

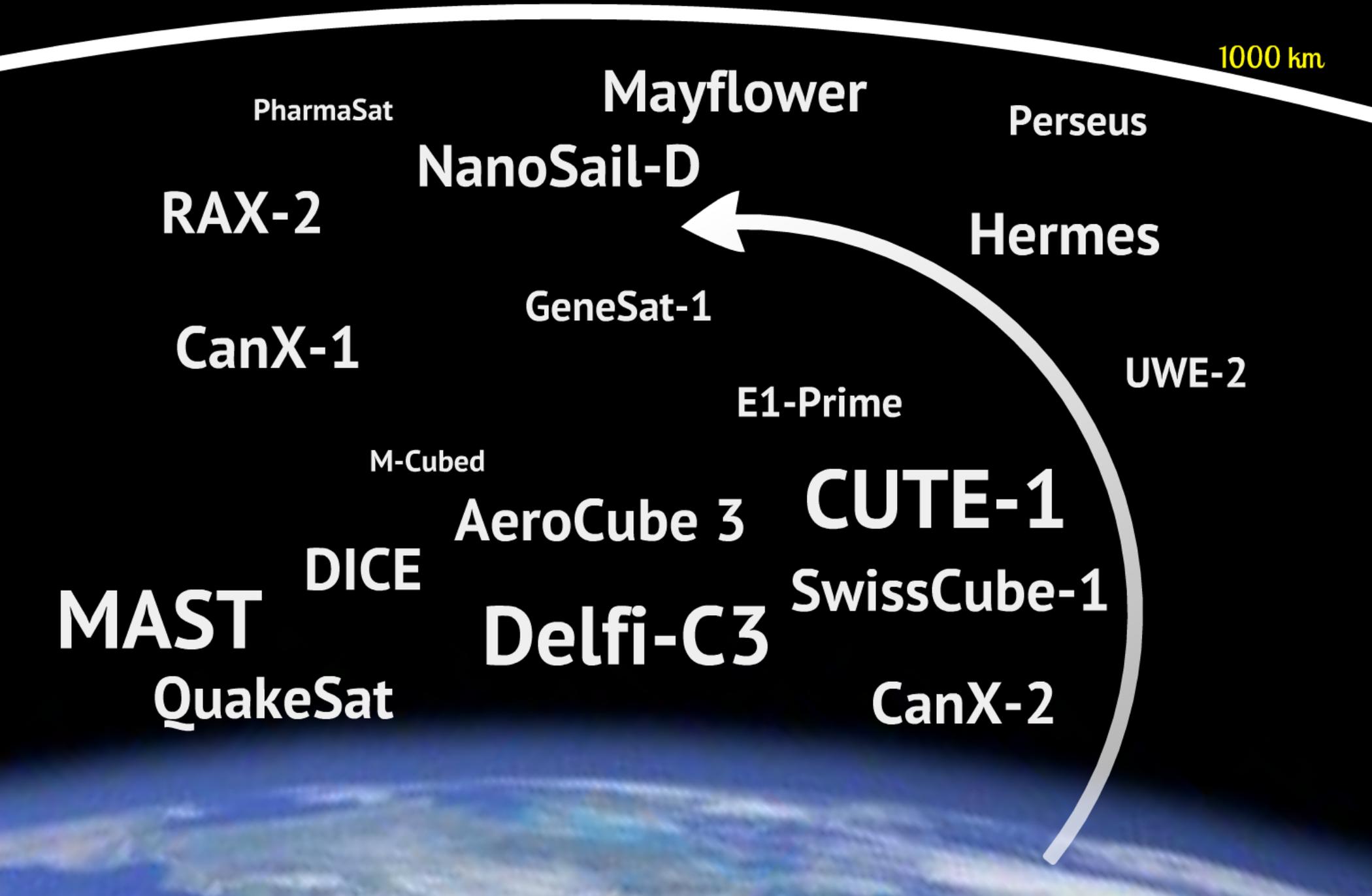


SolWise: Sailing On Light With Interplanetary Science and Exploration

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Many CubeSats, All LEO

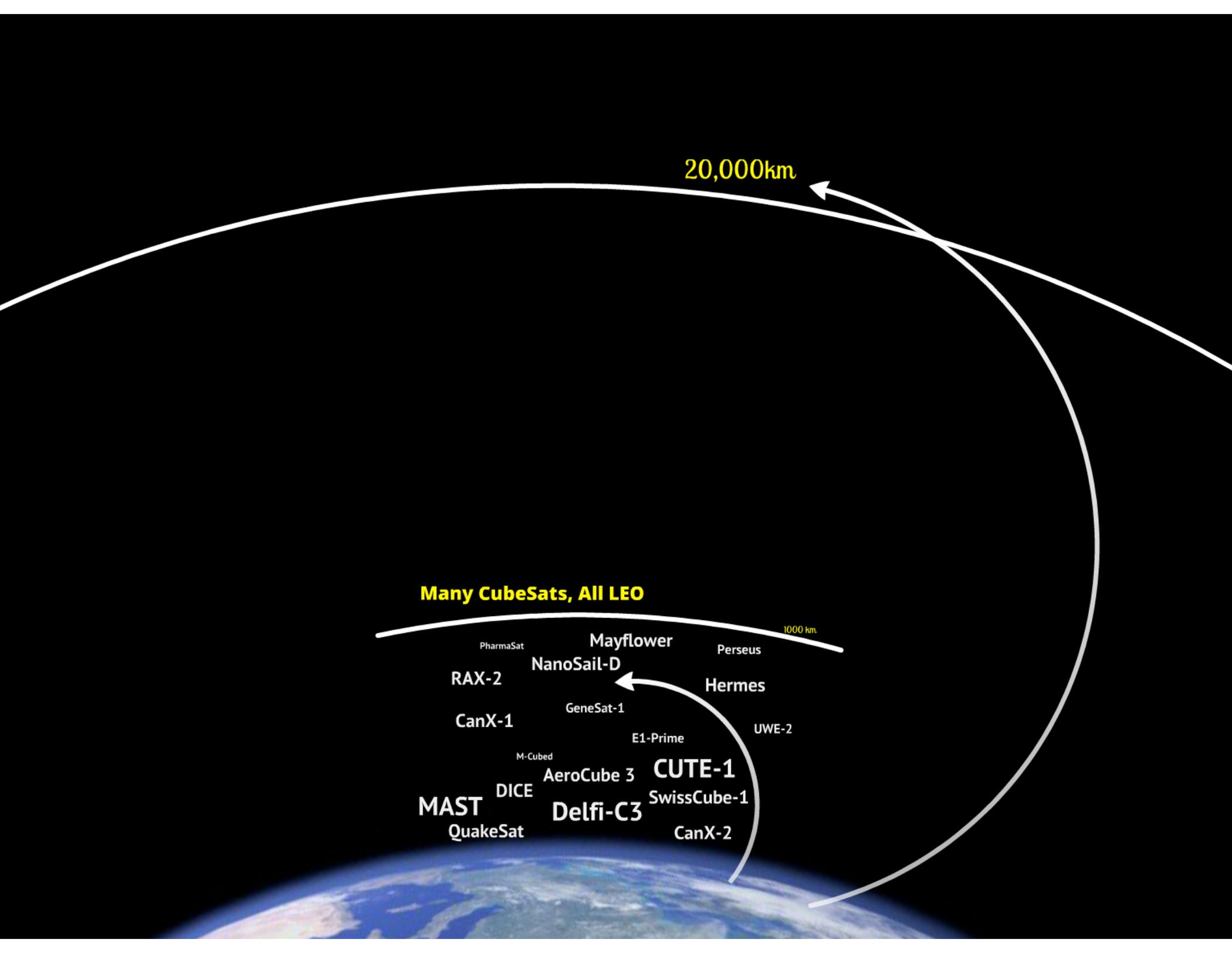


20,000km

Many CubeSats, All LEO

1000 km

- PharmaSat
- Mayflower
- Perseus
- RAX-2
- NanoSail-D
- Hermes
- CanX-1
- GeneSat-1
- E1-Prime
- UWE-2
- M-Cubed
- AeroCube 3
- CUTE-1
- MAST
- DICE
- Delfi-C3
- SwissCube-1
- QuakeSat
- CanX-2

