical capability)
- Medical evacuation and transport
- Waste management (including suction with an air/fluid separator)
- Hyperbaric airlock

Two of the more advanced developing technologies were a digital X-ray imaging system[8,10] and a medical informatics computer system. Hardware was also developed to suction surgical fluids and then separate the fluid/air with a centrifuge prior to disposal.

It is hard to imagine how ambitious the 1986 HMF concept was. Digital X-rays and electronic medical records were unheard of in conventional terrestrial medicine. Medical hardware for use during spaceflight, such as defibrillators, monitors, ventilators, IV pumps, chemistry analyzers, and OR tables in spaceflight were almost unbelievable. The concept of "telemedicine" was in its infancy. Performing procedures such as ACLS, CPR, ATLS, and general anesthesia (and even more so performing an open surgical procedure) were considered by many as fantastic and just simply not feasible. However, a full size HMF mockup was built at KRUG Life Sciences (that had the medical support contract for the NASA Johnson Space Center) and ground simulations were carried out to fine tune how medical care would be performed in space using telemedicine (**Fig. 1**). Prototype hardware was developed and constructed and used in these simulations.[12] Extensive simulations using anesthetized animals were performed in parabolic flight to demonstrate that CPR and surgery could be performed in weightlessness.[4,13,17] ATLS, ACLS, and defibrillation were also performed and demonstrated in parabolic flight.[6,13] Much was learned and there were lots of surprises and unexpected difficulties to overcome. Bleeding was always felt to be an enormous problem in weightlessness, but was found to be easy to control due to surface tension forces. Methods of patient, operator, and instrument restraint were developed and simplified.[5,7]

As the SSF size, power, and construction constraints were descoped and made progressively less capable, so too did the HMF begin to lose capability.[2] The digital X-ray capability and the hyperbaric airlock were the first to be deleted. The waist level OR table (**Fig. 2**) became a simpler floor-level soft crew medical

From Paris, TX.

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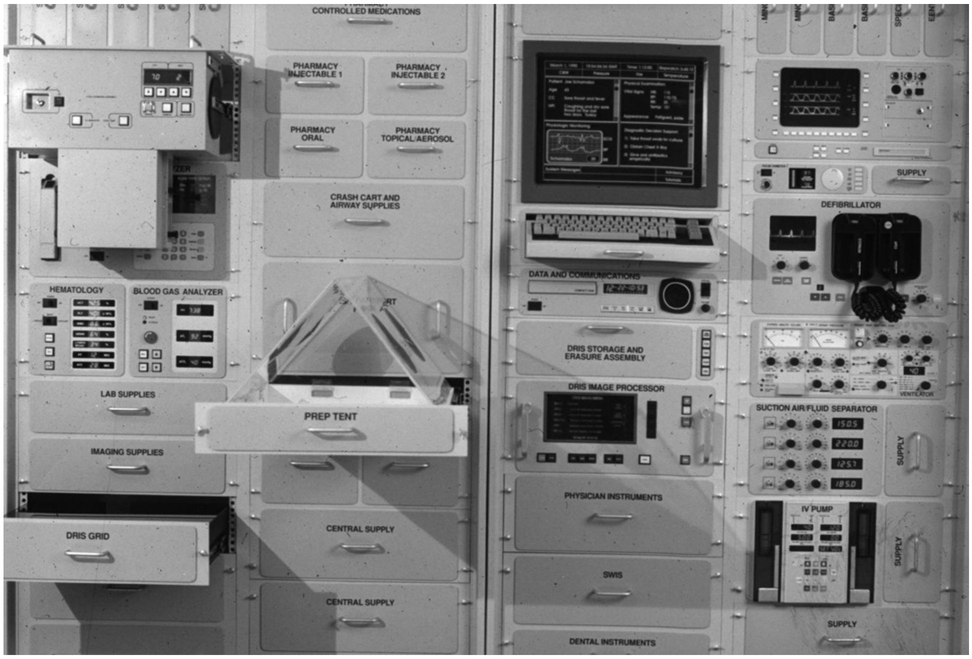

Fig. 1. The Health Maintenance Facility mockup used by KRUG Life Sciences to perform medical care simulations in 1990. It would have taken up two double racks in the Freedom Habitation Module. On the left is the digital X-ray hardware and just to the right of center is the medical computer. Also notice the telemetry monitor, defibrillator, ventilator, suction separator, and IV pump on the far right and the chemistry analyzer on the far left.

restraint system. Volume, weight, and power requirements were progressively and radically decreased. A dedicated M.D. as the Crew Medical Officer was never approved. The solution to the decreased medical capabilities was the inclusion of a requirement for an Assured Crew Return Vehicle for medical evacuation.[3] This also had its own dynamic evolving spiraling down concepts—HL-10, the European winged vehicle, X-38, and finally a Soyuz spacecraft. The concept of extensive medical capability

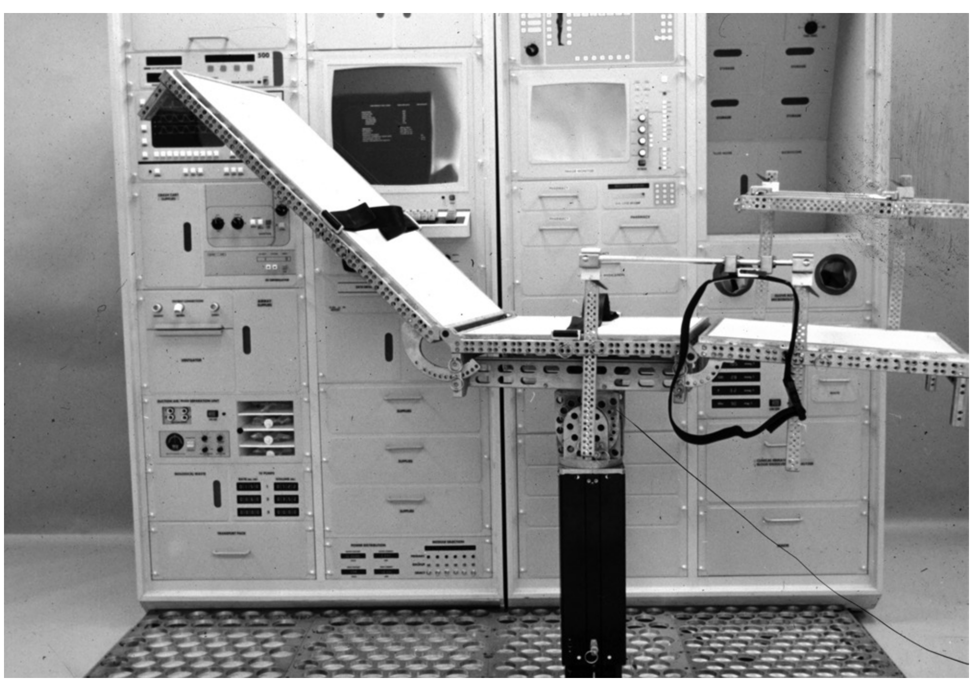

Fig. 2. An earlier, lower fidelity Health Maintenance Facility mockup that was used by KRUG Life Sciences. The waist level OR table is still present with a cumbersome rigid restraint system (grid floor and waist belts).

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to prevent medical evacuations changed to emphasizing stabilization and transport back to Earth for any serious medical condition.

Unfortunately, Space Station Freedom and the Health Maintenance Facility were never developed further. But the research performed in anticipation and support of their development greatly advanced our understanding of medical and surgical care in space.

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