FY06 IRAD Focus Areas

Light Weight Composite Structures with Integrated Health Management

One of the major challenges in the implementation of the space exploration initiative is the reduction of mass carried to orbit and/or the Moon and Mars. One major corollary challenge is the maintenance of structural and functional integrity of structures. The use of lightweight alloys and composites, along with sufficient health measurement and management techniques, offers a solution to these challenges that will significantly contribute to mission safety and success. Two, near-term, new business opportunities are available for investment that will allow NASA to meet these challenges and both have significant heritage within MSFC. The development of advanced, light weight, composite cryogenic tanks for space propulsion systems and the development of health sensing and management techniques have been technology focuses for some time and valuable advancements and accomplishments have been made over the past few years.

The time is now right for the center to capitalize on these advancements and proceed to project implementation where opportunities exist. One such opportunity is to engage with the Rocket Plane Inc. via a Space Act Agreement to design, fabricate, test, and deliver the needed composite LOX tank for Rocket Plane. The tank would take advantage of recent advances in materials, fabrication techniques, and integrated thermal/structural/acoustic health sensing technologies to provide a significant weight, reliability, and safety advantage over other materials and techniques previously available.

The other significant opportunity, that would be leveraged by the Rocket Plane application, is to endeavor to provide an overall health management set of technologies for the agency that would offer similar reliability and safety advantages to the upcoming CEV and other spacecraft including lunar and Mars habitats and surface mobility systems. An investment in these technologies would be compensated in part by cost sharing with Rocket Plane for the systems provided to that application. This would provide significant visibility to the agency in the advancements made by MSFC in light weight structures and health management technologies and would provide focus for the exploration initiative's technology program.

A tangential benefit to the agency would be the early flight application of these technologies for flight verification and validation of the sensing, analysis, and probabilistic prognostics algorithms and techniques. The Space Act partnership between MSFC and Rocket Plane, Inc. will provide application feedback information as early as September, 2006. This will allow MSFC to more intelligently propose a leadership role in the agencies' need for a technology lead in the exploration initiative's health management technology program. The overall result would be, not only a near term business opportunity for immediate revenue income via the SAA with Rocket Plane Inc., but a long range health management technology program to provide leadership and technology development for the exploration initiative in this domain.

A High Fidelity Non-Nuclear Simulation Test bed for Nuclear Surface Power Systems

Surface nuclear power is recognized as enabling for both long duration (more than a few days) lunar surface missions and human Mars missions and has the greatest acceptance as being absolutely enabling for extended surface operations. MSFC can secure a significant near term agency role potentially leading systems development, testing and flight verification for the surface power program using IRAD resources; posturing the center thought establishment of a focused hardware test bed. Initial systems would range from 10 to 50 kWe and can be achieved utilizing experienced personnel and hardware capability developed over the last several years at MSFC (commonality with reactors that have already flown in space such as the SNAP-10a which incorporated both non-nuclear and nuclear test beds). The proposed effort would involve assembling an integrated system level end-to-end hardware demonstrator using experience gained from the MSFC's Early Flight Fission Test Facility (EFF-TF) for testing nuclear systems through non-nuclear test methods and leveraging one of the three existing EFF-TF reactor simulators, heat pipe, pumped liquid metal or direct gas cooled). Key directed technologies to be addressed and matured by the test bed include reactor control methodologies (realistic simulated nuclear response characteristics by non-nuclear methods) and thermal-hydraulic performance (couple reactor, power conversion and heat rejection loads) and test evaluation of potential operating conditions (startup, steady state, shutdown, variation in power levels, off nominal conditions potential freeze/thaw, etc.) providing relevant data to anchor system models. To meet the power requirements envisioned reactor thermal power level could range from 40 to 200 kWt coupled to high efficiency Stiriling units (1 to 3 kWe range each) using a modular compact heat exchanger topology. The primary reactor coolant loop high temperatures could range from 850 to 1050K with cold side heat rejection spanning 350 to 550 K; incorporating radiator technologies such as such as water loop heat pipes or pumped recirculation (goal target mass range is 3 to 5 kg/m^2). For ease of manufacturing and durability in relevant operating environments the construction shall utilize stainless steel or super alloy for the primary high temperature pressure boundary and components. Potential government and industry teaming opportunities exist including GRC (power conversion/PMAD), Sun Power Systems/Stiriling Technology Corporation (Stiriling converters), Advanced Cooling Technologies (heat rejection subsystems) and DOE Los Alamos National Laboratory (reactor/primary design). The near term development of a surface power unit in the stated power range has key relevance to NASA's mission for general science application (such as rovers/monitoring/communication stations), in-situ resource management (regolith processing, water extraction etc), and thermal/electrical power for habitats and closed loop life support systems in all environmental conditions (support human presence beyond earth).

