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1990-91 PROJECT SUMMARIES

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INTRODUCTION

The Mechanical Engineering Department at The University of Texas at Austin participated in the NASA/USRA University Advanced Design Program on both an undergraduate and a graduate level during the 1990-91 academic year. The focus of study was on four design projects that fall into one of the following areas: (1) the establishment of a lunar base and (2) mission planet Earth. The design projects were incorporated into already existing design courses and students worked together in groups of three to five. A background of each area of study is provided, along with synopses, conclusions, and recommendations for further study for each design project.

LUNAR BASE PROJECTS

Background

NASA has a long-range goal of constructing a fully equipped, manned lunar outpost on the nearside of the Moon by the year 2015. The proposed outpost includes landing pads, an oxygen pilot plant, oxygen storage tanks, and an inflatable habitat. The lunar outpost mission consists of three phases: emplacement, consolidation, and utilization. The emplacement phase, to be completed by the year 2003, places a habitat with one-year life support capabilities on the Moon. Along with the initial habitat, the emplacement phase delivers laboratories, airlocks, and any required support systems. An expanded habitat, constructed during the consolidation phase, is scheduled to be completed by the year 2010. The expanded habitat contains crew quarters, science laboratories, medical facilities, and other facilities necessary for missions of long duration. The final phase, utilization, is the phase in which crew members conduct experiments on the Moon.

One of the primary design concerns during background research was the effect of the harsh lunar environment on humans and structures. NASA has been studying the Moon's environment for many years. During their studies, they found that radiation and extreme temperatures in the zero-atmosphere lunar environment pose a serious threat to human life and potential damage to structural materials. Tests on lunar soil, or regolith, showed that covering habitats with the soil can provide adequate protection from radiation and thermal effects. Prior to initiation of the emplacement phase, work crews and/or robots will excavate the lunar surface to provide a site for the initial habitat. This excavation process can provide some of the regolith necessary to cover the habitat.

Construction of the expanded habitat will begin at the conclusion of the emplacement phase. The expanded habitat houses larger crews for longer-duration missions than the habitat of the emplacement phase. NASA considered several alternate structures for the habitat during their initial studies. Structures considered include Space Station *Freedom*-derived modules, heavy lift launch vehicle diameter modules, prefabricated large-diameter cylinders, and inflatables. Inflatable structures consist of an outer shell, which acts as a pressure boundary, and internal structures, which provide support for floors and walls. Because of their low weight-to-volume-ratio, inflatable structures are especially useful in space applications. In addition to being lightweight, inflatable structures offer the advantage of being deflatable. Existing vehicles, such as the space shuttle, can transport the compact deflated structure into Earth orbit and a transport vehicle can transfer the structure to a lunar orbit and emplace the structure on the lunar surface. Due to weight, space, and fuel considerations, an inflatable structure can be transported at a lower cost than a prefabricated structure. For these reasons, NASA chose inflatable structures as the most feasible solution for conceptual design.

The construction of an outpost on the Moon presents many challenging and unique problems. The excavation and transportation of lunar regolith for this construction will require highly specialized equipment. This equipment must perform efficiently in the abrasive lunar environment at extreme temperatures, under intense radiation, and in a near-perfect vacuum. The highly abrasive lunar dust poses a constant threat to this equipment and other surfaces. Innovative solutions to these problems will be needed that minimize weight, space, power consumption, human exposure, and operating times. These solutions or designs should be adaptable to other tasks as well as performing their primary functions. The following three sections briefly summarize two undergraduate design projects completed during the fall semester of 1990 and a graduate design project completed in the spring of 1991.

Inflatable Habitat Support Structures

This report presents a design for the internal support structures of an inflatable lunar habitat. The design solution includes material selection, substructure design, assembly plan development, and concept scale model construction. The internal support structures have been designed for an inflatable sphere that is 16 m in diameter with 5 interior levels.

