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LUNAR LANDER GROUND SUPPORT SYSTEM

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PROJECT BACKGROUND DESCRIPTION

This year's project, like the previous Aerospace Group's project, involves a lunar transportation system. The basic timeline will be the years 2010-2030 and will be referred to as a second-generation system, as lunar bases would be present. The project design completed this year is referred to as the Lunar Lander Ground Support System (LLGSS). Not many projects have been attempted in this area because they involve the design of a system that is not nearly as glamorous as it is necessary.

Present plans for lunar colonization call for a phased return of personnel and materials to the Moon's surface (1). During the first phase, a base will be set up with power supplies, basic supplies, and various necessary equipment. The first base personnel would land at the base(s) and stay for a period of roughly 30 days and return to Earth. Shortly after that, a second group would land at the base(s) and stay for periods of 60 to 180 days and perform long term experiments to prepare for further explorations in the future. At these times, the lunar lander will be stationary in a very hostile environment and will have to be ready for use in a contingency plan in case of an emergency. Cargo and personnel will have to be removed from the lander and transported to a safe environment at the lunar base. This project addresses these systems and the problems encountered.

The interaction of the following three types of vehicles will have to be analyzed: a reusable lunar lander; a servicing vehicle; and a transportation vehicle.

The basic operational scenario is as follows: A lunar lander descends from a transportation node in low lunar orbit (LLO) to the surface and lands at a prepared area close to the base. The transportation node will be a stopover point for the lander delivering vehicle traveling from Earth to the Moon. A transportation vehicle will then bring out a servicing vehicle to be attached through umbilicals to the lander. The cargo or personnel would be removed and transported from the landing pad to the lunar base. Some of the transferral operations will be performed through the use of remotely operated cranes or robots, referred to as teleoperations. Once the personnel or cargo items have returned to the base, a "servicer" vehicle will keep the lander in a state of readiness.

The lander will be of a similar design to lunar landers of the Apollo era. It has been stated that a reusable lander that burns liquid hydrogen and liquid oxygen would be necessary for such missions. The lander will be able to perform standard docking functions with an orbital lunar node.

The servicer will provide several servicing functions to the lander, including: (1) reliquifying hydrogen and oxygen boil-off, (2) supplying power, and (3) removing or adding heat as necessary. It has been observed that a drive system would be unnecessary for a "vehicle" that would be immobile most of the time.

The transport vehicle will be made to operate manually or through the use of teleoperations and robotics. It will serve the dual purpose of carrying the servicer out to the landing pad and transporting cargo or personnel back to the base. The basic configuration will be similar to that of a lunar roving-type vehicle.

A great deal of practical engineering was applied to the various systems and interactions of the project. Several NASA and contractor personnel showed interest in particular areas of our proposed project. None of the personnel contacted had seen a detailed design and analysis of a project involving many systems interacting between three vehicles such as ours. Specific areas of interest of industry personnel included (1) vehicle interactions, (2) vehicle interfaces and associated procedures, (3) heat rejection while on surface, (4) fuel storage and reliquification procedures, (5) radiation protection, and (6) dust problems in all systems. Practical knowledge of materials selection, heat transfer, electrical engineering, and structure design can be applied to most aspects of the project.

EMPHASIS OF DESIGN

The area chosen for analysis encompasses a great number of vehicles and personnel. The design of certain elements of the overall lunar mission are complete projects in themselves. The fundamental designs of bases, lunar landers, heavy moving vehicles, lunar nodes, and Earth-to-Moon transportation systems are extensive projects in their own right. For this reason the project chosen for the Senior Aerospace Design is the design of specific servicing vehicles and additions or modifications to existing vehicles for the area of concern involving servicing and maintenance of the lunar lander while on the surface.

The design of certain vehicles and structures not directly related to but interfacing with the servicing system was assumed. Examples of the vehicles and structures that were considered as outside design parameters that the lander servicing system depended on are as follows: lunar lander, lunar orbiting node, space transportation system, central lunar base systems, and lunar heavy moving vehicles.

