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Environmental Evaluation and Recommendation for NASA Routine Payload Categorization of the GRAIL Project

The proposed GRAIL mission has been reviewed in accordance with the Routine Payload criteria established by the "*Final Environmental Assessment for Launch of NASA Routine Payloads on Expendable Launch Vehicles from Cape Canaveral Air Force Station Florida and Vandenberg Air Force Base California,*" dated June 2002 and Finding of No Significant Impact (FONSI) dated June 18, 2002. This review shows that the GRAIL mission meets all of the Routine Payload Criteria and therefore it is recommended that GRAIL be designated a NASA Routine Payload. Supporting mission description and Routine Payload Checklist documentation are attached.

Approval:

[signature] 10-6-08
V.S. Ryan, Supervisor, Launch Approval Engineering Group — Date

Concurrence:

[signature] 10/6/08
R. E. Wilcox, Manager, Cross-Program Launch Approval Engineering — Date

Concurrence:

[signature] 10/7/2008
Dave Lehman, GRAIL Project Manager — Date

Description of Proposed Mission:
The Gravity Recovery and Interior Laboratory (GRAIL), a NASA Discovery Program Mission, would utilize two orbiting spacecraft to map the lunar gravity field in order to reveal the internal structure and thermal evolution of the Moon, with particular focus on the role of impacts and volcanism. GRAIL would be a lunar version of the successful NASA Earth System Science Pathfinder Program (ESSP) gravity mapping mission called Gravity Recovery and Climate Experiment (GRACE). Like GRACE, GRAIL would utilize two spacecraft, each acting as a reference mass flying in tandem around the Moon. As they fly above the lunar surface, the gravity field of the Moon would influence the motion of the center-of-mass (CM) of each spacecraft. Any surface feature (such as craters or mascons) or deep interior core motion would perturb the spacecraft orbits and introduce signatures in the relative motion between the spacecraft. The gravity field would be determined using the same technique as GRACE, by observing the relative and absolute motion of the CM. The twin GRAIL orbiting spacecraft would launch from Cape Canaveral Air Force Station (CCAFS), Florida aboard a single Delta II Heavy launch vehicle during an opportunity that would begin September 8, 2011.

The GRAIL mission was proposed in response to NASA's Announcement of Opportunity for the Discovery Program. The mission selection was based on the GRAIL Discovery Step 2 Concept Study Report dated June 20, 2007. The Discovery Program is part of NASA's initiative for lower-cost, highly focused, rapid-development scientific spacecraft. It is an ongoing program that offers the scientific community the opportunity to assemble a team and design focused science investigations that complement NASA's larger planetary science explorations.

The GRAIL mission has two primary science objectives:

- Determine the structure of the lunar interior, from crust to core.
- Advance understanding of the thermal evolution of the Moon.

GRAIL would accomplish its science objectives with the two three-axis stabilized spacecraft flying in a low-altitude (55 kilometer [km] [34 miles]) polar orbit, and acquiring, down linking, managing, and analyzing precise ranging measurements between them. The mission is an application of existing technology that would make a significant, revolutionary leap in our understanding of the structure of the Moon.

The GRAIL payload consists of the following two elements onboard each of the two GRAIL spacecraft:

- The Lunar Gravity Ranging System (LGRS) – a scientific instrument to map the Moon's gravity.
- MoonKam - a commercial nadir-pointing camera that would support Education and Public Outreach efforts by enabling students to image the lunar surface.

The LGRS instrument has been selected in order to maximize GRACE design heritage and applicable experience while minimizing resource consumption so as to maintain high system margins for the GRAIL spacecraft.

After launch, GRAIL would begin a trans-lunar cruise phase that would consist of a 3.5-month low-energy transfer via the Sun-Earth Lagrange point 1 (L1). Both spacecraft would approach the Moon under the South Pole where they would execute approximately a 40-minute Lunar Orbit Insertion (LOI) maneuver to put them in an elliptical orbit with a period of just over 14 hours. Both LOIs, separated by one day, would be simultaneously visible from the Madrid and Goldstone Deep Space Communication Complexes.

Special Considerations:

<u>Hydrazine Propellant Load – Launch</u>

Each of the two GRAIL spacecraft would utilize a maximum of 113.5 kilograms (kg) (249.7 pounds [lb]) of hydrazine propellant and would launch on an Delta II Heavy, which uses 2,064 kg (4.540 lb) of hydrazine and 3,922 kg (8,630 lb) of nitrogen tetroxide (NTO) for the propellants and 9 rocket motors for augmented thrust. The total of 227 kg (499 lb) of hydrazine is within the threshold listed in the Envelope Payload Characteristics (EPC) of the current NRP EA. The Delta II Heavy is covered under prior NEPA documentation by both NASA and the USAF which states that the quantities of hydrazine on the Delta II Heavy do not create a substantial impact for launch accidents. Thus, the 227 kg (499 lb) of propellant aboard the two GRAIL spacecraft is not expected to substantially increase impacts to the environment due to a launch failure.

Launch Failure Resulting in a Suborbital or Orbital Reentry

NASA is in the process of updating the NASA Routine Payload Environmental Assessment. Once the Agency issues the updated Final Updated EA for routine payloads, NASA will review the potential environmental impacts of the proposed GRAIL mission in the context of the new analysis and information contained in that Final EA. If NASA determines that there are substantial new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts, NASA will formally reopen the NEPA process for this mission.

Statement of Purpose and Need:

The Moon plays a key role for understanding how the terrestrial planets evolved because it is the most accessible planetary body that preserves a surface record spanning most of solar system history. Reconstructing planetary evolution also requires an understanding of the structure of the planetary interior. Despite mapping from numerous orbital platforms, it has not been possible to develop a comprehensive understanding of the interior structure of the Moon due to the lack of reliable farside gravity data. Knowledge acquired about the Moon from the GRAIL mission would be extended to understand the broader evolutionary histories of the rocky planets in the inner solar system: Earth, Venus, Mars, and Mercury. Also, findings from the GRAIL mission would support NASA's proposed exploration goal of returning humans to the Moon by 2020. GRAIL would reduce risk to future lunar robotic or human science and exploration missions by providing a high resolution, global gravity field that would be used to eliminate gravity uncertainties for precision lunar navigation and landings.