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# THE LOGISTICAL IMPORTANCE OF DESIGNING AND BUILDING SUPPORTABILITY, MAINTAINABILITY, AND COMMONALITY INTO EQUIPMENT USED FOR A HUMAN MARS MISSION

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## Abstract

"This paper is entitled: "The logistical importance of designing and building Supportability, Maintainability, and Commonality into equipment used for a Human Mars Mission", and it will review some of the concepts learned in the support and maintenance of high technology aircraft, and aerospace systems and apply them to the design and planning of future manned Mars missions. With proper advanced planning, the significant logistical and supportability challenges resulting from long mission duration, extreme operating environment (extreme cold, dust, wind, etc.) and very long logistical pipeline can be successfully met. Using the concepts of keeping mission equipment as simple and robust as possible, using commonality (interchangeability) for high usage hardware items such as light bulbs, switches, gaskets, valves, etc., and having onboard a rudimentary repair capability will be very important in achieving mission success. Also, the criteria used in determining what type of spare parts and tooling should brought on a human Mars mission, will review basic concepts such as; 1). mission criticality of component, 2). can the component be changed or repaired in the field, 3). component failure rate and/or shelf life, and last, but certainly not least, 4). size and weight.

Additionally, this paper will review the success of some part standardization initiatives in the U.S. Navy and the airline industry, that can be incorporated in the planning and design of Mars mission equipment. It is very important that for humanity's first mission to another planet that the crew will have maximum flexibility and independence to successfully complete the mission. This can be greatly facilitated, through the coordinated design of their equipment (avoiding suboptimization), interchangeabilty and commonality of their hardware and consumables, and a well thought out plan for common tooling, as well as the ability to perform field repairs, to successfully handle any contingency that may occur."

## Lesson of Apollo 13

The Apollo 13 mission was truly a space emergency that, if not for the innovation and resourcefulness of the crew, and engineers on the ground, could have resulted in a tragic and complete loss of crew and equipment. The Apollo 13 malfunction was caused by an explosion that ruptured the number 2 oxygen tank in the service module about 56 hours into the mission. Within about 3 hours after the explosion, the service module was rendered unusable. The crew was forced to use the lunar module as a "lifeboat", since that was the only source of power and consumables.

A serious problem developed because the lunar module was designed to support 2 astronauts for 2 days, but to return the Apollo 13 crew safely to Earth, it would have to support 3 astronauts for 4 days. The critical life support constraint was the removal of carbon dioxide. Carbon Dioxide scrubbers, using lithium hydroxide canisters, were used to perform this function. The only way the crew could make it back to Earth alive would be to use the canisters from the command module. The problem was that the command module, built by North American Aviation, used **square** canisters, and the lunar module built by Grumman, used **round** canisters.[1] Without some innovative "jerry rigging', using plastic bags, cardboard, and tape, the crew would have perished.

A key lesson to learn, is that: **all critical parts, interfaces, receptacles, and software should be made as standardized and interchangeable, as possible, for all mission ships and systems**. In a mission architecture, that may involve many different contractors, and possibly other nations, there should be interagency oversight and discipline to ensure that standardization and commonality goals are met.[2] This would go a long way in ensuring the success of a two and a half year Human Mars mission.

## Supportability

In a perfect world, where no equipment fails, there is no possibility of equipment damage, and service life of all components exceeds mission length, no spares would be required. However, considering a Human Mars mission, with long mission duration, harsh operating conditions, and very long logistical pipeline, it would be most prudent to bring along some spare parts.

In the process of determining the type, breadth and depth of spare parts to bring, the following aerospace guidelines can be used:

1. Mission Criticality of Component – Sparing should be focused on vital, mission essential systems and subsystems. These would include life support, electrical power generation and communication systems.

2. Can component be changed in the field? – Due consideration must be given to the harshness of the Martian environment, and the difficulty of performing complex maintenance in space suits. (This would only apply to components that must be changed outside of the hab).

3. Component Failure Rate (or projected service life) – Engineering data and field test reliability data can be used to determine Mean Time Between Failure (MTBF) rates for critical components. These rates can be used in a statistical sparing model to ensure adequate sparing requirements are provisioned for with a high degree of confidence.

4. Size and Weight – This is of primary importance for a Mars mission. A key logistical question will be - What percentage of total mission weight can be allocated for spare part? Using an example from the airline industry, which utilize Fly Away Kit's (FAK's) when operating in remote areas. A 767-200 aircraft would bring approximately 1,200 lbs of spare parts in a converted LD2 container, which is contoured to fit in the belly of the aircraft. This is less than half a percent of total gross take off weight of the aircraft.

Consideration also needs to be given to the types (or classification) of parts which are brought along. These would include: Line Replaceable Units (LRU's), expendable parts and expendable Repair Kits (electrical, hydraulic, etc.), consumable fluids (oils, hydraulic fluid, etc.) and tooling. As we will discuss later in this paper, standardization and commonality of parts, will go a long way in reducing the number of line items required, overall weight of spares, and improve overall mission operational readiness.

