Solar Imager Radio Array (SIRA) High Energy Transfer

System Overview

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Competition Sensitive

Outline

- Requirements / Customer Inputs
- Baseline Configuration
- Trades / Options
- Comments, Issues, Concerns

Study Overview

- **Mission objective**
  - Image low frequency (<15 MHz) from coronal mass ejections, interplanetary shocks, etc."
  - Also serve as a pathfinder for more complex interferometry missions
- **Additional constraints, challenges**
  - Up to 16 satellites within MIDEX cost constraints
- **Purpose of Study**
  - Establish baseline requirements in preparation of a MIDEX (SEC) Proposal
- **Length of Study**
  - 4 days

Science Overview

	Mission Objective	Measurement	Performance Drivers	Priority
1	Image and track propagation of CMEs from 2 R_sun to 1 AU	Image type II and type III radio bursts from 2 R_sun to 1 AU; image thermal emission from CMEs from 2 to 20 R_sun	system sensitivity~100 kJy; ~16 microsats = >100 baselines; uniform u-v aperture plane covereage in 20 km constelllation	1
2	Understand particle acceleration by flares and CME-driven shocks	Image type II and type III (particularly type IIIL) bursts from 2 R_sun to 1 AU	same	4
3	Improve the prediction of CME Earth arrival times for space weather forecasting	Image type II bursts from 2 R_sun to 1 AU; need snapshot image within ~24 hr (12 hrs preferable), update every 5 min	same	2
4	Provide global imaging of Earth's magnetosphere to better understand its response to CMEs, etc.	Image the terrestrial magnetosphere (scattering limited resolution); 5 min time resolution	same (L1 halo orbit not favorable)	3
5	6) Image galactic and extragalactic radio sources from 0.3-15 MHz, providing the first high resolution full-sky map at these frequencies	Image the full sky at 16 log-spaced freq. from 0.3-15 MHz w/ angular resolution in antisunward direction ~10 arcsec at 15 MHz	higher system sensitivity required (100 Jy) obtained by integrating over entire mission	5

High Energy Transfer Concept, Baseline System Configuration

Mission	Launch	Orbit Type	Stationkeeping	Mission total delta-v
	10/1/2009 Launch in early phase of solar maximum desired ~ 2009-2010 (no later than 2012)"	Distant retrograde orbit" (DRO) at 500.000 km from Earth Orbit inclination relative to the ecliptic ~20 degrees DRO instertion take 7 days using Lunar gravity assist plus 500 m/s for orbit insertion (alt. option is low energy transfer: takes 272 days plus 50 m/s)	Distribute nanosats over a spherical shell of 5 - 25 km radius Station coordinates calculated on gnd and uplinked Inter-microsat ranging to 3 m Absolute orientation of the constellation knowledge 0.5 deg	Dispersion Correction: 10 m/s Orbit Insertion: 500 m/s Stationkeeping / Repositionings: cold gas ACS / Momemtum Unloading: cold gas EOL Disposal: n/a
LV	LV 1	LV 2	Stack Propulsion Module	Alternate Orbit Inject. Motor
	Delta 2925H-10 Throw mass: 1495 kg	Delta 2925-10 Throw mass: 1240 kg	Custom Built biprop system	Star 24, 560 kNs, 218.2 kg w/ 200 kg propellant (Not suitable for LV dispersion correction)
MA, QA	Life	Size Consumables / Quote	Redundancy	Disposal
	2 yrs req / 4 yrs goal	4 yrs	Single string for each microsat System level redundancy for common functions (Stack / Layer Controllers in Cruise Phase, Time reference)	Not required
Observe Ops	Boresight	Attitudes	Observations	Data Rates
	12 - 16 s/c All sky monitoring Each microsat has 2 orthogonal dipoles with receivers	Microsats are 3-axis stabilized Dipole antennas parallel to within 2 deg (know to 1 deg) on all microsats	Absolute timing ~0.1 sec Relative timing of μsats ~1 μsec Oscillators phase locked to a common reference	Science data downlink rate 8 Mbps Vary observ. duty cycle Downlink microsats sequentially over 6 - 7 hrs once per day

