CONCEPTUAL SECOND-GENERATION LUNAR EQUIPMENT

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N91-18129

INTRODUCTION

The spring 1990 *Introduction to Design* class was asked to conceptually design second-generation lunar vehicles and equipment as a semester design project.

The basic assumption made in designing second-generation lunar vehicles and equipment was that a network of permanent lunar bases already existed. The designs were to facilitate the transportation of personnel and materials. The eight topics to choose from included flying vehicles, ground-based vehicles, robotic arms, and life support systems. Two teams of two or three members competed on each topic and results were exhibited at a formal presentation.

A CLEAN-PROPELLANT-POWERED LUNAR FLYING TRANSPORT

The existence of lunar bases at different points of interest across the lunar surface would call for transportation means much more demanding than the original simple lunar rovers. A flying craft capable of traveling point-to-point distances in the range of 50-500 km is developed in order to shorten mission time and overcome inhospitable terrain. This report concerns the conceptual development of a cleanly fueled lunar flying vehicle to meet the second-generation requirements of material and personnel transportation between lunar bases. The possibility of exploration of remote areas by the same craft is also pursued. Three basic modes of operation are performed by modifications made at the lunar bases. The final design was named the Multi-Purpose Flying Vehicle (MPFV).

Modes of Operation

A lunar flying vehicle should be designed to be as versatile as possible, and to perform a number of functions by means of modifications performed at lunar bases. The lower unit of the MPFV resembles a lunar lander design and remains the same for all modes. This unit contains the control, fuel, and propulsion systems for vehicle operation in all modes. The top sections are different for each of the modes. Through these modifications, the design should perform three basic functions: (1) the transportation of materials from a main base or depot to other bases or construction sites; (2) the transportation of personnel from base to base; and (3) the exploration of specific points on the lunar surface.

Propulsion Systems

The requirement of clean propellants effectively limited the choice of fuels and oxidizers to one combination. With the exception of cold jets and electrical propulsion, the hydrogen-oxygen reaction is one of the cleanest forms of combustion known. Fortunately, the hydrogen-oxygen rocket engine also has one of the highest specific impulses known. The MPFV uses a centrally mounted LH_2-LOX rocket for main thrust and oxygen cold jet rockets for stabilization during ballistic flight.

Conclusion

The MPFV represents a second-generation conceptual design for a multipurpose flying transport to operate on the Moon during the years 2010-2030. The MPFV can be operated in three basic modes with conversions made at appropriately equipped bases. Cryogenically stored hydrogen and oxygen are used as fuel to reduce the emission of toxic materials. Transportation from point to point is accomplished through the use of ballistic flight techniques consisting of short bursts of power followed by long periods of free parabolic flight.

EVA LIFE SUPPORT SYSTEM

The goal of the second-generation EVA suit is to increase operating time, safety, and efficiency without sacrificing the flexibility and geometrical character of the current Extra Mobility Unit (EMU). The basic design addressed to meet this goal has three distinct parts: (1) the redesign of the current EMU life support system; (2) the adaptation of an EMU oxygen rebreather and cooling system permanently affixed to a lunar vehicle; and (3) the interfacing of the two above systems to work in concert.

The new extended life support system will allow the crew member maximum flexibility and safety while performing extravehicular activities. The advantages of the suit for typical missions great distances from the lunar base are (1) the crew members do not expend the EMU's consumables while riding in the lunar vehicle to and from a destination and (2) the possibility of a system failure resulting in a fatality is greatly decreased.

The new EMU design is basically a technological update of the current design's computer, oxygen delivery, and cooling systems. New features include the use of cryogenically stored oxygen, the ability to operate from an external life support system (LSS), liquid refreshment, and waste management.

System Redundancy

The safety of the crew member using the EVA suit is the primary concern of the life support system. A failure of one of the suit systems should not result in a life threatening situation. The linear architecture of the current EVA suit presents many such cases, even with the use of in-line redundancy. The new EMU design will correct this deficiency by using a doubly redundant bilinear cross connect (BLCC) architecture developed for cave diving. Though this system is more complex, the use of improved technology and materials should allow the overall geometry of the existing system to remain the same. The improved system can be shown to be 14 times less likely to have a failure that would cause a fatality.

