Solar Imaging Radio Array (SIRA)

Mission Operations

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25-28 August 2003

Competition Sensitive

Topics

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- Technology Required
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- Risk/Issues and Concerns
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Study Activities

- **Provide a grass roots cost analysis based upon the supplied customer requirements for the following options:**
  - Baseline: Spacecraft **is not** reoriented to dump the data
  - Option 1: Spacecraft **is** reoriented to dump the data
  - Option 2: Spacecraft **is not** reoriented to dump the data
- **Note that this presentation reflects the Baseline. The difference in cost for Option 1 and Option 2 are detailed in the Cost slides.**

Customer Requirements and Assumptions

- **Launch date: 2009**
- **Mission Life: 2 Year Requirement, 4 Year Goal (assumes Lunar Swing-By Insertion of 7 days)**
- **Orbit:**
  - Near Retrograde Orbit (NRO) at < ≈ 500,000 Km from Earth
  - Orbit inclination relative to the ecliptic should be less than 10 degrees
- **Constellation: 12 microsats required, 16 microsat goal**
- **Data Rates: ≈ 2.245 Mbps aggregate for all 16 microsats**
  - Instrument Collection Rate: ≈ 120 Kbps per microsat
  - 2 Kbps Engineering/Housekeeping
  - 15% CCSDS Overhead (Reed-Solomon Encoded)
- **Data Latency Requirements:**
  - 24 hour Level Zero product delivery for all 16 microsats
- **Data Recovery:**
  - Assume 90% recovery requirement (end-to-end)

