# GRAIL: Achieving a Low Cost GDS within a Multimission Environment

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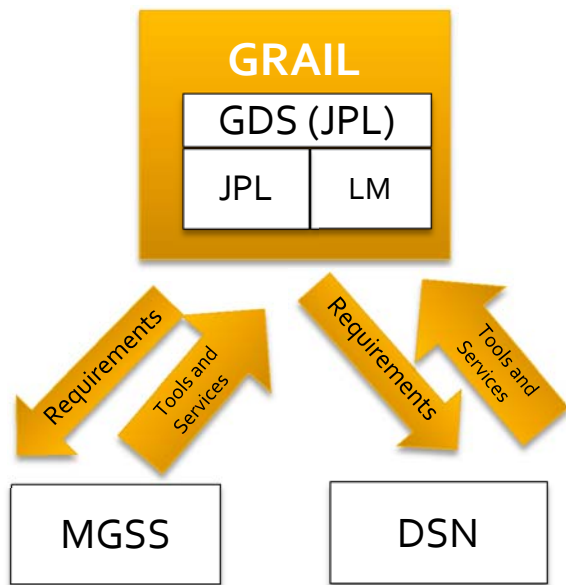
Grail Overview

- GRAIL : **G**ravity **R**ecovery **a**nd **I**nterior **L**aboratory

    - NASA Discovery Program
    - Two spacecrafts working in tandem to determine the structure and interior of Moon, and thermal evolution
        - Spacecrafts provided by Lockheed Martin

    - Sally Ride Science (SRS) 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
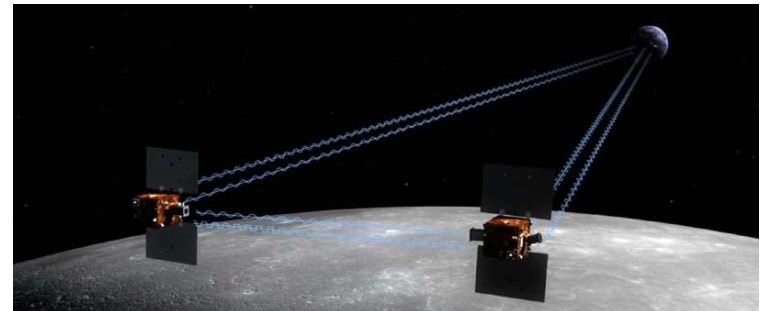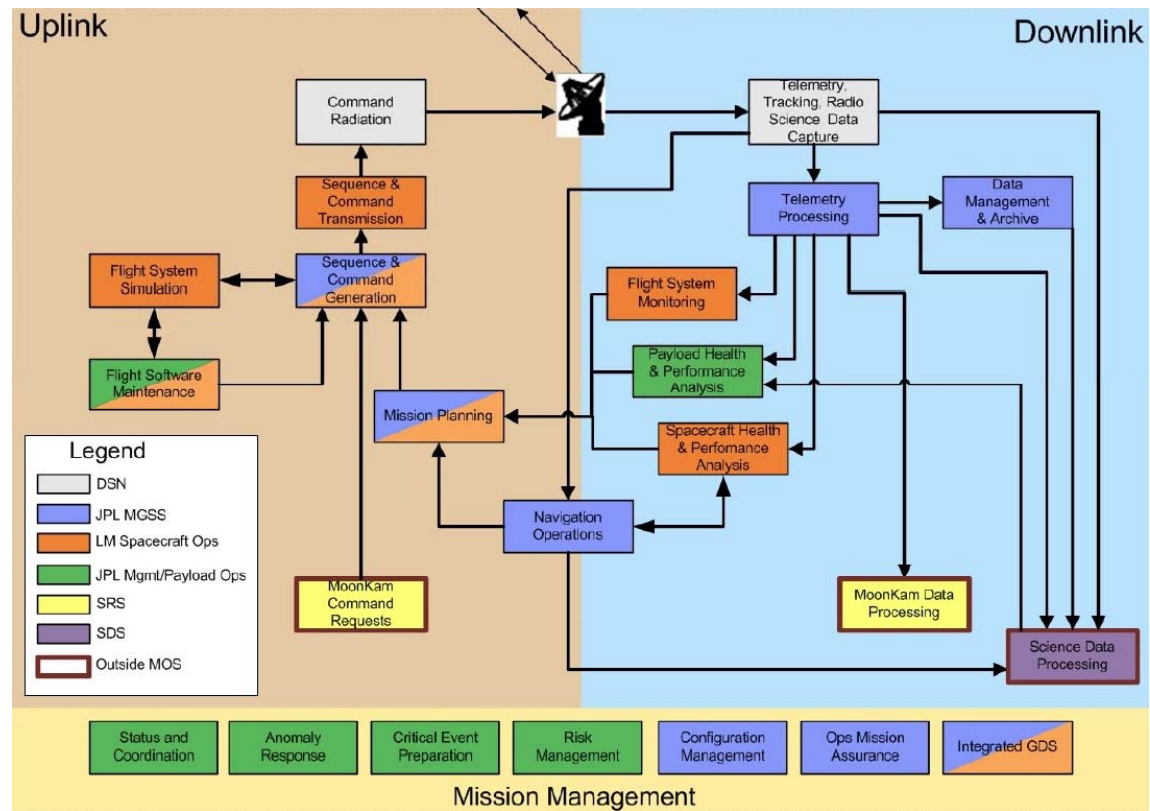
GRAIL and Multimission Organizations

