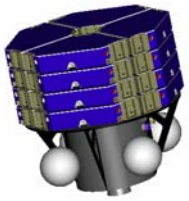
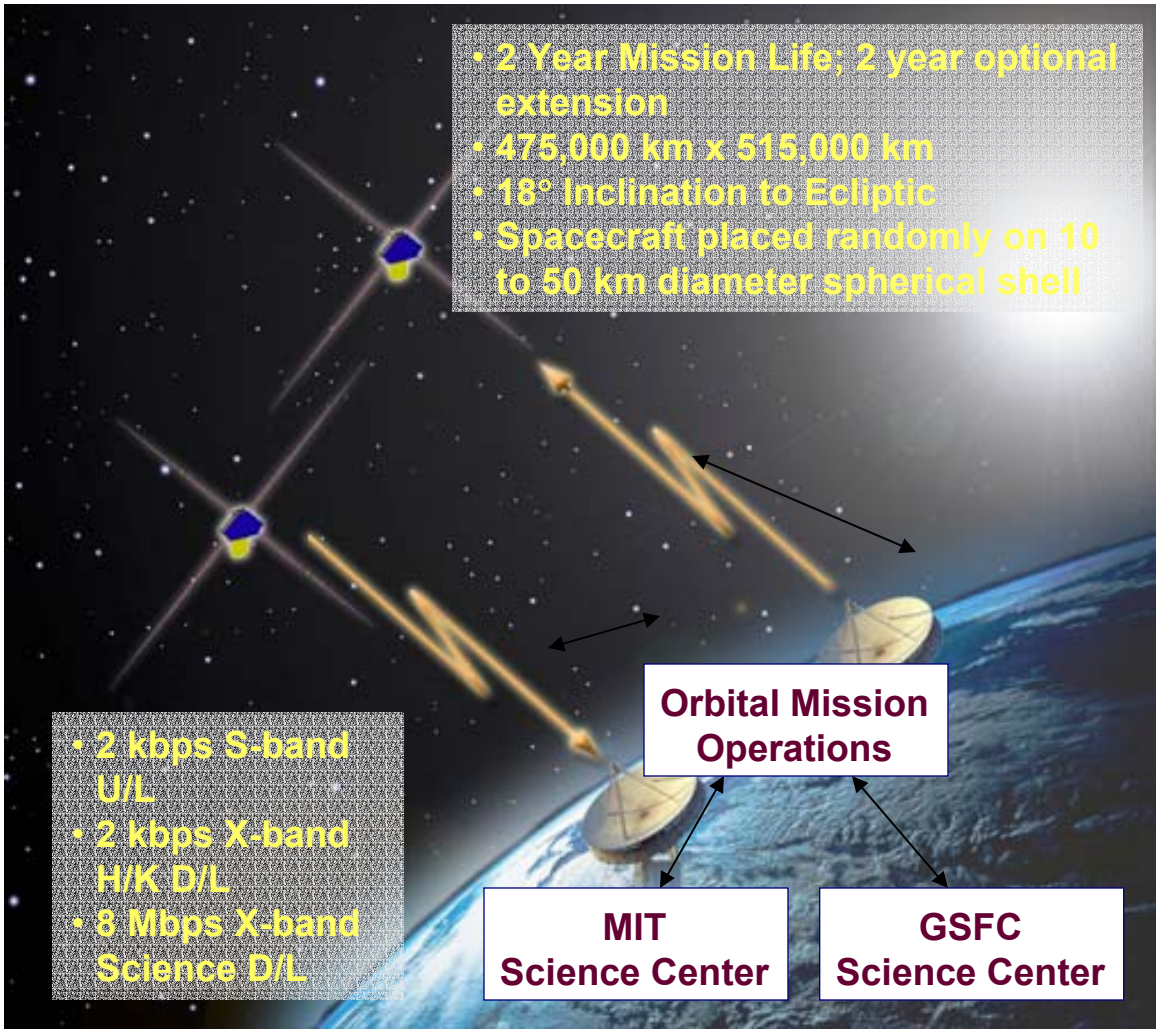
SIRA Mission Overview

- Delta 7925 from KSC
- C3=0.135 km2/s2
- Lunar Swingby to DRO orbit



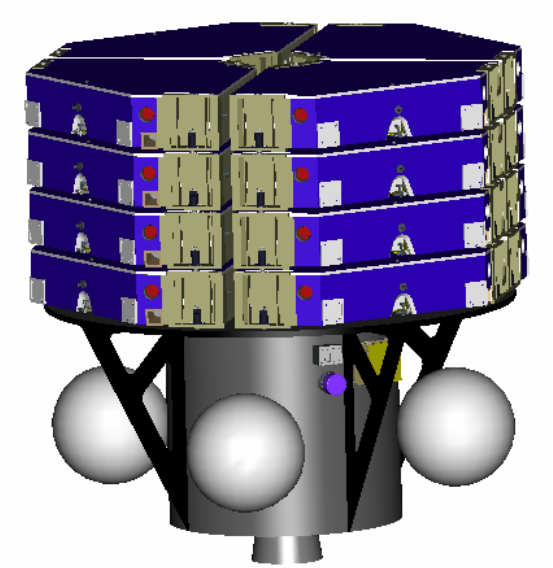
- 12 to 16 Sun pointing Microsats
- Liquid bi-prop carrier