Conclusion

The redesigned EMU suit incorporates double redundancy in both separate systems and computer controllers. Three onboard computers can be used with a "majority rules" decision making process for diagnostic decisions during suit operation. A full manual operation mode can also be used if all control systems fail completely. The suit increases distance traveled and reduces the chance of failures resulting in fatalities.

PRESSURIZED LUNAR ROVER FOR GREATER DISTANCES

The goal of this project was to design a ground-based vehicle that will travel for longer distances than a 37.5-km radius from a lunar surface base. The existing design is limited to a 37.5-km radius due to the limitations of current EVA suits. Designing the pressurized vehicle would eliminate these restrictions and would allow for much more comfortable operation in the vehicle. The manned vehicle would operate on a three-day mission, traveling within a radius of 150 km at a speed of 10-15 km/hr, with a four-member crew. The primary function would be of an exploratory nature, involving experiments, photography, and computer analysis. Primary design considerations were structural, power, and control components.

Structural Design

The vehicle consists of a pressurized cabin that contains the life support for the crew members. It accommodates up to four crew members for an average mission time of three days. The windows are similar to those used on the space shuttle in that they consist of three separate structural members. A transparent film covers the outside glass and is periodically rolled over it in order to clear dust-impaired vision, with the rolls of plastic to be cleaned at the lunar bases.

Power System

The power source used in the design is the Isotope Brayton Cycle, which transfers thermal energy into shaft work by turbines. The closed loop Brayton power cycle consists of four separate loop systems involving argon gas, sodium-potassium, freon, and propylene glycol. The isotope fuel may be either Pu^{238}, Po^{210}, or Cm^{244}. These isotopes can be packaged into convenient fuel modules that can be shielded to prevent crew exposure to radiation and configured to eliminate the possibility of combining into a critical mass. The power load is maintained at as constant a level possible by the use of battery arrays to even the load. The power system is transported in a separate trailer behind the main vehicle in order to reduce the dangers presented to crew members by this energy source.

Conclusion

The first goal of the second-generation pressurized lunar rover will be to establish itself on lunar bases and to develop a database on the lunar surface such that the accuracy of the topographic mapping can be confirmed for future development of unmanned missions. Based on present studies, the lunar vehicle will be feasible, but further development and research is needed to verify assumptions.

ROBOTIC ARM DESIGN PROJECT

This project represents a group effort to explore the possibility of deploying a robotic arm on the Moon. The arm was originally conceived as a specimen-gathering device to be fitted on a lunar vehicle, but it has been revised to satisfy a wider range of tasks. The design of the Extendable Robotic Collection System (ERCOS) incorporates key issues of compactness, versatility, reliability, accuracy, and weight. The arm can be used on both lunar vehicles and at lunar bases for a variety of functions.

Arm Structure

The robotic arm is composed of 9 links and attains 6 degrees of freedom. It combines the concepts of both revolute and cylindrical robots. A telescoping tower assembly is used for the majority of the arm's movement with revolute and cylindrical joints at the extremity for detailed motion. The telescoping assembly has the ability to collapse into a compact sealed structure when the arm is not in use. The material used throughout the arm is aluminum 2014-T6. With the material and structure known, computer modeling was then used for stress and deflection measurements.

Environmental Considerations

The environmental condition that would have the greatest effect on the ERCOS system would be the variation of temperatures causing expansions and contractions. This problem is overcome by placing thermal sensors at even increments along the links and using their output in the controller program to actively compensate to assure positional certainty.

Conclusion

The ERCOS system is a direct descendant of the robotic arm on the Viking lander used on the surface of Mars. The primary mission of the ERCOS design is similar in the respect of soil gathering operations, but it can provide a wide range of services to both stationary and mobile platforms. Different end effectors can be used with the basic robotic arm to provide the different functions as needed.