NEMO-HD

HIGH-RESOLUTION MICROSATELLITE FOR EARTH MONITORING AND OBSERVATION

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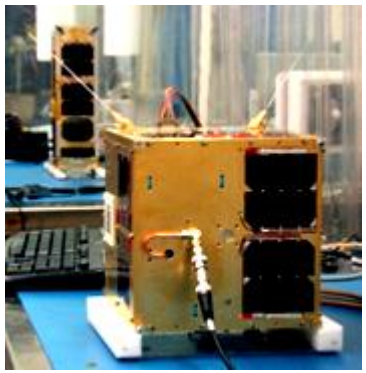
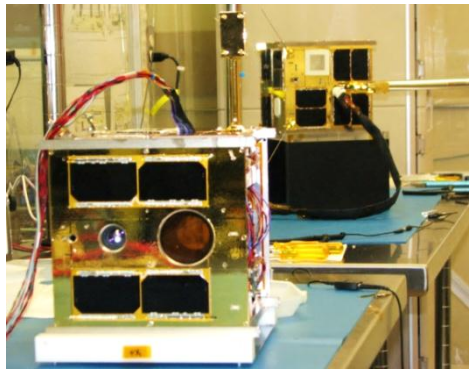
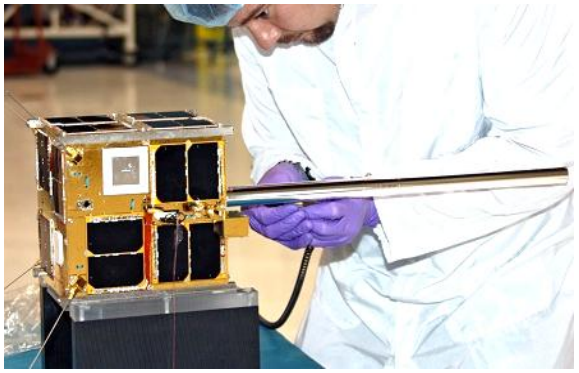
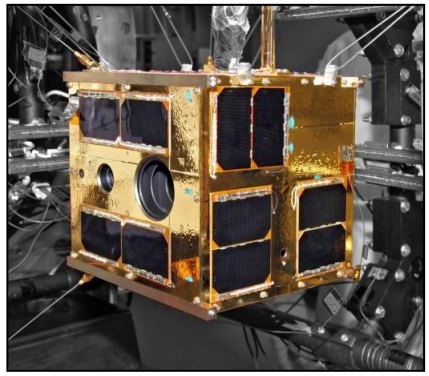
Presentation Outline

- UTIAS Space Flight Laboratory
- Spacecraft Overview
- Primary Instrument Overview
- Preliminary Layout
- System Architecture
- Modes of Operations
- Systems Budgets
- Conclusion

Space Flight Laboratory

- Develops high-performance missions using nanosatellite and microsatellite for end-user around the world while training students
- Four operational spacecraft, 12 spacecraft under construction
- End-to-end in-house capability: mission analysis ⇒ design and manufacturing ⇒ assembly and verification ⇒ launch ⇒ on-orbit operations
- 28 full-time professional staff engineers, 12 graduate students
- Self-managed launch procurement and launch campaign
- New Microsatellite Science and Technology Center (MSTC)

NEMO-HD Program

- High-Resolution Multi-Spectral Imaging with Realtime HD Video
- SPACE-SI Slovenian Centre of Excellence for Space Sciences and Technologies

- RFP issued in August 2011
- Contract awarded in Dec 2011
- SFL-designed bus and instruments
- Preliminary Design Review on 31 May 2012

