LOW-COST UNMANNED LUNAR LANDER

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Abstract

Two student groups designed unmanned landers to deliver 200 kilogram payloads to the lunar surface. Payloads could include astronomical telescopes, small lunar rovers, and experiments related to future human exploration. Requirements include the use of existing hardware where possible, use of a medium-class launch vehicle, an unobstructed view of the sky for the payload, and access to the lunar surface for the payload. The projects were modeled after Artemis, a project that the NASA Office of Exploration is pursuing with a planned first launch in 1996.

The Lunar Scout design (see Figures 1 and 2) uses a Delta II launch vehicle with a Star 48 motor for insertion into the trans-lunar trajectory. During the transfer, the solar panels will be folded inward and the spacecraft will be powered by rechargeable nickel-cadmium batteries. The lander will use a combination of a solid rocket motor and hydrazine thrusters for the descent to the lunar surface. The solar arrays will be deployed after landing. The lander will provide power for operations to the payload during the lunar day; batteries will provide "stay-alive" power during the lunar night. A horn antenna on the lander will provide communications between the payload and the Earth.

Introduction

Project Artemis is NASA's program to put a lander on the lunar surface in 1996. The lander will carry payloads such as a lunar telescope, a possible robotic lunar rover or various other experiments. These payloads will be used ultimately to determine the feasibility of developing a lunar outpost for future manned missions and to demonstrate mining equipment to process hydrogen, nitrogen, and helium from the moon's soil. Thus, the lander project is named Lunar Scout since it will go up and survey the lunar surface to provide information as to the possibility of future lunar missions.

Requirements

The requirements for Lunar Scout are as follows:

- Use off-the-shelf hardware for economy.
- Provide a two-year spacecraft lifetime.
- Allow for systems shutdown during lunar night except for equipment to provide heat to critical components.
- Launch in 1996.
- Make a soft landing on the lunar surface between +/- 60 degrees latitude.
- Deliver 200 kg payload to lunar surface.
- Provide 10 Watts power during two-week lunar night to heat the spacecraft.
- Use Delta II launch vehicle.

Orbital Dynamics and Propulsion

A two-body problem with the Earth and moon was used to do a patch conic transfer. A Delta II launch vehicle carries the 3775 kg spacecraft to a 1366.7 km circular orbit where a Star 48A lunar insertion motor kicks the Scout into the elliptical transfer orbit which passes through the center of the moon. The three-dimensional view of the problem shows the launch point at Cape Canaveral at 28.5 degrees North latitude. The launch is slated for 1996 when the moon's orbital plane will also be at its maximum inclination of 28.5 degrees which will provide for a minimum energy transfer. At the patch point at an altitude of approximately 66,300 km above the lunar surface, the lander enters the moon's sphere of influence. At an altitude of 200 km the retrograde liquid rocket will fire for 135 sec to reduce the velocity to zero. The remaining 30 km to the lunar surface will be computer-controlled using the radar altimeter and thrusters. Table 1 shows the breakdown of the mass budget.

Table 1 Mass Budget

Component	Mass (kg)
Payload	200.0
Structure	45.0
Electronics	25.0
Communications	18.84
Batteries	8.18
Solar array	33.0
Attitude control sensors	20.06
Solid rocket motor	2547.32
Propellant	675.36
Propulsion support hardware	108.74
Main engine	51.2
Attitude control thrusters	32.24
Total	3775.0

There is a total mass of 3775 kg at takeoff; mass upon touchdown is approximately 530 kg. Attitude control sensors consist of a wide angle sun sensor and a star tracer. There are sixteen 2-Newton thrusters arranged in four four-engine clusters to provide for the variation of the center of mass due to the burning of the liquid propellant. There are also four 4.5-Newton vertical thrusters located around the lander body.