SIRA Space Segment Overview

- The SIRA Space Segment is a stack 12 to 16 Microstar based microsats with direct-to-ground communication plus a simple Carrier
- Each microsat is identical
  - Mass = 50.5 kg (Dry) (bus, payload, and contingency)
  - 3-axis control with star tracker attitude knowledge
  - 0.5 m^2 fixed solar array provides 117.5 W
    - ~0.2 m^2 edge solar array contributes power for stack
  - Single axis articulating X-band high gain antenna S-Band uplink, X-Band downlink
  - UHF ranging and timing distribution
  - Cold gas (GN2) propulsion
- Stacked launch configuration uses flight-proven ORBCOMM program separation mechanisms.
- Carrier based on Orbital's GEO spacecraft heritage
  - Liquid bi-propellant propulsion system has 500 m/s delta-V capability and has been flown successfully on Telkom-2 and PanAmSat. Currently in production.
  - Structure supports 2 to 16 microsats
  - Redundant 3-axis control from two of the microsats. Selection of control microsat is harness dependent.

View of SIRA Stack during Transfer

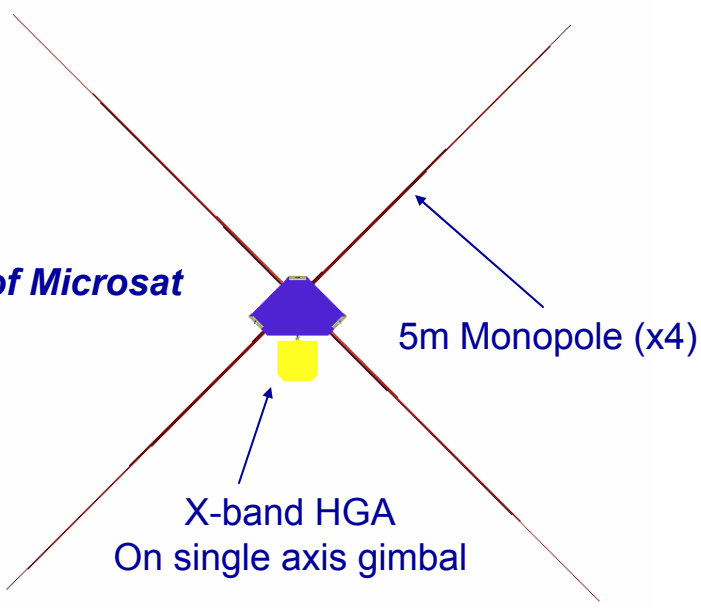


SIRA Microsat Overview

- **Payload Accommodation**
  - Switched 14V Power & Serial Data Interface
- **Mechanical**
  - Al honeycomb wall with Al facesheets
    - Conductive surface reduces charging
  - NEA enable plug for deployment safety
- **Propulsion**
  - Blow-down Cold Gas w/(6) canted Thrusters for delta-V and ACS support
- **Thermal**
  - Passive controls with heaters for battery
- **Attitude Determination and Control**
  - 3 reaction wheels with star tracker
  - Safe mode for >7 days
- **Power**
  - Triple junction GaAs solar arrays
  - Li-ion batteries
- **Command and Data**
  - Absolute time stored commanding
  - 40 Gbit (5 GB) Data storage

- **Communications and Ranging**
  - S-band uplink at 2 kbps
  - X-band downlink at 2 kbps (using omni) and 8 Mbps (using HGA)
  - UHF Intermicrosat Ranging and Timing Distribution with OCXO for 10^{-10} stability
  - Space-Ground Ranging using 1-way Doppler ranging with DSN 34m net