High Energy Transfer Concept, Baseline S/C Bus Subsystems Configuration

Mech	Structure, Mat'ls.	Payload Accommodations	Mechanisms	Volume and CG	Comments
	Triangle, composite		structure, comm antenna mount, deployable& articulate solar array		Cost - Copies 1-4 (ETU, Prototype, 2 flight units) - $1.36M FY03 Copies 5-n - $1.06M FY03
ACS	Driving Requirements	ACS type	Sensors	Actuators	ACS Modes:
	Cost	Control: +/- 2 deg Knowledge: +/- 1 deg	Three-Axis Stabilized with Momentum Bias	Star Tracker (1) Sun Sensor (1) Reaction Wheel (1)	Earth Pointing Sun Pointing Safehold (optional)
Therm.	Requirements	Technologies	Radiators	Heaters, Htr Pwr:	
	Maintain S/C bus between -10C and 40C, propulsion system at 15C	Passive, heaters, thermostats, MLI, coatings	0.5 m2 with NS43G paint	10C	
Prop.	Prop. types	Thrusters	Delta-v's	Propellant quantities	Tanks
	ST5 style cold gas	4 x 2N	64 m/s for 4 years	4.5 kg	1@10"d X 16"length, 16
Power	Max. avg. load, Bus Voltage:	Arrays, Cells	S/A Drives:	Energy storage, cycles:	PSE
	Bus at 104.1 watts, MAP like 28 Vdc EPS. 20% partial eclipses assumed. Battery discharge during Com Transmitt Mode	28% efficent solar cells @ .467 M2 at 70 Deg C. 20 deg cosine angle.	Single axis solar array drive.	Single Saft 9 ah, 8 cell battery	MAP Like PSE
C&DH	CPU	Redundancy	Data storage	Bus(ses)	
	Power PC 603/750	20 Gbits	Single String 1 us relative timing accuracy	CpCI MIL-STD-1553	50 krads
RF Comm	Downlink data volumes	Bands, Gnd Stations	S/c antennas	Contacts	Ranging Solution
	8 Mbps Downlink,2 kbps HSK Range tones -1Mbps crosslink	X-Band, VHF, UHF	0.6 M HGA, 6 omnis	1-25 min contact/s/c/day	Crosslink tones, DSN
Flight SW	SS Config Descr:	Key s/w functions:	Development approach	Test approach	Support
	C&DH, ACS, PSE flight software	3-axis stablized ACS	MAP/ST-5 C&DH and PSE FSW heritage		
Mission Ops	GND stations	MOC, Staffing Approach	Latencies	Communications Protocols	Error Correction, BERs
	Greenbank, WV	MOC/LZP @ GSFC, 8x5, 9.8 FTEs @ L+12 to EOM	Sixteen 25 Minute Downlinks/Day	CCSDS	10-5 Reed-Solomon for Downlink
Stack Prop.	Prop. types	Thrusters	Delta-v's	Propellant quantities	Tanks
	biprop + cold gas	1x440N 4x22N Biprop and 4 1N spin-up spin-down	500m/sec	250kg	4 12" tanks

High Energy Transfer Concept, Baseline Cruise Phase Overview

- **Configuration overview**
  - Two microsats dedicated as stack controllers (A/B redundancy)
    - Stack controller microsats ON during the entire cruise
    - Star tracker FOV on side of stack: placement OK for cruise
    - Comm w/ ground thru omni antennas on side of stack: placement OK for cruise
  - Bottom row microsats' batteries are pooled to power the Stack Propulsion Module
- **Timeline**
  - Dispersion correction 6 – 12 hrs after launch
  - Orbit insertion burn L+5 to L+7 days
    - Biprop system heaters on a few hours before operations
    - Ground trajectory verification and telemetry check before burn
    - Firing via uplinked timed commands
  - Jettison the Stack Propulsion Module
    - Let it slowly drift away

High Energy Transfer Concept, Baseline Destack and Disperse Operations

- **24 hours DSN support required during destack and disperse ops**
  - Two microsats (for redundancy) dedicated in each layer (6 microsats) as “layer controllers A/B”
- **Destack**
  - Destack all three (four) layers at the same time
    - Wait for layers to drift apart to a safe distance before any action is taken
    - Perform ranging and downlink it to ground
    - Ground to compute coordinates / attitudes / velocities and uplinks commands
  - Disperse all microsat in all three layers
    - Each microsats issues its own jettisoning command simultaneously
    - Wait for all microsats to drift apart to safe distances before any action taken
    - Perform ranging and downlink it all to the ground for every microsats
    - Ground to compute coordinates / attitudes / velocities and uplink fire commands for each microsat
- **Microsat cold gas systems must be sized with sufficient authority to recover from worst case drifting apart**
  - Assess max time durations before firings take place

