HyspIRI Mission Concept

Bogdan Oaida,
with contributions from
Michael Mercury [JPL]

[bogdan.oaida@jpl.nasa.gov]

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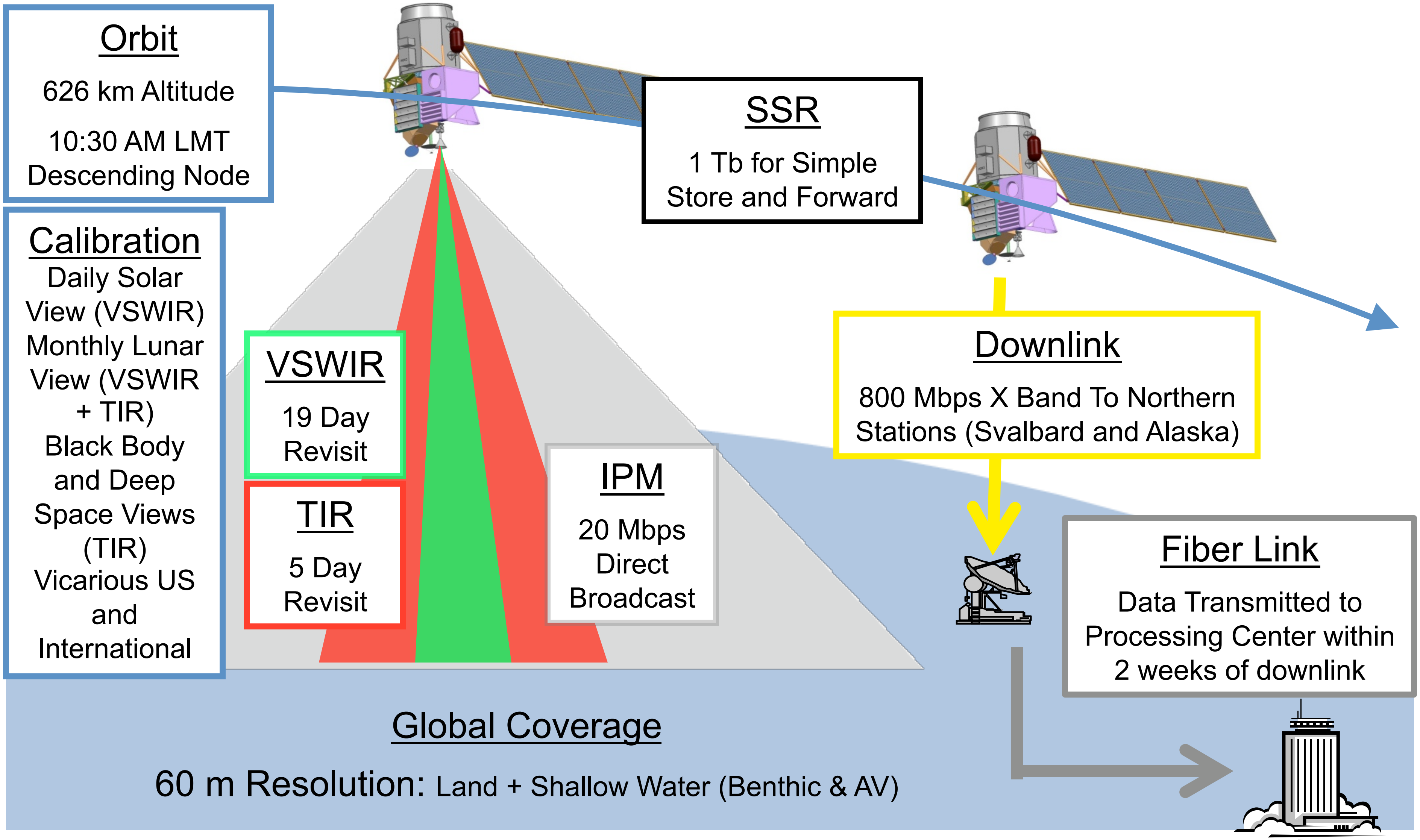
Pasadena, California

