Fresnel Lens Gamma Ray Telescope

Mission Operations

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January 10, 2002

Mission/Science Operations Topics

- Recommended Implementation Approach
- Recommended Operations Staffing Approach
- Critical Requirements and Assumptions
- Cost Summary
- End-to-End Cost Summary
- Technology Development Needs
- Additional Trades to Consider
- Risk Assessment
- Issues and Concerns
- Back-up Slides

Mission/Science Operations Recommended Development Approach

- **Use COTS-based MOC as basis for FL Gamma Ray MOC implementation, with automation to allow unstaffed operations**
  - Will provide sufficient capabilities to satisfy all requirements
  - Several software packages (ITOS, EPOCH 2000, ALTAIR) are commercially available and provide required functionality
  - No mission requirements which drive MOC technology -- technology required is readily available and operational today for several spacecraft.
    - Formation control is performed “on-board” using crosslinks/appropriate technology and is not controlled by MOC.
- **Level 0 processing requirements can be satisfied with COTS hardware and heritage software.**
  - No significant latency requirement
  - Very low data rates:
    - 6 kbps for Detector spacecraft
    - 5 kbps for Lens spacecraft

Mission/Science Operations
Recommended Operations Staffing Approach

- **Recommend 8x5 (weekday, prime shift) staffing profile for routine mission operations**
  - **Most cost-effective solution**
- **Relatively simple mission operations concept allows 8x5 operations approach to be pursued:**
  - **Most instrument operations can be planned/scheduled prior to mission – modifications identifying new targets of interest do not require immediate response.**
  - **Infrequent space-ground contacts, nominally once daily for recorder dumps/command uploads**
  - **Maneuvers and formation control performed using on-board technology and are not controlled from the ground.**

Mission/Science Operations Critical Requirements and Assumptions

- **Data rates:**
  - Instrument detector data rate: 1 kbps (Detector spacecraft only)
  - Engineering data rate: 4 kbps for each spacecraft
- **Data Latency and Quality:**
  - No driving data latency requirement
    - Assumption: Level 0 (L0) data sets will be created and distributed daily, constituting of all data (~24 hours) from single recorder dump daily.
    - Nominal latency would be ~1 hour after ground receipt of all instrument data to complete L0 processing.
  - Data Recovery Requirement = 98%
- **Space-Ground contact profile**
  - Return Link:
    - Ground Stations: Single contact per day @ DSN Goldstone (34m) @ 1 Mbps (using Ka-band)
      - Single downlink contains all detector data plus engineering data from both spacecraft
    - Forward Link: Single uplink per day at 2 kbps (using X-band)
      - Uplink contains commands for both Sensorcraft and Lens Spacecraft – commands are transmitted to Lens Spacecraft from Sensorcraft via crosslink
  - MOC functionality:
    - MOC provides "standard" set of functionality to support Mission Operations (e.g., S/C and instrument commanding,mission planning/scheduling, RT TLM monitoring, offline analysis), plus Level Zero processing.

Mission/Science Operations Costs 2 spacecraft option (1 Lens SC, 1 Detector spacecraft)

($K, FY 2002 $)

	3 Year	5 Year
Implementation/Maintenance		
Mission Operations		
Development		
Maintenance		
Ground Communications		
Sci Data Processing		
Development		
Maintenance		
Archival costs		
Operations		
Mission Ops		
Science Ops		
Grand Total		

Notes: o Above cost summary derived from separate cost spreadsheet
o Ground Station/space-ground link costs covered in Data Systems package

Mission/Science Operations Costs 3 spacecraft option (1 Lens SC, 2 Detector spacecraft)

($K, FY 2002 $)

	3 Year	5 Year
Implementation/Maintenance		
Mission Operations		
Development		
Maintenance		
Ground Communications		
Sci Data Processing		
Development		
Maintenance		
Archival costs		
Operations		
Mission Ops		
Science Ops		
Grand Total (3 S/C)		
Grand Total (2 S/C)		
Cost Difference		

Differences from 2 spacecraft option
--- Additional $XXX K needed in development to provide 4th operational string within MOC
--- Additional $XXX K needed for pre-launch testing and operations
--- Additional ~$XXXK/yr needed for operations (staff grows by one person to handle additional spacecraft management as well as planning and scheduling within MOC).

Mission/Science Operations Cost Basis of Estimate

- **Mission Operations Cost Assumptions**
  - MOC located at GSFC, but really could be anywhere (i.e., not a cost driver)
    - Costs do not assume reuse of any existing hardware or software
  - For MOC real-time and data processing support, assuming 3 logical strings
    - Prime, Backup, and Dev/Test support
    - Provides required automation functionality and necessary RMA
  - L0 data sets are electronically delivered to science processing system @ GSFC when complete.
- **Operations Staffing Cost Assumptions (2 spacecraft option)**
  - First year (L-30 mos. to L-18 mos.): 1.2 heads for ops planning activities
  - Second year (L-18 mos. To L-6 mos.): 3.3 heads for development/test of ops products and plans
  - L-6 mos. to L+3: 6.1 heads for pre-launch ops rehearsals/sims, launch support, early orbit checkout, etc.
  - Nominal (4.1 heads) staffing level reached at L+12

Total End-End Cost (Includes Data Systems/Communications/Mission Science Ops)

Total costs for 3 years/5 years of operations

- Data Systems/Hardware costs = $XX M
- Data Systems/I&T costs = $XX M
- Data Systems/Operations = $XX M/$XX M
- Mission/Science Operations = $ XX M/$XX M
- Total = $XX M/$XX M

Mission/Science Operations Technology Development Needs

- None -- all technologies required to allow unstaffed operations/remote user access on off-shifts currently available and in use on several other missions.

