Technical Failure Report: Beresheet Lunar Lander Crash

Introduction

The Beresheet lander, developed by SpaceIL and Israel Aerospace Industries (IAI), was an ambitious attempt to perform Israel's first lunar landing. However, the mission ended in failure when the spacecraft crashed onto the Moon's surface. This report outlines the sequence of technical events leading to the crash and analyzes the key reasons behind the failure.

Sequence of Technical Events

1. **Initial Descent**
    - The spacecraft initiated its descent from an altitude of approximately 30 km, traveling at a velocity of ~1700 m/s.
    - The main engine, responsible for deceleration, was operational at the start of the landing phase.
2. **Gyroscope Failure**
    - At an altitude of around 14 km, a malfunction occurred in one of the Inertial Measurement Unit (IMU) gyroscopes.
    - The IMU is a crucial component for attitude control, helping to stabilize the spacecraft during descent.
3. **Manual Reset Attempt**
    - Engineers at the ground control center attempted a system reset to recover from the IMU issue.
    - During the reset, a critical command inadvertently caused the main engine to shut down.
4. **Loss of Control and Rapid Descent**
    - With the main engine off, the spacecraft lost its ability to slow down effectively.
    - Gravity pulled Beresheet toward the Moon at increasing speeds, leading to a rapid free fall.
5. **Impact on the Lunar Surface**
    - The team managed to reactivate the engine, but it was too late to compensate for the velocity.
    - The lander impacted the Moon's surface at high speed (~134 m/s), far exceeding the safe landing threshold (~2.5 m/s).

Key Technical Causes of the Failure

1. **IMU Malfunction**
    - The failure of a gyroscope within the IMU compromised the spacecraft's attitude control.
2. **Software-Related Engine Shutdown**
    - The emergency system reset triggered an unintended shutdown of the main engine.
    - No automatic recovery mechanism was in place to restart the engine promptly.
3. **Insufficient Backup and Fail-Safe Mechanisms**
    - The control system lacked redundancy to handle IMU failures without requiring a reset.
    - There was no fail-safe process to ensure the main engine would remain operational after a system reset.
4. **Late Response Time**
    - By the time engineers reactivated the engine, the lander had already accelerated beyond a recoverable state.

Conclusion

The Beresheet lander's crash was primarily caused by a sequence of technical failures, starting with an IMU malfunction and exacerbated by a software-induced engine shutdown. The absence of robust fail-safe mechanisms and the delayed response ultimately resulted in the mission's failure. Future missions can learn from these issues by implementing better redundancy, automated recovery procedures, and rigorous software testing to prevent similar failures.