**Design Competition and Development Track For A Low Cost Reusable Interplanetary Crewed Spacecraft,**
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**Introduction:** This presentation describes a design competition and development program for interplanetary vessels, composed mostly of water, that utilize simplified RF engines for low thrust, long duration propulsion. The system emphasizes simple components and processes based on older technologies, many well known since the 1960s, that are understandable, can process a variety of materials, and can be serviced in flight. The goal is to radically simplify systems and their inter-dependencies, to a point where a reasonably skilled person can learn to operate these vessels, not unlike a sailboat, and to eliminate many design and testing bottlenecks in their construction. The use of water is multiply advantageous because it can be used for structure, consumption, irrigation, radiation and debris shielding, and thermal regulation, and thus greatly reduce dead weight by creating an almost fully consumable and refuelable ship. This also enables the ship to utilize a wide range of in situ materials, and eventually obtain reaction mass from lower gravity sites. One can think of them as "spacecoaches", not unlike the prairie schooners of the Old West, which were rugged, serviceable by tradesmen, and easily maintained. These craft can be built using existing technology and launch platforms, and have the potential to dramatically reduce the cost of missions to the Martian system, while simultaneously mitigating numerous safety and health issues. We propose a staged public/private design competition and development program that could realistically result in crewed missions to the Martian system within ten to fifteen years.

Phase IA would begin with an X-Prize ($I_{sp}$ Prize) competition to identify the most promising electrothermal engines. This competition, which would require funding of $1 to $10 million, could easily be supported by public or private sources, with space science agencies providing access to testing facilities. Engine designs will be evaluated on several criteria: the ability to operate at an $I_{sp}$ of 800s or greater using water/water vapor as reaction mass, technology readiness level, mean time before failure greater than 5,000 hours, modular design with standardized form factor, replaceable parts or replaceable components that are susceptible to wear, and packaged to enable servicing from inside the vehicle to eliminate the need for EVA. Microwave electrothermal thrusters appear to be especially promising for this application.

Phase IB commences with a similar design competition to identify one or several detailed ship designs derived from the spacecoach concept, where water is used as reaction mass and is used for multiple purposes throughout a mission. Ship designs will be required to meet criteria including: ships and/or components must be launched using existing or near-term launch platforms (e.g. Space X Falcon 9/Falcon 9 Heavy, Delta IV Heavy, Atlas V Heavy, etc), must utilize electrothermal engines with water as reaction mass, water should be used for multiple purposes (e.g. radiation shielding, irrigation, environmental control, etc), should use existing or near-term available habitable modules (i.e. Bigelow Aerospace), and must use feasibly available solar photovoltaic arrays or sails. Designs will be evaluated for their ability to perform multiple round-trips from high earth orbit or LML-2 to the Martian system and/or moons (we assume surface operations will be done via teleoperated probes controlled from astronauts in Mars orbit, or a lunar base). This Phase can be conducted in parallel with Phase IA, with mission modeling and performance analysis to be done once results from the engine design competition are available.

Phase IC commences with a design competition to build tele-operated probes that provide a wide field of view, low communication/control latency, and tactile extensions with sensory feedback to operators. This design competition would produce working probes that are tested in realistic environments with operators controlling the probes from offsite, over communication channels that simulate bandwidth, latency and data loss expected when controlling devices from a nearby orbit. These competitions can be completed within a short period of time, 1-2 years at most, and at little cost, while enabling diverse, multidisciplinary teams to participate.

Phase II would build and fly a partial or scaled down, unmanned craft derived from Phase I that operates in earth orbit. The scaled down ship would simulate the delta V of a round trip Mars journey via a series of step-up/step-down maneuvers whose aggregate delta V equals a roundtrip Mars journey. Electrical, propulsion, life support and other systems would all be evaluated during this test flight. The craft could be resupplied and upgraded as needed until program managers are confident enough to fly a full-scale crewed version of the vehicle, which would be designed during Phase II. Meanwhile Earthbound tele-operated probes would be tested by remote operators onboard the International Space Station, providing a highly realistic simulation of tele-operated exploration and science experiments from local orbit.

Phase III would proceed to larger, crewed vehicles which would initially simulate a Mars mission both in terms of delta V and mission duration while remaining in the Earth-Moon system to provide abort capability. The crew could also simulate surface missions via teleoperated probes either on Earth or the lunar surface, enabling these components to be thoroughly tested prior to delivery to the Martian surface environment.

In Phase IV, the ship flown in Phase III would be resupplied and upgraded, then proceed to Mars orbit, or possibly to one of the Martian moons. The crew would teleoperate surface probes, possibly at many sites of interest, with minimal control/communication latency. This strategy defers the risk and cost of crewed surface missions, while establishing a persistent forward operating capability akin to McMurdo station, as well as high return science mission capability.

**References:**

[1] McConnell, B.S, Tolley, A,M, REFERENCE DESIGN FOR A SIMPLE, DURABLE AND REFUELABLE INTERPLANETARY SPACECRAFT, *Journal of the British Interplanetary Society, Vol. 63, pp.108-119, 2010*