Extended Abstract (>500 words)

For consideration in the special session on flight dynamics aspects of the LADEE mission

Attitude Design for the LADEE Mission

Ken Galal, Craig Nickel, Ryan Sherman

The Lunar Atmosphere and Dust Environment Explorer (LADEE) satellite successfully completed its 148-day science investigation in a low-altitude, near-equatorial lunar orbit on April 18, 2014. The LADEE spacecraft was built, managed and operated by NASA's Ames Research Center (ARC). The Mission Operations Center (MOC) was located at Ames and was responsible for activity planning, command sequencing, trajectory and attitude design, orbit determination, and spacecraft operations. The Science Operations Center (SOC) was located at Goddard Space Flight Center and was responsible for science planning, data archiving and distribution.

This paper details attitude design and operations support for the LADEE mission. LADEE's attitude design was shaped by a wide range of instrument pointing requirements that necessitated regular excursions from the baseline one revolution per orbit "Ram" attitude. Such attitude excursions were constrained by a number of flight rules levied to protect instruments from the Sun, avoid geometries that would result in simultaneous occlusion of LADEE's two star tracker heads, and maintain the spacecraft within its thermal and power operating limits. To satisfy LADEE's many attitude requirements and constraints, a set of rules and conventions was adopted to manage the complexity of this design challenge and facilitate the automation of ground software that generated pointing commands spanning multiple days of operations at a time. The resulting LADEE Flight Dynamics System (FDS) that was developed used Visual Basic scripts that generated instructions to AGI's Satellite Tool Kit (STK) in order to derive quaternion commands at regular intervals that satisfied LADEE's pointing requirements. These scripts relied heavily on the powerful "align and constrain" capability of STK's attitude module to construct LADEE's attitude profiles and the slews to get there. A description of the scripts and the attitude modeling they embodied is provided.

One particular challenge analysts faced was in the design of LADEE maneuver attitudes. A flight rule requiring pre-maneuver verification of in-flight maneuver conditions by ground operators prior to burn execution resulted in the need to accommodate long periods in the maneuver attitude. This in turn complicated efforts to satisfy star tracker interference and communication constraints in lunar orbit. In response to this challenge, a graphical method was developed and used to survey candidate rotation angles about the thrust vector. This survey method is described and an example of its use on a particular LADEE maneuver is discussed.

Finally, the software and methodology used to satisfy LADEE's attitude requirements are also discussed in the context of LADEE's overall activity planning effort. In particular, the way in which strategic schedules of instrument and engineering activities were translated into actual attitude profiles at the tactical level, then converted into precise quaternion commands to achieve those pointing goals is explained. In order to reduce the risk of time-consuming re-planning efforts, this process included the generation of long-term projections of constraint violation predictions for individual attitude profiles that could be used to establish keep-out time-frames for particular attitude profiles. The challenges experienced and overall efficacy of both the overall LADEE ground system and the attitude components of the Flight Dynamics System in meeting LADEE's varied pointing requirements are discussed.