High Energy Transfer Concept, Baseline One Microsat Mass Summary

SCIENCE PAYLOAD [kg]		
	Actual	Contingent
Payload	3.0	3.9
Total	3.0	3.9
S/C BUS SUBSYSTEMS. & STRUCTURE [kg]		
	Actual	Contingent
Mechanical	24.4	29.2
ACS	3.0	3.6
Thermal	2.0	2.4
Propulsion (4.5 kg cold gas, 3.5 kg plumbing)	7.0	8.4
Power	8.3	10.0
C&DH	9.7	11.6
RF Comm 1-3	25.0	30.0
RF Comm 4-16	23.0	27.6
Total (s/c 1-3)	79.4	95.2

High Energy Transfer Concept, Baseline Mission Mass Summary

TOTAL MASS w/ 16 Microsats [kg]		
	Actual	Contingent
PAYLOAD TOTAL	48.0	62.4
BUS SUBSYSTEMS DRY TOTAL	1243.8	1495.7
Observatory Stack Total Dry Mass	1380.8	1597.1
PROPELLANT	245.0	245.0
OBSERVATORY WET MASS	1625.8	1842.1
Launch Venicle capability to baseline orbit	1495.0	1495.0
Margin [kg]	-130.8	-347.1
Margin [%]	-8.7	

TOTAL MASS w/ 12 Microsats [kg]		
	Actual	Actual
PAYLOAD TOTAL	36.0	46.8
BUS SUBSYSTEMS DRY TOTAL	934.3	1124.8
Observatory Dry Mass	1045.3	1196.6
PROPELLANT	245.0	245.0
OBSERVATORY WET MASS	1290.3	1441.6
Launch Venicle capability to baseline orbit	1495.0	1495.0
Margin [kg]	204.7	53.4

High Energy Transfer Concept, Baseline First Microsat Bus Subsystems Cost

	Actual	w/ Cont.
Mechanical Hardware	0.1	0.2
Mechanical Labor	0.0	0.0
ACS Hardware	0.2	0.3
ACS Labor	0.0	0.0
Thermal Hardware	0.1	0.1
Thermal Labor	0.1	0.1
Propulsion Hardware	0.6	0.8
Propulsion Labor	1.4	1.8
Power Hardware	1.6	2.1
Power Labor	0.5	0.7
C&DH Hardware	1.8	2.3
C&DH Labor	2.9	3.8
TT&C Hardware	2.1	2.7
TT&C Labor	0.3	0.4
Flight Software Hardware Recurrent	0.1	0.1
Flight Software Labor Recurrent	0.1	0.1
Direct GSE (5% overhead on s/c hardware)	0.0	0.0
Spacecraft Bus Total	11.9	15.5

High Energy Transfer Concept, Baseline Mission w/ 16 S/C Total Cost

TOTAL COST w/ 16 microsats per SMAD Mass Prod Est. S= .85 [$M]	2003 $'s Actual	 w/ Cont.
PROJECT MANAGEMENT	6.6	7.3
PRE-LAUNCH INSTRUMENT TEAM SUPPORT	5.3	5.3
INSTRUMENTS TOTAL COST	excl.	excl.
16 SPACECRAFT BUS SUBSYSTEMS TOTAL COST	120.0	156.6
STACK PROPULSION MODULE TOTAL COST	1.1	1.4
FLIGHT SOFTWARE TOTAL COST	11.4	14.9
MISSION SYSTEMS ENGINEERING	3.9	4.9
ATLO & MISSION READINESS	20.8	26.2
LAUNCH VEHICLE	75.2	75.2
GROUND SYSTEM DEVELOPMENT	9.0	10.8
MISSION READINESS VERIFICATION	1.9	2.2
OPERATIONS	5.7	6.8
MISSION TOTAL	260.8	311.5

High Energy Transfer Concept, Baseline Mission w/ 12 S/C Total Cost

Mission TOTAL COST w/ 12 microsats [$M]	2003 $'s	
per SMAD Mass Prod Est. S=.85 [$M]	Actual	w/ Cont.
PROJECT MANAGEMENT	6.6	7.3
PRE-LAUNCH INSTRUMENT TEAM SUPPORT	5.3	5.3
INSTRUMENTS TOTAL COST	excl.	excl.
12 SPACECRAFT BUS SUBSYSTEMS TOTAL COST	96.0	124.8
STACK PROPULSION MODULE TOTAL COST	1.1	1.4
FLIGHT SOFTWARE TOTAL COST	11.4	14.9
MISSION SYSTEMS ENGINEERING	3.9	4.9
ATLO & MISSION READINESS	20.8	26.2
LAUNCH VEHICLE	75.2	75.2
GROUND SYSTEM DEVELOPMENT	9.0	10.8
MISSION READINESS VERIFICATION	1.9	2.2
OPERATIONS	5.7	6.8
MISSION TOTAL	236.8	279.7