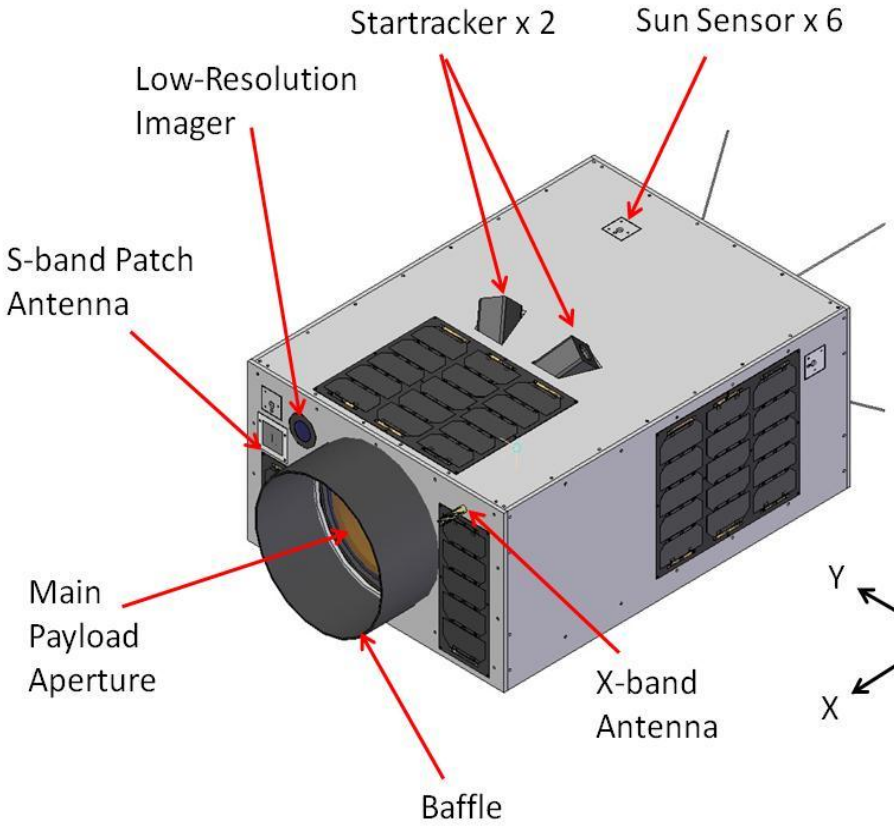
Spacecraft Overview

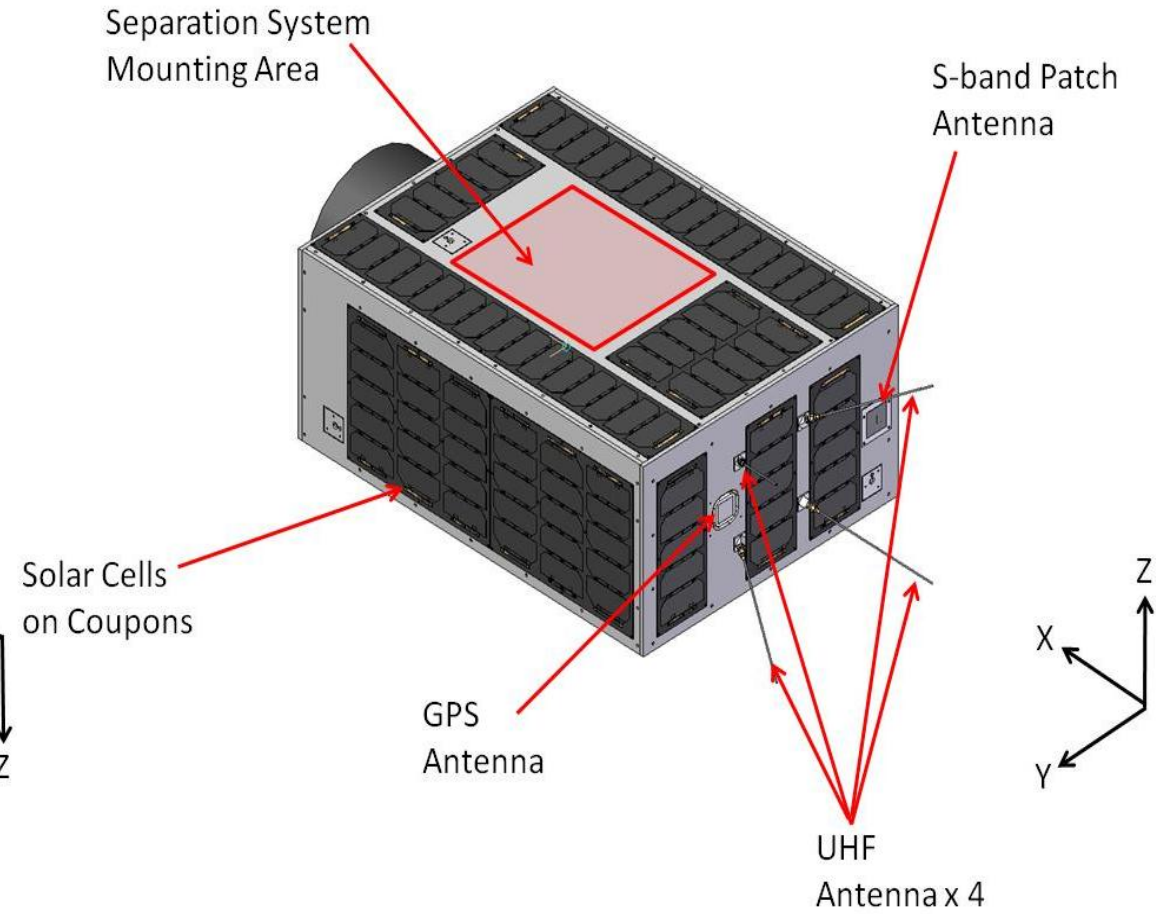
Specification	Value
Primary Instrument	6-channel Multi-Spectral Imaging, RGB 1080p HD
	200 mm optical aperture
	2.8m/5.8 m GSD (Pan+HD/MS), 10.8 km swath
	400-900 nm (Panchromatic) 450-520/520-600/630-690/760-900 nm (Landsat 1/2/3/4)
Secondary Instrument	RGB Snapshot, 1080p HD
	< 75 m GSD, 81 km swath @1080p
Design Altitude	600 km
Overall Dimensions	43 x 29 x 65 cm
Launch Mass	50 kg (including margins)
Power Generation	50 W
Battery	150 Wh Li-Ion
Command Uplink	4 kbps UHF RX
Telemetry Downlink	32 – 128 kbps S-Band TX
Payload Data Downlink	50 Mbps X-Band TX
Determination Precision	15 arcsec (1σ)
Pointing Precision	120 arcsec (2σ)

