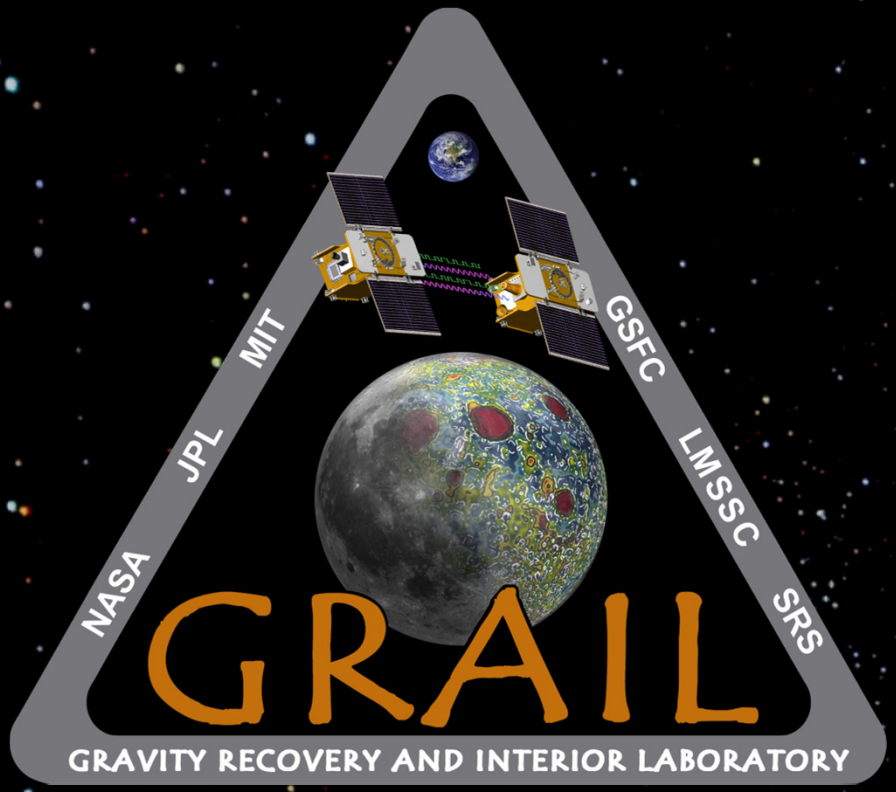

Case Study: GRAIL Acquisition Strategy and Contract Management

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GRAIL Project Summary

- Science objectives:
  - Determine structure and interior of the Moon, from crust to core
  - Understand thermal evolution of the Moon
  - Extend knowledge to other terrestrial planets
- Mission outline:
  - Twin spacecraft launched on a Delta 7920H-10
  - 9-month mission; launch in Sept 2011
  - Low altitude, 50-km polar orbit
  - 82-day primary mapping mission
  - Spacecraft operates at ~200 km separation
  - Extensive science data analysis
  - Education and public outreach (E/PO) MoonKAM cameras engage public
  - Heritage: GRACE-like mission concept
  - Heritage: Spacecraft from Lockheed Martin (LM): XSS-11 and MRO
- Science measurements and payload:
  - Ka-band ranging system (with GRACE heritage) measures relative velocity of CM of two spacecraft
  - Deep Space Network used for absolute position determination
- Mission management:
  - MIT: Principal Investigator, Sally Ride Science contract for E/PO
  - Goddard Space Flight Center (GSFC): Gravity science modeling and data analysis
  - JPL: project management, systems engineering, mission assurance, mission operations and ground data system, payload, LM spacecraft system contract, data processing

GRAIL Timeline

- Jan. 2008: Start of Phase B
- Apr. 2008: Project Mission System Review (PMSR)
- Nov. 2008: Project Preliminary Design Review (PDR)
- Jan. 2009: Confirmation Review/Key Decision Point (KDP)-C
- Mar. 2009: Start of Phase C
- Nov. 2009: Project Critical Design Review (CDR)
- Jun. 2011: Project System Integration Review (SIR)
- Jul. 2011: Start of Phase D
- May 2011: Ship to Florida
- Sept 2011: Launch!

Acquisition Strategy Overview

- For the NASA AO Step-1 competition, the project team was selected—major make/buy decisions settled at this point
- For the Step-2 (down-select) competition, we included in the proposal:
  - Summary of project hardware and software acquisition approach
  - Long-lead Items for funding in Phase B
  - Subcontracting Plan for small/etc. business
  - SOWs for NASA contracts/JPL subcontracts for MIT, GSFC, LM, SRS, and NASA Launch Services
  - Incentive Plan for JPL, LM
  - International agreements
  - Compliance with U.S. Export Laws
  - Incentive Plan
- Having all of these in place early facilitated quick getting-on-contract for Phase B

Acquisition Strategy Overview (cont.)