Grassroots Costing Guidelines

- **Subsystem Hardware Costs Include**
  - Cost of all items and services purchased for the given Subsystem of the given Mission
    - All purchased components, materials, devices, etc.
    - All shipping costs, incoming inspection, and acceptance tests
  - All specialized tools, manufacturing and lab supplies, test equipment specifically purchased for and charged to the given Mission
  - Facility and services costs if used specifically for the given Subsystem of the given Mission
    - Such as subsystem level vibration test facility costs
  - All specialized support services when specifically purchased for and charged to the given Mission
    - Examples: EMI verification of an in house electrical box by outside lab; Spectral characterization of an optical components by outside lab; Finite element analysis by outside agent of a structure designed in house
  - The cost of all business travel directly related to acquire and manage the foregoing
- **Subsystem Labor Costs Include**
  - All direct subsystem production manpower
    - All the labor cost required to carry out all work for the given subsystem, that results in the subsystem product delivered to observatory/mission level I&T
    - Include the cost of analyses, design, validation, construction, subsystem testing, subsystem integration, subsystem verification
  - All subsystem manpower that supports observatory/mission level I&T, launch operations, and in orbit checkout
    - Usually a dwindling number of key subsystem engineers
  - All subsystem manpower that supports mission operations
    - Usually a fairly low figure, if any at all
  - The cost of all business travel directly related to carry out the foregoing

Orbit Trade

Low energy transfer

- Long (>230 days) cruise & associated costs
- Needs a hydrazine “cluster level” propulsion system w/ ~ 50m/s

High energy transfer w/ Lunar gravity assist

- Short (7-8 days) cruise
- Needs a byprop or solid “cluster level” propulsion system w/ ~ 500m/s

CONCLUSION

- High energy transfer baselined

Insertion Config Trade

Individual insertion Pros

- Each microsat uses its own propulsion
  - No separate hardware item to build and test
- Cruise phase doesn't represent a distinctly separate mission phase
  - No cruise phase: controllers, power configuration, thermal configuration, and associated software, verification, etc.

Individual insertion Cons

- Composite result of uncertainties: possibly excessive or irrecoverable dispersion of microsats
  - Uncertainties / differences in propulsion and/or gravity assist maneuvers,
  - Varying cruise phase disturbances

CONCLUSION

- Clustered (all microsats under one propulsion) insertion baselined

Mother-ship Trade

Standalone mother-ship PROS

- Easy dispersing and ranging to keep satellites on surface of sphere
- Acts as central time reference broadcast
- Acts as central RF comm relay to/from ground
- Allows microsats to have small (S band?) comm subsystems

Standalone mother-ship CONS

- Must be fully redundant, fully capable s/c
- Not a cost effective solution: ROM estimate > ~$60M

CONCLUSION

- No mother-ship used, microsats simply clamped to each other
- A “stack propulsion module” is clamped to the bottom of the stack

Structure Layout Trade

Orbcomm-like layout

- Solar arrays are hidden during cruise phase
- Orbcomm-like layout well adapted to Pegasus not Delta

Brick-like microsats in a flat side-by-side wall-like layout

- Stack is non spinning during cruise phase, s/a's sun pointing
- Stack propulsion unit at bottom of stack
- Advantage is that all microsats solar arrays see the sun at all times.
  - Either microsat can run in cruise phase solely on it's own solar cells, no interconnected power system / batteries required.
- Front panel area available for s/a's is limited by fairing
  - 1.64m x 1.64m base area x 5.1 m height allows for .41m x 1.26 m s/a panels on each microsat

Triangle base for individual microsats, clustered into hexagons

- Fit nicely in fairing, forming a hexagon base
- Spinning through the cruise phase
- Interconnected power system / batteries required

CONCLUSION

- **Triangle base microsats selected**

Microsat Attitude/Ops Trade

- **Baseline**
  - 3-axis stabilized stabilized
  - Fixed-mounted high gain antenna always faces earth
  - Articulated solar array
  - No reorienting satellite between data-taking and data-dump attitudes
- **Option 1**
  - 3-axis stabilized
  - Fixed-mounted high gain antenna
  - Fixed-mounted solar array
  - Satellite reorienting each day between data-taking and data-dump attitudes
- **Option 2**
  - Slow spinner (<5° per second, which is <0.8rpm)
  - Fixed-mounted antenna always pointing to earth
  - Solar arrays on deployed and fixed panels
  - No reorienting satellite between data-taking and data-dump attitudes