HyspIRI Mission Architecture



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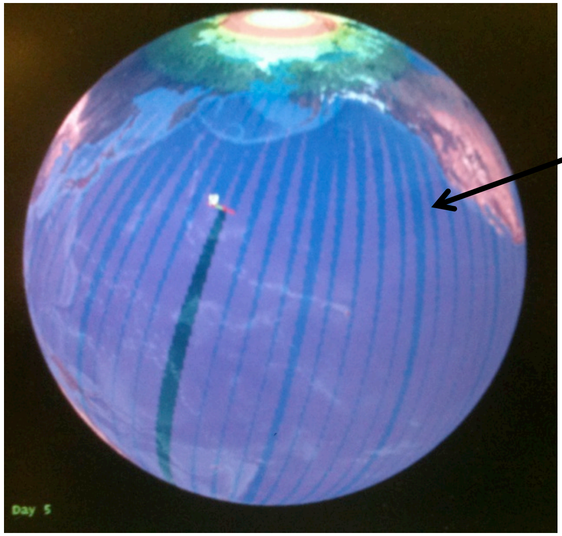
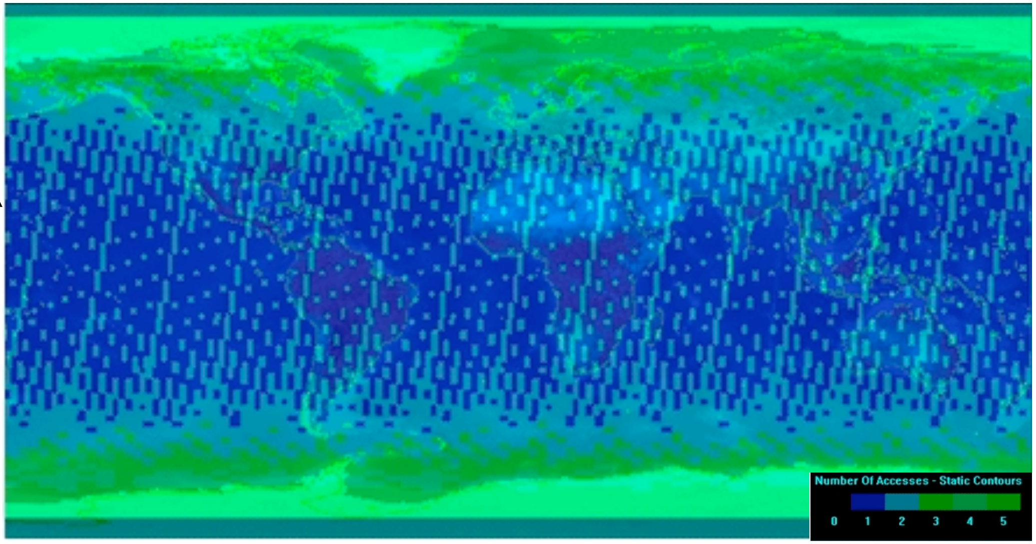
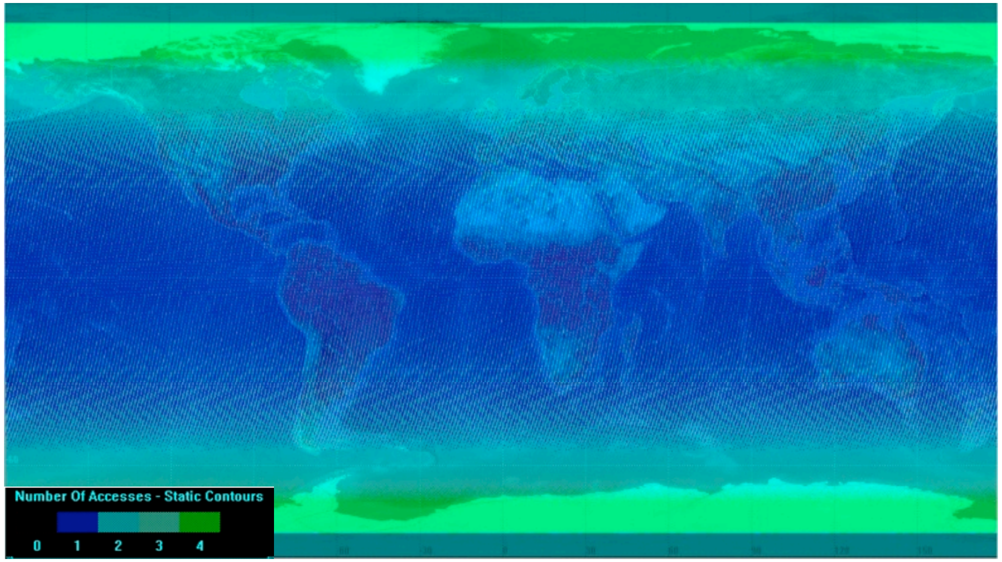
HyspIRI Global Coverage



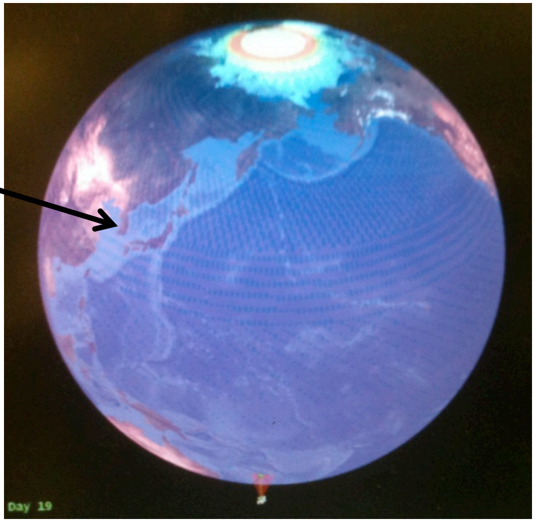
TIR Coverage after 5 days





VSWIR Coverage after 19 days

Due to the min 20 deg Sun elevation angle constraint on the VSWIR acquisition, the latitudes covered change with the seasons