- Key drivers in our acquisition strategy:
  - Offer a world-class science team (the who's who of gravity science)
  - Demonstrate low implementation risk via an experienced team and design (not hardware) heritage
  - Aggressive but doable program schedule, to launch earlier than the AO requirement, with commensurate cost savings
  - Limited and clean interfaces, robust technical resources margins, healthy cost and schedule reserves
  - Comprehensive Phase B work plan to generate gate products, complete key trade studies, and perform testing of the (few) technology development items
  - Offer an unprecedented E/PO program (America's first woman in space + flight cameras dedicated for outreach)

Acquisition Strategy Overview (cont.)

- Key team members:
  - MIT—contract from NASA
  - GSFC—“bypass funding” from NASA
  - JPL—task order from NASA
  - LM—Cost-plus-fixed-fee/incentive-fee (CPFF/IF) subcontract from JPL
    - Initiated by CPFF contract
    - LM had many lower-tier subs (fixed-price)
  - Applied Physics Laboratory (APL)—CPFF subcontract/SWO from JPL (for instrument assembly)
    - Phase B initiated by letter contract, as longest-lead item on the project
  - Space Systems/Loral—Firm-fixed-price (FFP) subcontract from JPL (for instrument assembly)
  - CMI—FFP subcontract from JPL (for instrument assembly)
  - Ecliptic—FFP subcontract from JPL (for E/PO cameras)
  - (Various)—FFP purchase orders for instrument components and electronic parts
    - Late start in ordering necessitated tiger team

LM Subcontract Summary

- Phase A—FFP study
  - NASA-funded
  - Plus LM bid and proposal (B&P)/internal research and development (IRAD) contribution
- Phase B—CPFF preliminary design
- Phase C/D—CPFF/IF design/build/launch
  - Includes catastrophic failure clause
  - Incentive payments
    - Based on
      - Successful launch and transition to operations
      - Percentage of Science Phase completed
      - Percentage of engineering and science data returned
    - Includes provisional payment of incentive fee
- Phase E—CPFF
  - A priced option in the Phase C/D subcontract

LM Subcontract Surveillance Approach

- JPL surveillance (insight/oversight) is intended to be value-added and reflective of the project risk management program
- In the proposal phase (Phase A), JPL and LM management agreed on use of each organization's proven spaceflight development practices
- Surveillance centers on document submittals, reviews, and itinerant personal presence
  - Document submittals: JPL Standard Subcontract Data Requirements List/Document Requirements Descriptions (SDRL/DRDs), with some items using LM equivalents and/or delivered in place ("engineering submittals")
  - Reviews: Monthly Management Reviews (MMRs) at LM, plus mutual participation in many peer reviews
  - People: colleague-to-colleague telecons, on-site reps during key activities (implemented so as to avoid any contractual direction or change)

Subcontract Experiences/Lessons: Make/Buy

- LM's make/buy decisions held up well, with some exceptions:
  - Avionics: originally going to Broad Reach for hardware with LM doing software; revised to have LM do both
    - This occurred after the completion of the project Inheritance Reviews (IRs), so a special IR was required
    - Funded by IRAD up until that point, and partially thereafter
    - In practice, the "make" decision has had
      - Pluses (the flight software development has been far smoother than normal) and
      - Minuses (the avionics development has been rocky)
    - Once in the bag, LM will have a product line usable for multiple moderate-class missions
  - Instrument KBR: originally going to LM, transferred to JPL
    - The engineering interface and the work skills set were not optimal for LM
    - In practice, even after the transfer JPL got a late start on the job, but did complete it successfully and in time to support instrument delivery

Subcontract Experiences/Lessons: Inheritance Reviews

- As proposed, the project instituted a battery of IRs, covering all appropriate elements of the flight system
  - Preliminary IR during Phase A
  - Individual element IRs during Phase B
- These reviews established the necessary heritage as applicable to GRAIL, or indicated the need for additional design, testing, and/or analyses
- LM's subcontract for Reaction Wheel Assemblies (RWAs) was moved from one supplier (foreign) to another (domestic) as a result of information provided at its IR
  - Due to export-control issues, this was the first opportunity to review detailed design information and mission suitability