Customer Requirements and Assumptions

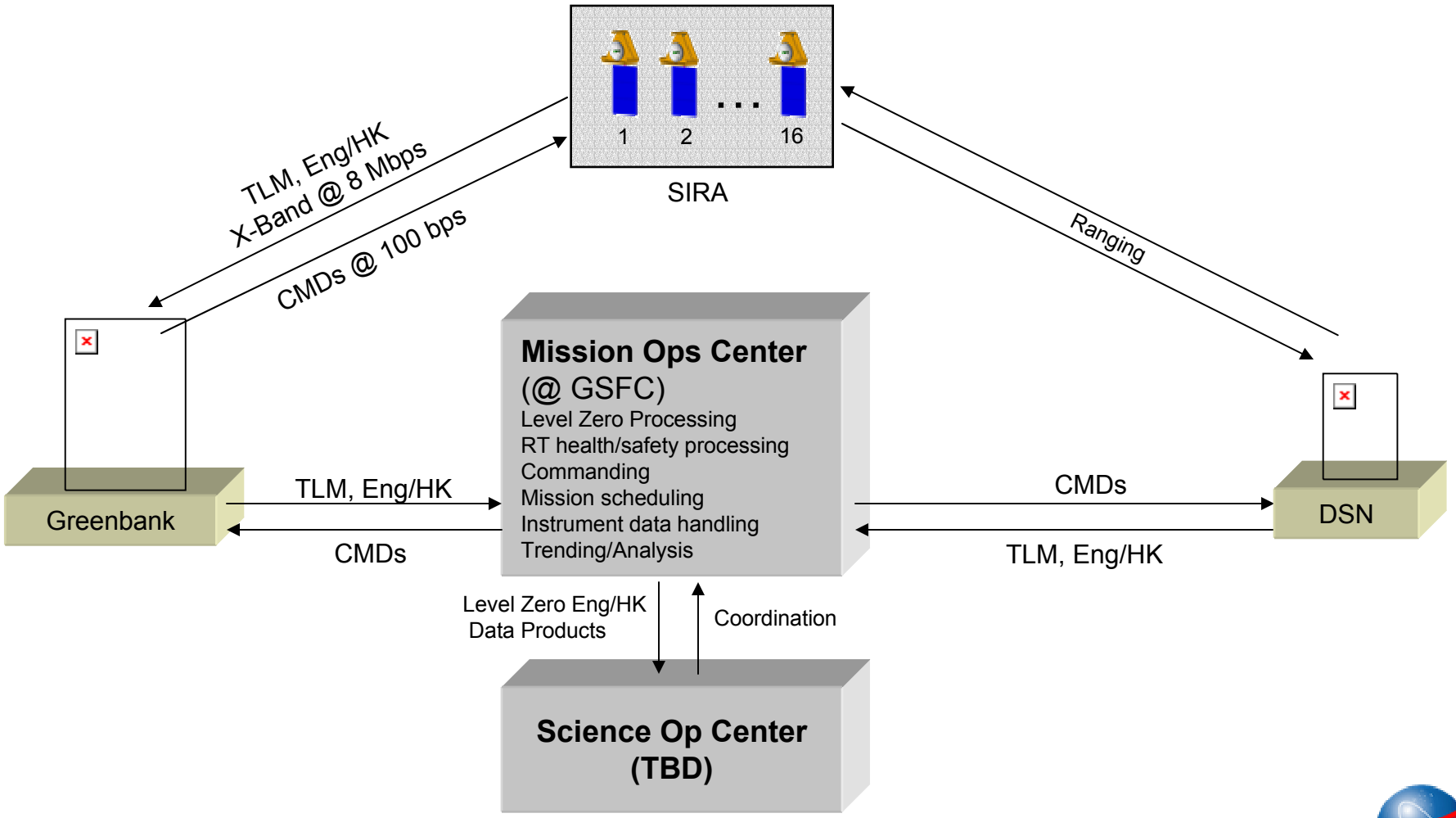
- **Space-Ground contact profile**
  - Return Link:
    - Sixteen (one for each satellite) 25 minute X-Band contacts/day to Greenbank, WV @ 8 Mbps
    - Each satellite maneuvers to point at the Earth, dumps data, and maneuvers back
    - Each satellite dumps one after the other in a successive manner
  - Forward Link: X-Band @ 100 bps (assume once/day for each satellite)
  - 2 days on-board storage (20 Gb)
- **No orbit maintenance over life of mission, but periodic ground Orbit Determination assumed, and constellation maintenance assumed**
- **Level 0 Products: Time-ordered, quality annotated data sets produced for each contact (minimizes data latency)**
- **Mission Operation Control (MOC):**
  - Located at GSFC, but could be anywhere
  - Provides “standard” set of functionality to support Mission Operations (e.g., S/C and instrument commanding, mission planning/scheduling, and RT TLM monitoring, trending and analysis), plus Level Zero processing.
- **Level Zero Processor (LZP):**
  - Co-located with MOC at GSFC (cheaper comm link costs), but could be anywhere

Technology Required

- **Use COTS-based MOC as basis for MOC implementation**
  - Will provide sufficient capabilities to satisfy all requirements except for planning and scheduling, and constellation monitoring.
  - Software packages are available to satisfy most MOC required functionality:
    - Instrument Remote Control (IRC) was developed by the Government and provides required functionality for instrument commanding and monitoring. It is XML based and highly flexible.
    - ITOS, ASIST, EPOCH 2000, ALTAIR are commercially available today and provide required functionality for Spacecraft Command/Control and Level Zero Processing.
  - Additional automation can be developed to allow unstaffed operations on off-shifts
- **Technology Readiness Level: 5, 8-9**
  - All required technologies have been at least demonstrated, most in currently operational systems, except for control and monitoring related software (TRL 5)
- **Technology Complexity: Minimal, currently available/operational technology proposed in virtually all instances, except control and monitoring related software.**

Ground System Functional Architecture

Integrated Mission Design Center



Cost Summary

Integrated Mission Design Center

(FY 2004 $K, includes Full Cost Accounting)