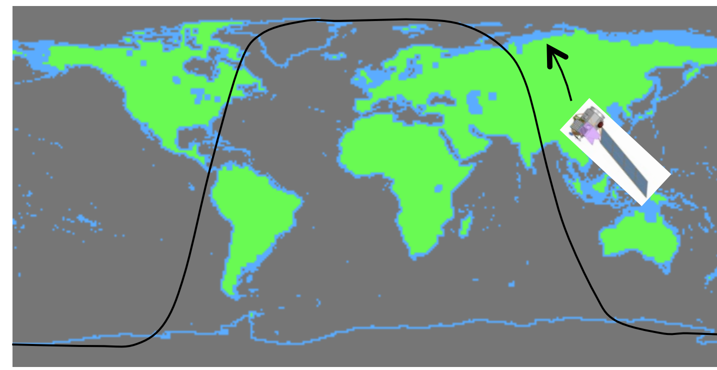
Data Acquisition Strategy

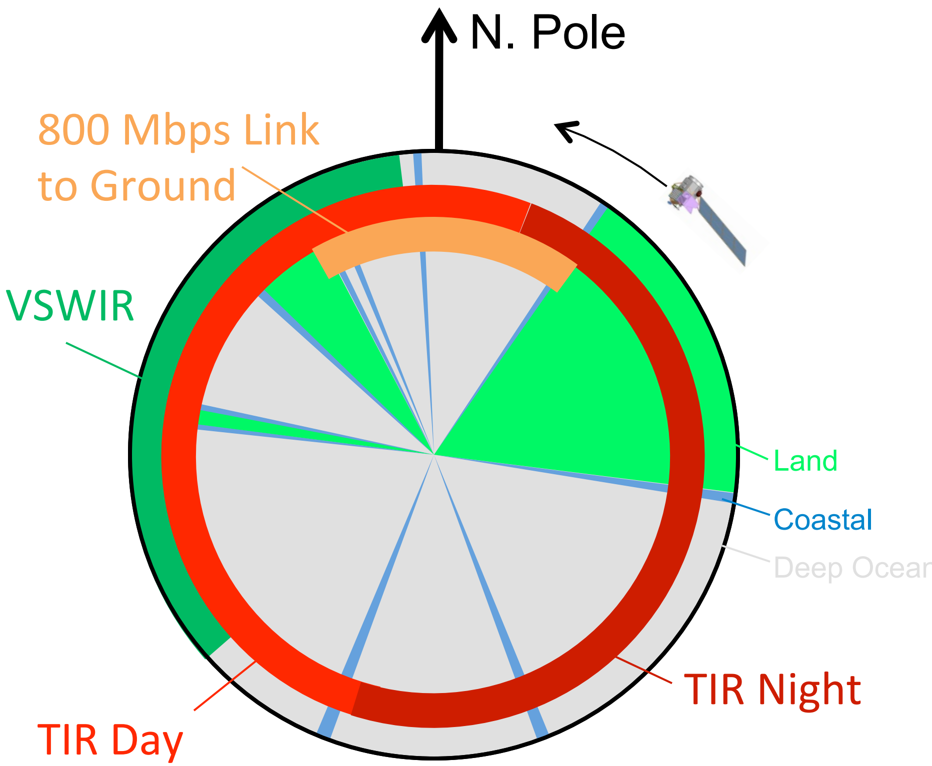
- Instrument modes change multiple times each orbit, but are clearly defined by geography and spacecraft location

Imaging Mode

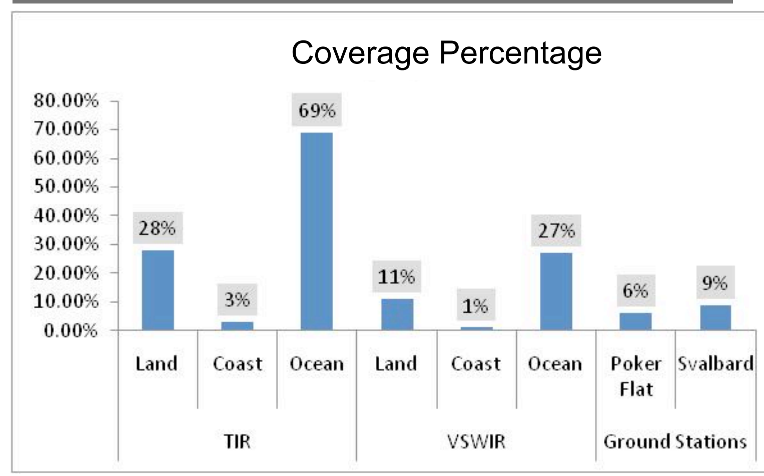
Instrument	Land	Coastal	Deep Ocean	Greenland	Antarctica
VSWIR	60 m	60 m	1 km	1 km	1 km
TIR	60 m	60 m	1 km	1 km	1 km

Target Map





Cut away of earth with slice taken along plane of orbit



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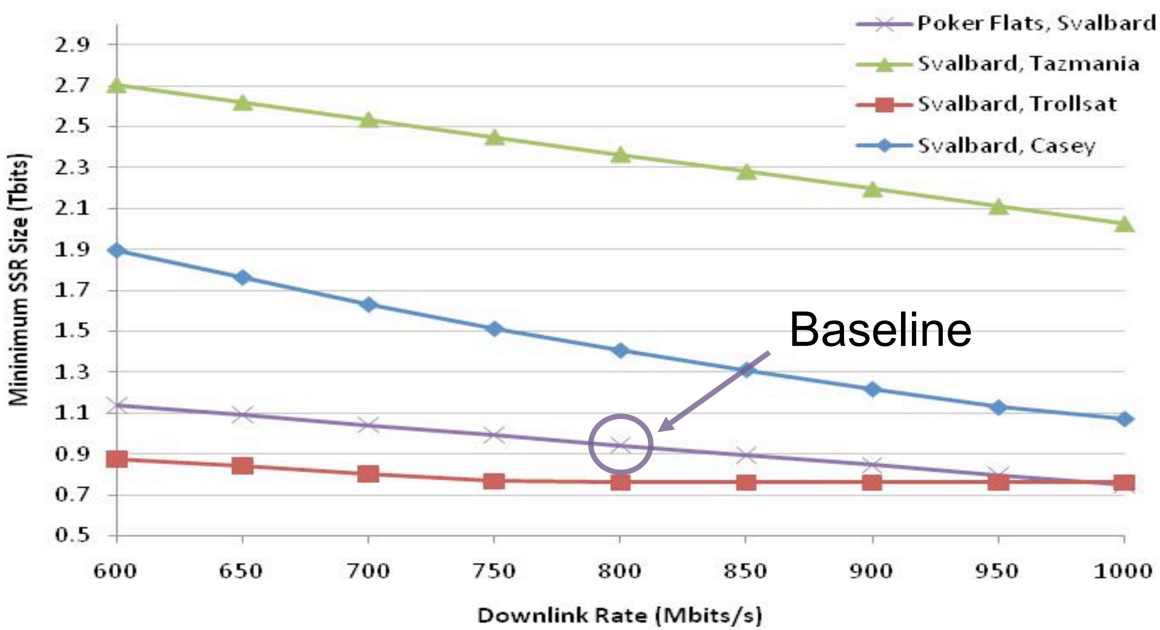
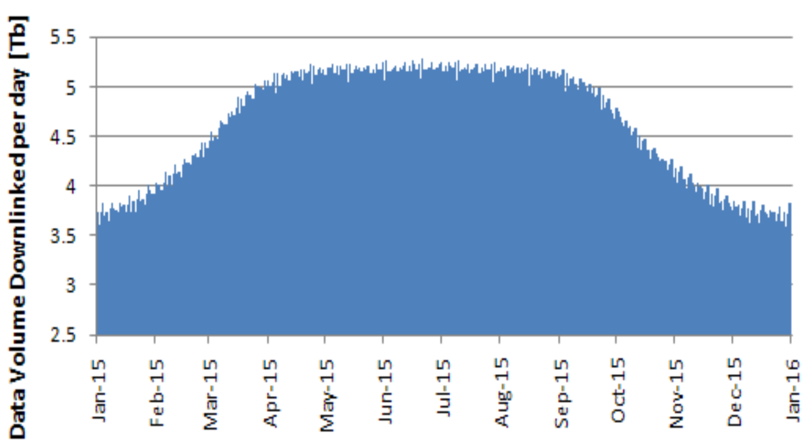
HyspIRI Downlink Data Volume



