Small Spacecraft Design for the GRAIL Mission

SSC12-II-5

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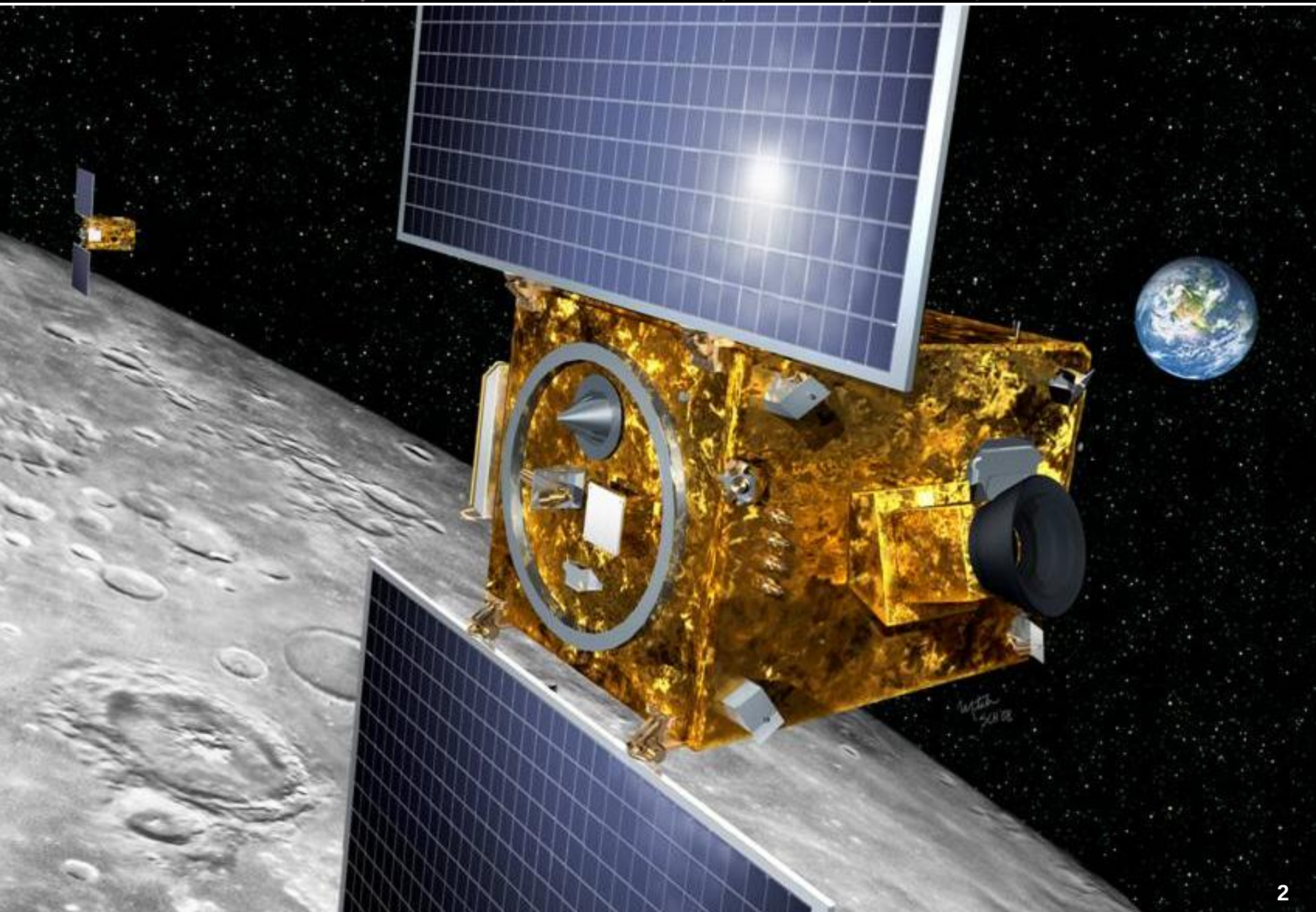
What is GRAIL?



