La SEINE

Kyutech
Kyushu Institute of Technology

The 8th

Mission Idea Contest

for Multiple Nano-satellites

The design of a 6U nanosatellite constellation for passive debris tracking and monitoring

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Motivation

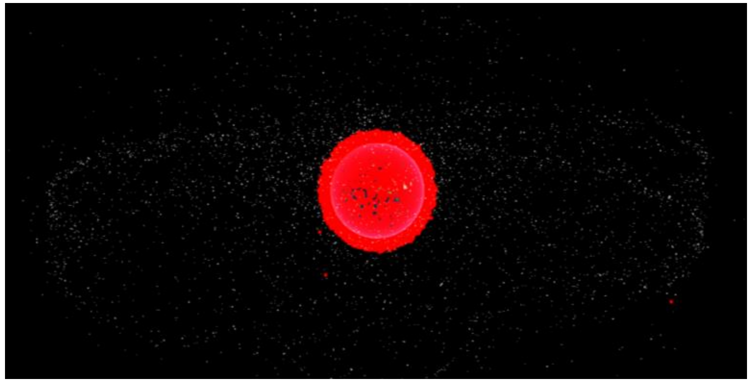

Fig 1. Low Earth orbit (14 320 of 19856 satellites)

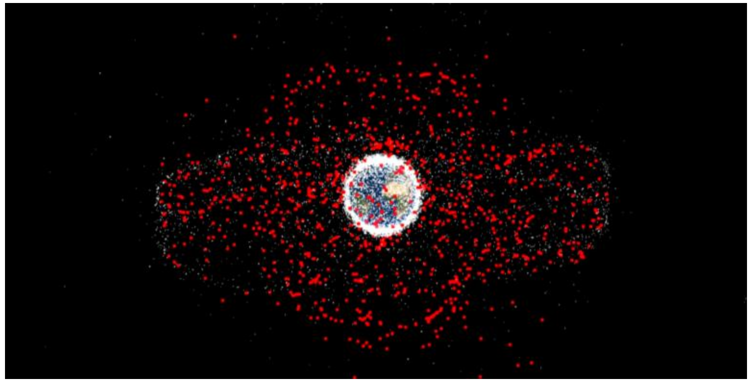

Fig 2. Medium Earth orbit

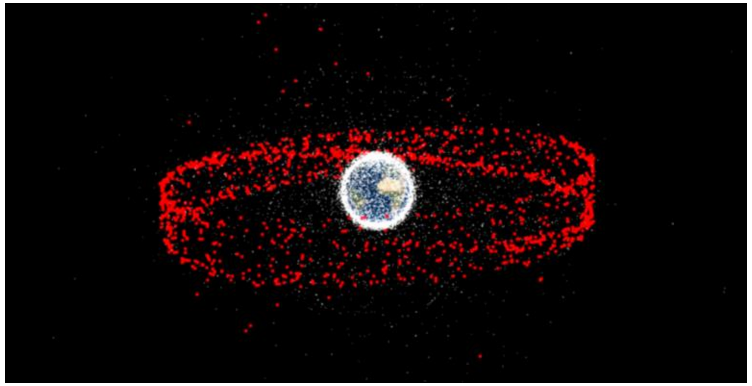

Fig 3. Geosynchronous Orbit

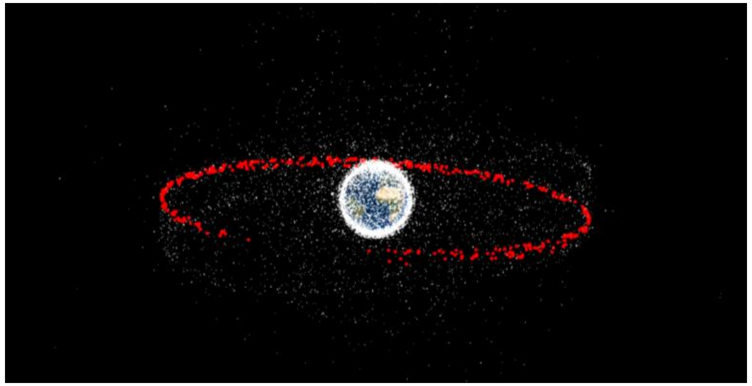

Fig 4. Geostationary Earth Orbit

https://maps.esri.com/rc/sat2/index.html#

Motivation

Recorded Debris Incidents

1. 1996, Functional French satellite collision with exploded French rocket.