	Rate	On-board Compression
VSWIR_land	804.1 Mb/s	3:1
VSWIR_shallow	865.9 Mb/s	3:1
VSWIR_ocean	3.9 Mb/s	3:1
TIR_land	130.2 Mb/s	2:1
TIR_shallow	130.2 Mb/s	2:1
TIR_ocean	0.6 Mb/s	2:1

	Avg (Tb)	Min (Tb)	Max (Tb)
Per Day	4.64	3.59	5.29
Per Orbit	0.31	0.00	0.81

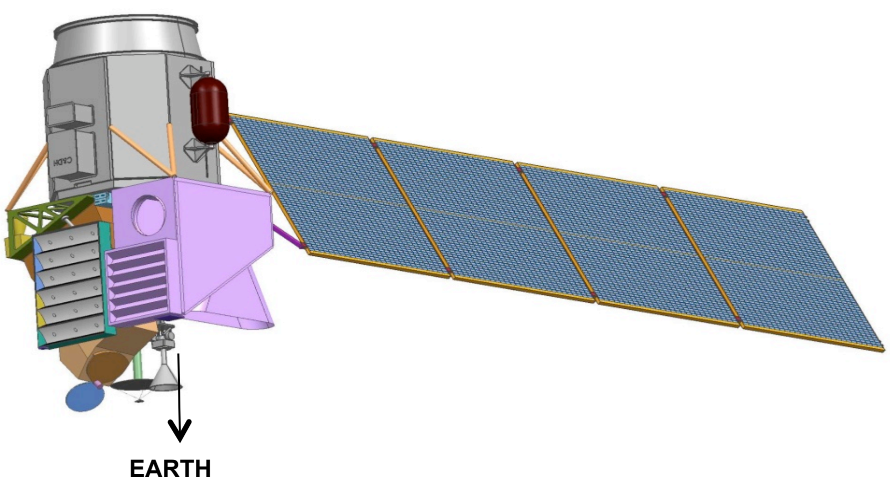
Total downlinked data volume for the 3 year mission: 5024 Tbits

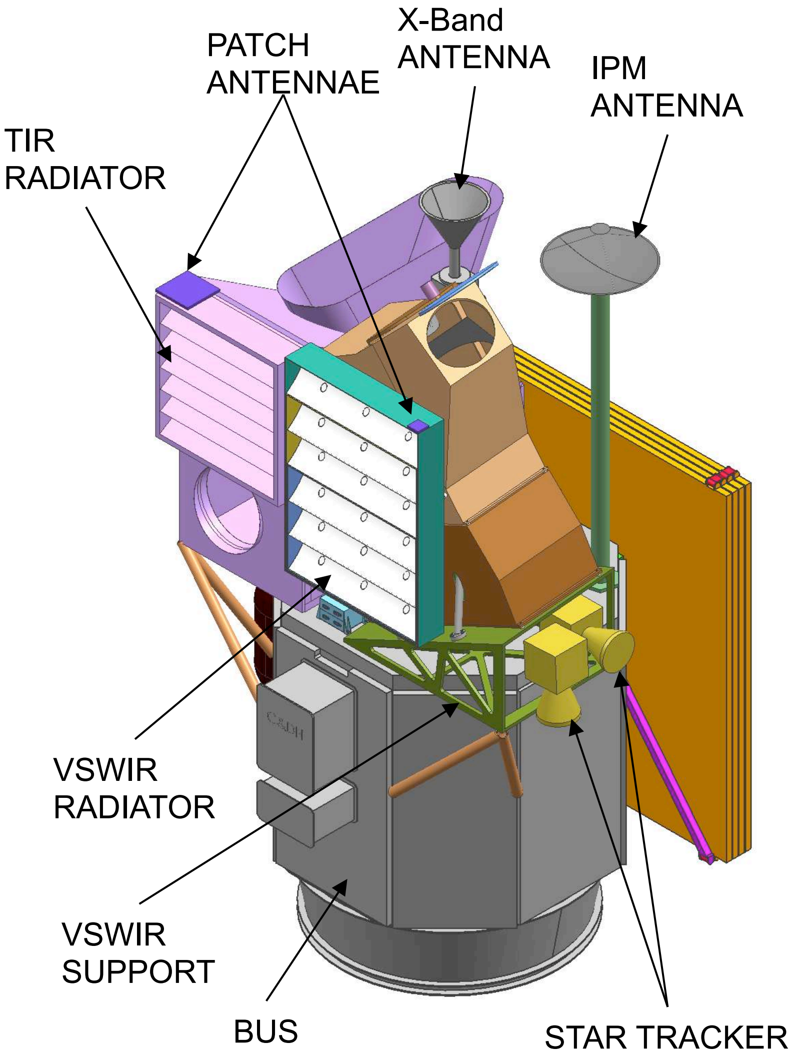


- Baseline selected to minimize system level cost and risk
- On-board storage capacity
  - 1 Tb
  - 0.31 Tb/orbit
- WorldView-1 and -2 have 2.2 Tb SSR
  - WorldView1: 0.33 Tb/orbit
    - Different downlink strategy requires larger SSR than HyspIRI
  - WorldView2: 0.52 Tb/orbit
- 30% margin added to calculated required SSR size