Gravity Recovery And Interior Laboratory

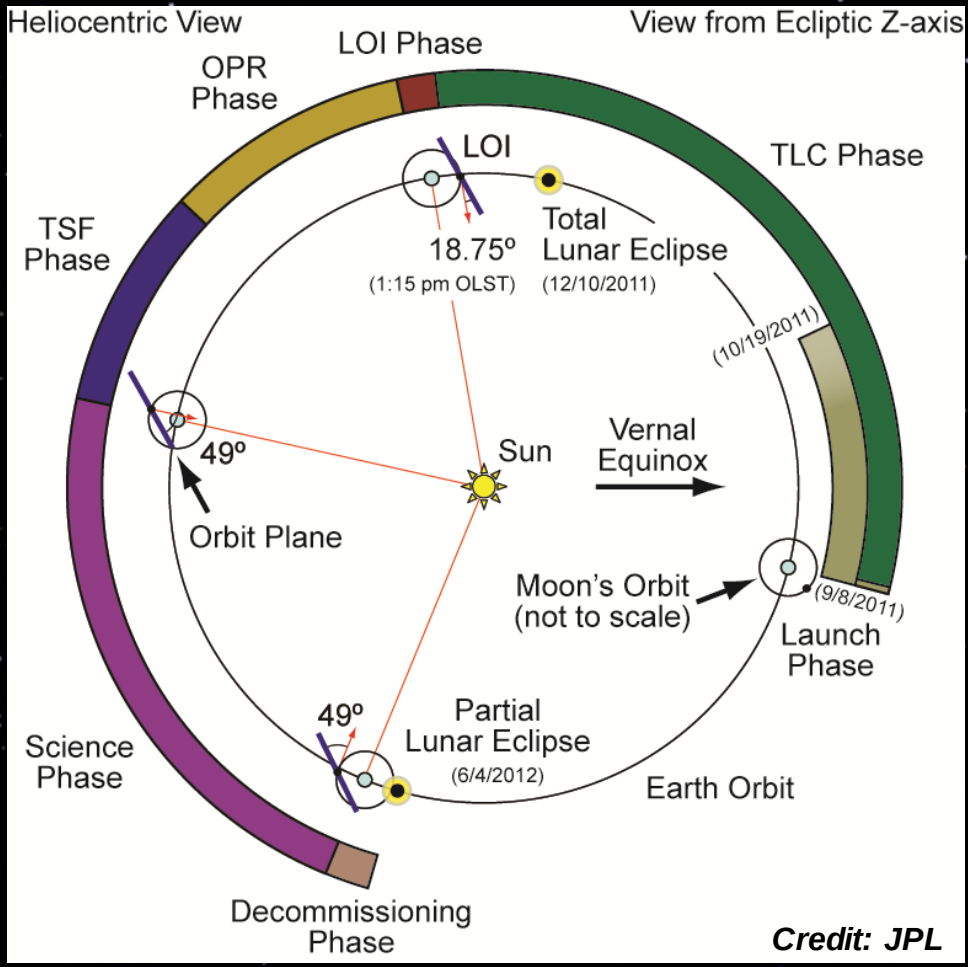
- Description: NASA Discovery-class science mission to map the global gravity field of the Moon

- Science Goals:
  - Determine the structure of the lunar interior, from crust to core
  - Advance understanding of the thermal evolution of the Moon
  - Extend knowledge gained from the Moon to the other terrestrial planets

- Major Teams:
  - Massachusetts Institute of Technology
  - Jet Propulsion Laboratory
  - Lockheed Martin Space Systems Company

