GRAIL: Achieving a Low Cost GDS within a Multimission Environment

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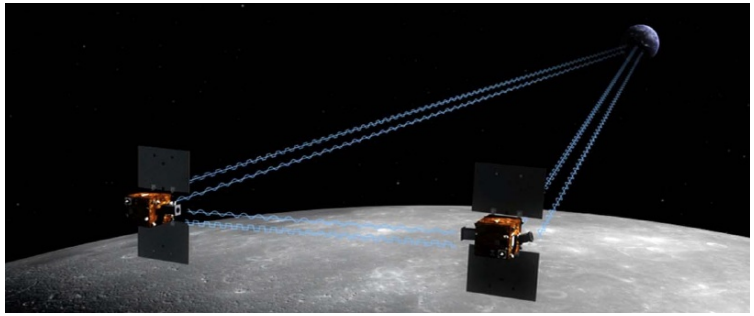
Grail Overview

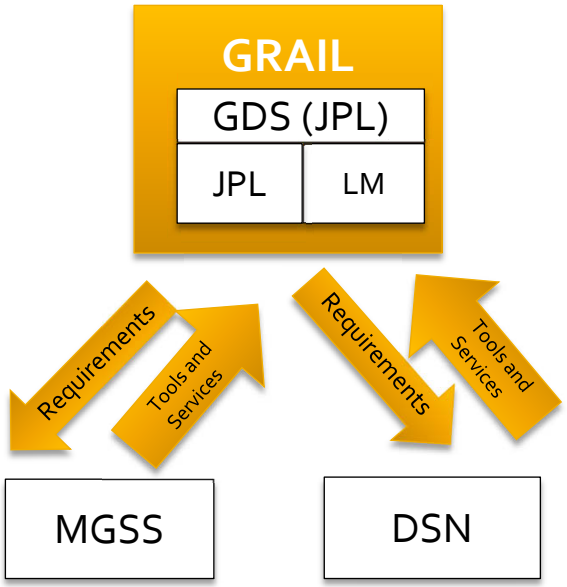
- GRAIL : Gravity Recovery and Interior Laboratory
  - NASA Discovery Program
  - Two spacecrafts working in tandem to determine the structure and interior of Moon, and thermal evolution
  - Sally Ride Science (MoonKam)
    - Education Public Outreach
      - Middle School students
        - Identified points of interest on the moon
      - 4 MoonKAM camera per spacecraft
  - Launched: September 10, 2011
  - Completed: December 17, 2012



- Successfully obtained gravity map of the Moon at a level of detail never obtained before

GRAIL and Multimission Organizations

- GRAIL
  - MGSS (Multimission Ground System and Services)
  - DSN (Deep Space Network)
  - LM (Lockheed Martin) – External Partner