After studying the proposed lunar habitat and background information, several project requirements were identified. The first project requirement was the development of substructure designs that satisfy the spatial and equipment layout concepts. Substructures include vertical supports, horizontal supports, and structural connections. During the design of the substructures, several construction materials were investigated. The next requirement was the development of an assembly plan for constructing the substructures. The assembly plan includes investigation of equipment to aid in habitat construction and investigation of assembly sequences. Site preparation, airlock design, inflatable shell design, and foundation design were not included in the project requirements.

The support structure design solution includes a cylindrical core, expandable trusses for horizontal support, a truss system for vertical support, and pins, nuts, bolts, and welds for connecting the members. The advantage of employing expandable trusses is that structures can be assembled on Earth, transported to the Moon in a compacted state, and be erected easily and efficiently on the lunar surface. Properties of 7075 T73 aluminum served as a basis for structural design. Assembly of the structures involves several stages including preassembling parts on Earth, shipping, preparation and arrival, and support structure assembly inside the inflated sphere.

Further research is recommended in several areas. Use of fiber-reinforced polymers for structural support may allow future designers to decrease the mass of the structure. Another area that deserves further consideration is the possibility of automated assembly. Also, possibilities of adapting the habitat to various geometries and environments should be considered in future designs, Finally, the building of a mock-up of the entire assembly to test assembly methods, loading conditions, and interior layout concepts is recommended.

Design of Equipment to Excavate and Transport Regolith

The report entitled "Conceptual Design of Equipment to Excavate and Transport Regolith from the Lunar Maria" presents design concepts for excavation and transportation of lunar regolith as well as characterizing the regolith and determining the power requirements for excavation. The high cost of transporting payloads to the lunar outpost from Earth can be reduced by fabricating products from material available on the lunar surface. Excavation and transportation of lunar materials for processing will require highly specialized and efficient equipment.

After studying the design concepts of the proposed lunar outpost, three important project requirements were identified. The first requirement was to characterize the material properties and elements composing lunar regolith. The next requirement was to conceptually design the equipment needed for mining operations and transportation. This equipment needed to achieve three basic functions: loosening, collecting, and transporting. Several design criteria for this equipment were specified including safety, modularity, simplicity, minimum power consumption, minimum mass and volume, and reliability. The final requirement was to calculate the power requirements for excavation and transporting the lunar regolith to a processing site.

A modular Main Drive Unit (MDU) has been designed to provide mobility for loosening, collection, and transport function modules. The MDU is powered by fuel cells and travels on hemispherical wheels. It serves as the source of mobility and electrical power for its modular attachments. The MDU is designed to operate by telecontrol from the lunar base.

A scarifier has been designed to loosen, a bucket conveyor to collect, and a haul-dump unit to transport the lunar regolith. The scarifier and bucket conveyor are connected to one MDU and a regolith bin used for hauling and dumping is attached to another MDU. The scarifier has a variable depth of cut and organizes the regolith into a row to make collection easier. The bucket conveyor is powered by a motor that receives electrical energy from the MDU. During operation, a haul-dump unit closely follows the scarifier/conveyor assembly and is loaded continuously. Several haul-dump units can be employed to increase efficiency of the system. The power required to operate each MDU to operate is calculated to approximately 35 kW.

Further research is recommended in five areas. More information is needed about lunar soil mechanics, particularly those properties that vary with depth. The fine portion of regolith is most valuable, so adding a benefication process to the excavation process will prevent the collection of large pieces of regolith. Large rocks can interrupt the operation of equipment and a method for handling the rocks needs to be devised. More research needs to be done on the automation of equipment on the Moon. Finally, a regolith bagging system should be developed that can be attached to the excavation and transportation equipment.

Design of Equipment for Lunar Dust Removal

The objective of this project was to design a system or a device that will effectively remove lunar dust from material surfaces in a zero-atmosphere, one-sixth gravity environment. The scope of the project was restricted to the design of a device capable of removing the dust from delicate optical surfaces such as camera lenses and mirrors. A design capable of successfully removing lunar dust from optical surfaces may be extended to cleaning other devices where surface finish is not of great importance.