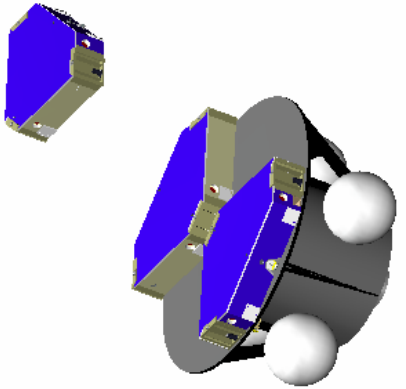
Sunward View of Microsat

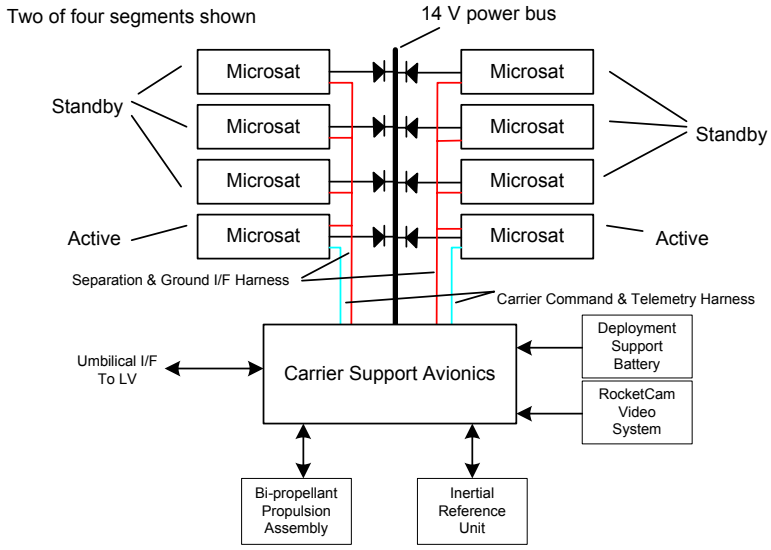


SIRA Carrier Overview

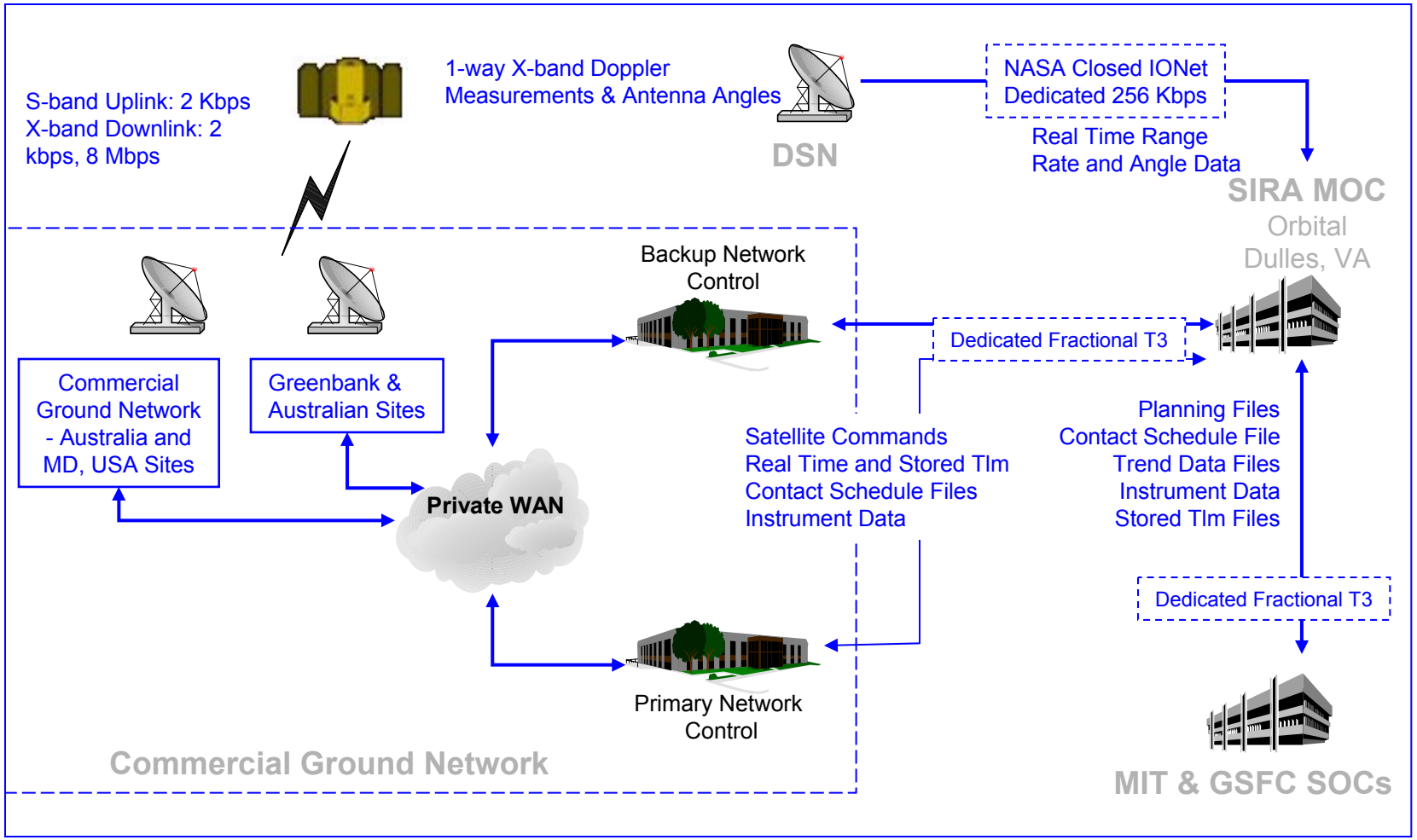
- **Microsat Accommodation**
  - 2 to 16 microsats
  - Deployment Monitoring with RocketCam video system.
  - Separation telemetry provided by flight proven bridgewire circuits.
  - Control microsats self deploy on ground command
- **Command and Data**
  - Stack commanded by two control microsats on the bottom layer
  - Redundant commanding and telemetry collection
- **Communications**
  - Microstar communication subsystem supports 2kps S-band uplink and 2 kbps X-band downlink
- **Attitude Determination and Control**
  - Microstar star trackers supply attitude knowledge
  - Control via thrusters
- **Mechanical**
  - Primary Structure: Thrust tube and deck w/ Orbcomm separation system
- **Propulsion**
  - 450 N bi-propellant LAE (NTO & N2H4) & (4) 22 N thrusters
- **Power**
  - Power from bussed 0.2 m^2 microsat edge arrays, batteries and deployment support battery