	Pre-Launch 2 / 4 Year	Post-Launch 2 / 4 Year	Total 2 / 4 Year
Development, Mission Ops	$4,420 / $4,420		$4,420 / $4,420
Development, Science Ops	$0 / $0		$0 / $0
Pre-Launch Testing/Ops	$1,852 / $1,852		$1,852 / $1,852
Post-Launch Operations		$4,937 / $7,289	$4,937 / $7,289
Maintenance / Consumables		$1,386 / $2,692	$1,386 / $2,692
Communications Links	$98 / $98	$270 / $536	$368 / $634
Total	$6,370 / $6,370	$6,592 / $10,517	$12,963 / $16,887

Option 1 *increases* the total 2 / 4 Year cost by $168K / $429K due to increased FTEs
- Pre-Launch Testing/Ops + $75K, and
- Post-Launch Operations + $93K / $174K

Option 2 *lowers* the total 2 / 4 Year cost by (-$102K / -$195K) due to fewer FTEs
- Pre-Launch Testing/Ops -$7K
- Post-Launch Operations -$95K / -$188K

Cost Basis of Estimate

- **Development Cost Assumptions**
  - MOC/LZP co-located at GSFC (but could be anywhere)
    - Costs do not assume reuse of any existing hardware or software
  - For MOC planning/scheduling, command load generation/validation and data processing support, assuming 5 logical strings
    - Three Prime (one string handles 5 or 6 microsats), One Backup, One Dev/Test/Support
    - Provides required Redundancy, Maintainability and Availability (RMA)
  - MOC functions (including Level Zero Processing and distribution) are provided by commercial and/or GOTS software
  - Mission-specific software development labor included for planning/scheduling, automation and other mission unique software, e.g. constellation monitoring specific software, etc.
- **Operations Staffing Cost Assumptions (*Includes estimates for Full Cost Accounting*)**
  - 8 x 5 operations staff
  - Size of operations staff during orbital operations (L+12 to EOM) = 9.8 FTEs
    - Option 1 increases FTEs by 0.2 for "Command/Memory Load Generation/Validation" and "Flight Dynamics" support due to repositioning spacecraft for downlinks
    - Option 2 lowers FTEs by 0.25 for Flight Software Maintenance because there is no articulated array nor is the spacecraft repositioning for downlinks
  - Ops staff costs begin around L-30 months to support pre-launch activities
  - Ramp-down to nominal operations planned for L+12 months

Cost Basis of Estimate (cont.)
FOT Staffing

Integrated Mission Design Center

WBS Item	Base (Annual)	Description
Mission Planning & Scheduling		
Planning On-Board Instrument Operations	0.00	1 Instrument, but no instrument ops planning
Planning On-Board Spacecraft Operations	0.50	Elevated s/c ops planning needed due to 16 s/c, and complexity of downlink
Planning Contacts	0.50	Effort for scheduling 16 contact/day
Command/Memory Load Generation/Validation	0.30	Covers one load/day average per s/c, increase by 0.1 if complicated by reorienting for dumps
Flight Dynamics (orbit & attitude)	0.10	Nominal constellation maintenance and OD required, increase by 0.1 if complicated by reorienting for dumps
Real-Time Operations		
Monitor and Command	0.40	7 hours/day (assumes significant automation)
Ground Communication/Troubleshooting	0.20	1 ground station
Offline Analysis		
Spacecraft Performance/Anomaly Analysis	1.25	FOT personnel to perform S/C performance assessment
Instrument Performance/Anomaly Analysis	0.20	FOT personnel to perform Instrument performance assessment
Data Processing/Mgmnt (Level 0)		
Product Management	0.50	16 Level 0 dataset/24 hr
Scheduling/Space-ground data management	0.30	Nominal retransmissions expected
Miscellaneous Support		
Data Base/File Management	0.10	
Configuration Management	0.10	
Network/LAN Management	0.10	
System Administration	0.10	
Flight Software Maintenance	1.25	Baseline/Option 1 at 1.25, Option 2 drops to 1
Shift Overhead (to cover vacation, sick leave, etc.)	1.48	
Operations Team Travel/Coordination		Only needed for travel/coordination for international missions
Operations Team Management/Admin Support	0.47	
Subtotal (# of Heads)	**7.8**	
Ground System Manager/System Engineer		Covers SOM through Commisioning
Mission Director	1.00	Covers Implementation through 3 months after EOM
Project Administration Support	1.00	
Total (# of Heads)	**9.8**	

Cost Basis of Estimate (cont.)