Primary Instrument

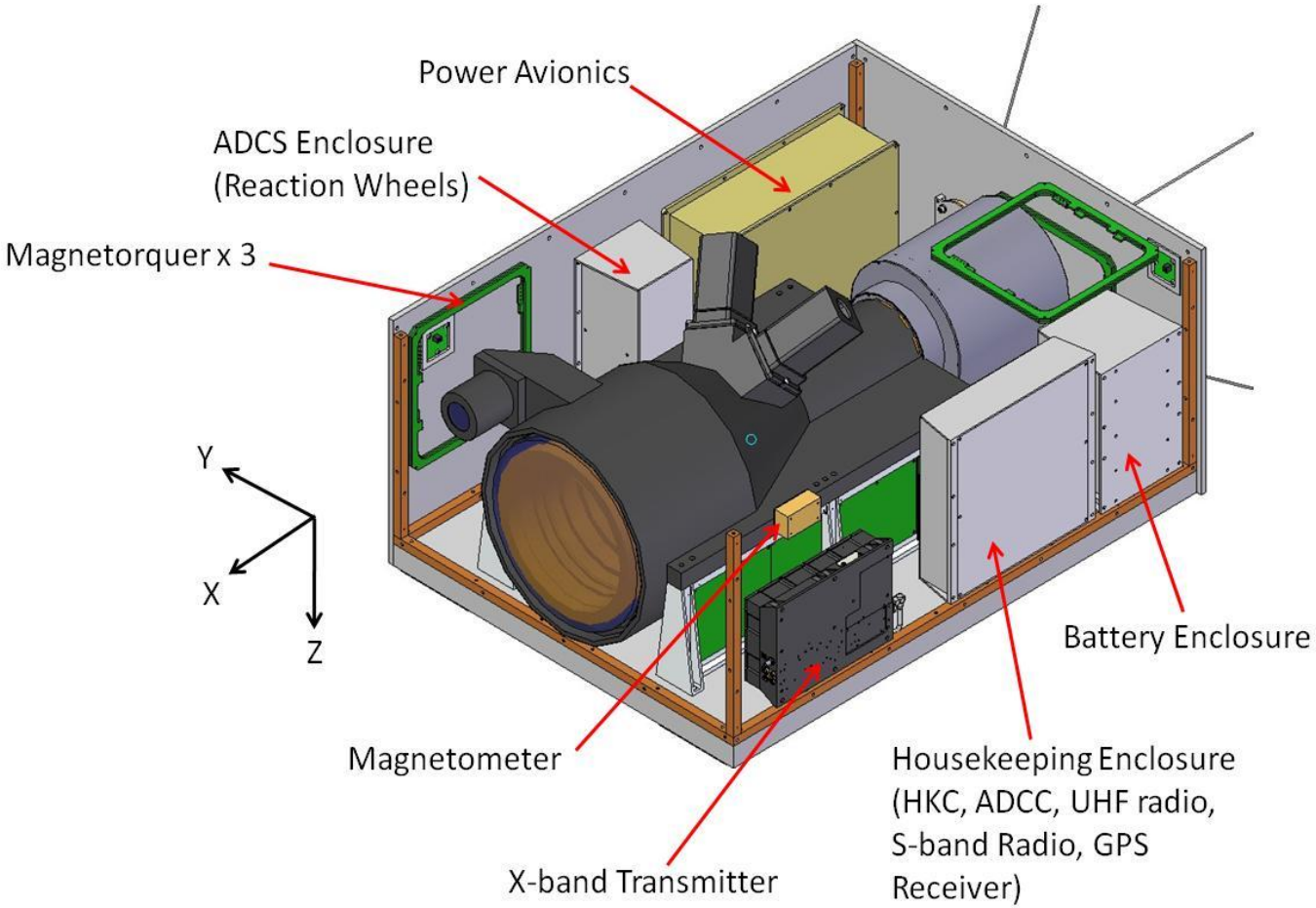
Specification	Value	
Primary Instrument	6-channel Multi-Spectral Imaging, RGB 1080p HD	
	200 mm optical aperture	
	2.8m/5.8 m GSD (Pan+HD/MS), 10.8 km swath	
	400-900 nm (Panchromatic) 450-520/520-600/630-690/760-900 nm (Landsat 1/2/3/4)	
MTF (Theoretical)	0.40	*Required MTF > 0.1*
SNR	78.1	*Required SNR > 75*
	88.4	
	104.3	
	84.4	
	75.1	