## Maintainability

It is essential that all mission equipment is designed to be as simple and robust as possible, and also that there is project oversight to ensure part commonality objectives are met, and that system suboptimization does not occur. In conjunction with part commonality objectives, it is important that repairable components are designed to be repaired with a basic set of tooling (minimize need for "special tooling"). Obviously, a common measurement system (English vs. Metric) must be agreed upon and adhered to. Coordinate and plan overall system design to ensure common interfaces, with upgradeable functionality. Integrate logistics considerations into mission design upfront.[3]

Another aspect of maintainability is the capability of the crew. It is important that crew members are provided extensive maintenance training before the mission, and that technically savvy, capable technicians are part of the crew. An important maintenance consideration is the difficulty of performing "field" repairs in the martian environment. Factors such as; dust, sand and windstorms; extreme cold temperatures; and clumsiness of wearing spacesuit, gloves, etc; will severely degrade the quality and efficiency of any martian "field" repairs. One possibility to research in order to improve in this area, is the use of an inflatable, tent like, "garage". This could be extremely valuable in performing outside, field repairs to systems such as; the rovers, power generation system, and communication system.

## Commonality

A "Big Picture" or the macro view of commonality, and a key element to achieve the goal of the Vision for Space Exploration (VSE), is that the Crew Exploration Vehicle (CEV) and Crew Launch Vehicle (CLV), used for our return to the Moon, are the same or as similar as possible to the equipment used for the Human mission to Mars. Key advantages of this approach are:

1. Significant cost savings and time savings can be realized by designing, from the beginning, equipment that can be used for either the Moon or Mars missions.

2. By using the same design equipment, the equipment can be prototyped on the Moon and lessons learned can be applied to the Mars mission.

3. By using the same design equipment, reliability data can be obtained which will greatly assist in the logistical and material support planning for the Mars mission.

Looking at commonality in a more "micro" aspect, significant gains can be achieved by standardizing the high use, expendable parts for all mission equipment. Line items such as light bulbs, batteries, switches, valves, etc. can be standardized to reduce weight, reduce the number of line items carried, and would enable "part cannibalization" from mission non-critical to mission critical systems/subsystems, if the situation warrants. Another area with significant potential for standardization are consumable fluids. Overall project oversight should minimize the different types of fluids used, and ensure that fluids such as; brake/hydraulic fluids, and oils/lubricants can be used among all mission systems and subsystems. Additionally, from the start, overall mission design should also incorporate the use of standard size (diameter) flex lines, when feasible, in place of uniquely made hardlines. This greatly improves repair capability, and reduces sparing requirements.

A prime example of a parts standardization program, for a complex, high technology project (in this case a nuclear powered, attack submarine), is the U.S. Navy's USS Virginia (SSN 774) program. In this program major life cycle benefits were achieved from the implementation of standardization goals achieved early in the design phase. These benefits included:

1. Reduced Logistical Footprint - The Bill of Materials was reduced from 67,834 for Seawolf class submarines to 27,014 for Virginia class. Additionally, a 32% reduction in on-board test equipment over previous classes was achieved.

2. Improved Operational Readiness – By reduced the number of line items required, critical part shortages are minimized and a significantly higher sparing rate can be achieved through out operations.

3. Significant Cost Reductions – Part standardization is a key initiative in projected (life cycle) cost reductions of approximately $400M per ship.[4]

The key factors that led to the success of this program were: **program instituted at the beginning** of design phase; **management commitment** and enforced contractual requirements; part standardization facilitated by CAD architecture; and standardization principles were **adhered to throughout design, construction and modification**.

## Summary

Part standardization and commonality are vital to a successful Human Mars mission and are in keeping with the Mars Direct philosophy of “keeping it simple”. It is very important that program oversight and discipline prevent the suboptimization (designing each system independently for optimal performance, but without regard for the overall mission as a whole), which led to the serious (yet easily preventable) problems that were encountered on the Apollo 13 mission. The Human Mars mission will be the grandest achievement ever contemplated by the Human species. It will clearly be the farthest and most difficult human exploration ever attempted, by many orders of magnitude. At its’ closest point, Mars is over 140 times farther than the Apollo mission was on the Moon (56,000,000 Km vs. 400,000 Km), transit times at the very best are over six months, and overall mission duration approximately 2.5 years (1.5 years on martian surface, and over six months transit for each leg) . The logistical and support challenges for this mission will be significant. A successful mission will require that many different systems (Hab, Rovers, Communication, Power generation, etc.) are well integrated and operate well together. Advance planning to ensure that part standardization and commonality objective are incorporated in the initial and overall design of Mars mission equipment, will go a long way to ensure the success of the mission, and provide maximum flexibility for the crew to handle any contingencies or emergencies that may come up.

In my opinion, the Human Mars mission will be the most magnificent challenge and greatest opportunity for mankind. Exploration, discovery, and expanding the horizons for all of humanity, is at the very core of our success as a species. With noble challenges, we expand and grow, without challenges we wither and contract. I believe this is so, both at the civilization level and at the individual level. I am still inspired by the courage and the vision expressed in the words of John F. Kennedy, “ We choose to go to the moon in this decade, and to do the other things, not because they are easy, but because they are hard.” On to Mars!!

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[1] Jim Lovell and Jeffrey Kluger. "Lost Moon". Houghton Mifflin Company: New York, NY, 1994; p. 250.

[2] Peter Kock, Lessons Learned for the International Space Station from Apollo 13. www.asi.org/adb/06/09/03/088/apollo13-lesson.html.

[3] NASA Space Exploration Logistics Workshop Proceedings, Washington, DC, Jan 17-18, 2006.

[4] James Conklin (PMS450B), Realizing Cost Savings through Standardization. www.dsp.dia.mil/2006-DSP-conf/Conklin.ppt.