High Energy Transfer Concept, Option 1 Resources Summary

SCIENCE PAYLOAD [kg]		
	Actual	Contingent
Payload	3.0	3.8
Total	3.0	3.8
S/C BUS SUBSYSTEMS. & STRUCTURE [kg]		
	Actual	Contingent
Mechanical	11.7	14.7
ACS	5.0	6.0
Thermal	2.0	2.4
Propulsion	7.0	8.4
Power	9.5	11.4
C&DH	9.7	11.6
RF Comm	23.0	27.6
RF Comm 4-16	21.0	27.3
Total	67.9	82.1
Biprop Stack Propulsion System Dry Mass	75.0	25.0
Biprop Stack Propulsion System	245.0	245.0
TOTAL MASS w/ 14 Microsats [kg]		
	Actual	Contingent
PAYLOAD TOTAL	42.0	52.5
BUS SUBSYSTEMS DRY TOTAL	927.2	1125.6
Observatory Dry Mass	1058.2	1217.1
PROPELLANT	245.0	245.0
OBSERVATORY WET MASS	1303.2	1462.1
Delta 2925H-10 capability	1495.0	1495.0
Margin [kg]	191.8	32.9
Margin [%]	12.8	

Configuration overview
- 3-axis stabilized
- Fixed-mounted high gain antenna
- Fixed-mounted solar array
- Satellite reorienting each day between data-taking and data-dump attitudes

- **Mass only slightly less than Baseline Option**
- **Costs nearly identical to Baseline Option**

CONCLUSION
- **May accommodate 14 microsats**
- **Option not baselined**
  - Dismissed based on the risk and complications associated with w/ RF Comm operations
  - This option is a close runner-up to the Baseline, and could just as well be flown

High Energy Transfer Concept, Option 1
First Microsat Bus Subsystems Cost

	Actual	w/ Cont.
Mechanical Hardware	0.1	0.1
Mechanical Labor	0.0	0.0
ACS Hardware	0.3	0.3
ACS Labor	0.0	0.0
Thermal Hardware	0.1	0.1
Thermal Labor	0.1	0.1
Propulsion Hardware	0.0	0.0
Propulsion Labor	0.0	0.0
Power Hardware	1.7	2.2
Power Labor	0.5	0.7
C&DH Hardware	1.8	2.3
C&DH Labor	2.9	3.8
TT&C Hardware	2.0	2.5
TT&C Labor	0.3	0.4
Flight Software Hardware Recurrent	0.1	0.1
Flight Software Labor Recurrent	0.1	0.1
Direct GSE (5% overhead on s/c hardware)	0.0	0.0
Spacecraft Bus Total	9.8	12.8

High Energy Transfer Concept, Option 1
Mission Total Cost w/ 16 S/C

per SMAD Mass Prod Est. S=.85 [$M]	Actual	w/ Cont.
PROJECT MANAGEMENT	6.6	7.3
PRE-LAUNCH INSTRUMENT TEAM SUPPORT	5.3	5.3
INSTRUMENTS TOTAL COST	excl.	excl.
16 SPACECRAFT BUS SUBSYSTEMS TOTAL COST	100.0	130.0
STACK PROPULSION MODULE TOTAL COST	1.0	1.3
FLIGHT SOFTWARE NR TOTAL COST	11.4	14.9
MISSION SYSTEMS ENGINEERING	3.9	4.9
ATLO & MISSION READINESS	20.8	26.2
LAUNCH VEHICLE	75.2	75.2
GROUND SYSTEM DEVELOPMENT	9.0	10.8
MISSION READINESS VERIFICATION	1.9	2.3
OPERATIONS	5.8	6.9
MISSION TOTAL	240.9	285.0

High Energy Transfer Concept, Option 1
Mission Total Cost w/ 14 S/C

per SMAD Mass Prod Est. S=.85 [$M]	Actual	w/ Cont.
PROJECT MANAGEMENT	6.6	7.3
PRE-LAUNCH INSTRUMENT TEAM SUPPORT	5.3	5.3
INSTRUMENTS TOTAL COST	excl.	excl.
14 SPACECRAFT BUS SUBSYSTEMS TOTAL COST	90.0	117.0
STACK PROPULSION MODULE TOTAL COST	1.0	1.3
FLIGHT SOFTWARE TOTAL COST	11.4	14.9
MISSION SYSTEMS ENGINEERING	3.9	4.9
ATLO & MISSION READINESS	20.8	26.2
LAUNCH VEHICLE	75.2	75.2
GROUND SYSTEM DEVELOPMENT	9.0	10.8
MISSION READINESS VERIFICATION	1.9	2.3
OPERATIONS	5.8	6.9
MISSION TOTAL	230.9	272.0