After studying the characteristics of lunar dust and the problems associated with dust contamination, several project requirements were identified. The use of various energy domains for removing dust in a one-sixth gravity, zero-atmosphere environment had to be characterized. A device or system capable of removing lunar dust from optical surfaces without degrading the surface finish was to be designed. The last requirement was to propose methods of preventing lunar dust from accumulating on finished surfaces.

Several possible design concepts including electrostatics, fluids, and mechanical cleaning devices were explored. Electrostatics appear to be feasible yet are not practical due to the large amount of power required, large system mass, and possible safety problems. Mechanical cleaning alternatives are inadequate due to the probable damage to the optical surface, but are energy-efficient and could be effective on surfaces where surface finish is not of great importance. A design concept employing a compressed gas was chosen for detailed investigation due to its apparent feasibility for portability and dust removal without damage to optical surfaces.

The dust removal concept developed consists of a small astronaut/robotic-compatible device that removes dust from contaminated surfaces with a small burst of gas. The design is composed of two major parts: a handle with gas exit nozzles and a removable pressurized gas storage tank. Either carbon dioxide or nitrogen can be used as the cleaning medium. Gas is released through three 6-mm-diameter focused nozzles by actuating a trigger on the handle. The three-nozzle design delivers 0.3 N of thrust with a mass flow rate of 48 g/min. A possible secondary application of this device is that it may be adapted for use as a fire extinguisher.

Upon completion of the design, several conclusions and recommendations for further study were made. This design employs circular nozzles, but the use of slit orifices should be researched in the rarified gas regime as a slit may produce a more useful thrust area. Also, these nozzles were designed with the constraint of not allowing the expelled gas to condense. This condensation could possibly be used beneficially to carry dust off surfaces without damaging them. And finally, the process of removing dust is time consuming and expensive, so methods of preventing dust contamination should be employed where possible.

MISSION PLANET EARTH

Background

"Mission Planet Earth" seeks to use space and aeronautics technology for the sole purpose of improving the Earth. These issues include ozone deterioration, ecological improvements, weather studies, ocean studies, and the prevention of harmful effects produced from previous and future space missions. The project discussed in this section concerns the latter of these issues, the deorbiting of space debris in Earth orbit.

It has been common practice to abandon used space vehicles and equipment and leave them in Earth orbit even though they can remain there for many years. Of the approximately 7000 objects currently tracked by NORAD only about 5% are operating vehicles. These objects consist of abandoned satellites, discarded upper rocket stages, other debris, and debris resulting from collisions between these objects. These inevitable collisions result in self-propagation of the debris over time even if the addition of new debris is halted entirely.

Two major problems result from space debris. A collision with debris can cause serious if not fatal damage to a functioning spacecraft. This results in considerable expense in designing for survivability. The second problem concerns mission planning. The launch of any vehicle becomes complicated as paths must be planned away from the known trajectories of all objects being tracked. The danger of collisions increases as new debris masses are added to an already self-propagating problem.

Design of an Unmanned, Reusable Vehicle to Deorbit Debris

An unmanned, reusable Deorbiting Vehicle (DOV) has been designed that uses the NASA Orbital Maneuvering Vehicle (OMV) command/propulsion modules and a Chain-And-Bar-Shot (CABS) module to deorbit space debris. This design is based on maximum reusability and component modularity. As a matter of fact, debris deorbiting with the attachment of a specialized module was considered in the original specifications of the OMV.

The CABS module contains projectiles that are designed to impart enough kinetic energy to deorbit a debris mass on the order of 2000 kg. Each projectile consists of a set of perimeter rods that are connected to a central core by aramid cords. The projectile is fired at high velocities from a rail-gun barrel that imparts a spin on the projectile, centrifugally spreading the rods into a whirling circle with enough area to capture debris. The rods are connected with strips of mylar to ensure uniform spacing and to increase the chances of capture. The CABS module carries six projectile packages in a revolver-type magazine that may be replenished in orbit.

The active removal procedure of the DOV will not solve the debris problem entirely. Space activity at the present rate will cause the debris problem to worsen even as a removal process is underway. The self-propagating debris will continue a geometric growth as well. A debris prevention plan is necessary and conventions should be established to protect the orbital environment from future damage.