Advanced Pressurization and Mixture Ratio Control for Spacecraft Propulsion Systems

Objective:

Demonstrate active mixture ratio control for use in either a cryogenic OMS/RCS propulsion system or a primary propulsion system using storable propellants.

Background:
Standard practice for storable propellants is to load approximately 4 to 6% propellant reserves to protect against mixture ratio variations and gauging inaccuracies. In a spacecraft it is desirable to minimize propellant reserves and to deplete the propellant tanks equally so as not to carry excess unused propellant in one tank. This imbalance can be attributed to inaccuracies such as propellant loading, errors in propellant mass gauging, and variations in engine flow rates. The desire to optimize propellant usage drives the need for variable tank ullage pressure and active mixture ratio control. With the operational flexibility of altering the propellant tank pressure, mixture ratio can be adjusted real-time to consume the propellants at a rate that minimizes the residuals at end-of-life.

Benefits/Products:
- Improved pressurization systems for active mixture ratio control and minimization of propellant residuals.
- Demonstration of system pressurization performance for pressure-fed spacecraft systems along with the controller schemes required.
- Demonstration of the pressure and flow rate measurement accuracies required for successful implementation of this approach.
- A spacecraft pressurization and cryogenic propellant systems model to be validated with test bed data.

Development of High Resolution Ultra Light Weight X-Ray Optics

We propose to investigate methods of accomplishing ultra-light-weight, sub-arc-second, X-ray optics. This type of research is imperative for future X-ray astronomy missions including the joint NASA-ESA mission Constellation-X and Xeus and more future missions such as NASA's Generation-X. There are a number of promising techniques that we have been contemplating studying including ultra-thin, small-element, X-ray-diffraction-limited optics at long focal lengths. Significant progress in this arena could serve to leapfrog a mission such as Generation-X to the head of the high energy astrophysics queue, restore US leadership in the field of X-Ray Astronomy, and restore MSFC's role as the lead NASA Center for X-Ray optics.

Solar Electric Propulsion Transfer Stage Technologies

Development of transfer stages that enable crew access to ISS, and crew and cargo transportation between the earth and moon will be important for early exploration missions. It is likely that an upper stage based on cryogenic bipropellants will be needed immediately for CEV access to ISS, and this could evolve to a transfer stage used for crew transportation to the moon. Studies in the past have pointed to the benefits of using high-performance solar electric propulsion (SEP) for stages dedicated for transportation of cargo and infrastructure to lunar orbit. The impact of low-thrust trajectory and longer trip times would be offset by the marked increase in specific impulse and associated reduction in propellant launch requirements.

This research offers MSFC an opportunity to promote the internal capabilities necessary for leading development of an SEP transfer stage. Eventual development of an SEP stage would require several technologies. Those of interest include, but are not limited to, 10-100 kilowatt-class thrusters, solar electric power generation (e.g., photovoltaics, high-temperature thermionics using solar concentrators), spacecraft power management and distribution, thermal management systems, large spacecraft structures, and other vehicle subsystems. Research funded under this area is expected to enhance the center's reputation as a leader in transfer stage development, to improve the center's posture to successfully compete for external funds, and to facilitate future collaborations with universities, industry, other NASA field centers, and other government agencies to develop electrically propelled transfer stages.

Long Term Behavior of Materials in the Lunar Environment

An early shuttle experiment was a Long Duration Exposure Facility (LDEF) for materials that were to be utilized for propulsion and for space vehicles. This structure was orbited into low earth orbit and remained there for approximately 5 years until retrieved by the shuttle. Each material sample was then assessed for long term behavior in low earth orbit, noting degradation and other material characteristics that had been affected by the space environment.