The most plausible design for a lunar lander for the years 2010-2030 was found in a conceptual lunar lander report by Eagle Engineering (2). The report describes a second-generation single-stage lunar lander and the related physical parameters. The lander is a reusable vehicle powered by liquid hydrogen and liquid oxygen chemical rockets. The basic design is shown in Fig. 1. All other significant parameters are assumed as given

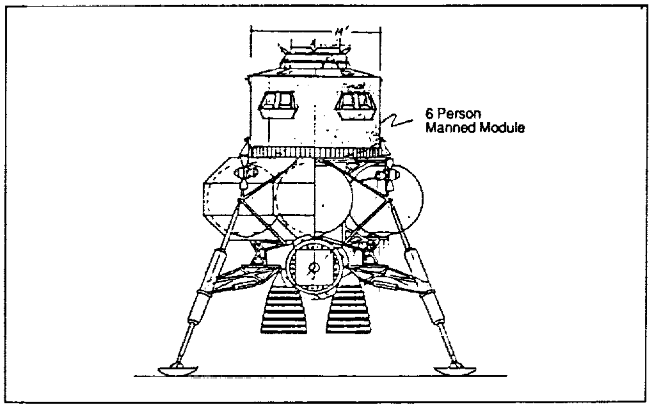

Fig. 1. Basic configuration of a lunar landing vehicle.

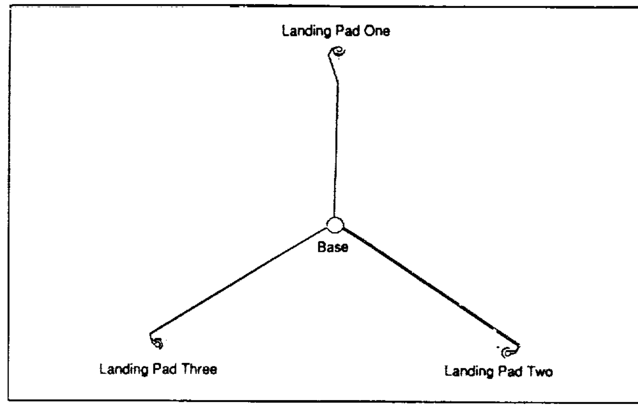

Fig. 2. Configuration of a lunar base

from this and similar reports. A large number of reports on base designs exist. The general layout varies a great deal from one report to the next, but the content and ideas are the same. The lunar bases previously designed exist across a broad spectrum, ranging from exposed rectangular structures to completely buried cylindrical structures. A typical design used for the servicing system project is one found a second Eagle report (3). The basic structure is one of a series of cylindrical pressurized structures attached together (see Fig. 2) and partially buried under regolith.

The current examples of space transportation systems (STSs), or space shuttles, were extrapolated or used without modification for design parameters to consider during the synthesis of a lunar lander servicing system. The particular STS configuration considered dictates the aspects of any lunar surface design through limitations on geometry, mass, and safety issues.

Many examples of predicted designs for second-generation lunar surface vehicles exist. The basic operations are modified for operations pertaining to lunar lander servicing. The vehicles designed in this project take advantage of existing vehicles when possible, and involve heavy modification where necessary. A primary concern in the design of any lunar system is the commonality of both components and complete vehicles when necessary.

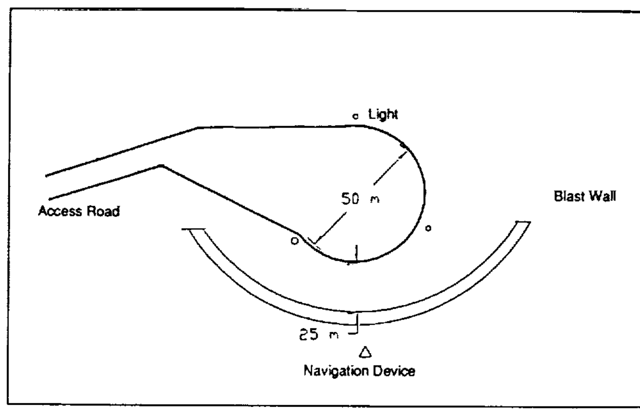

Fig. 3. Lunar base landing site layout.

Design Project Components

The Senior Aerospace Design Group project concentrates on the specific design of the servicing vehicle, various transport options for travel from the lunar base to the lunar lander, and the landing sites. The following vehicle and component designs are discussed in this report: servicer, heavy mover (tractor), large cargo/servicer trailer (including teleoperated crane), small servicer trailer, interface connections, and various modifications to existing equipment.

Landing sites. The landing sites are designated to be at a distance of 1000 m from the main central base structures, a restriction based on the blast damage caused by descending lunar landers (4). The lunar base has three separate landing pads that can have operations going on in any order. The landing sites are triangular, with the main base structures in the center (see Fig. 3). Graded regolith walls protect the lunar base and other landing pads from debris ejected upon landing. Graded travelways also connect the landing sites with the central base. A system of both electronic and visual landing aids would be present for aid in navigation to landing sites out of orbit.

