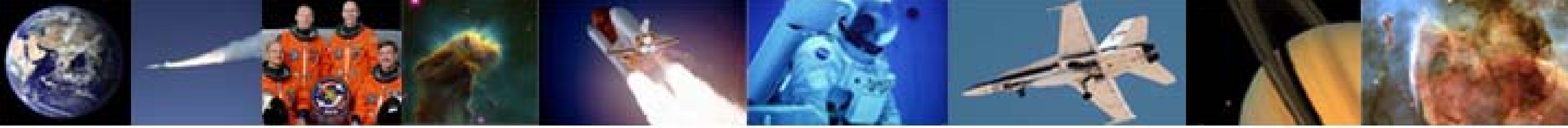

While You Were Sleeping:
The Loss of the Lewis Spacecraft

Leadership ViTS
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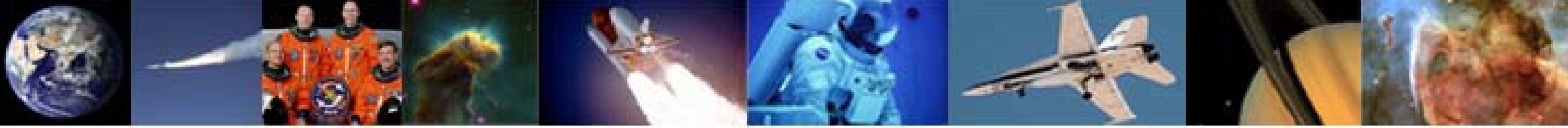
http://pbma.nasa.gov/pbma_main_cid_584



The Failure

- The Lewis Spacecraft program was initiated in the early 1990's under NASA's ***Faster, Better, Cheaper*** (FBC) paradigm. As such, the contract (awarded to TRW) did not include government-specified technical requirements, performance or quality assurance standards.
- To save money TRW planned to employ only a single shift of flight controllers even for initial on-orbit checkout operations and used a heritage design attitude control system (ACS).

Critical Event Timeline (EST)

August 23

2:51 a.m. Launch from Vandenberg AFB to 300km parking orbit.

August 25

10:17 a.m. Contact with the spacecraft is lost for three hours.

1:17 p.m.** Contact reestablished; spacecraft 28° off the Sun; batteries at 43% depth of discharge (DOD). Spacecraft restored to Safe Mode, and observed as stable for four hours. Batteries fully charged.

7:00 p.m.** Ground operations cease; staff begins nine hour rest period, electing not to request emergency backup ops team.

August 26

Early a.m. Autonomous ACS attempts to maintain intermediate axis mode, result in excessive thruster firings and eventual ACS shut-down.

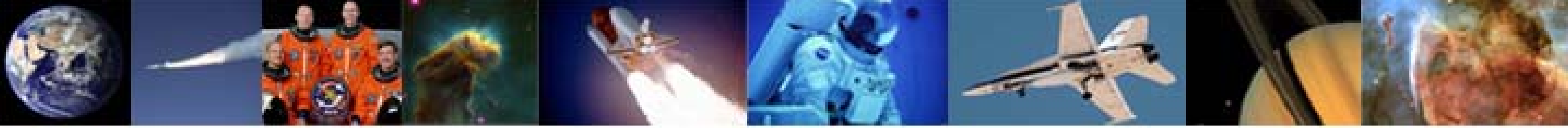
4:02 a.m. Edge-on spin discovered. Batteries at 72% DOD.

6:17 a.m. Flight Control attempts to arrest spacecraft rotation by firing ACS thrusters; contact never reestablished.

September 28

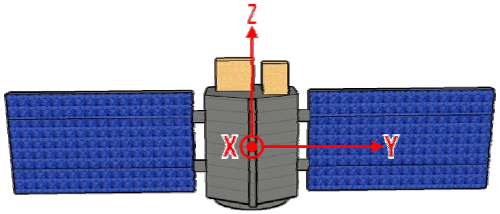
7:58 a.m.** Lewis re-enters earth's atmosphere and burns up.

** estimated time

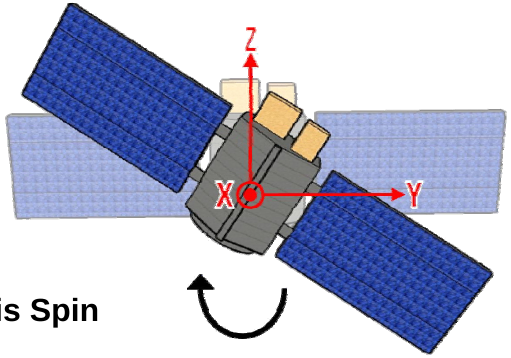


Safe Mode

- During periods of inactivity Lewis used an ACS “Safe Mode” that orientated the solar panels towards the sun. As part of cost saving measures the “Safe Mode” was taken from a previous TOMS spacecraft that had a different mass distribution and solar panel arrangement.