2. 2007, deliberate missile strike on defunct Feng -Yun 1C weather satellite by the Chinese during anti satellite test.

3. February 10, 2009, collision between functional Iridium 33 communication satellite and a decommissioned Russian Cosmos 2251 satellite.

4. Most recent, Russian anti-satellite test created thousands of debris pieces.

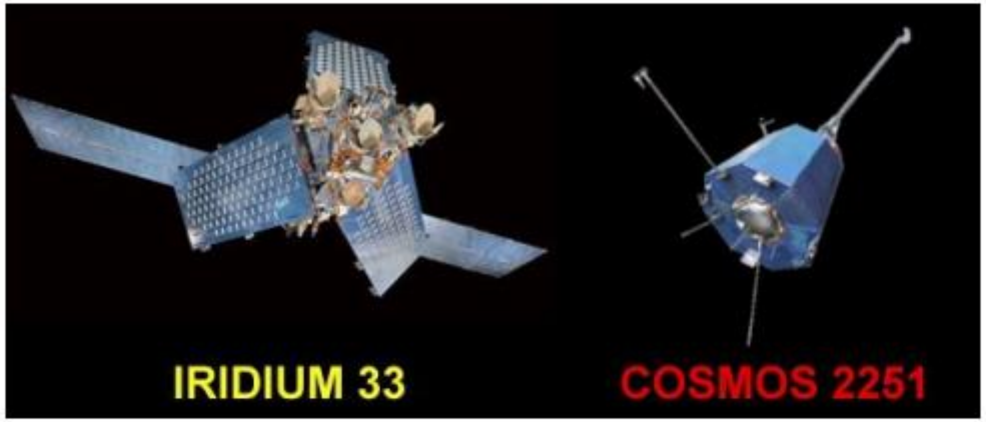

Fig 5. Iridium 33 and Cosmos 2251 Satellites

IRIDIUM 33 and COSMOS 2251: AN HISTORIC COLLISION By Michael A. Earl

Motivation

Motivations

- Need for Debris management in the LEO
- Traffic management of the LEO
- Improving accuracy on current debris models