Servicer. The servicer (see Fig. 4) is a stationary support vehicle placed next to the lunar lander while on the surface to provide basic functions of hydrogen reliquification, power supply, status communication, daytime cooling, and nighttime heating. The structure is a frame enclosing fuel cells, electronics, and spherical tanks. The exterior is covered with a rigid stand-off shield/thermal tile protection system. The upper surface consists of a fluid loop radiator for heat rejection of both fuel cell waste heat and waste heat from the lander during the day. Strip antennas are used for all communication with the base.

The loss of hydrogen fuel through boiloff due to heat conduction is generally not a large concern for short surface stay times. The boiloff becomes a real concern when the stay times are extended to 180 days, as is expected for third-phase lunar inhabitation. Simple calculations indicate that up to 50% of a lunar lander's liquid hydrogen can be lost to boiloff during

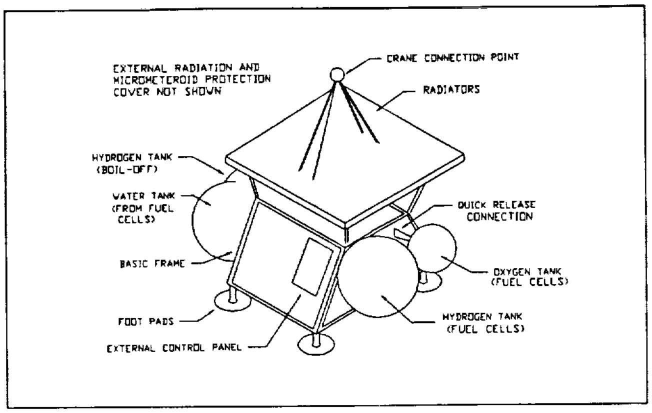

Fig. 4. Servicing vehicle for lunar lander.

a 180-day stay (2). This necessitates a system for storing H_2 boiloff and reliquifing it to pump back into the lander's tanks. The basic idea is to store the gaseous hydrogen that boils off during the hot lunar day in a large tank on the servicer. At nightfall the temperature drops to near absolute zero, allowing an extremely efficient helium cycle to be used to reliquify the hydrogen. The reliquified hydrogen would then be pumped back into the lander's tanks. Oxygen production is assumed during this time, making oxygen boiloff irrelevant, due to the availability of O_2 on the surface (5). Oxygen is also less susceptible to boil-off than hydrogen, due to its higher boiling point and lower heat conduction coefficient.

The power system for the lander would be designed for relatively short flight times, typically on the order of one hour. The additional system weight would be unwarranted for the 180-day stay times on the lunar surface. The servicer provides the additional power while the lander is on the surface, allowing the lander's power supply to be reserved for flight time only. The electronics and cooling system components would need power during the 180-day stay, along with controls testing to avoid seizing of components. The servicer fuel cell power supply would support the lander during the surface stay.

Communications would be provided through the servicer to the base concerning the status of both the servicer and the lander. This data would include all electrical and thermal aspects of both vehicles.

The additional daytime lander heat input from reflection from the lunar surface would require active heat rejection from the lander. The servicer would provide relief from this additional lander heat load by removing it through fluid loops to the servicer.

During the 14-day lunar night, the heat problem is completely reversed. The electronics and fluid loops of the lander must be kept in a state of readiness through heat input, otherwise the lander would cool down to the temperature of the lunar night. The electronics and fluid loops have to be kept warm in order to function at all, much less properly. The heat input from the servicer to the lander is through both electrical and fluid means.

A stand-off shield is necessary because of the increased probability of a meteorite impact during the 180-day stay time. Multilayer thermal tiles attached to the stand-off shields also provide protection from intense solar radiation on the servicer during the lunar day.

Transport options. The lander can deliver either cargo or personnel. When in cargo mode, the lander is assumed to be unmanned and is remotely piloted or computer guided. When in personnel delivery mode, the lander is expected to be piloted by a crew member. Each of these cases dictates different transport techniques upon landing. The simplified net result is that the lander is brought out to the landing site and cargo or personnel are retrieved to the base. Potentially confusing detailed descriptions of postlanding activities are described through diagrams and description in the following section. Alternative operations for some of the vehicles incorporated are also mentioned.

LANDING SCENARIO

The scope of the Senior Aerospace Group design project can be demonstrated best through "cartoons" demonstrating the course of activities that are to take place at a lunar base after a lander descent. As mentioned above, there are two distinct scenarios for a lunar landing: cargo or personnel. Much of the equipment used in one case may be used in the other, with an emphasis on commonality and duality when possible.

