Building a Shared Definitional Model of Long Duration Human Spaceflight

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OBJECTIVE

To establish the need for a shared definitional model of *long duration human spaceflight*, that would provide a framework and vision to facilitate communication, research and practice

BACKGROUND/MOTIVATION

In 1956, on the eve of human space travel Hubertus Strughold first proposed a "simple classification of the present and future stages of manned flight" that identified key factors, risks and developmental stages for the evolutionary journey ahead (Strunghold, 1956). As we look to new destinations (Figure 1 & 2), we need a current shared working definitional model of *long duration human space flight* to help guide our path. Here we describe our preliminary findings and outline potential approaches for the future development of a definition and broader classification system.

METHODS

Initial review of formal and grey literature augmented by informal and preliminary consultation with eight subject matter experts (SMEs) from the National Aeronautics Space Administration (NASA) and the Canadian Space Agency (CSA) from space life sciences, habitability and engineering. The search strategy focused on both the use of the term *long duration mission* and *long duration space flight*, as well as broader related current and historical definitions (Table 1) and classification models of space flight (Table 2). The related sea and air travel literature was then explored with a view to identify useful analogous models or classification systems (Table 3).

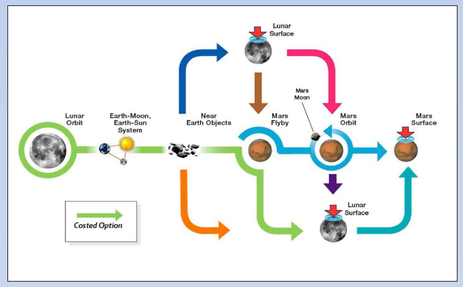

Figure 1: NASA Flexible Path strategy Source: Review of U.S. Human Spaceflight Plans Committee

ANALOGOUS DEFINITIONS

Few national and international standards defining long duration space flight missions exist. The NASA's Flexible Path strategy has determined possible future human space flight destinations (Figure 1 &2). Many terms have been sporadically used to define these missions (Table 1), and a shared definition of long duration human space flight would be beneficial. To begin to identify a useable definition, it is helpful to study precursors to human spaceflight such as robotic missions as well as other analogous expeditionary arenas such as sailing, which share operational considerations to human spaceflight.

Table 1: Current terms used in literature

Current terms used in literature
Exploration class missions
Beyond Earth Orbit (BEO)
Sub-orbital Mission
Extra-orbital Mission
Interplanetary (interstellar, intergalactic)
Orbital Mission
Exploratory Flights
Deep Space Mission

Table 2: Robotic Missions Spacecraft Categories

Robotic Mission Spacecraft Categories
Flyby spacecraft
Orbiter spacecraft
Atmospheric spacecraft
Lander spacecraft
Rover spacecraft
Penetrator spacecraft
Observatory spacecraft
Communications spacecraft

Table 3: Summary of United States Sailing categorization system

Cat	Description of U.S. Sailing Categories
0	Trans-oceanic races, including races passing through areas in which air/sea temp is less than 5 degrees Celsius, yacht crewmembers must be completely self-sufficient for very extended periods of time, capable of withstanding heavy storms and prepared to meet serious emergencies without the expectation of outside assistance
1	Long distance races, well offshore, in large unprotected bays, and waters where large waves, strong currents, or conditions leading to rapid onset of hypothermia are possible, yacht crewmembers must be completely self-sufficient for extended periods of time, capable of withstanding heavy storms and prepared to meet serious emergencies without expectation of outside assistance
2	Races of extended duration along or not far removed from shorelines, where a high degree of self-sufficiency is required of the yachts but with the reasonable probability that outside assistance would be available for aid in the event of serious emergencies
3	Races across open water, most of which is relatively protected or close to shorelines
4	Short races, close to shore in relatively warm or protected waters normally held in daylight

RESULTS

- The concepts of *long duration mission* and *long duration space flight* are infrequently and inconsistently operationally defined by research authors, and no commonly referenced standard definition emerged from the search. Interviewees did not identify any current initiatives to develop a common definition.
- Of the interviews conducted, a majority of interviewees believed a common definition would be of value to the space community. Though questions and concerns were raised regarding this (see Discussion).
- In the case that a multi-axial categorization system is developed, SMEs identified a number of constraints that should be incorporated (Table 4).
- The categorization system for sailing was found to be of potential analogous utility, with its focus on understanding the need for crew and craft autonomy at various levels of potential adversity and ability for outside support or return to a safe location, as well as factors of time, distance and location (Table 3).

Table 4: Potential axes for multi-axial classification system for Human Space Flight

Potential axes for multi-axial classification system for Human Space Flight
Distance from Earth
Destination
Sub-Orbital, Orbital, Extra-Orbital
Ability to return to Earth (in case of contingencies)
Communication Time Delay
Nature of mission (construction, science, exploration, maintenance)
Crew size
One-time versus multiple step mission

SOURCES CITED

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DISCUSSION AND IMPLICATIONS FOR THEORY AND PRACTICE

While a shared definition would be beneficial, concerns raised were:

- The potential users of a common definition for *long duration space flight missions* must be determined. NASA departments and disciplines use the terms in varying degrees in daily operations. This preliminary research suggests a shared definition would be most used by NASA Medical Operations, the NASA Behavioral Health Program (BHP) and by extension the NASA Human Research Program (HRP), in addition to their international counterparts, as well as any discipline that commonly uses the term in published papers.
- The scope of the definition must be determined. Loose definition, vs. a complex categorized system. SMEs advised a simpler definition is more relevant and easier to implement
- Technological advances in the near future may change the nature of constraints and mission requirements thus affecting the categorization system. Therefore, the system should attempt to be broad enough to accommodate these potential changes.

Questions emerged in considering the constraints for a multi-axial system:

- Nature of mission: This constraint will play a major role in the day to day experience of future astronauts. Very different selection, training, and mission profile will be experienced by crews depending on the focus of their mission: construction vs. science vs. maintenance
- In regards to the ability to return to Earth, the orbital mechanics on what are *points of no return*?
- As missions reach even longer durations, at what point does a mission become a relocation (a more permanent habitation in space)?

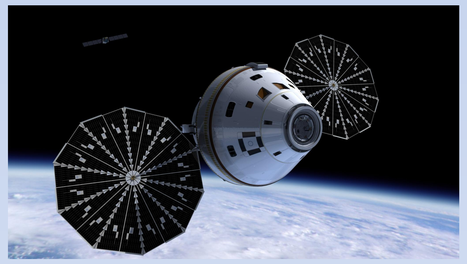

Figure 2: Multi-Purpose Crew Vehicle (MPCV: Orion) Spacecraft developed for multiple destinations

CONCLUSIONS

- There is a need to examine the drivers that cause a shift in mission profiles (spacecraft capabilities, technology, propulsion) where multiple crucial requirements change
- Broader survey of international perspective is needed
- To successfully implement a system, support should be encouraged amongst technical planners, international standards teams.
- Further research on analogous category systems is needed to inform the development of an adequate system
- Current standards documents should be reviewed for their relevance and utility.