Baseline Flight System Concept

- Industry procured spacecraft bus
  - SA-200HP used as an example for the study to identify and cost needed modifications
- HyspIRI specific
  - Payload integrated on the top plate (TIR, VSWIR) and inside the S/C
  - Configuration chosen to minimize/eliminate thermal impacts on the payload radiators
  - Spacecraft Dry Mass (CBE): 520 kg
  - Launch Mass: 681 kg
  - JPL DP Margin: 31%
  - Required Power (CBE): 620W
  - Available Power: 965W, 7.2 m^2 array





Baseline Flight System Concept

	Requirements	RSDO SA-200HP	HyspIRI SA-200HP	Modifications
Orbit	626 km 10:30 LTDN	✓	✓	-
Mission duration	3 years, selective redundancy	4 years, selective redundancy	3 years, single string	Remove redundancy to reduce cost
Thermal	Passive architecture	✓	✓	-
Downlink	800 Mbps	80Mbps	800 Mbps	Dual-pol X-band
Propellant	75 m/s 37 kg	131 m/s 67 kg tank	131 m/s 67 kg tank	-
Onboard recorder	1 Tbit	134 Gbits	1Tbit	SEAKR SSP-R
Payload mass	126kg	666 kg	666 kg	Support structure for Instuments
Payload Power	885 W	650 W	965 W	Single wing configuration, add one panel
Pointing Knowledge	See table below	0.5 arcsec (3σ)	<=0.5 arcsec (3σ)	Replaced one of two coarse Ball CT-602 star tracker with one fine Lockheed Martin AST-301 star tracker.
Pointing Accuracy		16 arcsec (3σ)	<=16 arcsec (3σ)	
Pointing Stability		0.1 arcsec/sec (3σ)	<=0.1 arcsec/sec (3σ)	

Pointing	VSWIR Requirement	TIR Requirement	Rationale	Driver
Knowledge	< 48 μrad (3σ/axis)	< 48 μrad (3σ/axis)	<30m (3σ) post-reconstruction orthorectification knowledge at 626km altitude	TIR
Accuracy	<4.5 mrad (3σ/axis)	<4.5 mrad (3σ/axis)	VSWIR: Limits cross-track error to < 3 km on the surface	VSWIR
Stability	±0.1 mrad/sec (3σ)	±24.7 mrad/sec (3σ)	VSWIR: Limit smear to < 0.6 meters as one pixel crosses a spot on the surface in 8.8 msec TIR: Time for 6 pixels in TDI string to cross a point on the surface at nadir is 0.39 msec.	VSWIR

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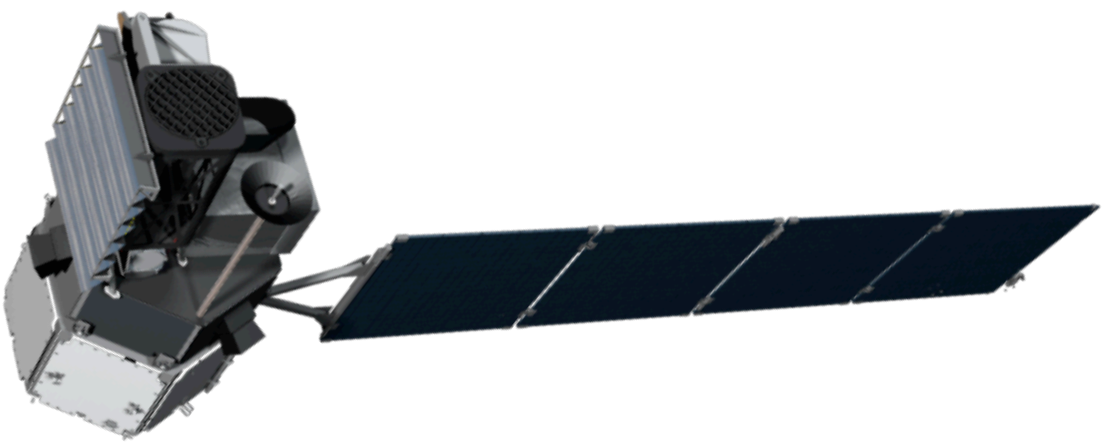
Alternative Flight System Concept

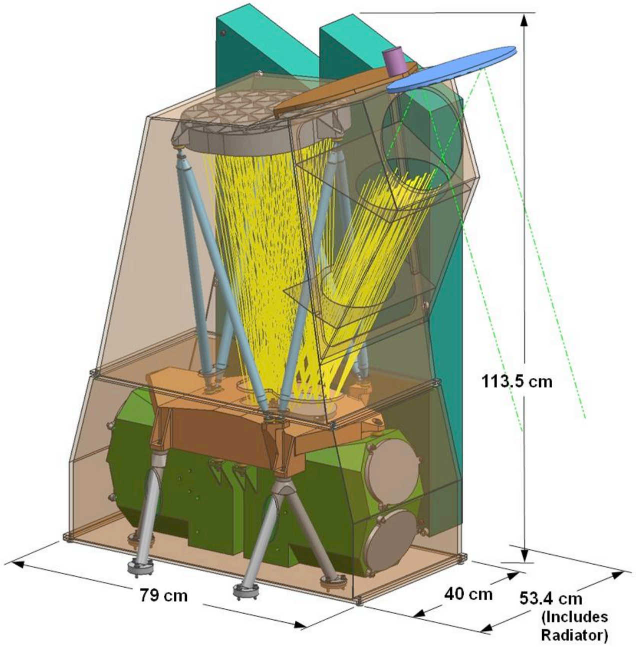
- Based on RFI response from ATK
  - Uses Responsive Space Modular Bus (RSMB) architecture
- HyspIRI specific
  - Spacecraft Dry Mass (CBE): 511 kg
  - Launch Mass: 671 kg
  - JPL DP Margin: 35% (assumes Taurus 3210)
  - Required Power (CBE): 640W
  - Available Power: 1028W