Safe Mode

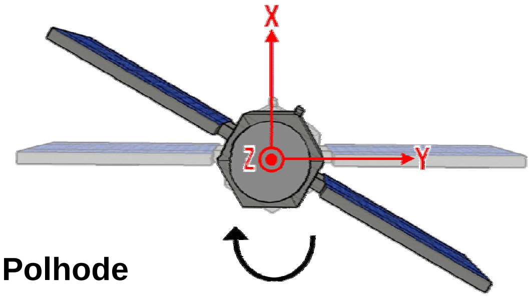


x-axis Spin

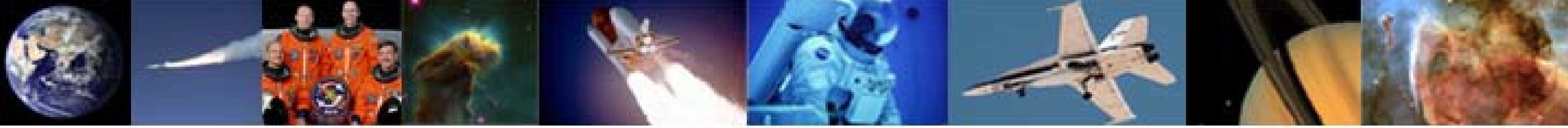
- During an attempt to stabilize Lewis the ACS inadvertently triggered a spin around the x-axis. The ACS system was controlled by a two axis gyro that provided no rate information about the x-axis.

- As mechanical energy dissipated Lewis underwent ***Polhode*** motion (by conservation of angular momentum). The spacecraft migrated from a spin about the x-axis to a spin about the z-axis with the edge of the solar panels facing the sun.

- Unable to maintain a charge on the batteries, the spacecraft shutdown and eventually burned up in the earth’s atmosphere.



Polhode

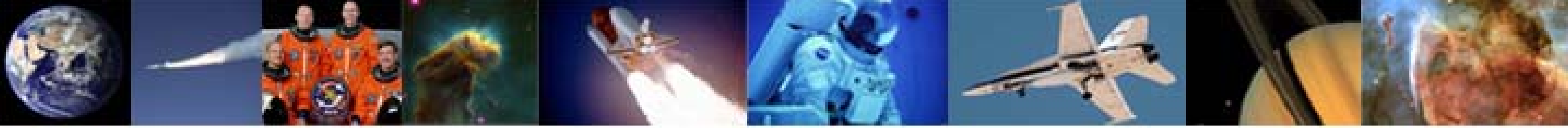


Proximate Causes in Event Chain

- Inappropriate application and lack of peer review of attitude control system design.
- Inconsistent monitoring of spacecraft during crucial early operating phase.

Causal Web – Underlying Issues

- Ineffective and inconsistent project leadership:
  - During a single 14 month period TRW saw four different Program managers and four General/Division managers.
- Incomplete and unsusainted articulation and communication of ***Faster, Better, Cheaper***:
  - By design, there were no government specified technical or quality assurance requirements. FBC relied on commercial best practices rather than traditional NASA management program control functions.
  - In the absence of higher level policy guidance NASA program executives struggled to define FBC in practical terms.
- Inadequate test and verification of heratige hardware/software:
  - The ACS verification process failed to address the improper application of software designed for a much different spacecraft.
  - FBC encouraged the use of heritage hardware and software, but verification procedures were slim and often only modeled a limited set of nominal scenarios.
- Insufficient budget to support robust ground operations:
  - Enormous cost containment pressures resulted in an understaffed ground support team that was off-duty during key early operational phases. An emergency backup team was not activated.
  - The decision to operate the early on-orbit mission with only a single shift ground control crew was not clearly communicated to senior TRW or NASA management.



Lessons Learned for NASA

- Don’t compromise safety and mission assurance reviews in the name of consolidation. There are simply no shortcuts in the fundamental life-cycle systems engineering disciplines.
- Ensure that schedule and budget goals are realistic and have sufficient margins to accommodate potential modifications or problems.
- Management sets the tone. Mission success cannot rely simply on process or textbook models. Consistent leadership is necessary for every project.
- Verify the correct implementation and use of heritage hardware and software.