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B&T—LUNAR LANDERS

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INTRODUCTION

In the early twenty-first century, astronauts will return to the Moon and establish a permanent base. To achieve this goal safely and economically, B&T Engineering has designed an unmanned, reusable, self-unloading lunar lander. The lander is designed to deliver 15,000-kg payloads from an orbital transfer vehicle (OTV) in a low lunar polar orbit and at an altitude of 200 km to any location on the lunar surface.

MISSION/TRAJECTORIES

Initially the OTV transfers the lander from low earth orbit (LEO) to low lunar orbit (LLO). For maximum efficiency, the Earth-Moon transfer will be performed during the nodal alignment of LEO with the Moon's orbit. From a stable 200-km lunar polar parking orbit, the lander will wait for the orbit to align with the landing site longitude and then descend to the desired position on the Moon to deliver the payload. After the lander unloads the payload, it returns to the same polar orbit to await the arrival of another payload from an OTV. The total ΔV required for one mission is 3.594 km/s.

PAYLOAD SYSTEM

The payload is carried on the top of the lander by a trolley system. The trolley system consists of a chain-driven pallet that rides on two rails. The drive system consists of a continuous chain connected to the pallet's rear wheels and to a high-torque drive motor. The drive system is sealed to protect it from lunar dust contamination. The pallet and payload are supported in flight by detachable hardpoints. In order to unload the payload, these hardpoints are detached and the pallet travels along the rails over the side of the lander and down to the lunar surface. Then the payload is detached from the trolley and the pallet is retracted. Although the payload is left on the surface, it is protected from the effects of the ascent engines by a distance of over 9 m and a minimum of blast shielding. The unloading sequence and the side of of the lander is shown in Fig. 1.

DOCKING AND REFUELING

Docking between the lander and the OTV is accomplished automatically (Fig. 2). First, the lander soft docks with extendable columns on the OTV and then the columns are retracted, pulling the lander into a hard dock with the payload. Refueling is accomplished through fuel lines running through the support packaging of the payload. After refueling, the lander will detach with the payload from the OTV and begin the descent sequence of the mission.

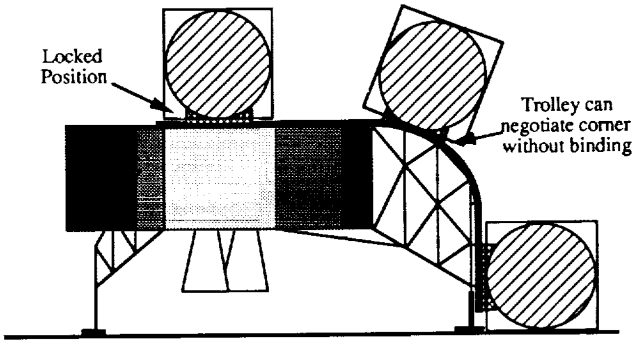

Fig. 1. The unloading sequence.

LANDER STRUCTURE

The lander is made of four modular tank/subsystem boxes that surround the central engine/subsystem box containing the main engines and avionics. These boxes have a rigid frame constructed of thin-wall box beams and honeycomb sandwich panels. These panels provide torsional stiffness as well as thermal and dust protection. In addition to being supported by the structural boxes, the tanks have internal stiffeners/baffles. The lunar lander will touch down on a four-strut asymmetrical landing gear configuration (Figs. 3 and 4). These struts will be equipped with a terrain-adaptive system to help keep the lander level on uneven terrain.

PROPULSION SUBSYSTEM

The main propulsion system consists of three H_2/O_2 engines capable of providing 30,000 lb of thrust each. Only two engines are needed to lift the lander, and each engine has a 10° gimbaling capability for thrust correction in case of engine out and to adjust for center of mass location. In order to simplify the refueling process, the Reaction Control System (RCS) also uses hydrogen and oxygen. The RCS consists of vernier thrusters

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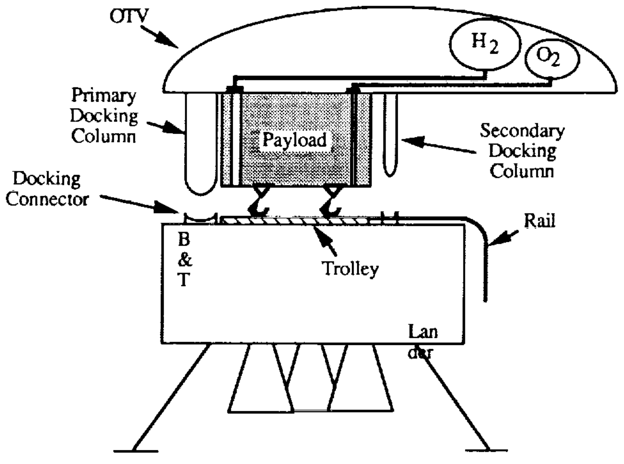

Fig. 2. Lander docking with OTV.