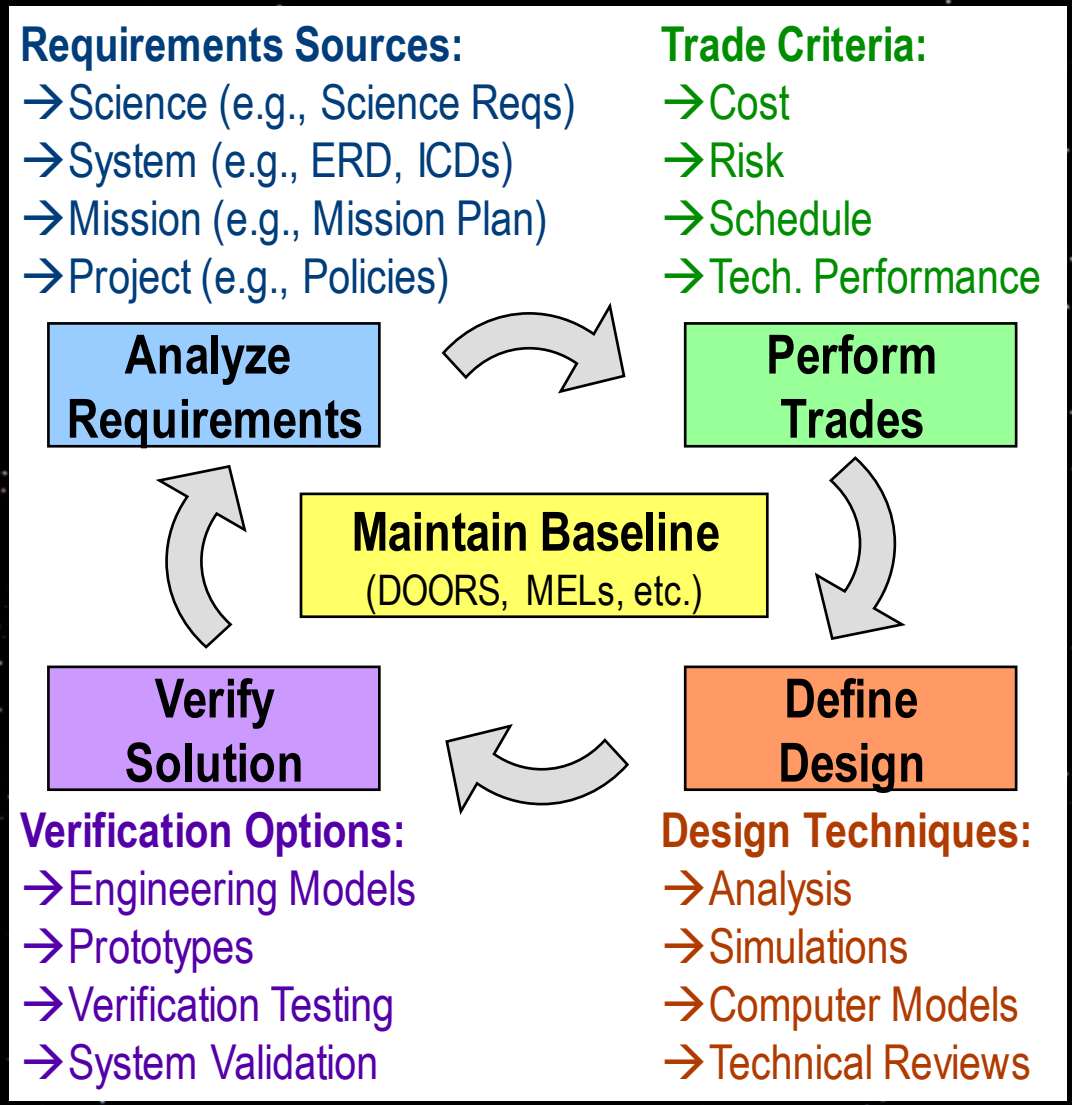
GRAIL Mission Overview

- Launch: Sep 10, 2011 (Kennedy Space Center)
- Cruise: 3.5-month low energy trajectory
- Lunar Orbit Insertion(s): Dec 31, 2011 / Jan 1, 2012
- Science Start: Mar 1, 2012 (7 days earlier than plan)
- Primary Mission Complete: May 29, 2012
- Extended Mission: will complete Dec 7, 2012



Spacecraft Design Process

- Spacecraft design was an iterative process
- Requirements analysis indicated a good fit with existing XSS-11 bus
- Several trades led to major design changes
- Detailed analyses resulted in other, smaller refinements
- Full verification was complete before launch
  - In-flight performance has matched predicts