High Energy Transfer Concept, Option 2 Resources Summary

SCIENCE PAYLOAD [kg]		
	Actual	Contingent
Payload	3.0	3.8
Total	3.0	3.8
S/C BUS SUBSYSTEMS. & STRUCTURE [kg]		
	Actual	Contingent
Mechanical	14.9	17.9
ACS	2.0	2.4
Thermal	2.0	2.4
Propulsion	10.0	12.0
Power	11.3	13.6
C&DH	12.7	15.2
RF Comm	25.0	30.0
RF Comm 4-16	23.0	
Total	77.9	93.5
Biprop Stack Propulsion System Dry Mass	75.0	25.0
Biprop Stack Propulsion System	245.0	245.0
TOTAL MASS w/ 13 Microsats [kg]		
	Actual	Contingent
PAYLOAD TOTAL	39.0	48.8
BUS SUBSYSTEMS DRY TOTAL	991.2	1193.9
Observatory Dry Mass	1030.2	1242.6
PROPELLANT	245.0	245.0
OBSERVATORY WET MASS	1275.2	1487.6
Delta 2925H-10 capability	1495.0	1495.0
Margin [kg]	219.8	7.4
Margin [%]	14.7	0.5

Configuration overview

- Slow spinner (<5° per second, which is <0.8rpm)
- Fixed-mounted antenna always pointing to earth
- Solar arrays on deployed and fixed panels
- No reorienting satellite between data-taking and data-dump attitudes

- **Mass only slightly less than with the Baseline Option**
- **Costs nearly identical to Baseline Option**

CONCLUSION

- **May accommodate 14 microsats**
- **Option not baselined**
  - Complications w/ data reduction (non-parallel antennas)
  - Less than optimal s/a utilization

High Energy Transfer Concept, Option 2
First Microsat Bus Subsystems Cost

SPACECRAFT BUS SUBSYSTEMS* [$M]		
	Actual	w/ Cont.
Mechanical Non-Recurrent HW	0.1	0.1
Mechanical Recurrent HW	0.0	0.0
ACS Non-Recurrent HW	0.2	0.2
ACS Recurrent HW	0.0	0.0
Thermal Non-Recurrent HW	0.1	0.1
Thermal Recurrent HW	0.1	0.1
Propulsion Non-Recurrent HW	0.0	0.0
Propulsion Recurrent HW	0.0	0.0
Power Non-Recurrent HW	0.0	0.0
Power Recurrent HW	0.0	0.0
C&DH Non-Recurrent HW	1.2	1.4
C&DH Recurrent HW	2.9	3.5
RF Comm Non-Recurrent HW	0.0	0.0
RF Comm Recurrent HW	0.0	0.0
Flt S/W Non-Recurrent HW	0.6	0.7
Flt S/W Recurrent HW	9.9	11.9
Direct GSE (5% overhead on s/c hardware)	0.0	0.0
Spacecraft Bus Total	15.0	18.0

ACS Trade

Earth sensor

- Earth is a at 1.4 deg visible (part of orbit) and infrared (entire orbit) source
- Unusable during portion of the orbit when the Earth is near the Sun (drowned out)
- Significant problem with Lunar disturbances

- **Radar receive signal strength peak-up**
  - +/-1 degree accuracy may be achievable when Earth and Sun vectors are at 90º, but error increases dramatically when Earth and Sun vectors are near coaligned
  - Risky scheme due to random misc. radar sources on Earth
  - Difficulty finding Earth initially
- **Star Sensor**
  - One single star tracker is sufficient even w/o any other fine sensor
  - Only disadvantage is relatively high cost (~$150K)

RF Comm Trade

- **Trade elements:**
  - X band vs. Ka band
  - Dish antenna / phased arrays vs. switched omni-s
- **Conclusion**
  - Mission not worth doing with “omni” range data rates (kbps)
  - Cut data rate a fraction of its intended original
  - Reduced orbit radius to 500,000 km
  - 8 Mbps downlink / 100 bps uplink (10 W on ground) chosen to 14 m antenna
  - Adjust duty cycle to fill data rate
  - Keep 2 bits sampling

