

2006 NASA EPSCoR Planning Grants

UNIVERSITY OF MAINE

Project title: Structural Integrity and Optimal Design of Rigidizable and Inflatable Systems for the NASA Lunar Habitat

Lead Principal Investigator: Dr. Vince Caccese, Professor, Department of Mechanical Engineering

Summary:

NASA is planning a journey to the Moon and eventually an expedition to Mars. The planned lunar visits are much more ambitious than those of Apollo and will require that astronaut undertake missions which may last up to several months. The earliest a lunar habitat may exist is by the year 2020. To meet this timeline requires that the structural integrity, functionality and reliability of the astronauts' shelter be proven by 2013. This new NASA vision will require tools and techniques that go beyond the current thinking regarding what constitutes a structure or even a space vehicle. The technical objective of this project is to provide some of the advanced mechanics research that will ultimately validate the integrity of key structural elements required for the realization of this vision.

At present, there are two competing architectures for the lunar habitat, one with a load bearing bladder developed by ILC Dover, and the other with load bearing Kevlar webbing by Bigelow Aerospace. These structures must be proficient at protecting the inhabitants from the high levels of radiation that exist on the Moon as well as from abnormal load events such as meteoroid strikes, extreme thermal conditions, and even moonquakes. There are details such as windows, bulkheads, hatches and interfaces that must be designed into the structure and their inclusion must not compromise the structure in any way. George Studor of the Structural Mechanics Division NASA Johnson Space Center (NASA/JSC) initiated interest in the proposed project. The PI, Dr. Caccese was previously involved in a project lead by Mr. Studor to develop a wing leading edge impact detection system (WLEIDS) for the space shuttle. The proposed effort is a direct result of the liaison developed with Mr. Studor. The WLEIDS system was successfully deployed on the post Columbia shuttle missions and won a NASA award for excellence.

Intellectual Merit - The proposed effort will focus on novel, rapidly deployable structures that can be packaged for transportation and expanded and assembled at the time of operation. These systems have the functionality of conventionally assembled structures, but are also able to undergo large geometric transformations from a small shipping configuration to a large useable structure. The focal subject of this research encompasses development of verifiable techniques to assess the structural integrity of the lunar habitat as well as to develop innovative manufacturing and construction methods, along with advanced mechanical and structural systems engineering. While these structures were considered in the past for lunar basing

options the current focus on manned exploration envisioned by NASA makes them critical to the next generation of space exploration. One of the first research phases of the effort to prove structural integrity will be to build an inflatable pressure vessel and fail it. This structural response data can subsequently be used to validate the analysis methodologies developed by this research team.

Research Team and Collaboration with NASA - The primary research objective of this planning grant proposal is to assemble a team, with cogent capacities, that can develop the knowledge required to successfully validate specific aspects of the structural integrity of the lunar habitat. This team will consist of researchers and teachers in academia at the K-12 through college level, NASA personnel and industry leaders in space exploration. This work is a follow on to some of Dr. Caccese's previous efforts on structural integrity of aerospace vehicles, which was funded under prior MSGC seed grants. This work will also leverage some of the current University of Maine research on inflatable structures, which has allowed the PIs to develop significant expertise in this field. The unique challenge afforded by space deployment and designs for these systems presents an additional level of challenge and opportunity for UMaine, the State of Maine and NASA. The PI, Professor Caccese is an expert in structural engineering with a focus on structural dynamics and vibrations and has extensive experience in the design and analysis of aerospace and naval structures using composites and other advanced materials. In addition to teaching at the university, Dr. Caccese has been teaching a five-period/week 11th grade science class, which provides the PI a valuable insight into how to reach out to high school and middle school students. The Co-PI's include Dr. Davids, who works in the area of code based design and computational mechanics of inflatable and membrane type structures, Dr. Vel, who has worked extensively in design optimization and is an expert in mechanical system design and theoretical mechanics and Dr. Peterson, who has worked on the measurement of constitutive properties of polymeric and elastomeric materials and woven structures. Also included in this research team is a recent UMaine Ph.D. graduate, Dr. Kabche, who has experience working in the area of computational modeling of inflatable structures. Dr. Kabche is included in this planning phase to provide a timely and smooth transition of the knowledge he has on modeling of inflatable structures to the incoming students. Student research assistants will be essential to the success of this effort. Included will be graduate students who will perform structural modeling and investigate methods required for experimental validation. There will also be several undergraduate students assisting in this research effort and interfacing with the K-12 students.

Infrastructure Development - This work will dramatically extend the capabilities of the UMaine Hybrid Structures Laboratory (HSL) into a research area that is very uncommon across the U.S. Research on inflatable structures is rarely carried out at universities and virtually never taught in class, even at the Ph.D. level. This effort will place the University of Maine and the state of Maine at the forefront in developing research knowledge, journal publications, and course material, which can be used to engineer inflatable structures. This will be a significant enhancement to our capabilities. The HSL is housed in the UMaine Advanced Manufacturing Center. Researchers there have focused on dynamic testing and analysis of conventional structures for use in such entities as ships, engines and machines. The lunar habitat structure

represents a significant departure from these current efforts and can place UMaine as one of the lead university research institutions for this high profile NASA lunar mission. As a complement to this effort, the researchers will work with ILC Dover to develop knowledge that is required to prove out lunar habitat designs. A letter of support from Mr. David Cadogan, their R&D manager is included with this proposal. This liaison is a unique opportunity for the University of Maine to work with a prominent aerospace development company that will be heavily involved with future space exploration. Furthermore, the team will work with Glenn Miller of NASA/JSC who is the NASA liaison to the Bigelow Aerospace lunar habitat development team.

Broader Impact - An primary objective of this effort is in education, and the knowledge developed from this research will be integrated into K-12, undergraduate and post-graduate education. We will work with teachers involved in K-12 education and persons with experience in developing space based lessons for children, such as Ms. Sharon Eggleston of Lockheed Martin Technology Services, who has agreed to work with us on this effort. A major task in the mission to the Moon, Mars and beyond must be the education of our young children. This mission is long term and the children are our future. To accomplish a mission to Mars we must put away short term thinking of what we might and might not see in our own lifetimes. We must leave our future engineers, scientists and astronauts a legacy that will allow them to achieve this goal and more. For success, we must instill the knowledge into their minds and the desire into their hearts, right now. That is why significant efforts will be put forth by the PIs and the student assistants to reach out to K-12 students and their teachers in an effective manner. It is important to understand the new generation's attitude toward NASA and science in general. If we can instill excitement in them about exploration, hope in them about their future possibilities, and provide good science and engineering career choices for them, we will succeed.