Marshall Problem/Project Statement - Senior Design Topic

Problem/Project Title: _In-Space (including planetary surface) Propulsion System Maintenance__________

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Indicate which discipline(s) is/are most appropriate to work on this problem (e.g., aerospace, mechanical, electrical, chemical, industrial, civil, computer, physics, materials, test, nuclear, earth science, other)

All the above disciplines, since this is system design. While there is no expectation of human factors coursework, since few universities offer it, the team will be expected to become familiar with human factors analysis methods.

Marshall Problem Statement

Background: The big picture with references to previous work (Why would a senior design student be excited about this work?)

Deep-space exploration requires that all spacecraft systems be operated for years without access to earth-based maintenance capabilities. This means that in-space maintenance will be required; this may be accomplished by the human spacecraft occupants or by electromechanical systems – generically, robots. While maintenance of systems on the International Space Station has become routine, this process is highly dependent on proximity to earth, for spares resupply, and for access to engineering support and procedures, developed as needed. Importantly, no propulsion systems have been maintained in space. In the Apollo missions, multiple single-point failures in the Lunar Module ascent stage would have resulted in Loss of Crew and Loss of Mission. This risk was accepted, in part, because of the significant weight impacts of designing the propulsion system to be maintainable, including mass allocations for spares and tools. This issue must be addressed for missions lasting months to years and ranging beyond the moon's orbital distance. For example, an Earth-to-Mars transit vehicle will have a propulsion system that will be used to leave the Earth solar orbit, and then may not be used at all until orbit insertion at Mars, eight to twelve months later. The same system will be needed, one to three years later, for the return transit. Thus, it will have long periods of quiescence, after which it must perform perfectly. The Mars lander and return vehicle will likely be a separate vehicle, and it may be loaded with propellants at earth, up to a year prior to use in landing. It will then stand on the Martian surface for one to three years before reactivation to carry explorers back to Martian orbit. While there are other mission designs, all place similar constraints and demands on propulsion systems. To date, no one has designed propulsion systems, with the thrust capability required for human exploration that must operate intermittently over periods of months to years. Such systems will require human attendance in checkout and test, such as is currently performed at all launch sites and in maintenance and repair, again performed at all launch sites.

Recent/on-going research on the problem (What resources, if any, are available to the senior design team, such as equipment, software, facility utilization)

As noted, there is no actual precedent for this work. The expectation is that the team will rely heavily on human-centered workstation design principles, as found in NASA-STD-3000, NASA-STD 3001, MIL-STD-1472, FAA HF-STD-001/HFDS, and similar design standards. The concepts embodied in these focus on human work interfaces and are the same concepts as those applied to robotic interfaces. Human modelling and design simulation will be useful, though much can be accomplished through mockups. MSFC facilities could be used, though that would require travel; one solution to this problem would be to have one team member assigned to MSFC as an intern during one of the semesters.

Details of the problem; design constraints, requirements (if any), outcome expected. One semester Senior Design course lasts 15 weeks; two semester course lasts 30 weeks. (What do you expect the senior design team to accomplish?)

The design project will evaluate the issues identified in the problem statement and develop concepts for addressing them. It is expected that analyses will be performed to identify mission-appropriate propulsion systems; these choices may, in fact, drive the mission design. Analyses will identify maintenance items within the propulsion systems chosen and propose design solutions. These design solutions must address how humans and/or robots will achieve access to the maintenance items and how work envelopes will be provided for maintenance activities. They must identify tool requirements and account for tool mass, for all the conceivable maintenance. This will result in requirements on tool and/or robot design; the specific requirements should be identified. They must identify how the systems can be safed, to avoid personnel exposure to hazardous materials. The analyses will also identify in-flight replaceable units (analogous to Line or Depot Replaceable Units) and evaluate the "cost" of their availability. For example, if an electrical or a mechanical component is to be manufactured in-space, how will this be achieved? What are the mass, volume, power, and resource requirements of the recommended Manufacturing Systems. If no in-space manufacture is planned, weight and other resource requirements for the spares which must be in place at the needed times. All design recommendations must be based on technical capabilities that can reasonably be expected to be mature in 2030. Deliverables will include mission design concepts, in an Operations Concept Document; trade studies; analysis reports; and top-level requirements on propulsion system design that are identified through the project. While models should be shared with NASA, they may be retained by the university. Mockups may be retained, and video/photo documentation of their use in analysis shared with NASA.

Senior Design Project Rules:

1. Weekly telecons will be scheduled to maintain proper progress and prevent dead-end ventures.

2. Deliverable(s) required (e.g., one semester course – a written final report; two semester course – written final report and a prototype/model (if practical))