External Layout

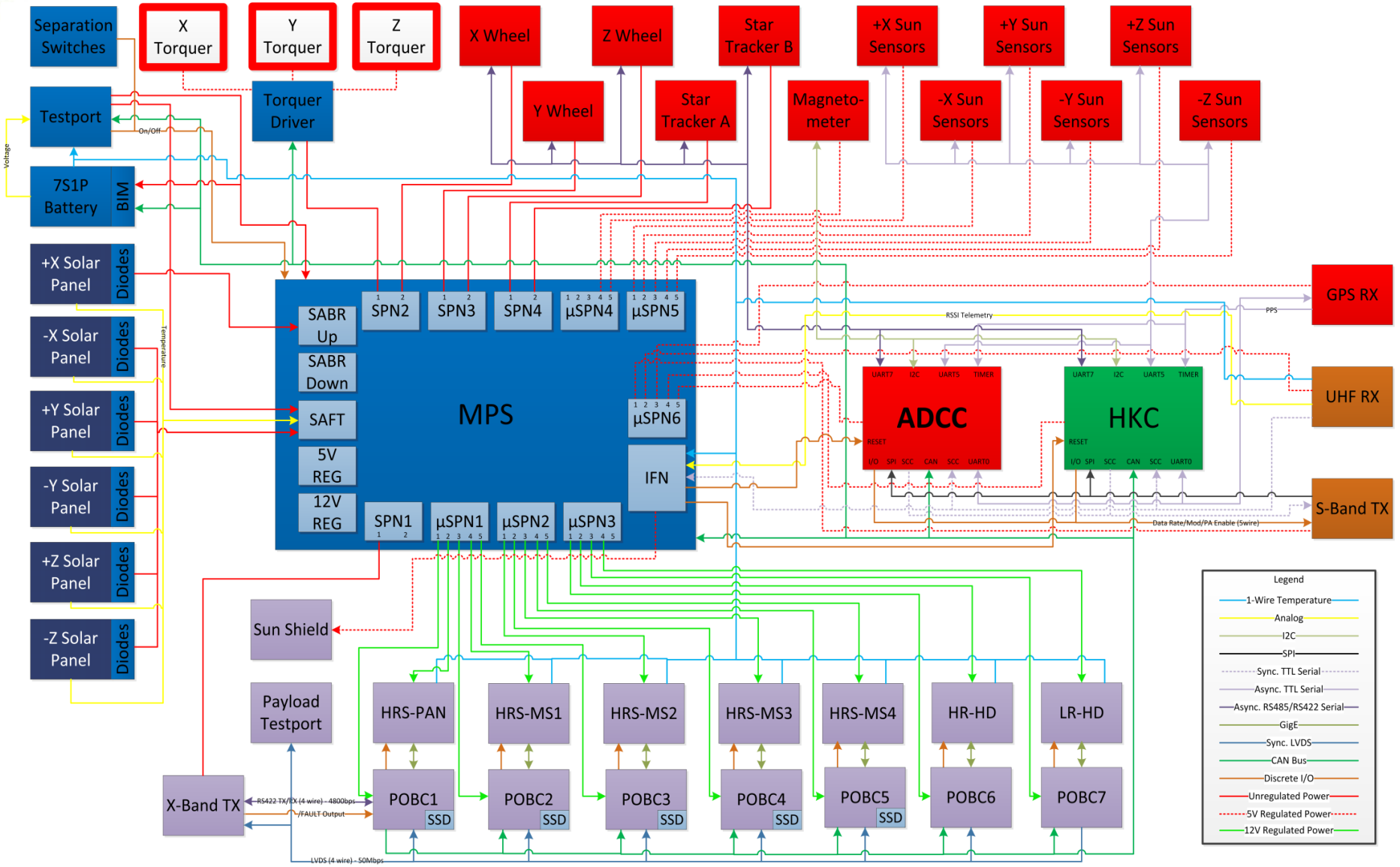




Internal Layout



System Architecture



Modes of Operations

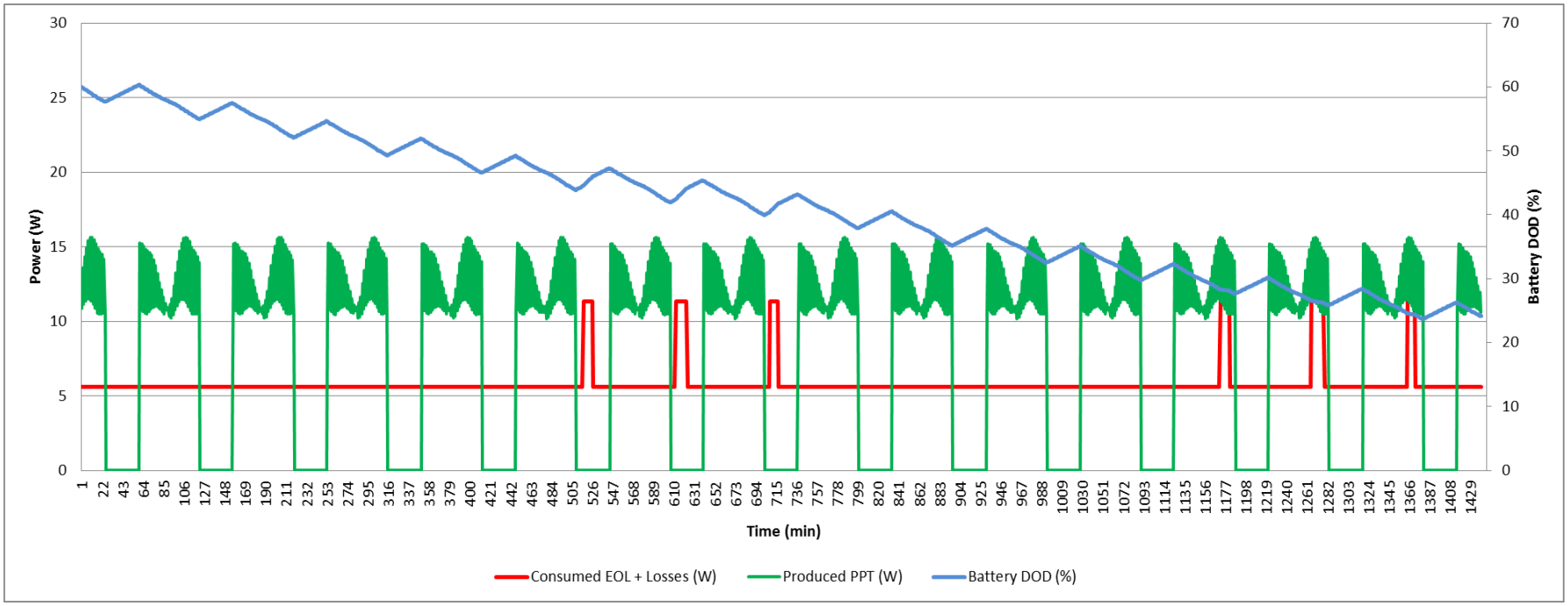
Mode	Description
Safe Hold	• Entered following launch vehicle separation or if an anomaly occurs • Passively safe state in which the spacecraft can remain indefinitely
Detumble	• Attitude control mode for reducing spacecraft rotation rates
Real Time Video	• Stream video from either primary or secondary 1080p HD cameras to ground via X-Band TX
	• **Interactive Mode**
Remote Imaging	• Remote imaging with primary instrument panchromatic and multi-spectral cameras. • Typically 16 seconds long for 10 km by 100 km swath
Sun Pointing	• Maximizes power generation when not imaging
Data Downlink	• Downlink payload data to ground using X-Band TX during eclipse periods

From/To	Safe Hold	Detumble	RTIM-Video	RTIM-MS	RIM-Video	Sun Pointing	Downlink
Safe Hold		C	C	C	C	C	C
Detumble	L2, L3, F, C		C	C	C	C	C
RTIM-Video	L2, L3, F, C	C		C	C	L1, C	C
Remote-MS	L2, L3, F, C	C	C		C	L1, C	C
Sun Pointing	L2, L3, F, C	C	C	C	C		C
Downlink	L2, L3, F, C	C	C	C	C	L1, C	