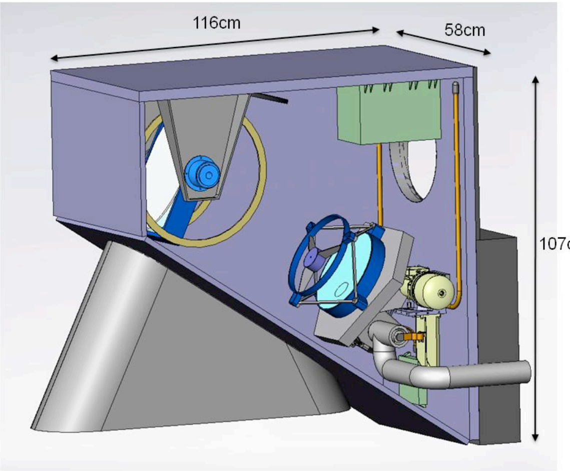


Science Payload Accommodation and System Margins

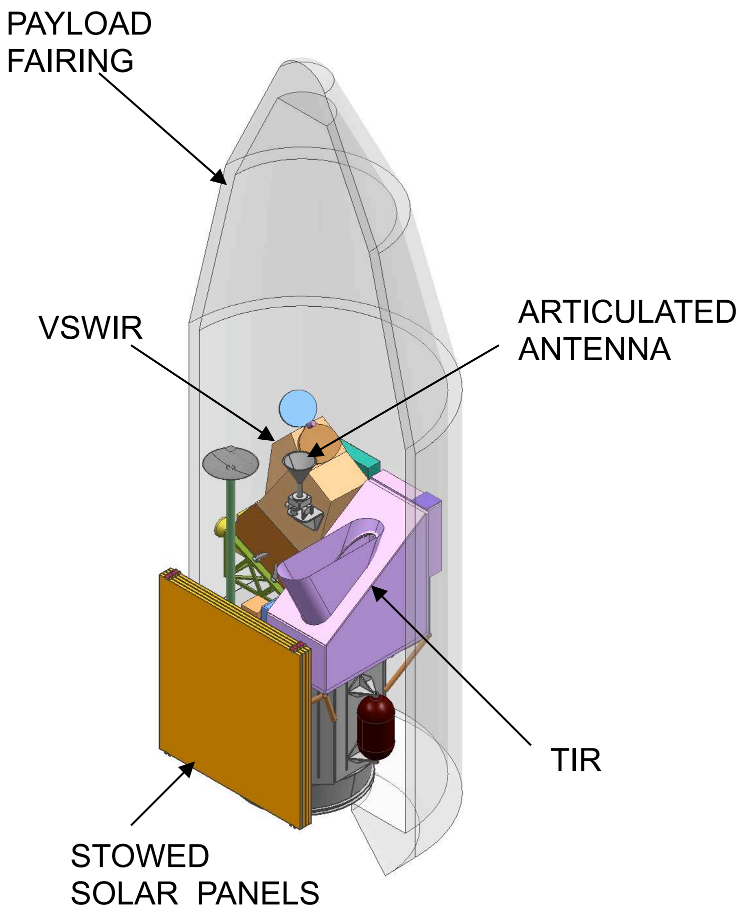
Accommodations	VSWIR	TIR
Mass (CBE)	55 kg	60 kg
Volume	1.1 x 0.5 x 0.8 m	1.2 x 1.1 x 0.6 m
Power	41 W	103 W
FOV (crosstrack)	13.62 deg	50.7 deg
FOV (alongtrack)	95.9 microrad	95.9 microrad
Orientation	4 deg to starboard	nadir

	Required	Design	Margin (D-R)/D
Swath width VSWIR	141km	151 km	6%
Swath width TIR	536km	600 km	11%
Recorder capacity	0.8 Tb	1.0 Tb	20%
Power	620 W (CBE)	965 W	36%
LV mass capability	520 (CBE, dry)	790 kg	34%

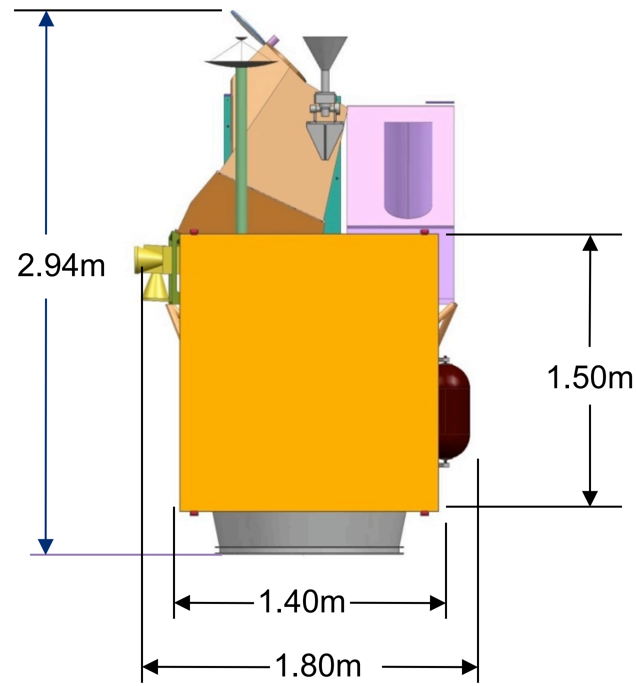




Launch Vehicle Concept



- Taurus 3210 can meet the mission needs
  - Closest fit among currently NASA approved launchers
  - 31% margin (per JPL Design Principles) with a Taurus-class launch vehicle
  - Fits dynamic volume envelope
  - 790 Kg launch capacity for HyspIRI Orbit
- Launch window
  - Mapping orbit reachable once per day



