

## *Orbital Debris Mitigation Requirements and the GRAIL Spacecraft*

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NASA's Orbital Debris Program Office, which is part of the ARES Directorate at JSC, has been instrumental in reducing the growth of orbital debris in Earth orbits through research and development of orbital debris mitigation requirements. It has now begun a new era in which lunar orbits are also protected.

Although NASA's original orbital debris mitigation policies and safety standard during the 1990s did not address orbits beyond the Earth, NPR 8715.6, NASA Procedural Requirements for Limiting Orbital Debris, issued in 2007, for the first time addressed objects in orbits about the Moon. NPR 8715.6A, issued in 2009, states that NASA program and project managers "shall not plan to leave objects in lunar orbit unless a documented need is stated in the ODAR" (Orbital Debris Assessment Report).

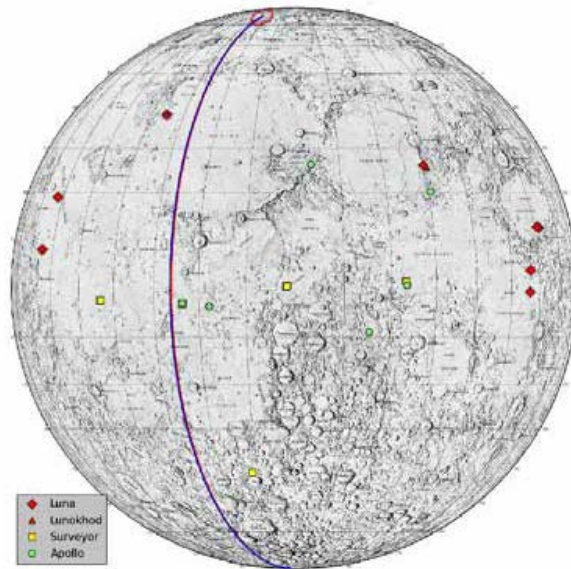
Two NASA Gravity Recovery and Interior Laboratory (GRAIL) spacecraft completed their year-long mission in orbit about the Moon December 17, 2012, when they were sent to make a controlled impact into a lunar mountain. This disposal action was in compliance with recommendations in NPR 8715.6A that were designed to protect historic and scientifically valuable lunar surface sites.<sup>1</sup>

Affectionately known as Ebb and Flow (figure 1), the two 200-kg dry mass spacecraft entered lunar orbit on New Year's Eve 2011 and New Year's Day 2012, respectively, and worked primarily from a 55-km altitude science orbit. As their reservoirs of hydrazine propellant dwindled, plans were made to target their crash onto the lunar surface rather than let them fall randomly.

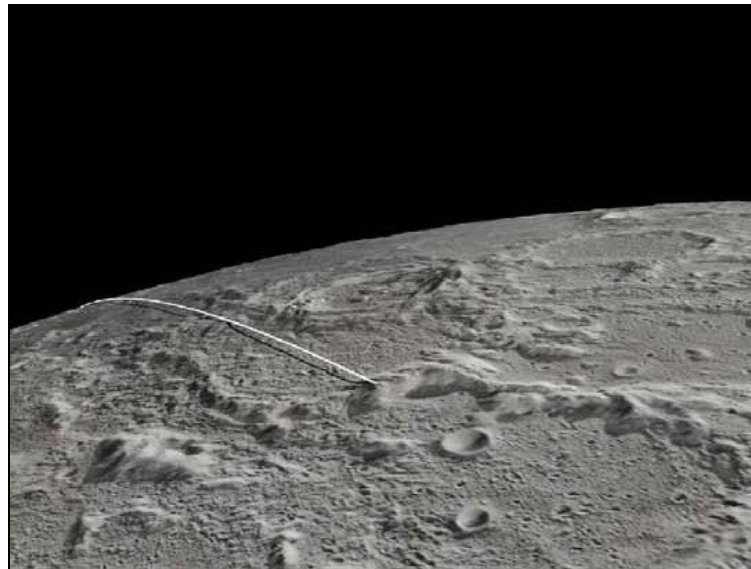


*Figure 1.— Artist's view of the two GRAIL satellites flying in close formation in lunar orbit.*

For the disposal of the two GRAIL spacecraft, a trajectory was selected to carry the spacecraft toward an unnamed lunar mountain near the north pole (figures 2 and 3). The final resting place for the two GRAIL spacecraft has been named for the late Sally Ride, the first U.S. woman in space and a proponent of the Moon KAM (Moon Knowledge Acquired by Middle School Students) cameras carried by the GRAIL spacecraft.



*Figure 2.— The final ground track of the two GRAIL spacecraft.*



*Figure 3.— The two GRAIL spacecraft struck the lunar surface just 30 seconds apart at a speed of nearly 2 km per second.*

1. NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6A, May 14, 2009, Section 3.3.3.