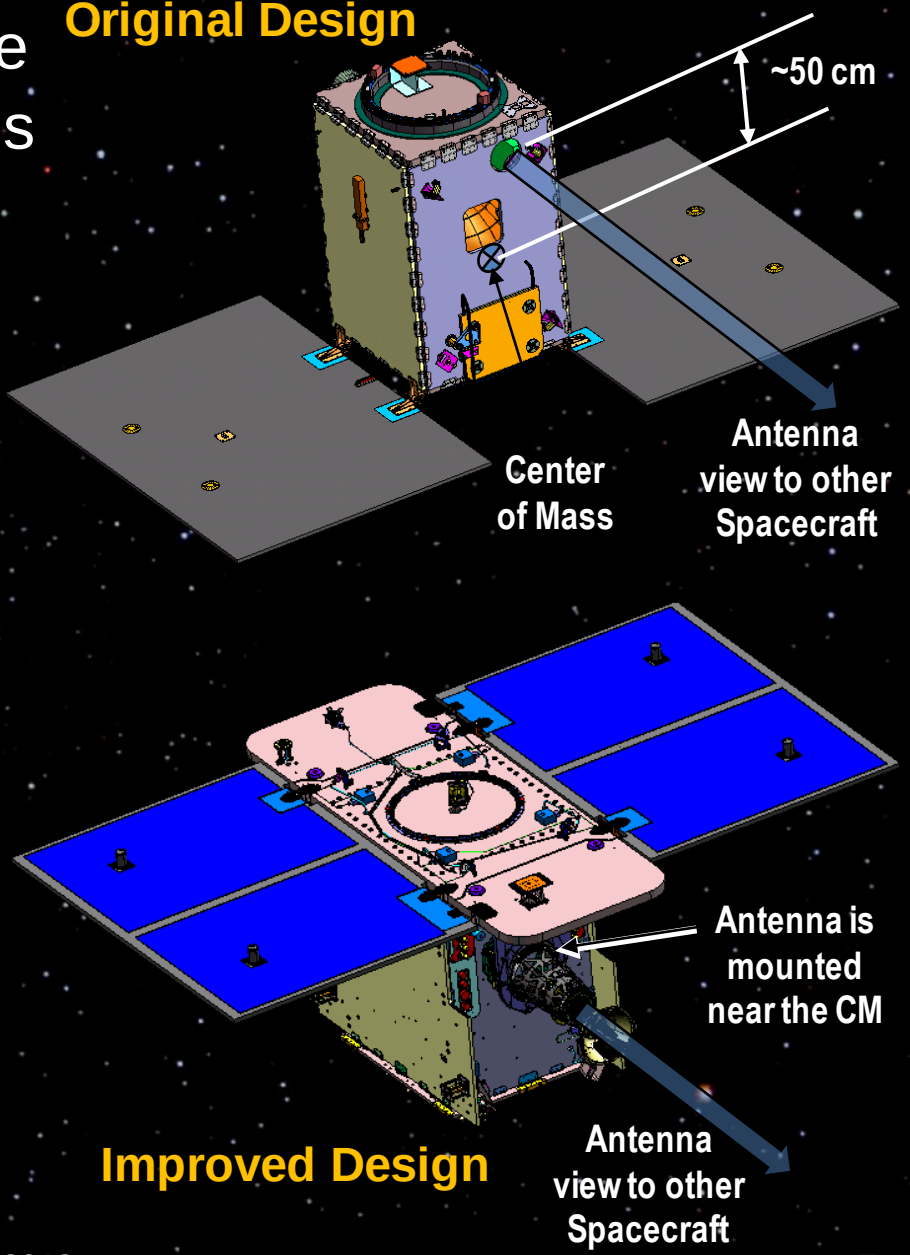
Key Spacecraft Requirements

Key Requirement	Value	XSS-11
Spacecraft Dry Mass, each	≤ 226.0 kg	Comply
Thermal-induced Structural Motion	≤ 15.0 μm/orbit	Comply
Ka Antenna Temperature Stability	≤ ±3.0 °C/orbit	Comply
Formation Flying Attitude Control	≤ 1.0 mrad/axis	Comply
Articulating Components	Not Allowed	Comply
Total Mission Delta-V	≥ 850.0 m/sec	Minor Mod
Mission Lifetime	≥ 9 months	Comply
Solar Array Power (end of life)	≥ 700 W at 1AU	Minor Mod