Stack Propulsion Trade

- **Star Motor**
  - Star 24 is appropriate for high energy transfer orbit injection, but is not suitable for LV dispersion correction, so hydrazine system for ~10 m/s still needed
  - Cost is on same order (~$1M) as custom built bipropellant system
  - Overall mass (Isp = 290) comparable to bipropellant (Isp = 320)

Name	motor	Lenght	Diam.	Mass		Thrust s.l.	Isp s.l.	Thrust vac	Isp vac	Propellant	Burn time	Flow rate	Total Imp.
		m	m	tons		kN	N*s/kg	kN	N*s/kg	tons	s	t/s	kN*s
Star-13A (Burner II)	TE-M-516		0,34	0,0381				5,87	2810	0,033	15,9	0,0021	93,6
Star-13B	TE-M-763			0,0474				7,60	2802	0,041	15,2	0,0027	115,8
Star-17	TE-M-479		0,44	0,0790				10,94	2807	0,070	18,1	0,0039	197,9
Star-17A	TE-M-521-5			0,11261				16,01	2812	0,112	19,9	0,0057	319,4
Star-20 (Altair IIIA)	TE-M-640-1		0,50	0,3009				27,13	2810	0,273	28,4	0,0097	771,8
Star-20A	TE-M-640-3			0,3143					2863	0,286			822,5
Star-20B	TE-M-640-4			0,3067				24,47	2835	0,274	31,7	0,0086	776,5
Star-24	TE-M-604		0,62	0,2182				18,55	2774	0,200	30,2	0,0067	560,5
Star-24A	TE-M-604-2			0,1980					2769	0,179			500,0
Star-24B	TE-M-604-3			0,2190					2774	0,200			561,5
Star-24C	TE-M-604-4			0,2394				21,46	2768	0,219	28,6	0,0078	613,9
Star-25	TE-M-184-3		0,64	0,2360					2354	0,217			599,3
Star-26	TE-M-442		0,66	0,2682				33,36	2658	0,231	18,5	0,0125	616,1
Star-26B (Burner IIA)	TE-M-442-1			0,2612				34,63	2664	0,238	18,3	0,0130	635,0
Star-26C	TE-M-442-2			0,2636				35,01	2668	0,232	17,8	0,0131	621,9
Star-27	TE-M-616		0,69	0,3612				26,73	2824	0,334			951,4
Star-27A	TE-M-616-1			0,3363					2821	0,309			879,8
Star-27B	TE-M-616-4			0,3447					2826	0,317			905,4
Star-27C	TE-M-616-5			0,3327					2819	0,305			868,7
Star-27D	TE-M-616-8			0,3320					2819	0,306			869,8
Star-27E	TE-M-616-9			0,3308					2818	0,305			866,2

CONCLUSION

- Bipropellant Stack Propulsion Module baselined

Risk & Technology

Integrated Mission Design Center

	Mechanical	Thermal	Propulsion	Electr. Power	C&DH	Mission Ops
RISK ITEM	Deployments			1. LiIon cell Failure	No Separate Safehold Processor	1. Failure of only Ground Station 2. 24 Hour Data Latency Requirement Cannot Be Achieved
LIKELIHOOD	green			#1 Green- LiIon cell open circuit will effect Com, Com could take longer certailing science also multiple spacecraft, so we have spacecraft redundancy.	Green	1. Red 1. Red
IMPACT	yellow			#1 Green we have solar array only mode, and multiple spacecrafts.	Red	1. Yellow 2. Yellow
CONSEQUENCES	stack/stack-loss of microsats in stack, microsat/microsat-loss of microsat, solar array-loss or minimal use of microsat			#1 Cost, Mass will go up and schedual will go out.	Spaceraft could lose power	1. One or more days worth of science will be lost 2. 24 hour data latency requirement cannot be achieved
FALLBACK PLAN	re-iniate separation sys			#1 solar array only mode reduce Com Power and multiple spacecraft.	Try to recover spacecraft	1. DSN can be used 2. None
IMPACT				#1 Less data or use redundant spacecraft.		1. Added cost and scheduling difficulty 2. N/A
MITIGATION				#1 select a good LiIon cells.	Add safehold processor	1. Add a second Ground Station 2. Add a second Ground Station
IMPACT					Increased mass, power, and cost	1. Eliminates a Single Point of Failure 2. Allows for the ability to have a contact every 12 hours
TRL	6	8	4	7 to 8	6	5, 8-9