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

GRAIL

GDS (JPL)

| JPL | LM |

Requirements
Tools and Services
Requirements
Tools and Services

MGSS   DSN

DSN - Deep Space Network
LM - Lockheed Martin
MOS - Mission Operations System
SDS - Science Data Systems
SRS - Sally Ride Science

Uplink / Downlink

Command Radiation
Sequence & Command Transmission
Flight System Simulation
Sequence & Command Generation
Flight Software Maintenance
Mission Planning
MoonKam Command Requests
Navigation Operations

Telemetry, Tracking, Radio Science Data Capture
Telemetry Processing
Data Management & Archive
Flight System Monitoring
Payload Health & Performance Analysis
Spacecraft Health & Performance Analysis
MoonKam Data Processing
Science Data Processing

Legend
- DSN
- JPL MGSS
- LM Spacecraft Ops
- JPL Mgmt/Payload Ops
- SRS
- SDS
- Outside MOS

Mission Management
Status and Coordination | Anomaly Response | Critical Event Preparation | Risk Management | Configuration Management | Ops Mission Assurance | Integrated GDS

GRAIL: Achieving a Low Cost GDS within a Multimission Env

Diagram courtesy of Glen Havens

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Multimission Overview

- **MGSS (Multimission Ground System and Services)**
  - **Shared Tools**
    - AMMOS (Advanced Multimission Operations System)
      - 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 team
      - Performed multimission and project specific testing

Multimission Overview

- Shared Services (GRAIL / Odyssey / Juno) - Continued

    - DSN (Deep Space Network) Scheduling
        - Coordinated and scheduled DSN antenna tracks for project
    - 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 shared projects at JPL and Lockheed Martin
        - Provided JPL Mission Support Areas and testbeds

- DSN (Deep Space Network) Tools and Services
    - Shared Tools
        - Command
        - Telemetry processing and analysis
    - Shared 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 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 to build new MSA for project at JPL
    - Utilized existing (remodeled) full functional MSA (JPL)
      - Power and network ports
        - Only need to swap/activate ports for project
      - Phone and Comm Units
      - Air Handling
      - Updated Audio-Visual capabilities
        - New projectors/screens and workstation projection capabilities
        - JPL TV Camera mounts
      - 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
    - 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 customer needs 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 <u>very</u> 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 shared 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 shared 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 <u>benefits</u> using the "multimission" environment outweighed the associated <u>costs</u>

- GRAIL GDS performed exceptionally from Launch to Lunar impact