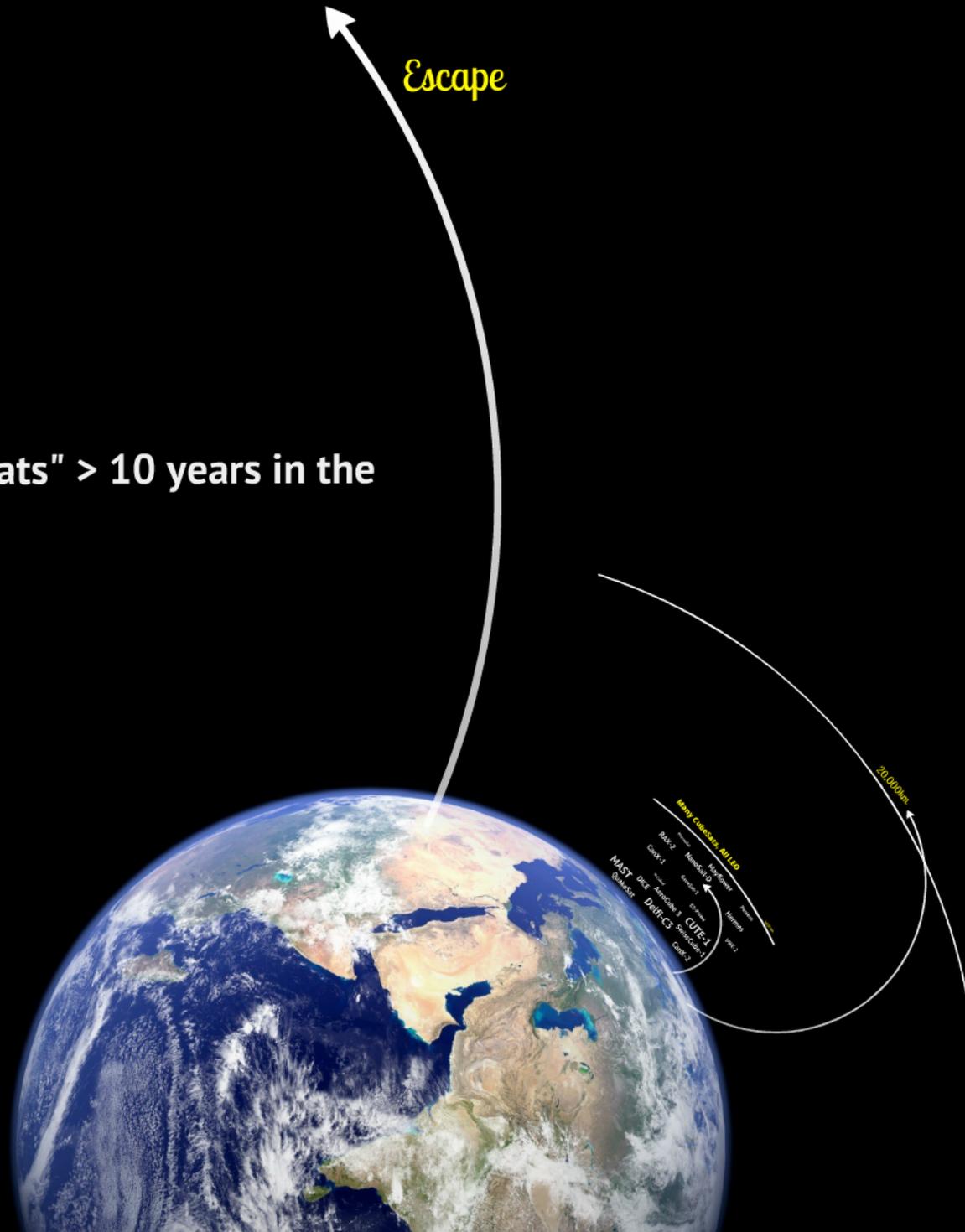


How do we escape?