Safe Hold Mode

Simulation Parameter	Value
Spacecraft Attitude	+X Sun Pointing
SSO Orbit Altitude	600km
SSO Orbit LTAN	10:30
Eclipse Fraction	36%
Panel Temperature	65°C

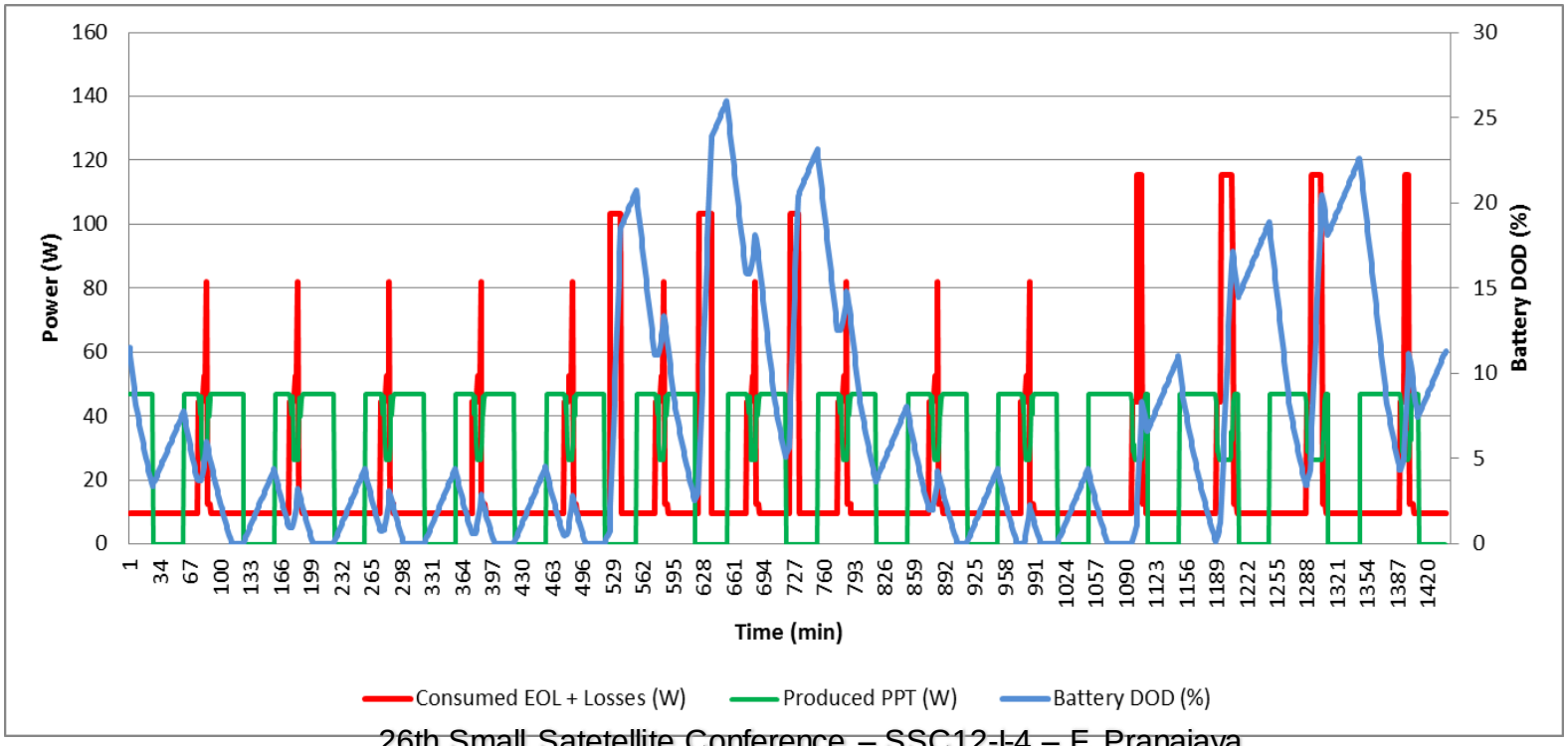
Simulation Result	Value
Average Power Produced	7.9W
Energy Produced	189.2Wh
Peak Power Produced	15.6W
Average Power Consumed	6.0W
Energy Consumed	143.8Wh
Peak Power Consumed	11.3W
Energy Margin	24.0%
Orbit Average Battery DOD	3.0%