Structure

The structure will be made of 1.25-in diameter 6061-T6 aluminum tubing with a 0.125-in wall thickness. The propulsion subsystem consists of bipropellant tanks and a thrust nozzle located at the bottom of the lander. The three lander legs will be stowed folded up in the payload fairing and will be springloaded to lock into place when the fairing splits away. The 0.30-m diameter landing pads will be made of aluminum flex-core to absorb the impact upon lunar touchdown. Upon landing, the spacecraft will deploy six 1.1-m^2 solar panels to provide power. The panels will rotate down to a 45 degree angle and be supported by the edges of the lander legs. The lander is equipped with a payload adaptor ring of 1.3-m diameter to allow for attachment of a variety of different 200 kg payloads. The available payload envelope is a cylinder of 1.7 m diameter and 1.8 m height. The payloads, however, can be slightly taller if their diameter is small, e.g., a lunar telescope.

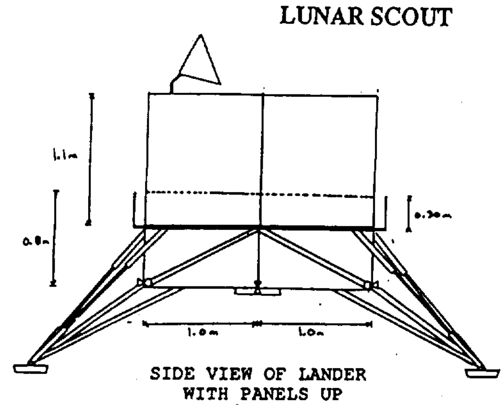

Fig. 1 Side view of Lunar Scout with panels up

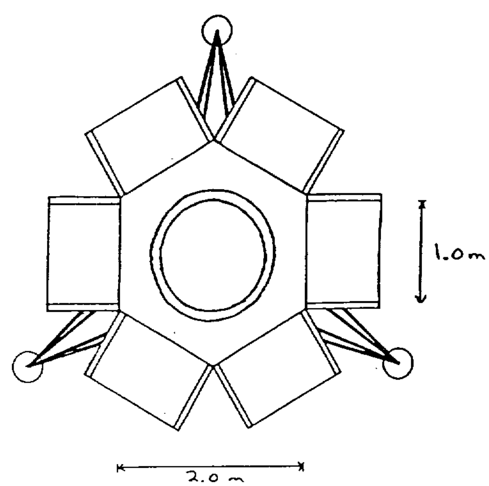

Fig. 2 Top view of Lunar Scout with solar panels folded out

Power

The goals of the power system are to provide 500 Watts via solar panels during the daytime and 10 Watts via batteries during the lunar night. Prior to launch, the batteries will be fully charged to provide power to systems intermittently during the trajectory to the moon. After landing, the solar panels will deploy and begin providing power. During the daytime, the solar panels will provide between 240 W and 750 W of power to the payload depending on the position of the sun relative to the spacecraft. The solar cells used are 4 cm by 4 cm gallium arsenide on germanium to provide for lighter weight and smaller size arrays. In the nighttime, all systems will shut down and the batteries will provide 10 W to heat the vital systems and the payload. The battery consists of 22 seven-A*hr cells and a 28 V bus. Degradation of the battery from charge and discharge was taken into account even though the battery will only undergo 28 cycles in its two-year lifetime.

Communications

Communications will be made in the S band using a 2.3 gigahertz, 0.13 m wavelength signal on the Deep Space Network. The telemetry downlink will use two 0.30 m omni-directional antennas with a bit rate of 10 BPS and 5.79 W power requirement. The data downlink will use a 19.5 W feedhorn antenna with a bit rate of 1000 BPS. The feedhorn antenna will provide for a 23 degree horizontal by 21 degree vertical bandwidth. Since the Earth stays in the same position in the lunar sky relative to the lander, the angle of the feedhorn will be set prior to launch and will only need to be rotated once upon landing to be aimed at the Earth. The ground station uplink will use a 4-m dish to communicate with the lander and will require 4.5 W of power. The small 4-m dish uplink was chosen so as not to tie up one of the larger antennas for the two-year projected lifetime of the Lunar Scout.