Carrier with 2 control microsats & one just deployed



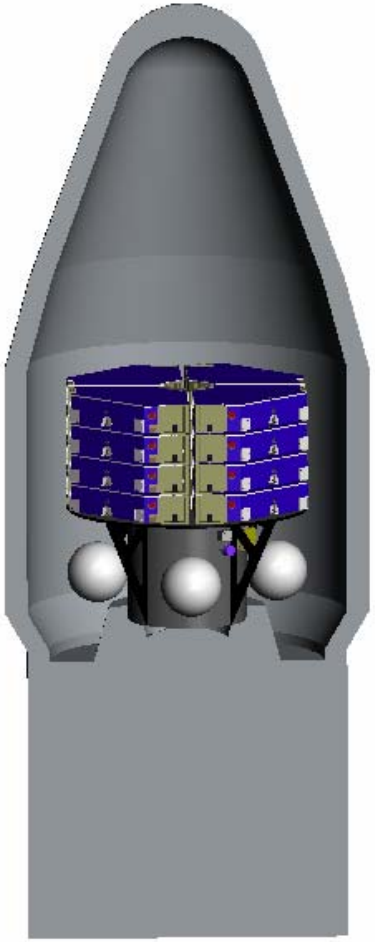


SIRA Ground Segment Overview



SIRA Launch and Transfer Overview

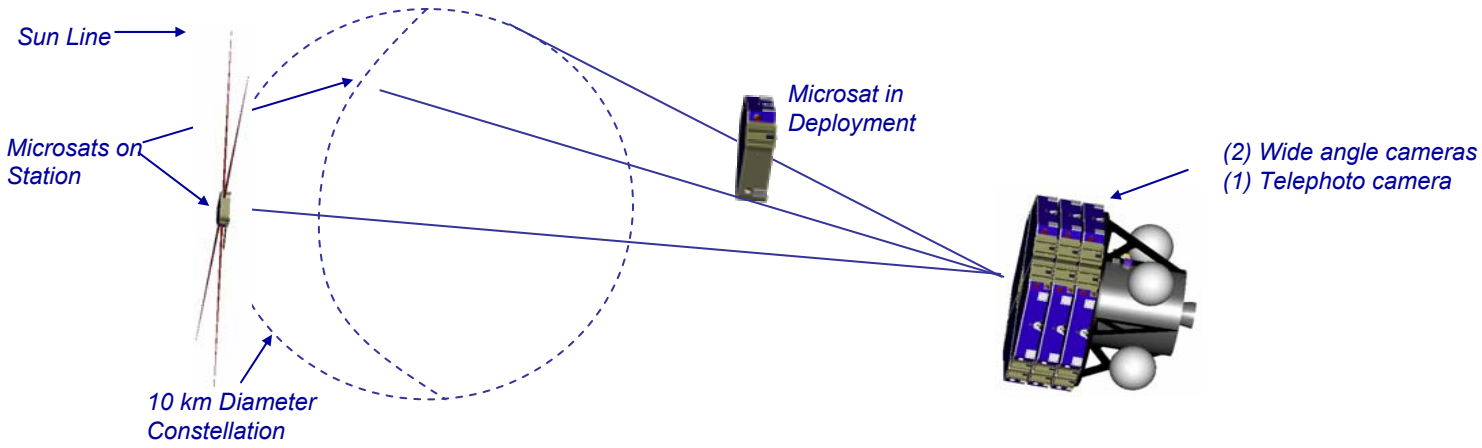
- **Launch on Boeing Delta II (7925)**
  - Stack fits comfortably in 2.9 m fairing using 3712 PAF
  - Interfaces for critical telemetry and battery charging
  - Standard Delta/launch range safety requirements
  - SIRA will radiate after LV separation
- **Launch to Transfer Trajectory**
  - 7925: 1250 kg launch capability for C3=0.135
    - 12 to 14 microsats
  - 7925H: 1500 kg launch capability for C3=0.135
    - Required to launch 16 microsats and meet mass margins
  - Despin stack to 1/2 rpm prior separation from LV
- **Delta-V budget**
  - Removal of launch residuals: 50 m/s
  - Correction for lunar flyby: 10 m/s
  - Post flyby correction: 10 m/s
  - DRO insertion burn 416 m/s