Key Advances in Space Technologies

- Technology miniaturisation (Radar Technology)
- Energy Efficiency

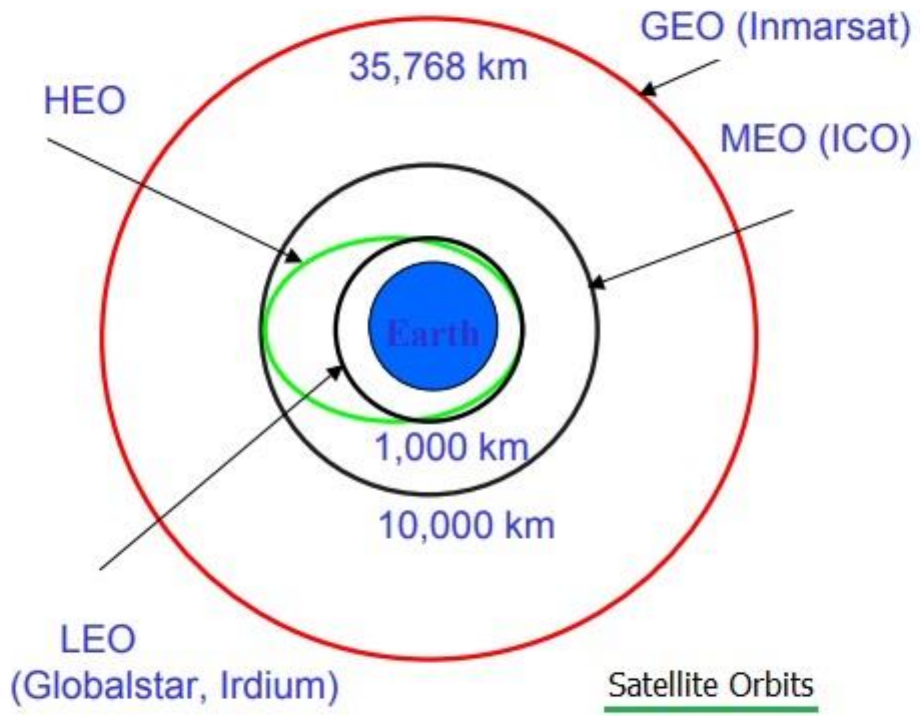

Figure 6: Orbits

https://www.javatpoint.com/types-of-satellite-systems

Mission Objectives

1. Creating a platform to improve debris detection and tracking efforts.

2. Improving the accuracy of current debris tracking catalogues .

3. Increasing the space situational awareness as far as debris is concerned.

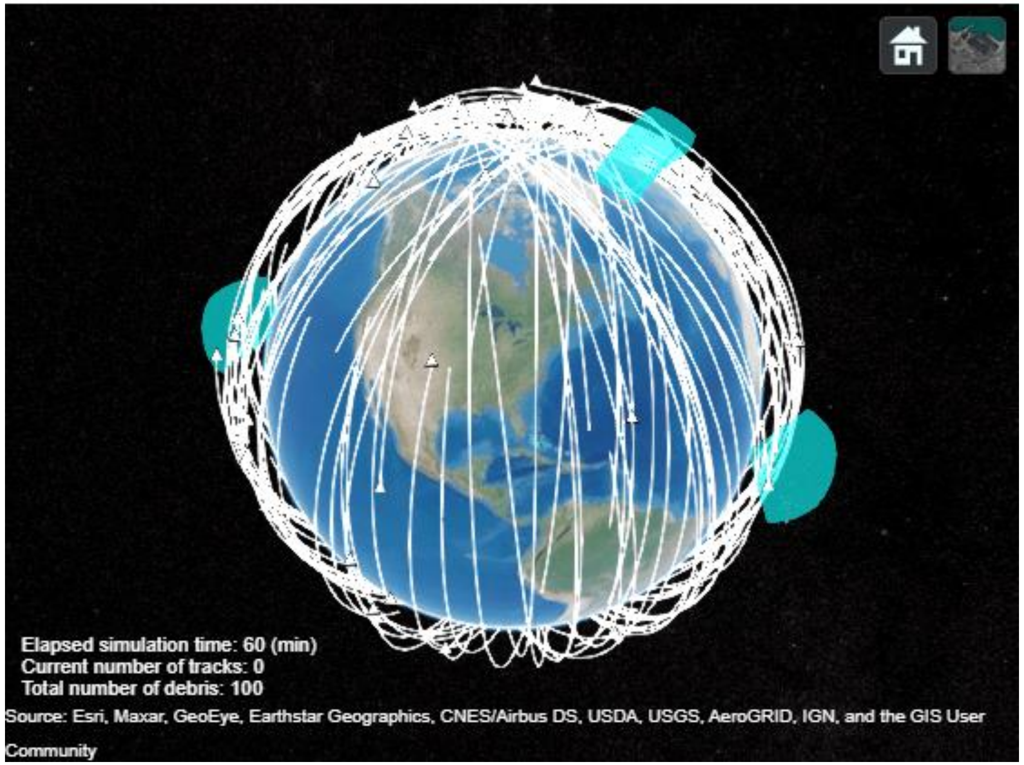

Figure 7. Debris tracking model

https://uk.mathworks.com/help/fusion/ug/track-space-debris-using-keplerian-motion-model.html

