INTEGRATION AND TESTING OF THE LUNAR RECONNAISSANCE ORBITER ATTITUDE CONTROL SYSTEM

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Extended Abstract:

Throughout the Lunar Reconnaissance Orbiter (LRO) Integration and Testing (I&T) phase of the project, the Attitude Control System (ACS) team completed numerous tests on each hardware component in ever more flight like environments. The ACS utilizes a select group of attitude sensors and actuators. This paper chronicles the evolutionary steps taken to verify each component was constantly ready for flight as well as providing invaluable trending experience with the actual hardware. The paper includes a discussion of each ACS hardware component, lessons learned of the various stages of I&T, a discussion of the challenges that are unique to the LRO project, as well as a discussion of work for future missions to consider as part of their I&T plan.

LRO ACS sensors were carefully installed, tested, and maintained over the 18 month I&T and prelaunch timeline. Care was taken with the optics of the Adcole Coarse Sun Sensors (CSS) to ensure their critical role in the Safe Hold mode was fulfilled. The use of new CSS stimulators provided the means of testing each CSS sensor independently, in ambient and vacuum conditions as well as over a wide range of thermal temperatures. Extreme bright light sources were also used to test the CSS in ambient conditions. The integration of the two SELEX Galileo Star Trackers was carefully planned and executed. Optical ground support equipment was designed and used often to check the performance of the star trackers throughout I&T in ambient and thermal/vacuum conditions. A late discovery of potential contamination of the star tracker light shades is discussed in this paper. This paper reviews how each time the spacecraft was at a new location and orientation, the Honeywell Miniature Inertial Measurement Unit (MIMU) was checked for data output validity. This gyro compassing test was performed at several key testing points in the timeline as well as several times while LRO was on the launch pad. Sensor alignment tests were completed several times to ensure that hardware remained on a rigid platform.

LRO ACS actuators were tested numerous times for their reliability, performance, and compliance with any software changes. The NASA GSFC designed

Demiseable Integrated Reaction Wheels (RW) were built to provide a quiet attitude slew capability while storing several weeks of momentum buildup in their nominal nadir pointing science orbits. This paper covers the testing of the reaction wheels to verify correct operation with the flight software. Additional RW tests were performed to monitor RW bearing performance. The paper also discusses the use of the Propulsion Deployment Electronics (PDE) component. The PDE exercises the propulsion hardware and switches power to both an instrument heater and the communication and tracking transmitter. The paper discusses how the Propulsion and ACS teams worked very closely to verify the propulsion system from end to end. Additionally, the paper describes how the testing of the PDE inhibit unit proved that the LRO spacecraft would not transmit Radio Frequency signals or allow the use of the propulsion system while attached to the launch vehicle. Extreme care was taken when testing the firing circuitry for the deployment activities of the High Gain Antenna and the Solar Array. The use of Non Explosive Actuators (NEA) as well as NASA Standard Initiators (NSI) was always a serious matter during the I&T activities.

Environment testing of the LRO spacecraft provided the ACS with valuable performance data, long-term trending data, and operational proficiency training with the LRO ground system. The paper describes the testing from the ACS point of view of the nominal spacecraft environmental tests. The vibration, electromagnetic interference (EMI), acoustic, shock, and thermal/vacuum testing allowed the ACS team to understand how the hardware would behave under various conditions and how their interaction with the software could be more fully understood. This quantity of testing provided large amounts of trending performance data. The environment testing also gave the ACS team time to improve the skills of using the ground system telemetry pages, hone our trouble shooting skills, and sharpen off-line analysis tools needed to provide immediate and accurate spacecraft operations during all mission phases.

The important task of verifying the ACS Phasing is discussed in this paper. Attention was given to this test because of its importance immediately after launch vehicle separation. During launch, the battery was drained and only left several hours of power for LRO. A phasing error would have increased the time for the spacecraft to reach a power-positive state, and thus risk the mission.

Early mission rehearsals were performed during I&T and the experience taught the ACS team how to work problems together, create better off-line analysis tools, understand the key time critical events, and improved operational proficiency. Operating the ACS with limited telemetry, time critical events, hardware failures, software bugs on an around the clock schedule for many days was a challenging demand for the ACS team. Two early mission rehearsals lasting six days each had many anomalies inserted in the timeline. Correctly identifying the anomaly, working with the proper subsystems to suggest recommended solutions, running off-line simulations, and keeping a tired but focused team flying the spacecraft was a beneficial exercise. These full timeline rehearsals were a small percentage of the overall total number of other smaller simulations which focused on specific critical operations such as Lunar Orbit Insertion burns, Mid-Course Correction burns, Safehold operations, and nominal science operation tests.

Lessons learned about the overall testing philosophy and implementations are discussed in the paper. New suggested techniques for testing hardware are also discussed in the paper in the hope that both satellite and hardware providers can improve the state of the art in ACS testing.