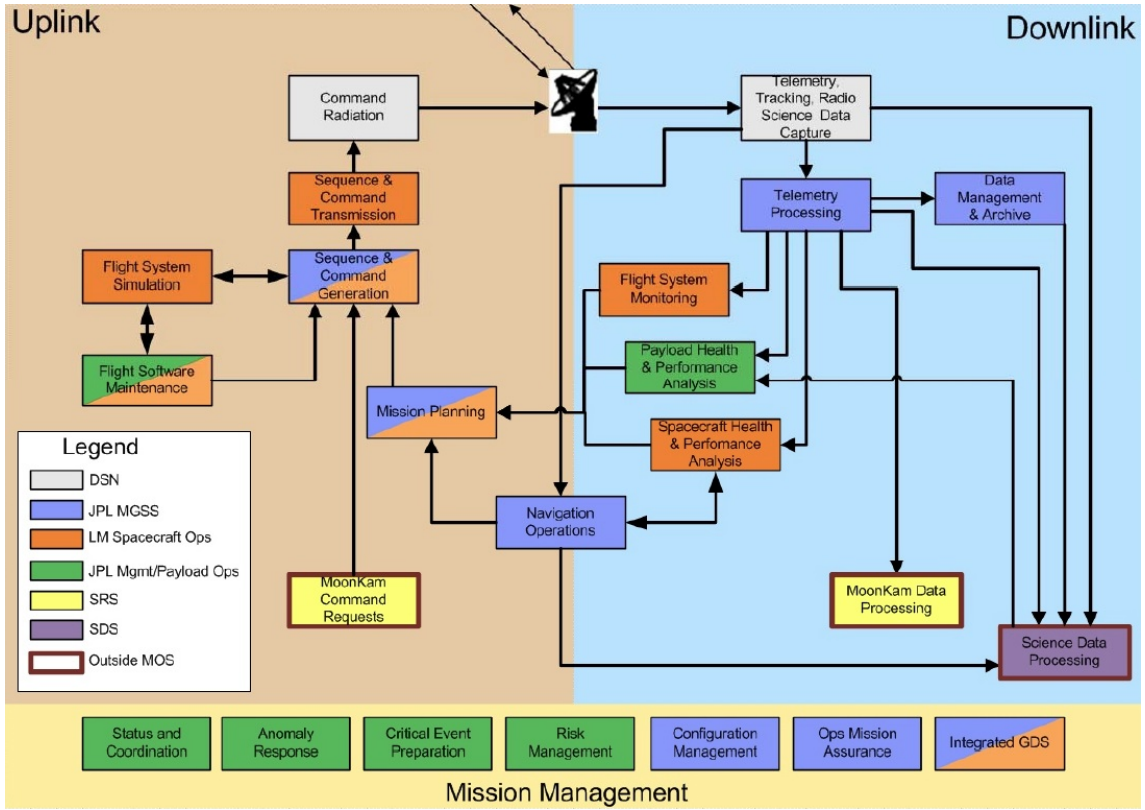


Diagram courtesy of Glen Havens

Multimission Overview

- MGSS (Multimission Ground System and Services)
  - AMMOS (Advanced Multimission Operations System) tools
    - Spacecraft Operations and Analysis
    - Sequence generation
    - Navigation
  - Shared Services (GRAIL / Odyssey / Juno)
    - Delivery and Deployment
      - Coordinated the deployment and delivery of AMMOS and Third Party Software to test and operational venues
        - Planned and presented test and delivery review and ensure mission schedules were met
    - Configuration Management
      - Coordinated with project for delivering software and associated documents
      - Received, archived, and installed delivered software to test and operational venues
      - Audited workstations for proper software installation
    - Network Services and System Administration
      - Procured and configure multimission hardware at JPL's and Lockheed Martin's test and operational venues
    - AMMOS System testbed and test
      - Performed multimission and project specific testing

Multimission Overview

- MGSS (Multimission Ground System and Services)
  - Multimission GDS support
    - Provided GDS support for test, trouble-shooting, and critical events
  - Network and Facilities
    - Provided shared workstations, servers, and storage systems between the 3 projects at JPL and Lockheed Martin
    - Provided JPL Mission Support Areas and test beds
- DSN (Deep Space Network) Tools and Services
  - Tools
    - Command
    - Telemetry processing and analysis
  - Services
    - Telemetry processing
      - Telemetry and storage processing tools
    - DSN station support

Benefits and Costs

- Multimission System Administrator
  - Benefit: Pool of experienced SAs shared between the 3 missions ensuring coverage without additional cost
    - 24/7 SA shared access without 24/7 cost
    - SAs experienced with knowledge from current and past missions
  - Cost: SA support due to overlapping mission critical events
    - Ex. Juno "KSC" launch support vs. GRAIL ORT and launch preparation
    - Mitigation: With careful coordination, SA resource contentions were alleviated
- Multimission Testbed
  - Benefit: Provided testbed hardware and facilities
    - Furnished facilities and established network connectivity
    - "Multimission" test workstations
      - Multimission workstations allowed testers to log into workstations (if needed) that were not "officially" dedicated to GRAIL. (e.g. Juno test workstations)
  - Cost: Required software deployment coordination between "partnered" missions
    - GRAIL and Juno scheduled software deployment windows conflicted occasionally causing delays and requiring additional coordination between MGSS Deployment Lead and affected missions

Benefits and Costs

- Multimission Support Area (MSA)
  - Benefit: Did not have build new MSA for project
    - Utilized existing (remodeled) full functional MSA (JPL)
      - Power and network port
        - Only need to swap/activate port for project
      - Phone and Comm Units
      - Air Handling
      - Updated Audio-Visual capabilities
        - New projectors/screens and workstation projection capabilities
        - JPL TV Camera mount
      - Close proximity to SA and GDS support
      - Backup/Overflow MSA support (Opposite room from main MSA)
    - Only need to add new workstations/monitors and activate ports
  - Cost (Minor): MSA was located in different building from the GRAIL project
    - At project request

Benefits and Costs

- Shared AMMOS Software Design and Development
  - Benefits: Software components were contained within the "multimission" family Planning and scheduling of multimission deliveries
    - Each mission brought along components, requirements, and oversight that added value to all missions
  - Cost: Shared software while beneficial to all missions, required additional "project" regression testing of the "core" multimission software updates made for other projects (e.g. Juno, Odyssey), but not required for GRAIL
- MGSS Multimission System Delivery Coordination
  - Benefits: Ensured software developments and delivery met customers need and schedule.
    - Supported system and subsystem reviews
    - Planning and scheduling of multimission deliveries
    - Coordinating the software delivery to CM and to the missions
  - Cost: Needed very close coordination between project representatives and MGSS Delivery leads for multimission shared GDS delivery contents, schedules and deployments
- Multimission Software Configuration Management
  - Benefits: Managed delivered software for the missions
    - Archived software
    - Provided workstation audits to ensure completeness and correctness of deployed software for each mission
    - Provide ongoing software configuration support between development organizations and missions
      - Maintained MCR (Mission Change Request) process for multimission customers.
      - Managed Multimission Change Control Board and resolved issues between the 3 missions.
    - Deployed software to the multimission (OPS/testbed) and Project specific environments (STL/ATLO)
  - Cost: Increased process time and mission representation effort to coordinate between 3 missions for MCR, delivery and deployment processes

Summary

- Using multimission services allowed GRAIL GDS to utilize the experience and services already available without having to "reinvent the wheel"
- Allowed GRAIL GDS to meet commitments and schedules within a limited budget without additional schedule
- The benefits using the "multimission" environment outweighed the associated costs
- GRAIL GDS performed exceptionally from Launch to Lunar impact