Current Technology

Current Players in Debris Monitoring and Mapping

- Leo Labs
- NASA
- European Space Agency
- Russia and China

Figure 8: Kiwi Space Radar

https://www.leolabs.space/company/

Technologies currently being utilised

- Ground based Radar
- Optical Radar

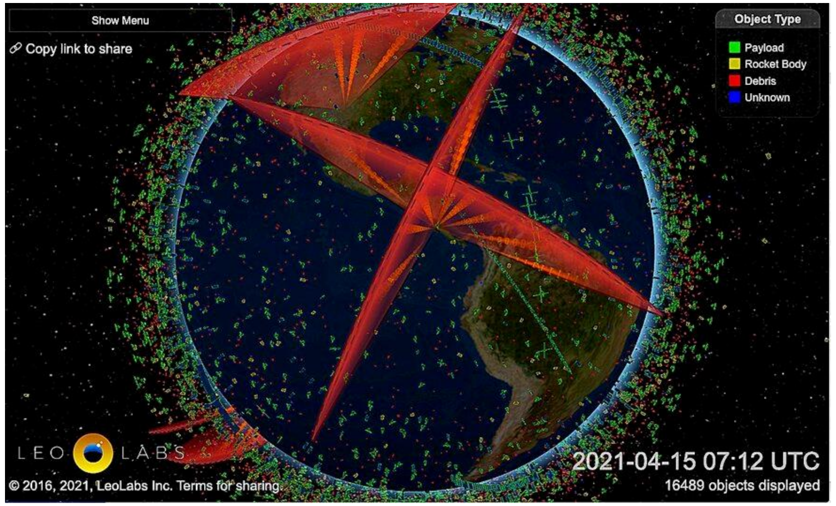

Figure 9: LeoLabs Radar Interface

How? (CubeSat and Instruments)

- 6U Cubesat Bus
- Deployable solar panels
- Deployable Radar (Modified RainCube Radar)
- Cubesat in Low earth Orbit (300km to 400km)
- 30 CubeSats in 6 orbits equally spaced by an inclination of 60 degrees.
- Deploy as secondary payloads on rocket launchers.
- On-board data processing prior to downlink.

Figure 10: 6U CubeSat with radar CAD Model

How? (CubeSat and Instruments)