Smaller RSDO Busses

- **Surrey SNAP**
  - Bus dry mass 6.5 kg, payload mass max 3.0 kg, payload power 2.5 W
- **Orbital Picostar**
  - Bus dry mass 52.7 kg, payload mass max 20 kg, payload power 10 W
- **Surrey Microsat 70**
  - Bus dry mass 44.7 kg, payload mass max 23.8 kg, payload power 18 W
- **Orbital Microstar**
  - Bus dry mass 58.6 kg, payload mass max 68 kg, payload power 50 W
- **Orbital Ministar**
  - Bus dry mass 100 kg, payload mass max 25 kg, payload power 25 W
- **TRW T100**
  - Bus dry mass 184.1 kg, payload mass max 36 kg, payload power 25 W
- **Spectrum Astro SA 200B**
  - Bus dry mass 90 kg, payload mass max 100 kg, payload power 86 W
- **Spectrum Astro SA 200S**
  - Bus dry mass 129 kg, payload mass max 200 kg, payload power 66 W
- **Ball BCP 600**
  - Bus dry mass 203   kg, payload mass max 90 kg, payload power 125 W
- **Surrey Minisat 400**
  - Bus dry mass 206.7 kg, payload mass max 200 kg, payload power 100 W

SA 200B

BCP 600

Payload Power specified is at OAV EOL

Bigger RSDO Busses

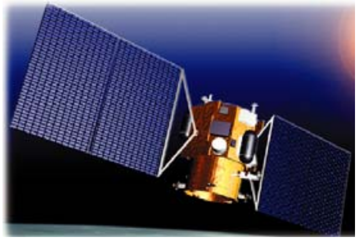
- **TRW T200A**
  - Bus dry mass 242.4 kg, payload mass max 75 kg, payload power 94 W
- **TRW T200B**
  - Bus dry mass 278 kg, payload mass max 95 kg, payload power 175 W
- **Swales EO-SB**
  - Bus dry mass 332 kg, payload mass max 236 kg, payload power 256 W
- **Orbital StarBus**
  - Bus dry mass 566 kg, payload mass max 200 kg, payload power 550 W
- **Ball BCP 2000**
  - Bus dry mass 608 kg, payload mass max 380 kg, payload power 730 W
- **Lockheed Martin LM 900**
  - Bus dry mass 492 kg, payload mass max 470 kg, payload power 344 W
- **Spectrum Astro SA 200HP**
  - Bus dry mass 354 kg, payload mass max 666 kg, payload power 650 W
- **Orbital Midstar**
  - Bus dry mass 580 kg, payload mass max 780 kg, payload power 327 W
- **Astrium Flexbus**
  - Bus dry mass TBD kg, payload mass max TBD kg, payload power TBD W
- **Orbital Leostar –2**
  - Bus dry mass TBD kg, payload mass max TBD kg, payload power TBD W
- **TRW T310**
  - Bus dry mass TBD kg, payload mass max TBD kg, payload power TBD W

Payload Power specified is at OAV EOL

EO-1

Midstar

SA200HP -DS1



Supporting Data

- **Supporting spreadsheets / tools**
  - Mission summary and quick orbit analysis tool:
    - "System_Sheets.xls"
  - Typical NASA mission's complete Work Breakdown Structure:
    - Generic_WBS_Template_by_GSFC_NOO.doc
- **Useful web sites**
  - Access to Space
    - http://accesstospace.gsfc.nasa.gov/ provides launch vehicle performance information and other useful design data.
  - Rapid Spacecraft Development Office
    - http://rsdo.gsfc.nasa.gov/ provides spacecraft bus studies and procurement services.
  - Space Environment Information System – SPENVIS
    - http://www.spenvis.oma.be/spenvis/

System Summary

- **Customer Contact:** Robert MacDowall, Code 695
- **GSFC Contact:** Gabe Karpati, 6-4468, Gabriel.Karpati@nasa.gov
- **Mission name and Acronym:** Solar Imager Radio Array (SIRA)
- **Authority to Proceed (ATP) Date:** 10/2005
- **Earliest Mission Launch Date:** 10/2009
- **Transit Cruise Time (months):** n/a
- **Mission Design Life (days):** 2/4 years
- **Length of Spacecraft Phase C/D (months):** 48
- **Bus Technology Readiness Level (overall):** 5-6
- **S/C Bus management build:** RSDO or TBD
- **Mission Liftoff Mass:** ~300 kg
- **Observatory Orbit Average Power:** 300 W