Earth Observation Mode

Simulation Parameter	Value
Spacecraft Attitude	Sun Pointing, Inertial Pointing, Nadir Tracking
SSO Orbit Altitude	700km
SSO Orbit LTAN	10:30
Eclipse Fraction	33%
Panel Temperature	80°C

Simulation Result	Value
Average Power Produced	28.4W
Energy Produced	681.7Wh
Peak Power Produced	46.9W
Average Power Consumed	18.8W
Energy Consumed	451.2Wh
Peak Power Consumed	115.6W
Energy Margin	33.8%
Orbit Average Battery DOD	11.1%



UHF Link

- Altitude: 600 km
  Minimum Elevation: 5°
- Information Data Rate: 4 kbps
- Transmitter Power: 250 W
- Transmit Antenna Gain: 23 dBi
- Receive Antenna Gain: -8 dBi
  Receiver sensitivity: -113 dBm

- Link Margin: 17.9 dB
- Command Earth station configuration is based on a similar installation at SFL

UHF Uplink Budget

Thursday, May 17, 2012

Uplink

	Input	Calculations	Unit
Frequency	403		MHz
Wavelength	0.7439		m
Transmit power (mWatts)	250000	53.98	dBm
Feed hamess loss	3	-3.00	dB
Antenna gain		23.00	dBic
Antenna beamwidth (half power)	10.00		degrees
Pointing error	5		degrees
Pointing loss		-3.00	dB
EIRP		**70.98**	**dBm**
Satellite orbital altitude (circular orbit)	600		km
Minimum elevation	5		degrees
Maximum distance to satellite	2329.03		km
Free space loss		-151.90	dB
Polarization loss	1		dB
Atmospheric loss	1		dB
Total propagation loss		-153.90	dB
Isotropic signal at Spacecraft		**-82.92**	**dBm**
Antenna gain		-8.00	dBic
Antenna Mismatch Loss (VSWR)	2.5	-0.88	dB
Antenna Interface Loss	0	0.00	dB
Power Splitter Loss	2	-2.00	dB
Feed hamess loss	1	-1.00	dB
Preamplifier Noise Figure	2		dB
Preamplifier Gain	15		dB
Receiver Noise Figure	10		dB
System Noise temp (K)	832.64	29.20	dBK
G/T		**-41.09**	**dB/K**
Receiver Signal Power	**-94.80**		**dBm**
Receiver Noise Power	**-123.96**		**dBm**
C/No		74.60	dB/Hz
Receive Bandwidth	35000	45.44	dBHz
C/N		29.16	dB
Information Data Rate	4000		bps
Coding Rate	1.00		dB
Channel Data Rate	4000		bps
Modulation Index	1		Hz/Hz
Occupied Bandwidth (98% Power BW)	8000		Hz
Implementational Losses	1	1.00	dB
Baseband S/N		**29.92**	**dB**
Required S/N for 10E-5 BT=0.5 GFSK	12	12.00	dB
Coding Gain	0	0.00	dB
Coded Required S/N for 10E-5 BT = 0.5 GFSK		12.00	dB
Uplink Margin		**17.92**	**dB**
C/N at Detector Input		28.16	dB
FM Threshold C/N (discriminator detector)		12.00	dB
FM Threshold Margin		**16.16**	**dB**

S-Band Link

- Altitude: 600 km
  Minimum Elevation: 5°
- Information Data Rate: 64 kbps, BPSK
- Transmitter Power: 350 mW
- Transmit Antenna Gain: -7 dBi
- Earth Station G/T: 17.1 dB/k