SIRA Deployment and Formation Control Overview

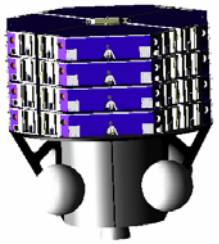
Retrograde Orbit with Lunar Gravity Assist

- **Deployment**
  - Initial formation of 10 km dia. spherical shell
  - Deploy one at a time from carrier using ORBCOMM/Pegasus separation system
  - Point and shoot (see below)
  - Budget 1 day for each microsat
  - Use RocketCam to observe Microsat and Microsat mechanism deployment
- **Formation Control**
  - Increase to 50 km diameter then return to 10 km diameter
  - Maintain formation control for 2 years with option for 2 years
  - Budget delta V of 1.5 m/s per S/C per month



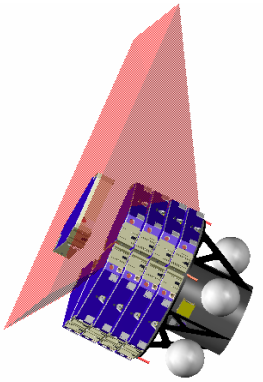
SIRA Deployment Sequence Overview

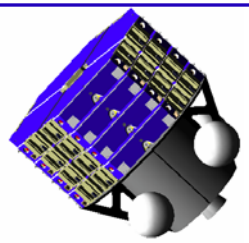
Sun line



- Stop thermal roll
- Attitude normal to sun line

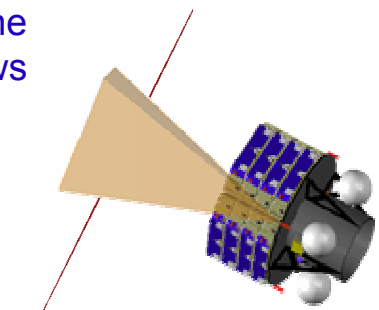
- Microsat powered and sending HK telemetry
- Two (2) Wide-angle cameras to view initial deployments





- Tilt to firing angle (also puts sun to microsat S/A)
- Enable microsat via command through control microsat & perform initialization & checkout
- Command microsat to eject itself

- Carrier reorients, and one (1) telephoto camera views monopole deployments



SIRA Mission Requirements and Accommodation

Requirement	Value	Accommodation
Mission Lifetime	2 year baseline with 2 year extension	Arrays, batteries, propellant and data storage sized for 4 years.
Orbit	Retrograde orbit at 500,000 km from Earth; 18° inclination to ecliptic	Launch to high energy transfer trajectory on a carrier.
Orbital Period	~40 days	Microsats are sun pointing with an Earth tracking, single axis, flat-panel, high gain antenna
Eclipse Duration	< 9 min Lunar penumbra in 4th yr	Battery capacity and star trackers handle this easily
Launch Vehicle	Delta II class	Delta 7925 baselined for 12 microsats; Delta 7925H baselined for 16 microsats
Launch Date	2/1/10	Launch date is accommodated by schedule. 42 months for design and development of the constellation.
Number of Microsats	12 to 16	Based on the single string ROCSAT-2 (Cosmic) design. 12 spacecraft provide good mass and cost margins.
Constellation Radius	5 km, to be extended to 25 km	1.5 m/s per month delta-V from microsat cold gas propulsion system
Frequency Range of Observations	30 kHz to 15 MHz	Flexible printed wire harnesses provide excellent EMI performance based on ORBCOMM experience
Payload Mass/sat	10 kg + ranging and timing unit masses	Light weight microsat structure accommodates receiver boxes and monopole assemblies
Payload Power/sat	10 W for 2 receivers	0.5 m^2 solar array provides adequate power