Subcontract Experiences/Lessons: Project Reviews

- Project life-cycle reviews (per NPR 7120.5D) were used as control milestones for the entire project team
  - PMSR (JPL institutional review), PDR, CDR, and SIR were all held on the dates originally proposed to NASA (the SIR even a week early!)
  - Forced everyone to complete required activities on a common schedule (e.g., gate products, trade studies, design analyses, drawings, cost estimates)
  - Allowed us to maintain robust schedule reserve for Phase D (in Denver and in Florida)
- Project Review Captain and team coordinated all necessary activities
  - Tried to take the burden off of the people working the job at JPL and LM
  - For details, see three IEEE papers (available from the presenter)

Subcontract Experiences/Lessons: Contract Changes

- Subcontract changes did not perturb project progress
  - Changes were not large in number or in significance (27 total in Phase B/C/D)
  - Some were the result of external factors (e.g., change in launch loads prediction by the launch vehicle provider required a loads attenuation system, introducing a new subcontract from LM to CSA)
  - Changes were issued on time and proposals and negotiations were completed efficiently
- The subcontract baseline was always clear
  - Controlling project requirements and incentive fee approach never changed

Subcontract Experiences/Lessons: Teaming for Success

- The subcontract was complied with by both parties with good discipline
  - No constructive changes
  - No unauthorized technical direction
  - JPL participation in the LM project Change Control Board (CCB)
- JPL volunteered help, subject to LM acceptance
  - This was valuable in some key technical challenges, notably the Reaction Wheel Assemblies subcontract
    - LM led a tiger team with its sub (Goodrich), with JPL on the team
    - JPL provided additional liaison to a NASA agency tiger team dealing with RWAs
- LM requested JPL help, subject to JPL acceptance
  - Due to resource conflicts involving QA personnel, JPL provided inspection support for specified activities
- We were all “the GRAIL team,” not primarily JPL or LM employees (quasi-badgeless)

Subcontract Experiences/Lessons: Surveillance Tools

- The most important tools were the personal interactions
  - “24 hour rule” allowed LM a short period of time to troubleshoot an issue before notifying JPL
    - Their management could get involved and the issue could be triaged without pressure from the customer
    - This demonstrated trust in the contractor, with the obligation to give a candid report the very next day
- Tools changed in importance over time
  - Early: completion of trade studies and drawings and release of procurement specs were important indicators of progress and problems
  - Middle: delivery of hardware elements and software modules gave a good indication of which areas were doing well and which not so well
  - Later: weekly ATLO schedule with daily status telecons allowed everyone to keep current in a very dynamic environment
- Earned-value management (EVM) was employed, but did not provide magic insights
  - On a well-run project, EVM is a trailing indicator (if the first time you find out there’s a problem is from a CPR, you’re 6 weeks too late)
  - Positive EVM metrics—schedule performance index (SPI) and cost performance index (CPI)—did help to counter independent evaluators’ parametric model projections that the project wouldn’t launch on time (NASA put more stock in the EVM)

Subcontract Scoreboard

- LM subsystems performance overall rate very positively
  - Electrical Power, Harness, Telecom, Structures and Mechanisms, Thermal, Propulsion, and Software deliveries were on time to support the baseline ATLO program
  - Attitude Control deliveries were on time, except for late RWAs, requiring ATLO workarounds
  - Command and Data Handling (avionics) deliveries were consistently late, necessitating significant replanning of the ATLO program
    - Establishing schedule reserve in the initial plan as baselined was a life-saver
    - Also had JPL deliver the payload early, so Denver work could continue to move forward
- LM in-house work rates very positively, aside from Avionics
- LM subcontract work was mostly positive, except for the RWA issues

GRAIL Project Success Factors

- GRAIL development has been largely successful to date (on spec, on schedule, on cost), though not without problems
- Key success factors so far:
  - Principal Investigator is hands-on and an excellent motivator
  - Key personnel named in the proposal are still on the job
    - Good blend of experience and skills (e.g., LM Program Manager an ATLO expert)
  - Level-1 requirements are unchanged from the original proposal
  - Robust technical margins (mass, power, processor) have allowed accommodation of technical issues without severe impacts
  - Technology development was quite limited
  - Disciplined IRs surfaced the big problems early
  - Project Risk Board (MIT, JPL, LM, NASA) was transparent and very helpful
  - Life-cycle reviews as control milestones kept the team focused and on schedule through Phase C

GRAIL—Where Do We Go from Here?

- “To the Moon!” —Dr. Maria T. Zuber, PI
- Six months to launch
  - Lots of work to complete
  - An excellent team to do it
  - Not the time to rest on laurels or get distracted
- Need to be a development success story but even more a mission success story
  - Look for exciting science discoveries and outreach products in 2012