Mission/Science Operations Additional Trades to Consider

- **May want to consider implementing some sort of on-board technology to autonomously determine spacecraft health and status, without ground system intervention.**
  - Similar technology (BEAM) implemented in JPL's Deep-Space One program
    - Unclear if this technology can detect/determine all possible spacecraft faults which could occur.
  - Will allow reduction in space-ground contact time required.
    - Science requirements do not "drive" current assumption of one dump per day, this was proposed to provide sufficient insight into spacecraft health and safety by ground system personnel.

Mission/Science Operations Risk Assessment

- **Mission Operations approach presented completely dependent upon successful deployment of appropriate technology (communications, ranging, orbit determination, flight software, etc) to control formation between Lens Spacecraft and Detector Spacecraft.**
  - Given the magnitude of the formation control requirements in terms of knowledge and accuracy, a solution with the ground in the loop is not feasible.

Mission/Science Operations Issues and Concerns

- No issues or concerns with proposed approach

Mission/Science Operations Backup Charts

Mission/Science Operations Driving Mission Characteristics

- **Launch: July 2012**
- **Mission lifetime: 3 years minimum, 5 years desirable.**
- **Orbit overview: Heliocentric, Drift away. Lens Spacecraft and Detector Spacecraft seperated by 750,000 km**
- **Space-Ground contacts:**
  - **1 station contact per day @ DSN Goldstone (34m)**
    - **1 Mb/s downlink (Ka-band)**
    - **2 kb/s uplink (X-band)**
- **Data rates:**
  - **6 kbps aggregate rate from Sensorcraft, 5 kbps from Lenscraft**
    - **Average instrument data rate: 1 kbps average**
    - **Engineering/HK: 4 kbps (assumed) for each spacecraft**
    - **Protocol overhead added (20%)**
- Spacecraft overview
  - **IP compliant**
  - **48 hours of on-board data storage**

Mission Operations Driving Requirements

- **Support operations of FL Gamma Ray Sensorcraft and Lenscraft**
  - Processing/display of real-time telemetry and status data
  - Spacecraft and instrument commanding
  - Ground Station (GS) scheduling
  - Engineering data analysis
  - Clock correlation/calibration
- **Interact with ground station for satellite communications**
  - Telemetry, command and status data
  - Electronic transfer of data to MOC during each contact
  - Station scheduling (as required)
  - Voice communications

Mission Operations Driving Requirements (cont.)

- **Provide automation to facilitate reduced operations staffing, to include "lights-out" operations on weekday off-shifts and weekends**
  - **Automatically recognize alarm conditions and notify remote operations personnel during unstaffed operations**
  - **Automatically handle receipt of data dumps from GS's and generation/delivery of Level 0 data products**

Mission Operations Assumptions

- "Lights-Out" operations approach acceptable for normal operations to minimize operations costs
- Satellite can nominally operate for up to 3 days without ground contact
  - Spacecraft and instrument autonomously manage health-and-safety (i.e., they will detect problems and safe themselves when necessary)
- Typical Real-Time System Reliability, Maintainability, and Availability (RMA) is required
  - Hot backups needed for critical telemetry and command processors
- Typical command constraint checking is sufficient
- Formation flying/formation control technology on-board both Lens spacecraft and Detector spacecraft.
- Minimal planning and scheduling needed given simplicity of instrument operations

Mission Operations Technologies Required

- **MOC must provide sufficient technology to automate handling of specific functions/activities**
  - **Automatically process real-time data (housekeeping and science)**
  - **Automatically monitor telemetry, recognize error/alarm conditions, and notify offsite operations staff**
  - **Provide remote offsite operations personnel with remote access to data without violating security requirements**
  - **Automatically perform engineering analysis on housekeeping data**
    - Generate trend plots, statistics reports, etc. for FOT analysis
    - Recognize error/alarm conditions and notify remote operations personnel

Mission/Science Operations Subsystem Summary

- **Technology Readiness Level: 8-9 (most required technologies have been at least demonstrated, most in currently operational systems)**
- **Space-GND contacts:**
  - DSN Goldstone (34m)
    - 1 Mb/s downlink (Ka-band)
    - 2 kb/s uplink (X-band)
- **Planning and Scheduling Requirements: Minimal**
- **Technology Complexity: Minimal, currently available/operational technology proposed in most instances.**
- **Risk: Low, assuming successful on-board operation of formation flight/control technology.**