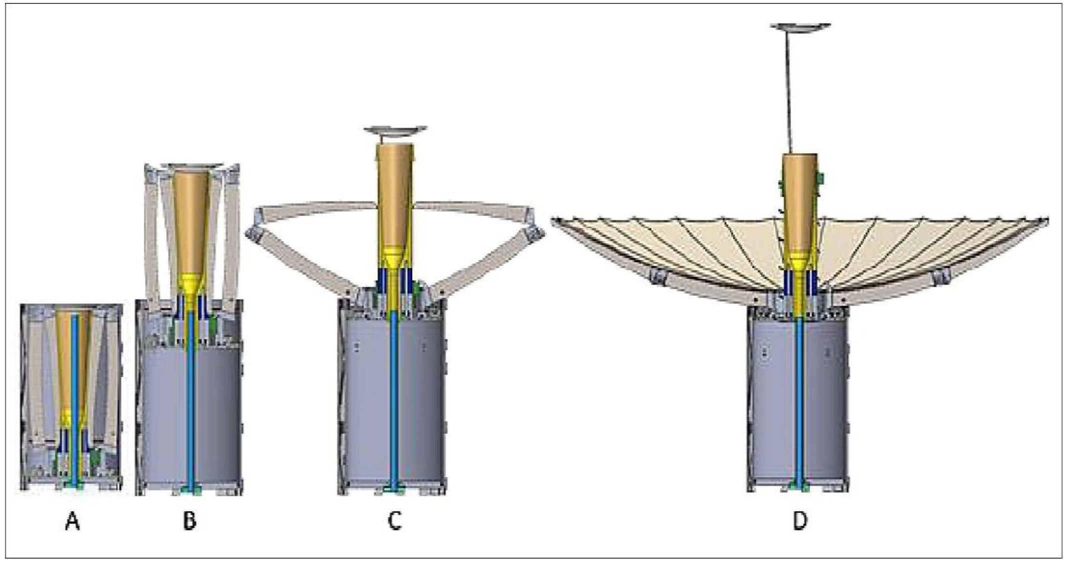

Figure 11: Deplorable Radar Antenna and Block Diagram

- The Radar is 2.5U including all the Radar and accompanying components.
- Designed for small satellites
- Tested on three 6U satellites that are currently in orbit.

https://www.nasa.gov/mission_pages/station/news/orbital_debris.html

Description	Value
Mass	5.5 kg
Volume (full assembly)	24.8 cm x 21.5 cm x 9.7 cm
Power (standby/Operation)	3 W /10W
Resolution	7.9 km (horizontal), 120 m (vertical)
Radar peak transmit power	22 W
Pulse chirp bandwidth	2.5 MHz
Pulse repetition interval	60 s
Data generation	Transmit mode: 50 kbit/s Receive mode: 10kbit/s
Antenna deployment power	4.5 W peak, 2.2 W average for a 3 minute deployment
Antenna gain	42.6 dBi

Table 1. Radar Specifications

Power Budget (Major Subsystems)

Choice of Power Source

Table 2. Power Source Comparison

	Solar Cells	**Fuel Cells**	**Nuclear Power**
Power Generated	Lowest	Highest	Medium
Complexity	Simplest	Medium	High
Cost	Lowest	Medium	Highest
Use on Cubesat	Possible	Not Possible (as of 2022 but research is underway)	Not Possible
Life after not getting Sunlight	Least	Medium	Highest (up to 10.75 years)

- From the table above and the budget constraints its evident that the choice of power source for the Cubesat is limited to Solar power cells.

Power Budget (Major Subsystems)