- **Communications Link Cost Assumptions**
  - Data Volumes (Driver for circuit costs): ≈ 23.8 GBytes/Day
    - ≈ 1.49 GB total contact data volume per spacecraft (with Eng/HK and CCSDS overhead)
    - 16 contacts/24 hours
  - Circuit required between Greenbank Ground Terminal and GSFC for raw data delivery
    - One T-3 circuit from Greenbank Ground Terminal to GSFC, $15K startup, $10K/mo
- **Product Delivery: ≈ 25 hour from each spacecraft to customer (*cannot be delivered in time** to meet requirements given 23.6 hours between contacts)**
  - 25 minutes from each Spacecraft to Greenbank Ground Terminal (assumes that for Option 1 the next spacecraft in line to dump is moving into position 15 minutes prior to the completion of dumping for the previous spacecraft to allow for consecutive dumps)
  - ≈ 4.5 minutes from Ground Terminal to GSFC
  - 30 minutes (estimated) Level Zero Processing assuming one dataset/contact to FTP server for customer pickup (nominal case). Retransmissions will delay delivery of Level Zero datasets.
  - Customer transfers data from the data distribution server located at GSFC

*** See issues**

Risk/Issues and Concerns

- There is no ground station backup planned for this mission. If problems occur, a significant amount of data could be lost, or the DSN will have to be used. DSN use is not factored in this study.
- With a 24 hour contact period, it is impossible to meet the 24 hour data latency requirement, given dump, transfer and processing times. The actual time calculated for this study is about 25 hours.

Additional Trades to Consider

- **Add a second ground station to allow for 12 hour contact periods in order to meet the 24 hour data latency requirement. In addition, the second ground station will eliminate a single point of failure.**
  - Adding the second ground station will increase the cost of operations due to communication links between second site and GSFC, and the FTE increases for Level Zero Product Management and Ground Station Troubleshooting. The cost, assuming Australia, of the second site would be around $500K-$600K.
- **With a launch date of 2008, IP could be considered as opposed to CCSDS. This study reflects a CCSDS protocol. The only change to the numbers in this study would be an added %5 of data acquired on the ground from the spacecraft. This study reflects CCSDS to minimize risk.**
- **Reuse of an existing MOC has the potential to save significant money**
  - Existing infrastructures could save the cost of MOC (maybe LZP) hardware
  - There will likely be Flight Operations Team (FOT) FTE savings. The exact number will have to be negotiated.
  - The cost of MOC development would likely be significantly reduced. The exact number will have to be determined.
  - Communication links and Level Zero Processor may still have to be provided.

Additional Trades to Consider (cont.)

- **9 Month Drift (low energy insertion)**
  - Mission duration increases from 2 years to 2.75 years
  - At L+1 down staff to minimal staffing profile
  - At L+8 restaff/prep for L+9 separation and operations
  - Cost increases from Lunar insertion by $736K

	Pre-Launch 2.75 / 4.75 Year		Post-Launch 2.75 / 4.75 Year		Total 2.75 / 4.75 Year	
Development, Mission Ops	$4,420 /	$4,420			$4,420 /	$4,420
Development, Science Ops	$0 /	$0			$0 /	$0
Pre-Launch Testing/Ops	$1,852 /	$1,852			$1,852 /	$1,852
Post-Launch Operations			$5,084 /	$7,436	$5,084 /	$7,436
Maintenance / Consumables			$1,876 /	$3,181	$1,876 /	$3,181
Communications Links	$98 /	$98	$370 /	$636	$467 /	$734
Total	$6,370 /	$6,370	$7,329 /	$11,253	$13,699 /	$17,624