- Link Margin: 10.6 dB
- Earth station is assumed to be the same as the X-band

S-Band Downlink Budget
Thursday, May 17, 2012

Downlink	Inputs	Calculations	Units
Frequency	2290		MHz
Wavelength	0.1309		m
Transmit power (mWatts)	350.00	25.4	dBm
Filter loss	0	0.0	dB
Feed harness loss	1	-1.0	dB
Antenna size			m
Antenna efficiency			%
Antenna gain		-7.0	dBic
EIRP		**17.4**	**dBm**
Satellite orbital altitude (circular orbit)	600		km
Minimum elevation	5		degrees
Maximum distance to satellite	2328		km
Free space loss		-167.0	dB
Polarization mismatch loss	1		dB
Atmospheric loss	1		dB
Total propagation loss		-169.0	dB
Isotropic signal power at Antenna		**-151.5**	**dBm**
Antenna size	5.2		m
Antenna efficiency	60		%
Antenna gain		39.7	dBic
Antenna beamwidth (half power)	1.8		degrees
Pointing error	0.1		degrees
Pointing loss		0.0	dB
Filter loss	0	0.0	dB
Feed harness loss	0.5	-0.5	dB
Receiver LNA Noise Figure	0.8		dB
LNA Gain	30		dB
Receiver Noise Figure	10		dB
System Noise temp (K)	181.9	22.6	dBK
G/T		**17.1**	**dB/K**
Receiver Signal Power	**-111.9**		**dBm**
Receiver Noise Power	**-124.9**		**dBm**
C/No		64.1	dB
Information Data Rate	64		Kbps
Coding Rate	0.5		
Channel Data Rate	128		Kbps
Modulation Order	1		bps/sps
Channel Symbol Rate	128		Ksps
Channel Bandwidth (Null-to-null)	256		KHz
C/N		13.1	dB
Implementational Losses	1	1.0	dB
Es/No		12.1	dB
Eb/No		**15.1**	**dB**
Required Eb/No for 10E-5 BER		9.6	dB
Coding Gain	5.1	5.1	dB
Coded Required Eb/No for 10E-5 BER		4.5	dB
Downlink Margin		**10.6**	**dB**

X-Band Link

- Altitude: 600 km
  Minimum Elevation: 5°
- Information Data Rate: 50 Mbps
- Transmitter Power: 10 W
- Transmit Antenna Gain: 2.0 dBi
- Earth station G/T: 30.1 dB/k

- Link Margin: 4.5 dB
- Based on existing the X-band Earth station

X-Band Downlink Budget
Thursday, May 17, 2012

Downlink	Inputs	Calculations	Units
Frequency	8400		MHz
Wavelength	0.0357		m
Transmit power (mWatts)	10000.00	40.0	dBm
Filter loss	1	-1.0	dB
Feed harness loss	1	-1.0	dB
Antenna size			m
Antenna efficiency			%
Antenna gain		2.0	dBic
EIRP		**40.0**	**dBm**
Satellite orbital altitude (circular orbit)	600		km
Minimum elevation	5		degrees
Maximum distance to satellite	2328		km
Free space loss		-178.3	dB
Polarization mismatch loss	1		dB
Atmospheric loss	2.5		dB
Total propagation loss		-181.8	dB
Isotropic signal power at Antenna		**-141.8**	**dBm**
Antenna size	5.2		m
Antenna efficiency	60		%
Antenna gain		51.0	dBic
Antenna beamwidth (half power)	0.48		degrees
Pointing error	0.1		degrees
Pointing loss		-0.5	dB
Filter loss	0	0.0	dB
Feed harness loss	0	0.0	dB
Receiver LNA Noise Figure	0.7		dB
LNA Gain	30		dB
Receiver Noise Figure	10		dB
System Noise temp (K)	108.3	20.3	dBK
G/T		**30.1**	**dB/K**
Receiver Signal Power	**-91.3**		**dBm**
Receiver Noise Power	**-101.3**		**dBm**
C/No		87.0	dB
Information Data Rate	50000		Kbps
Coding Rate	0.5		
Channel Data Rate	100000		Kbps
Modulation Order	2		bps/sps
Channel Symbol Rate	50000		Ksps
Channel Bandwidth (Null-to-null)	100000		KHz
C/N		10.0	dB
Implementational Losses	1	1.0	dB
Es/No		9.0	dB
Eb/No		**9.0**	**dB**
Required Eb/No for 10E-5 BER		9.6	dB
Coding Gain	5.1	5.1	dB
Coded Required Eb/No for 10E-5 BER		4.5	dB
Downlink Margin		**4.5**	**dB**

Mass Budget

Subsystem	Mass g	Contingency g	Total g	Fraction %
Structural	5447	1362	6809	14%
Thermal	100.0	25.0	125	0%
ADCS	1793	202	1994	4%
Power	4293	711	5004	10%
Computer	859	202	1061	2%
Communications	1308	95	1404	3%
Payloads	25128	6282	31409	63%
Integration	399	91	491	1%
Separation System	1000	250	1250	3%
Total	**39327**	**8969**	**49546**	**100%**

Collaborative Efforts

Research at SPACE.SI to be applied on NEMO-HD:

- Ground-based interactive tracking
  Interactive ground target tracking with automatic/manual ground-based controller

- Ground-based image processing

Conclusion

- Preliminary design completed, PDR on 31 May 2012
- Based on the SFL NEMO (Nanosatellite for Earth Monitoring and Observation) bus architecture and builds upon GNB (Generic Nanosatellite Bus) heritage
- Instrument Prototype Under Construction
- Detailed Design Phase On-Going