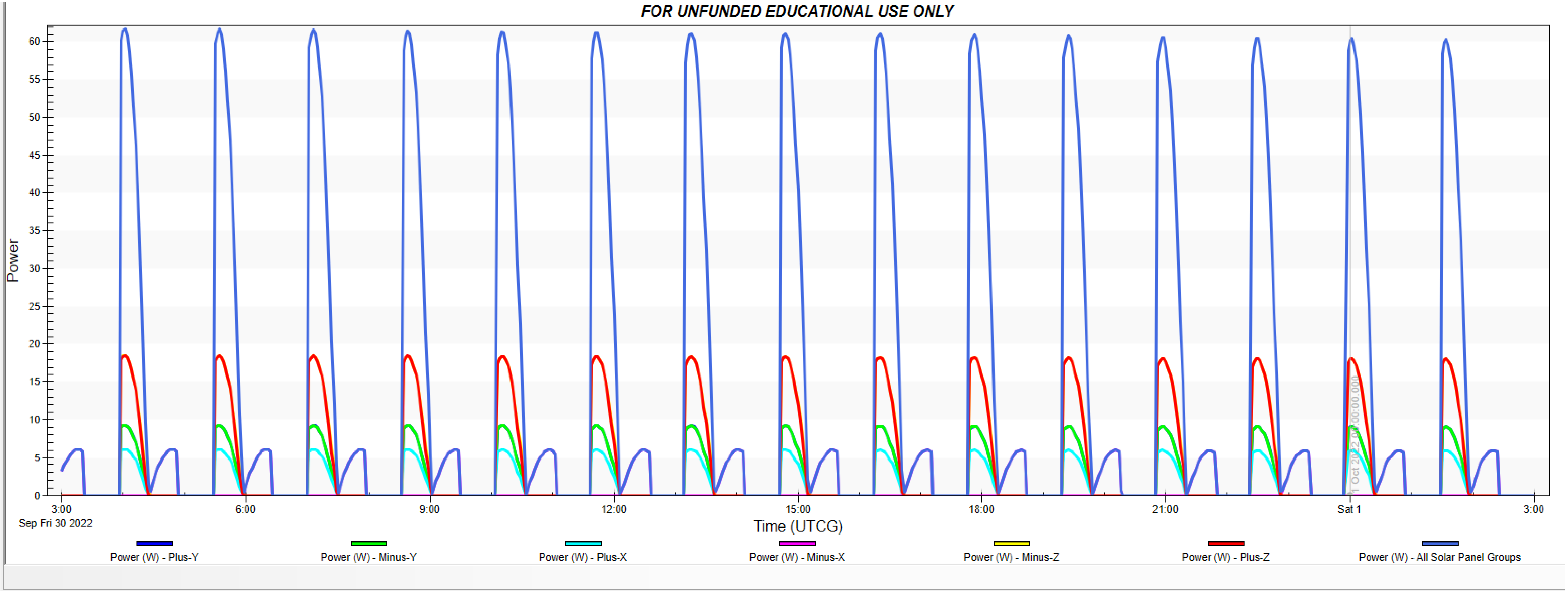

Figure 12. Power Generation in STK software

Power Budget (Major Subsystems)

Table 3. Power Budget Analysis

Subsystem	Component	Part description	Mass (g)	Average Power Consumption (W)	COTS/ Custom
Comms	Tx/Rx S-band antenna	ISISPACE S-band patch antenna	<50	2	COTS
OBC	Onboard Computer	---	~200	~1	Custom
EPS	Battery	GOMspace NanoPower BPX	500	6	COTS
	Power module	GOMspace Nanopower P60	191	0.6	COTS
	Solar panels	eHaWK 27L-50B (85W)	600	---	COTS
ADCS	3 axis ADCS	CubeADCS	554	0.571	COTS
	6 sun sensors	Cubespace cubeSense	0.03	0.1	COTS
	Star sensor	Cubespace cubeStar	55	0.284	COTS
	3 Magnetorquers	EXA MT01 Compact Magnetorquer	225	0.75	COTS
Payload	Ka-band radar	Modified RainCube radar	5500	~10	Custom
Structure	6U structure	6U CubeSat structure	~ 1000	--	Custom
Total			8875.03	21.31	

Link Budget

Table 4. Link Budget Analysis

		Unit	Data Downlink	UHF Uplink
Frequency		MHz	2245	437.5
Modulation			BPSK	GMSK
Data Rate		bps	9600	4800
Transmission Side	Output Power	W	1	50
		dBm	30.00	47.0
	Line Loss	dB	3.0	3.0
	Antenna Gain	dBi	6.50	10
	EIRP	dBm	33.5	54.0
	Antenna Pointing Loss	dB	3.0	3.0
Satellite Positiion	Altitude	km	400	400
	Elevation	deg	10	10
	Range	km	1440	1440
Path	Path Loss	dB	162.6	148.4
	Polarization Loss	dB	3.0	3.0
	Atmospheric Losses	dB	1.0	1.0
	Ionospheric Losses	dB	0.5	0.5
Receive Side	Isotropic Signal Level at Antenna	dBm	-136.6	-101.9
	Antenna Pointing Loss	dB	3.0	3.0
	Antenna Gain	dBi	6.5	2.15
	Line Loss	dB	3.0	3.0
	Receive Power at LNA Input	dBm	-136.1	-105.8
	LNA Gain	dB	20.0	-
	Effective Noise Temperature	K	300	-
	Thermal Noise	dBm/Hz	-173.8	-
	Signal-Noise Ratio (Eb/N0 or S/N)	dB	17.9	-
	BER		1.00E-05	-
	Required SNR	dB	9.8	-
	Receiver Sensitivity	dBm	-120	-120
Link Margin		dB	3.9	14.2

