Space Operations Digest

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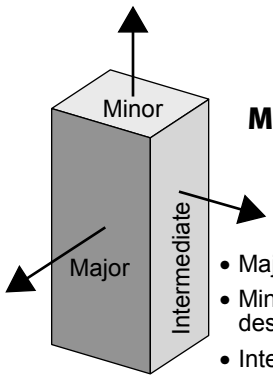
Editor's Note Three days after launch, NASA's Lewis Spacecraft lost ground contact and subsequently re-entered. The failure is recounted below (a full report is available on-line at http://arioch.gsf.nasa.gov/300/html/lewis_document).

The Loss of Lewis Spacecraft

Background. A trailblazer for NASA's fast-track acquisition approach, the satellite was developed in a branch office of TRW. It was launched into a 300-km parking orbit for initial checkout in August 1997.

Unattended Safe Mode Operation. Soon, a series of anomalies occurred. Controllers put the satellite in the safe mode and, after operating trouble-free for several hours, left for a 12-hour break.

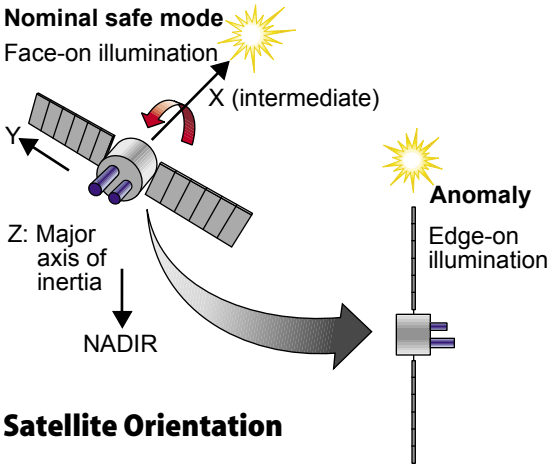
Safehold Mode Design Deficiency. The spacecraft relied on a single two-axis gyro for attitude control in safe mode. This gyro only sensed rotation about the major and minor axes, and could not handle torques around the intermediate axis, an inherently unstable situation.



Major-Axis Rule

- Major axis spin is stable
- Minor axis spin is stable but may be destabilized by energy dissipation
- Intermediate axis spin is unstable

Loss of Control. A small imbalance (probably in thruster or mass properties) caused Lewis to spin up around the intermediate axis. The thrusters autonomously fired to try to arrest the disturbance, but the firings occurred so often that the watchdog timer—designed to preserve fuel—shut the thrusters down. The satellite entered a flat spin around its principal axis. The solar arrays turned edge-on towards the Sun, and power was lost. When the operators returned, the battery was depleted.



Satellite Orientation

Why the Lapse Escaped Reviews. The Lewis attitude-control engineers reused a design from a simpler satellite, without accounting for the much more complex mission profile. When NASA's Investigation Board visited TRW's main campus, they discovered that the engineers there in fact used multiple gyros in similar safe mode, in anticipation of instability. If experienced peers had reviewed Lewis, they would have caught the vulnerable, one-gyro design.

Lack of Ground Attendance. Controllers opted to leave the satellite unattended for hours, presuming that stability in the eventual mission orbit (523 km) had been demonstrated. Unfortunately, steadiness in the lower parking orbit, where atmospheric drag is much more severe, had not been validated. Later, a simulation confirmed that attitude control would be lost in a few hours.

Lessons Learned.

- Controllers should be continuous present during spacecraft initialization.
- Analyze the effect of anomalies in all operating modes.

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