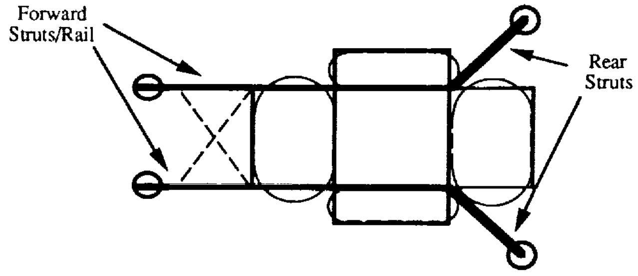

Fig. 3. The strut configuration.

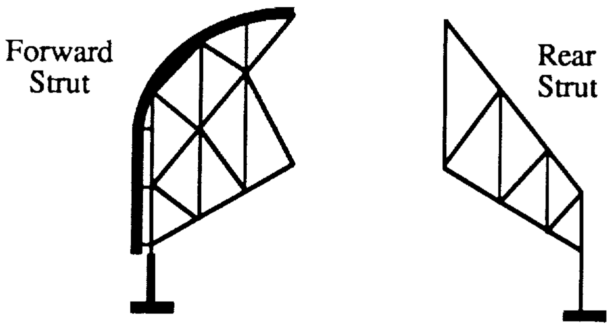

Fig. 4. The landing struts.

for low-thrust maneuvers and primary thrusters for more substantial attitude changes. The RCS motors are placed at symmetrical positions around the lander on a horizontal plane.

POWER SUBSYSTEM

The electrical power is supplied by a system of sodium-sulfide batteries for high-power and mission operations, and gallium-arsenic solar photovoltaic arrays for recharging and on-orbit power during the time spent between missions The photovoltaic arrays will be stored except when the lander is in LLO. These systems provide a peak power of 11 kW and nominal power of 0.5 kW. Peak power will be used for short durations in operations such as engine gimbaling and unloading. Nominal power is consumed by the lander systems that are in continuous operation.

GUIDANCE, NAVIGATION, AND CONTROL

The Guidance, Navigation, and Control (GN&C) subsystem will provide the lander with the ability to follow a preprogrammed mission objective. Guidance will be provided using two inertial measurement units (IMU) and two dual-cone scanners with Sun fans to periodically update the IMUs. These systems provide all orbital parameters and attitude information to the navigation system. Navigation will consist of software in the central computer and a link with the communication subsystem to allow for input command signals to change or correct the mission. In addition, a global or lunar positioning system will provide position information as the lander approaches the lunar surface. Rendezvous radar with transponders will be used for docking and refueling with the OTV as well as for the future case of landing near a lunar base. High-precision imaging radar with obstacle avoidance software will provide the capability to land autonomously on the lunar surface. The guidance and navigation systems will send signals through the central digital computer to notify the control system when maneuvers are required. The control system will consist of RCS for relatively large attitude adjustments, a control moment system for fine tuning the attitude during proximity operations, and engine gimbaling for c.m. adjustments.

COMMUNICATIONS

The three main communication links considered in this report are lander-Earth, lander-OTV, and lander-lunar base. For lander-Earth communications, a steerable S-band antenna will be used with infrared sensors for pointing. For lander-OTV communications, X-band radar will be used for rendezvous and a low-power VHF antenna will be used for transmission of data to be relayed to Earth. The low-power VHF antenna will also be used for communication with a lunar base. The communication with Earth will be performed through the Tracking Data Acquisition System (TDAS), the replacement for the present (Tracking Data Relay Satellite System) TDRSS system.

THERMAL CONTROL

The lander employs passive as well as active systems to maintain the temperature of the lander's subsystems. The lander's top side is designed to face away from the Sun to radiate heat more efficiently. Radiators from active cooling systems are placed on this side, and the bottom side is insulated and covered with reflective coatings to protect the lander from the Sun's heat. While the cryogenic fuel of the lander is only protected by passive thermal systems, the boiloff of the fuel is still useable by the RCS thrusters.

LANDER MASS STATEMENT

The total deorbit mass of the lander is 49,376 kg, which includes a 15,000-kg payload and 24,586 kg of propellant.