System Block Diagram

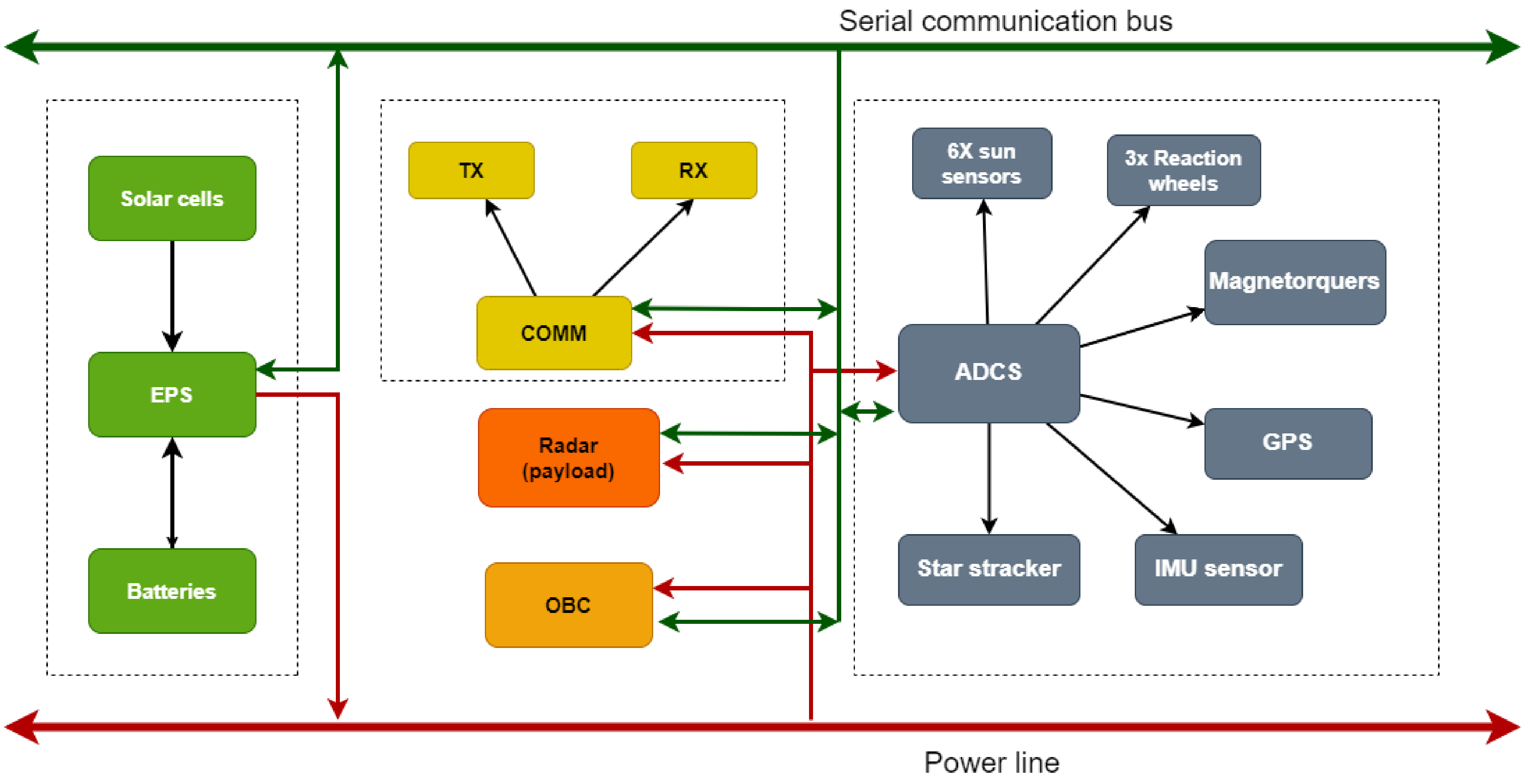

Figure 12. System Block Diagram

CubeSat Subsystems

1. ADCS (Reaction wheels and Magnetorquers)
2. Communications (S Band) for high speed data transfer
3. Payload Radar and data processing unit
4. Thermal control unit
5. Electrical power system EPS
6. Onboard Controller for mission control