Requirement	Value	Accommodation
Pointing Requirements	+/- 2.0°	Star trackers on each microsat provide accurate pointing knowledge
Clock Accuracy (absolute)	0.1+/- 0.01 sec	Ephemerides uploaded daily. On board OCXO and static thermal conditions
Bit stream synchronization	1 usec	UHF ranging and timing unit provides for bit stream synchronization
Ranging accuracy (rel)	3.0 +0.3 m (inter-microsat ranging)	UHF ranging and timing unit provides for intermicrosat ranging
Ranging accuracy (absolute)	300 m (from the ground)	~300 m accuracy one way Doppler ranging
Data/day (not limited)	38.2 GB	8 Mbps X-band down link
Data storage/sat	5 GB	5 GB data storage on each microsat (2 days storage)
Ground station contacts	1 or 2 per day (~7 hours each)	1 contact per day per spacecraft is baselined: additional supported
Data latency	4 hours after ground reception	Wide band ground net

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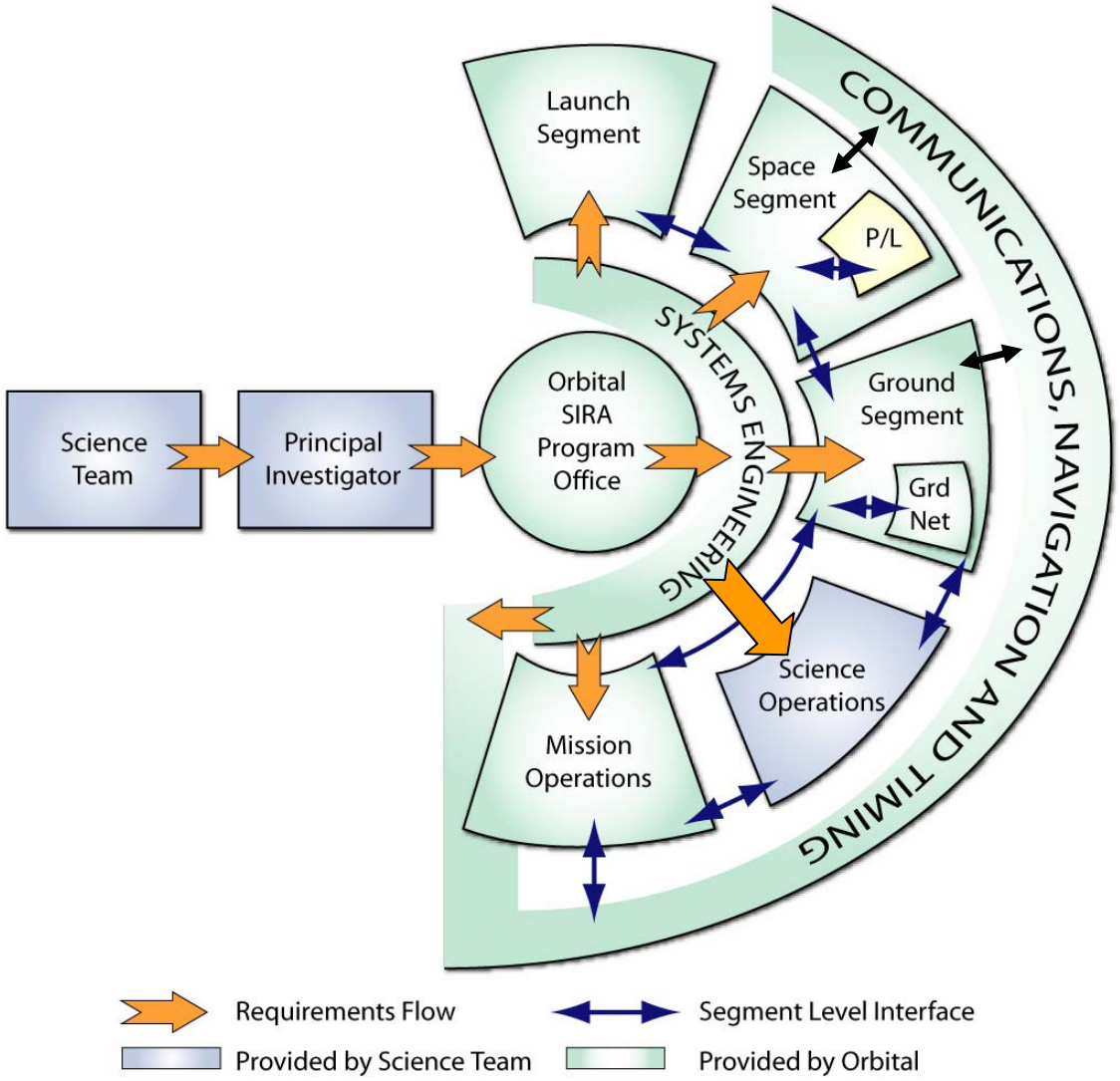
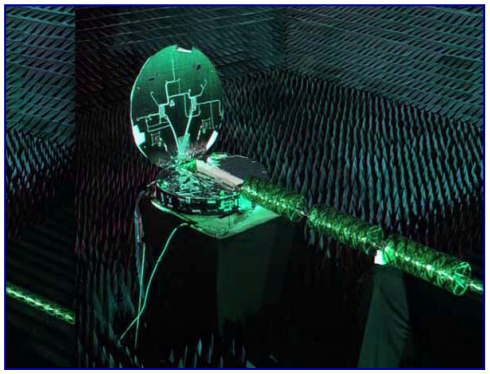
Orbital