This proposed research will determine the best methods of conducting planetary materials science experiments leading to materials selections for long duration human spaceflight. These study results will lay the groundwork for the materials and facilities simulations that will determine the essential characteristics of materials required to provide both spacecraft and human protection for living and traveling environments incurred in interplanetary, planetary, and earth return spaceflight missions. This research will thoroughly investigate existing experience bases and will extensively research and review materials databases to be used as points of departure. From this point the research will recommend simulations and experiments necessary to provide the data for the manufacturing of components and clothing materials for safe travel and a safe human presence on the Lunar and Mars surfaces.

MTRAP (Magnetic Transition Region Probe) Instrument Definition

Past and present studies have focused on the design of the optical telescope and its accommodation within the fairing of a Delta IV launch vehicle. The next step is to identify a set of science instruments that will match MTRAP's performance and can meet the mass, power and volume constraints of the ISAL* study. Before this study can begin it is necessary to demonstrate that the assumption that tuneable Michelson Interferometers with suitable prefilters can meet the field of view requirements across the full range of wavelengths propose for MTRAP and that a "slitless" variable line spaced grating can be combined with a suitable prefilter to provide a large field of view CIV vector magnetograph. The proposed one year study would include both analytical and experimental studies of these components followed by an accommodation study that would establish a baseline instrument complement. This would prepare us for a return visit to the ISAL to complete the science studies in preparation for the next step to evaluate the complete mission at the Integrated Mission Design Center.

* ISAL Instrument Synthesis and Analysis Laboratory

Situational Awareness Technology Testbed for Extraterrestrial Mobility Systems (Building Block #1)

An advanced **situational awareness** capability is needed for autonomous and intelligent surface mobility systems for extended and sustained Human and Robotic presence on any extraterrestrial surface. Investment in this capability will reduce cost and risk for human exploration missions, as well as, enhance overall mission success.

This proposal advocates an investment in a situational awareness (SA) testbed, purchase of state-of-the-art SA components & sub-systems (for test), and test of Lunar surface navigation & communication capability to coordinate Lunar Rover(s)/Lander interaction. Ground simulations/demonstrations of multiple SA configurations will be conducted to optimize mobility platform designs of surface mobility and Lunar ground support systems. Specific MSFC sub-systems such as Advanced Video Guidance Sensor (AVGS), HDMAX (High-Definition camera), Hyperspectral (spectrometer), the Autonomous Assembly of Modular Space Structures (AAMSS) sensor – MSFC IRAD 2004, and deployable puesdo-lite antenna masts. In addition, state-of-the-art commercially available SA components/sub-systems will be tested for functionality, compatibility and inter-operability to meet MSFC's future needs.

Marshall Space Flight Center (MSFC) is making a strategic investment to capture a Lunar Lander (mission #2) in the 2009-2011 timeframe with follow-on missions roughly 2-3 years apart. A building block approach will be used to develop capabilities in support of mission #2 and/or the follow-on mission #3 (2014). Situational awareness capability is the first "building block" required to make autonomous and mobility systems feasible. Multiple mission scenarios and hardware configurations are being studied. Lunar Lander configurations are expected to be capable of carrying a single large or multiple small "bug" robotic rovers. One configuration – the MSFC Lander carries a payload on wheels (trailer) – needs a rover/tractor to tow the payload from the Lander about the Lunar surface to a new safe location. A robust situational awareness capability will enable the rover/tractor to find, hitch, transport the payload/trailer on the Lunar surface, avoid hazards, arrive safely at a new location, un-hitch, and move-on to another task. A second configuration involves multiple robots of different sizes/types and also requires a robust situational awareness capability to operate independently, autonomously so as not to overburden mission support personnel. Although a set number of robots has not been determined for this mission, tele-operating a multitude of "bug" robots is too personnel intensive, is not economically feasible, and yields higher mission risk. Autonomous and intelligent operation/control in conjunction with the "bugs" being situationally aware not only makes this mission possible, it becomes an **excellent** technology demonstrator platform for the Lunar operations.