Figure 5 depicts the course of operations at the base after an unmanned cargo lander has descended. Step 1 shows the prime mover vehicle towing the large cargo/servicer trailer out to the landing pad where the cargo lunar lander waits. The servicer can be seen on the trailer along with the cargo-moving teleoperated crane. Step 2 shows the servicer having been removed and the crane readying the removal of the cargo atop the lander. In Step 3, the cargo has been placed on the trailer

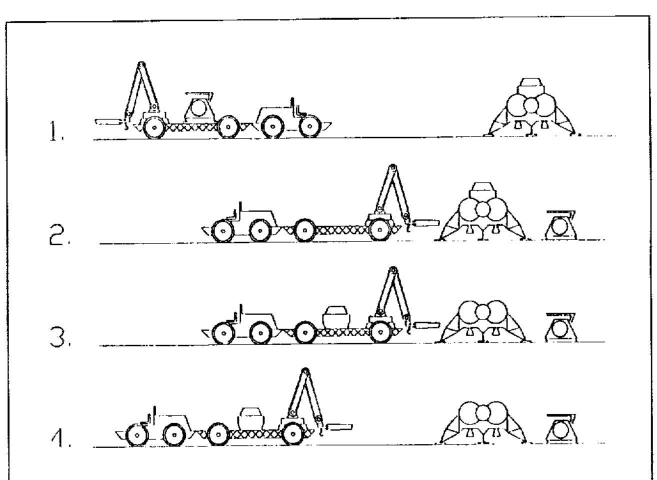

Fig. 5. Cargo mode post landing operations.

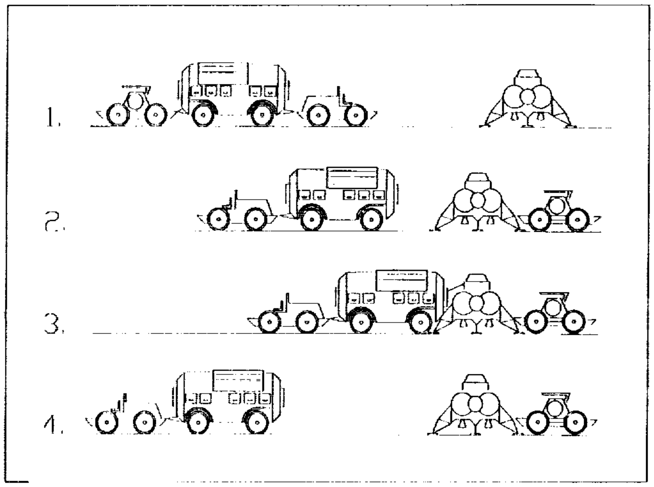

Fig. 6. Crew mode post landing operations.

by the teleoperated crane. Step 4 shows the prime mover vehicle towing the trailer with cargo back to the lunar base. It is possible that several trips may have to be made, depending on the size and weight of the cargo.

Figure 6 depicts operations after a human-piloted personnel lander has descended. Step 1 shows the prime mover towing a pressurized crew trailer out to the lander. The servicer can be seen atop a small trailer attached to the rear of the crew trailer. The trailer with the servicer is detached next to the lander, as shown in Step 2. Step 3 shows the crew trailer being attached to the crew hatch of the lander with personnel being evacuated. Step 4 shows the prime mover traveling back to the base. The crew trailer used in the personnel landing scenario is part of a pressurized long-distance exploration vehicle that would be present during a third-phase lunar inhabitation.

The crew trailer used in the personnel landing scenario would have its own drive system and steering, but would be controlled by the heavy mover via the power cart while on an exploration. Modifications or attachments would have to be made to the hatch on the rear of the crew trailer in order to attach directly to the lander. The crew trailer would already have been designed to mate with the base hatch system. This demonstrates a use of existing lunar equipment in the servicing project when possible.

In both landing scenarios, a crew in EVA suits will return to the landing site to finish connecting the servicer to the lander and to begin operations. A single or double EVA crew would return periodically to the site to perform maintenance activities and basic physical checks.

In both cases, the prime mover is piloted by a single EVA person. The existence of a teleoperated crane and EVA person on the same mission allows for parallel processing techniques to be used. While at the base, the crane is operated through IVA activities while the EVA person performs other activities.

There are several alternative operations for the prime mover vehicle used in the servicing activities. These include lunar soil mining and moving for oxygen production plants, base site construction, landing site construction and maintenance, and roadway grading. The large servicer/cargo trailer could also be used in some of these activities.

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