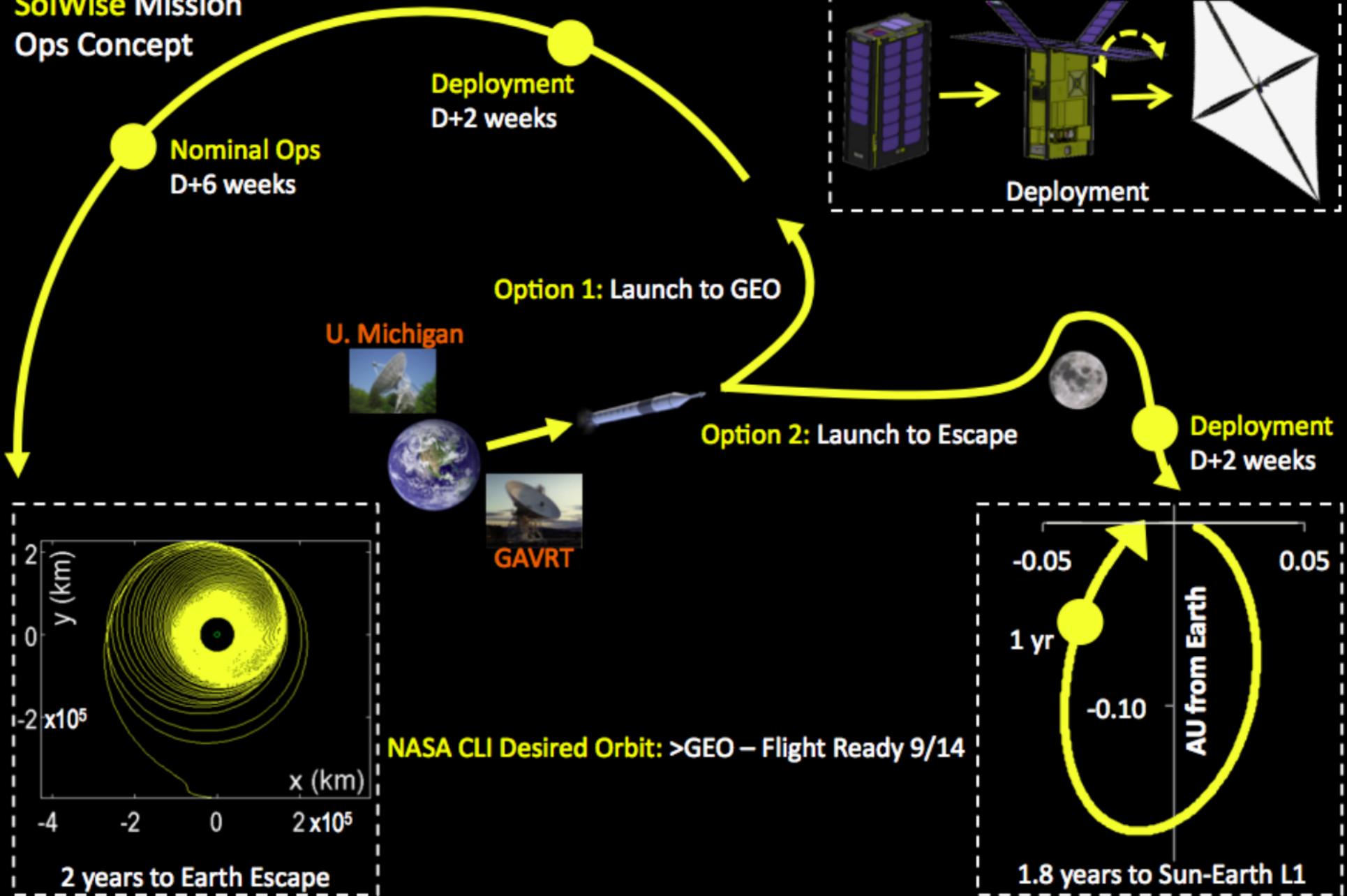
Needs:

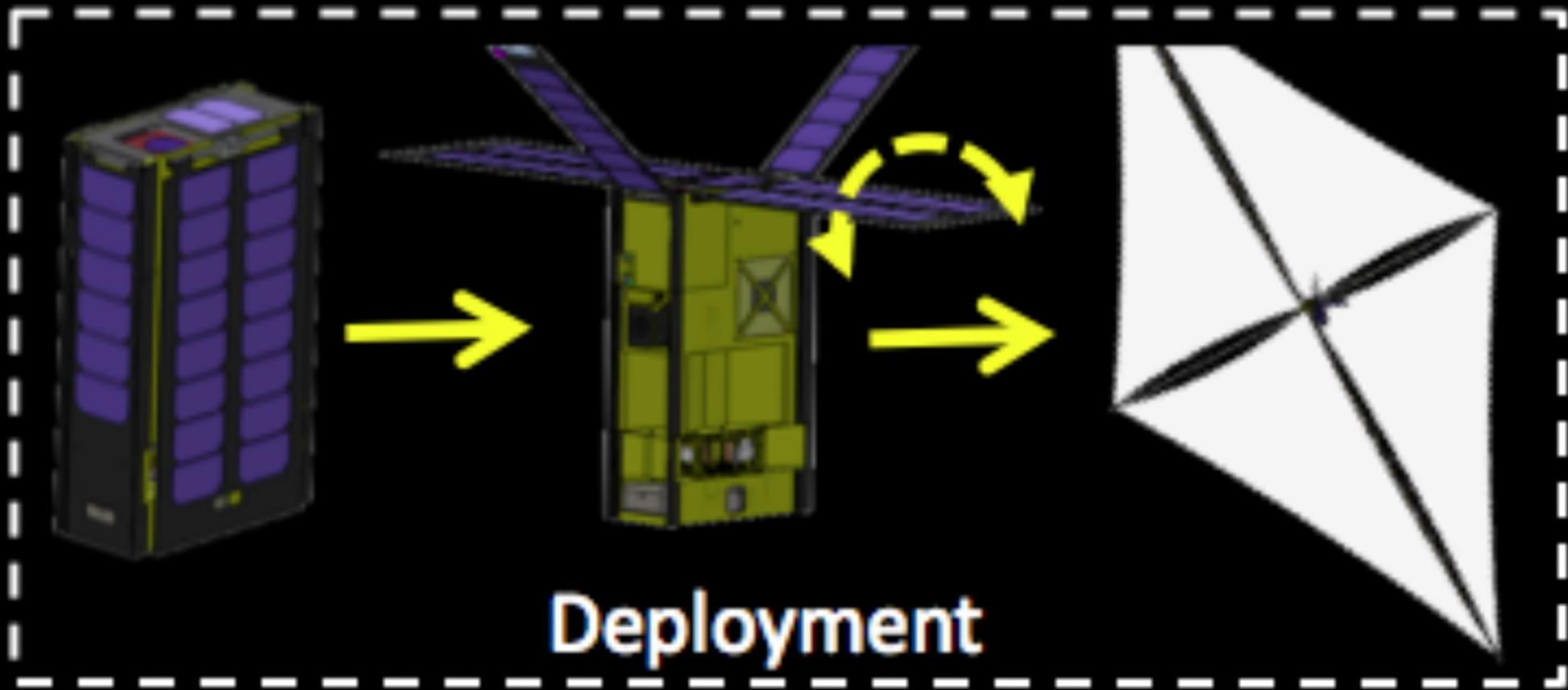
- Survivability
- Communication
- Navigation
- Attitude Control
- Propulsion