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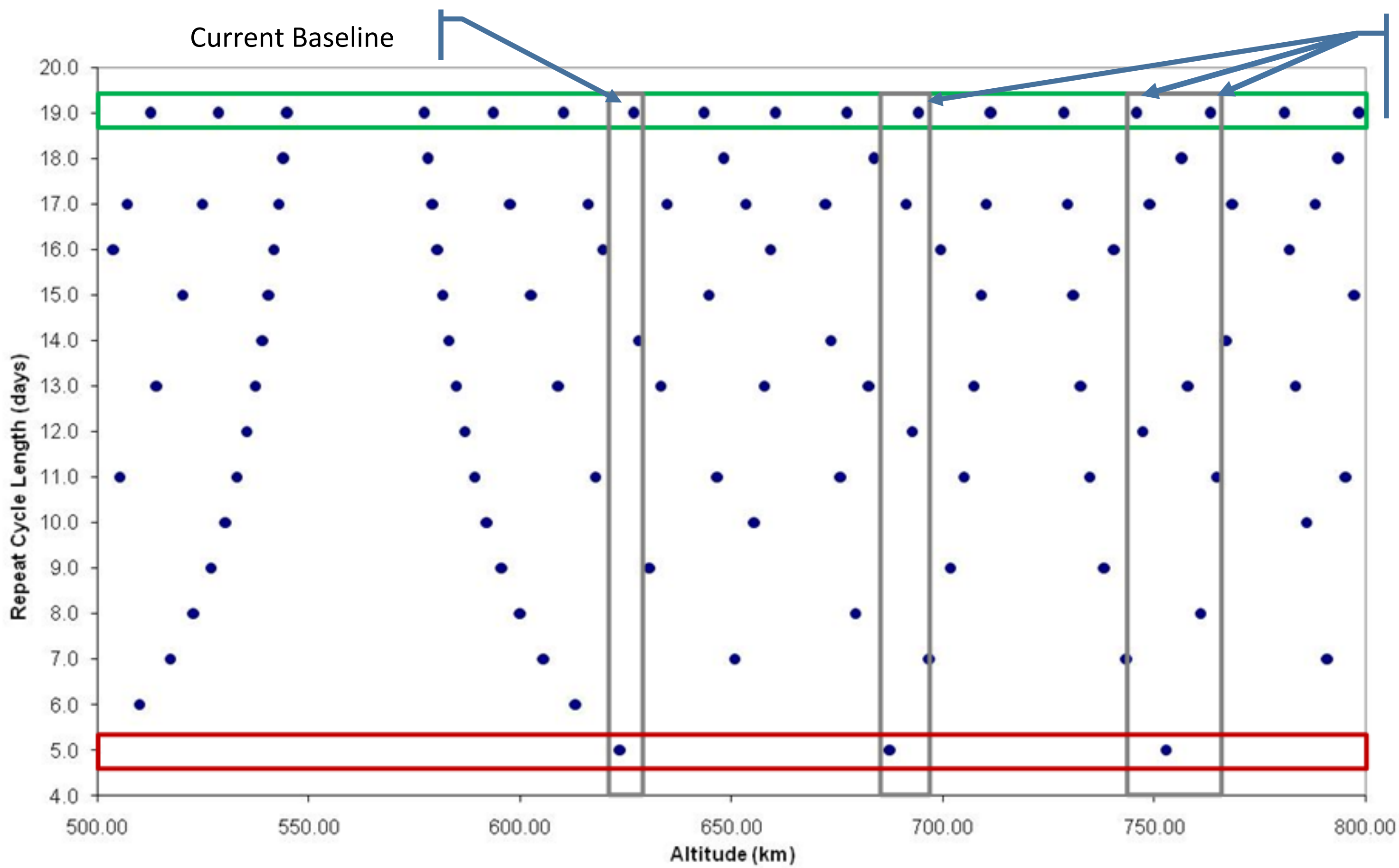
Alternate Orbits Compatible with HyspIRI

There is flexibility in the HyspIRI orbit design to accommodate a shared launch, should one be available, without sacrifices to science return



The VSWIR and TIR telescopes can be scaled to maintain 60 m spatial sampling at each of these orbits.

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U.S. Launch Vehicle Compatibility

LV	Throw Mass* (kg)	JPL Margin	Fairing (in)	Successful Launches	Availability	Estimated Cost	Comments
Taurus (3210)	790	31%	92	6/9 (1/1)	Yes	~$54M	Baseline; only one 3210 launch
Minotaur IV	1100	49%	92	2/2	DoD Only	~$50M	
Falcon 9	7500	>90%	204	2/2	Yes	~$55M	both flights were with Dragon capsule
Atlas V 4xx	~10000	>90%	157	17/18	TBD	TBD	401 had 9/10 launches
Delta IV Medium	8600	>90%	157	3/3	Yes	~$140	
Athena IIc	1700	69%	92	0/0	2012	TBD	2/3 launches of the II version

* For HyspIRI Orbit: 626km, sun-sync

Deorbit Analysis

NASA mandates compliance with NASA-STD 8719.14 Orbit Debris & Reentry

"A spacecraft or orbital stage with a perigee altitude below 2000 km shall be disposed of by … :"

"Atmospheric reentry option:

Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission but no more than 30 years after launch"

HyspIRI is compliant as analysis of the spacecraft orbit and the geometry of the observatory indicates reentry within 18 years from EOL

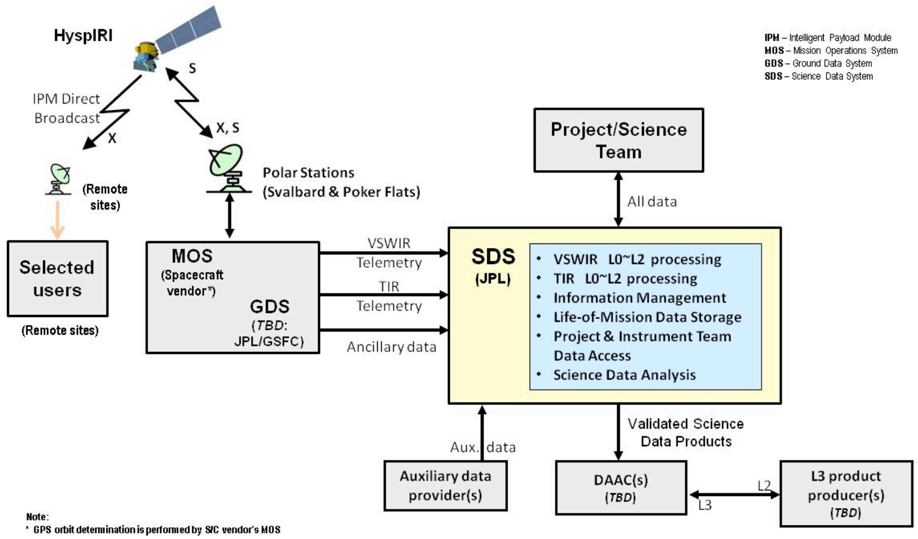
"The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 Joules: "