Figure 13: High Capacity battery pack

Figure 15: eHawk solar cells

https://mmadesignllc.com/product/ehawk-27l-50b/

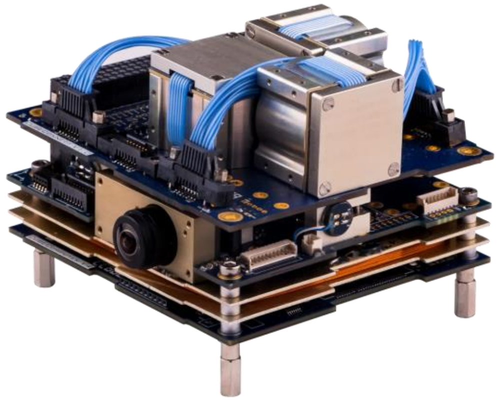

Figure 14: 3 axis ADCS control

https://www.cubespace.co.za/products/gen-1/integrated-adcs/cubeadcs/

Implementation plan

1. Start radar mission (One Orbit)
2. Satellite enters Idle mode to recharge and process data
3. Satellite starts data downlink
4. Satellite finishes data downlink and charging
5. Repeats radar mission

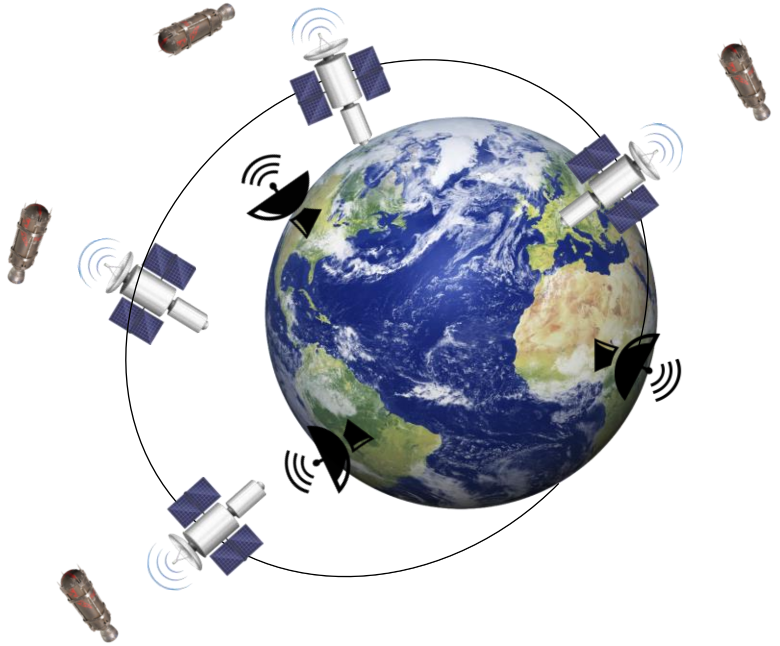

Figure 16. Implementation plan (not to scale)

Mission Summary/ Conclusion

- Generate 1.7 Gbit Data for a 90 minute orbit
- Data to be downlinked after onboard processing has been applied.
- The satellite can work on a 25% cycle duty
- One orbit with radar in transmit mode
- Three following orbits in radar standby to radiate waste heat, recharge batteries and downlink data.
- Use COTS to minimise development time and costs.

Figure 17: 6U CubeSat
(Radar deployed)

Thank You