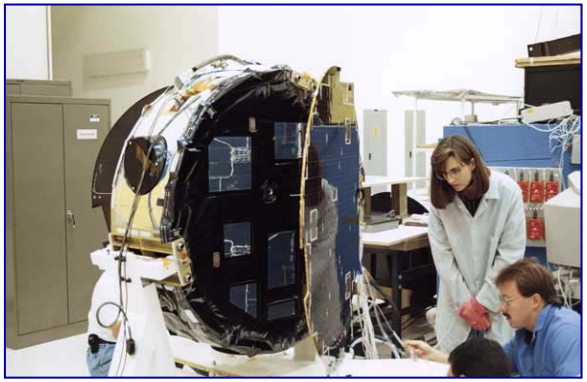
SIRA Mission Architecture



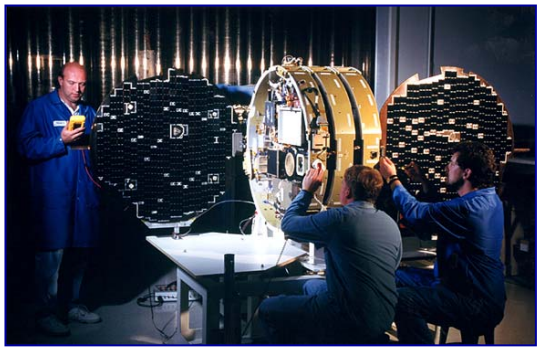
Orbital's Micro-Spacecraft Relevant Experience and Performance



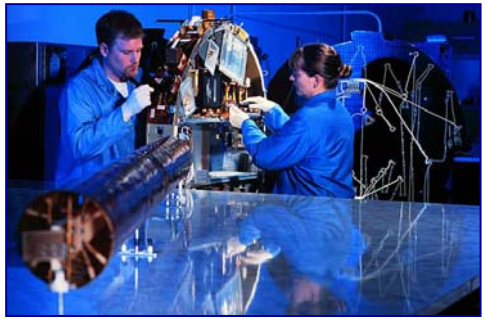
ORBCOMM - Communications
Launches from 1995-2000



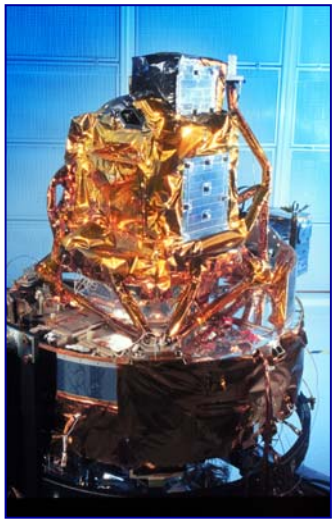
Microlab I - Remote Sensing
Launched Apr '95



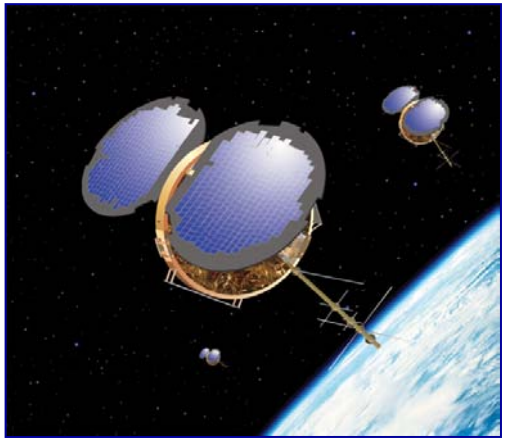
BATSAT/T1 - Communications
Launched Feb '98