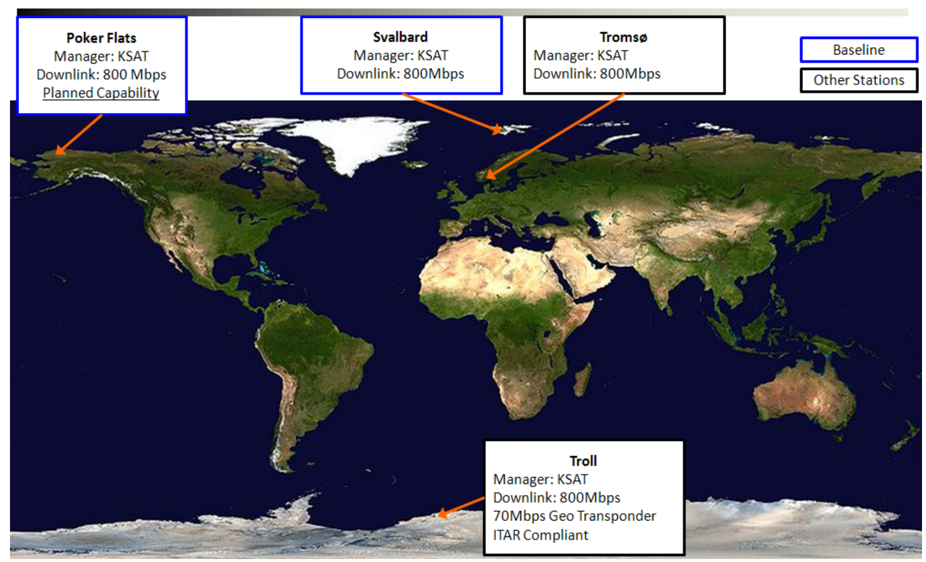
"For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000)."

HyspIRI is currently compliant as simulation performed with NASA's Debris Assessment Software (DAS 2.0.1) shows a probability of 1:42,300

Ground System Concept

- Data Downlink
  - KSAT Ground network
    - Svalbard @ 800 Mbps Dual-pole X-Band (existing)
    - Poker Flats @ 800 Mbps Dual-pole X-Band (in development)
    - Other stations available
  - Almost 100% data return with 1 Tbit SSR on spacecraft
- Data Processing
  - SDS sized to process L0 through L2 data for both instruments
  - Deliver L2 data products to DAAC
  - L3 data products produced by users





HyspIRI will utilize existing infrastructure with proven capability to downlink and process all science data

BACKUP

HyspIRI Mission Concept

Orbit Selection

- Key Orbit Design Considerations
  - Local time of observations
    - Sun-synchronous
    - 10:30 AM LTDN
  - Altitude
    - Low Earth Orbit
    - Repeating Ground track
  - Global coverage in a minimum number of days given the swath-width of each instrument.
    - VSWIR: 19 days revisit at the equator
    - TIR: 5 day revisit at the equator (1 day + 1 night)
- 626 km altitude at equator suits the needs of both instruments

Orbit selection and operations concept meet science requirements with infrequent ground commanding or maintenance.

Operations Concept

- Systematic mapping vs. pointing capability
- Target map driven - No need for uploading acquisition sequences
- High resolution mode and Low resolution mode
- Direct Broadcast capability
  - Uses Intelligent Payload Module
  - Applications-driven

Operational Requirement	VSWIR	TIR
10:30 am sun-sync orbit	✓	✓
626 km altitude at equator	✓	✓
19 days revisit at the equator	✓	
5 day revisit at the equator		✓
Day Observation	✓	✓
Night Observation		✓
Pointing strategy to reduce sun glint	✓	
Surface reflectance in the solar reflected spectrum for elevation angles >20	✓	
Avoid terrestrial hot spot	✓	
Monthly Lunar View calibration	✓	✓
Weekly Solar View Calibration	✓	
Blackbody View Calibration		✓
Deep Space View Calibration		✓

Key Driving SDS Design Requirements

- Data Downlink Volumes: 5.3 Tb/day Max. (4.6 Tb/day Mean)
- Data Product Types: 2 Level 0's, 2 Level 1's, 2 Level 2's, *tbd* L3
- Data Product Availability:

Product Application	Nominal Latency From Receipt of Required L0a Data at Processing Node	Comments
Routine Science	1 week – 2 weeks	Products meet science/calibration specifications
Priority Target Events	1 day	Data acquisitions are not routinely planned but event-driven Products are L1 and L2/3 in limited quantity Products may not meet science/calibration specifications
Intelligent Payload Module Direct Broadcast	No latency requirement for SDS	Data broadcast via the IPM will not end up at the SDS

- **Total Mission Data Volume***: 47.2 Tbits (6.2 Tb L0B's, 18.6 Tb L1B's, 22.5 Tb L2's) per day
  58.2 Pb over mission life
- **Processing Loading:** Sized to meet respective product latency requirements (no backlog and with margin to include *one* reprocessing campaign
- **SDS sized for 5.2 Tb/day**
  - 98.1% of the time, less than 5.2 Tb is downlinked per day

Notes: * Mission data volume based on maximum L0A downlink volume; exclusive of data from Direct Broadcast;
Assumes all L0 processed to L1 & L2; all in 16-bit per sample;
Assumes data compression ratios of 3:1 for all VSWIR and 2:1 for all TIR image bands; assumes no compression for ancillary bands;
Tb – Terabits (10^12 bits); Pb – Petabits (10^15 bits)