- Key spacecraft requirements were satisfied by the existing design from Experimental Small Satellite (XSS-11) except:
  - A larger fuel tank was required for GRAIL to increase delta-v
  - Larger solar arrays were required to increase power production
- Both modifications were minor and were rated as low risk

Trade Study #1: Antenna Mounting

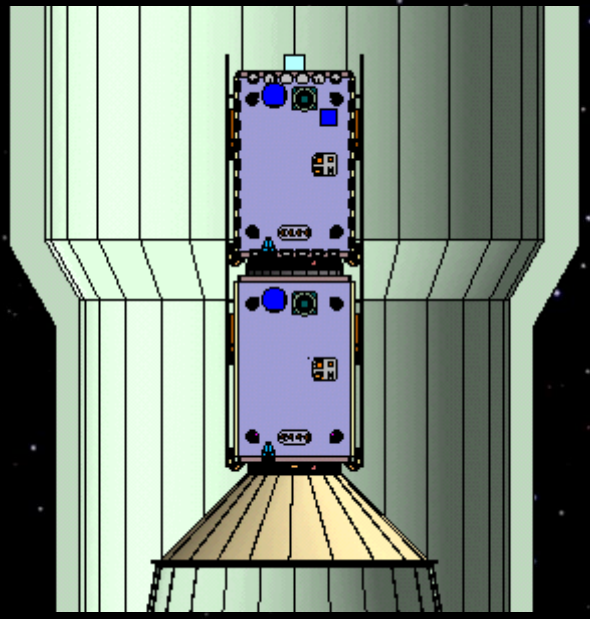
- Original Design had the science antenna mounted inside the bus
  - Created a large offset from the spacecraft center-of-mass
  - Attitude perturbations would be magnified at antenna boresight
  - The interior fuel tank prevented movement of science antenna
- An early trade study led to an updated antenna placement
  - Science antenna was mounted on the exterior of the spacecraft
  - Allowed it to be near the center-of-mass → ***Improved Science!***



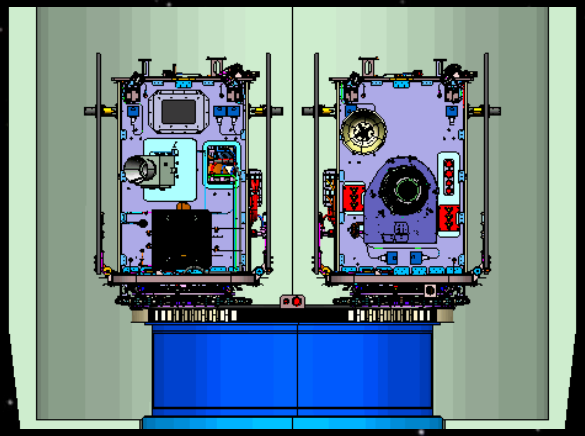
Trade Study #2: Launch Configuration

- Stacked Configuration Disadvantages:
  - Stronger bus needed for lower spacecraft
  - Lower bus must separate the upper bus
  - Heritage mechanisms were inadequate
  - Thermal concern with lower spacecraft
  - Handling concerns during Integration/Test
  - Additional flight software required
- Trade study was performed during Phase B to assess design options
- Side-by-Side Configuration Selected
  - Eliminated disadvantages shown above
  - Additional design and analysis work was minor and easily accomplished