MUBLCOM - Communications
Launched May '99

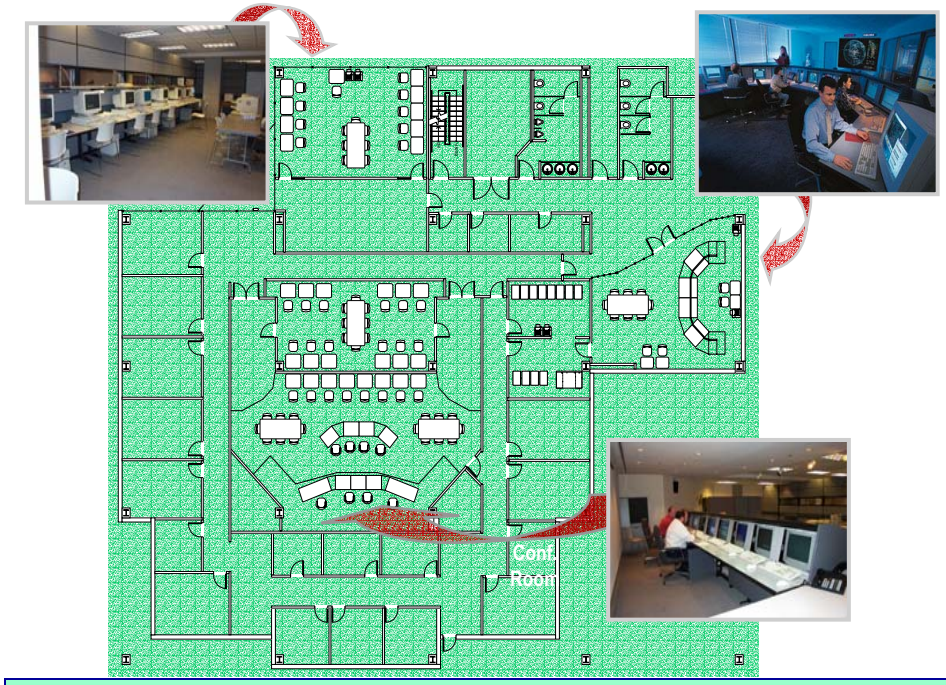


QuikTOMS - Science &
Technology
Launched Sep '01



ROCSAT-3 - Science & Technology
Launch Aug '05

Orbital's Multi-mission Operations Center



Orbital Mission Support

- Seamless from I&T through end-of-life
- Minimized NRE, minimized risk
- 24/7 staffing supports multiple missions

Orbital Mission Operations Center

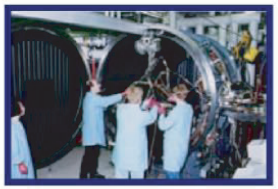
- Three Full Control Centers
  - Two for Launch/Early Operations & Sustaining Engineering
  - One Operational (GALEX)
- Two Control Rooms
  - One operational (MUBLCOM)
  - One backup support (ACRIMSAT)
- Several customer support rooms provide real-time telemetry for anomaly support
- Facility support features
  - Telecommunications room
  - Network and data line monitoring
  - UPS and generator backup

Orbital Has Extensive Mission Operations Experience

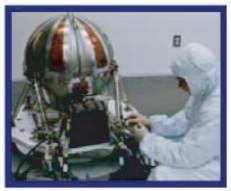
Launch Through Hand-Off	Launch Through Ops
•ORBCOMM Constellation	•MUBLECOM
•SeaStar (OrbView-2)	•BATSAT
•ACRIMSat	•GALEX
•BSAT-2A,-2B,-2C	•OCO*
•Galaxy 12,14*,15*	•Glory*
•OrbView-3	
•Telkom-2*	
•Optus D1* & D2*	

* Future Mission on Contract

Orbital's Manufacturing and I&T Facilities Enable Shorter Implementation Schedules



Thermal Vac. Testing



Mechanical Integration

Electrical Integration

P/L Accommodations

Assembly Areas or Major S/C

Mechanical assembly, propulsion welding, blanket & harness fab

Test Equipment for static loads, vibration, acoustics, thermal cycle/vac, antenna range, EMI/EMC, mass properties, alignment

EMI/EMC

Spacecraft Integration (Class 100,000)

Pick and Place Manufacturing

Class 10,000 Clean Rooms

Precision Assembly

Large Clean Rooms

Mat. Control & Handling

Vibe. & Mech. Testing

Welding and Assembly

Orbital's Multiple Spacecraft Launch and Operations Experience

- **Multiple Spacecraft Launches**
  - ORBCOMM spacecraft were launched up to 8 at a time on a Pegasus launch vehicle
  - Several launches on Taurus launch vehicle with multiple spacecraft
    - KompSat with AcrimSat
    - ORBCOMM FM3 & 4 with GFO1
    - OV-4 with QuikTOMS
  - ROCSAT-3 will involve launching 6 spacecraft simultaneously on a Minotaur
- **Multiple Spacecraft Deployment**
  - Extensive experience in deployment of multiple s/c including Orbital's patented method for deploying a satellite network (U.S. Patent # 5,199,672)
- **Multiple Spacecraft Operations**
  - Orbital developed ORBCOMM satellite control and operations system for 35 spacecraft
  - Several Orbital GEO communications spacecraft operated in a single orbital slot
    - BSAT-2 and N-Star c both involve multiple s/c in single orbital slot
    - Each s/c has unique ID, all receive commands and only the one with specified ID executes command