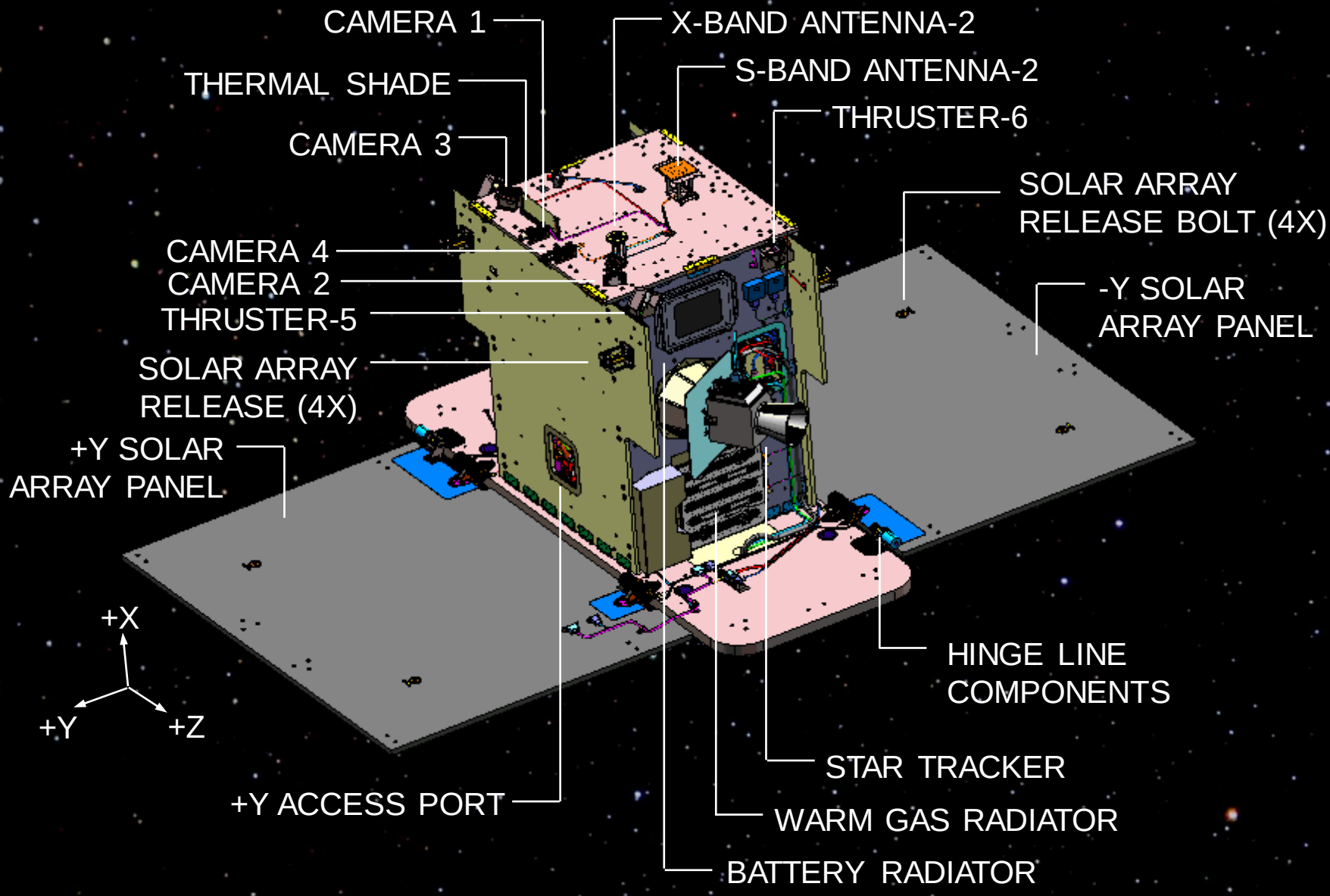
Original Design



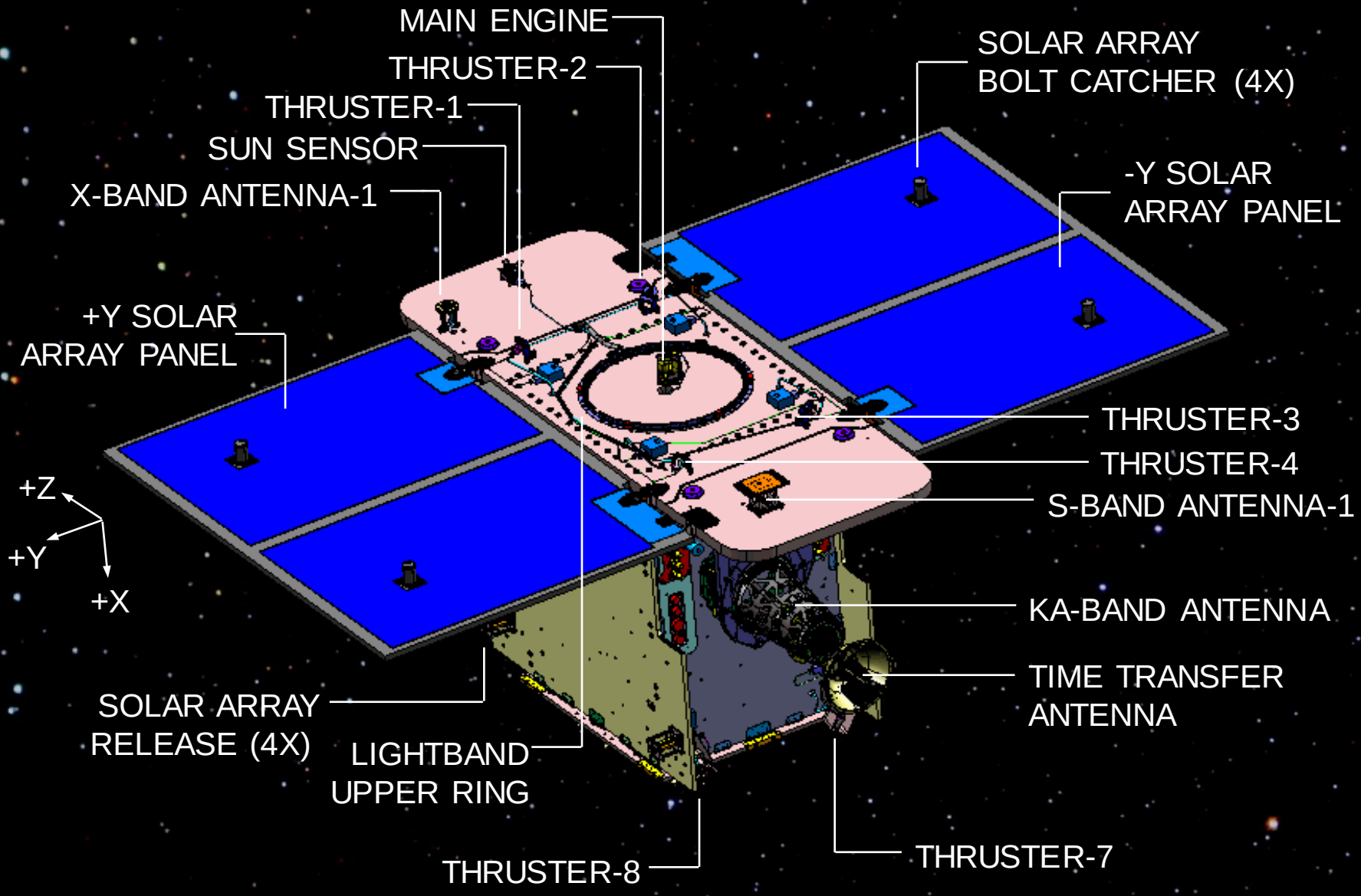
Improved Design



Final Spacecraft Design: Top View



Final Spacecraft Design: Bottom View



Summary

- The twin GRAIL spacecraft have demonstrated formation flying around another celestial body
- The small, stable design enabled the spacecraft to comply with the tight requirements for a gravity-mapping mission
- The GRAIL science results during the primary mission have been outstanding → ***Full Mission Success!***
- GRAIL is just beginning its extended science mission and the team fully expects to continue its successful trend