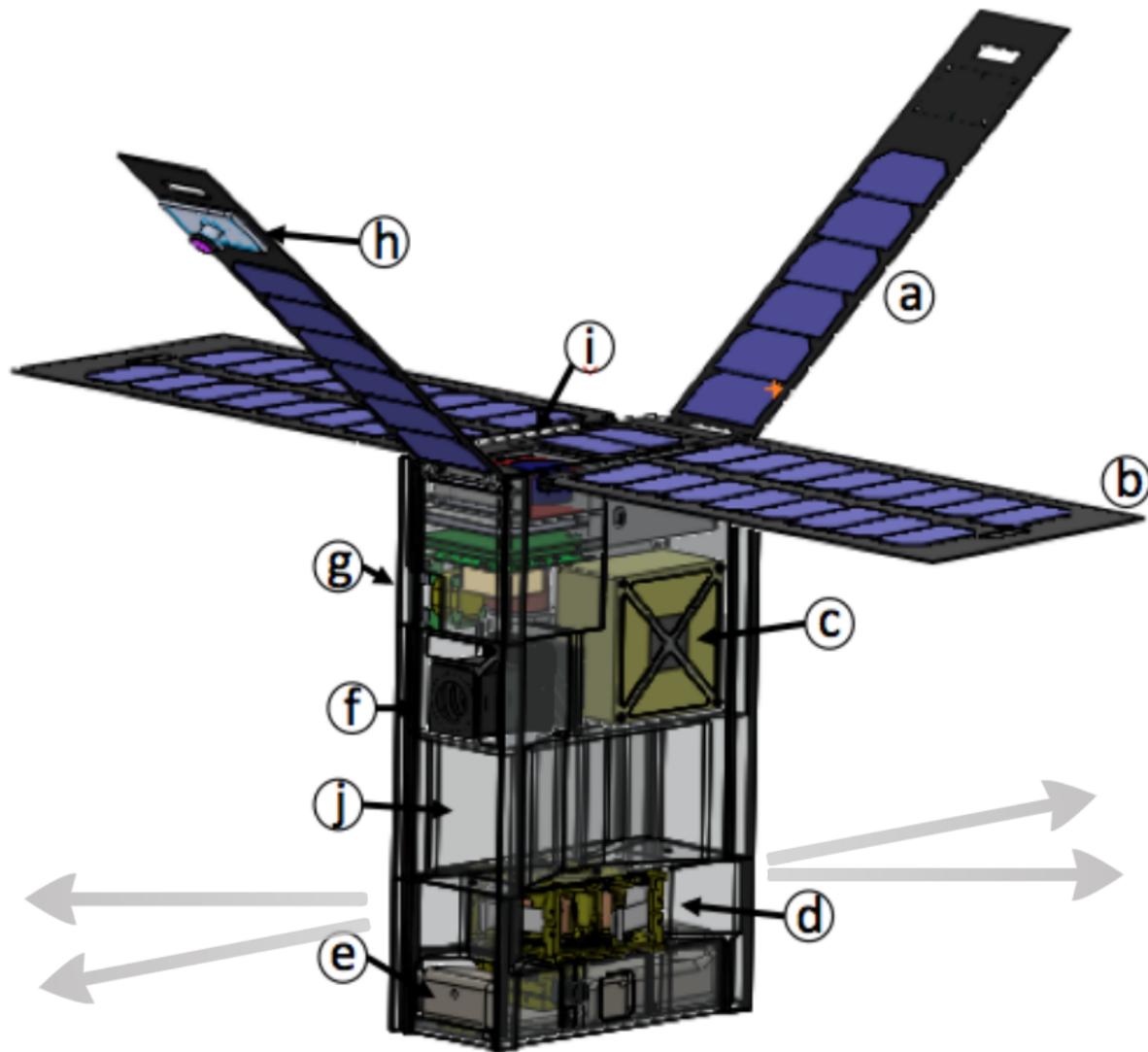
NIAC "Interplanetary CubeSats" > 10 years in the future ... we disagree.



SolWise Mission Ops Concept





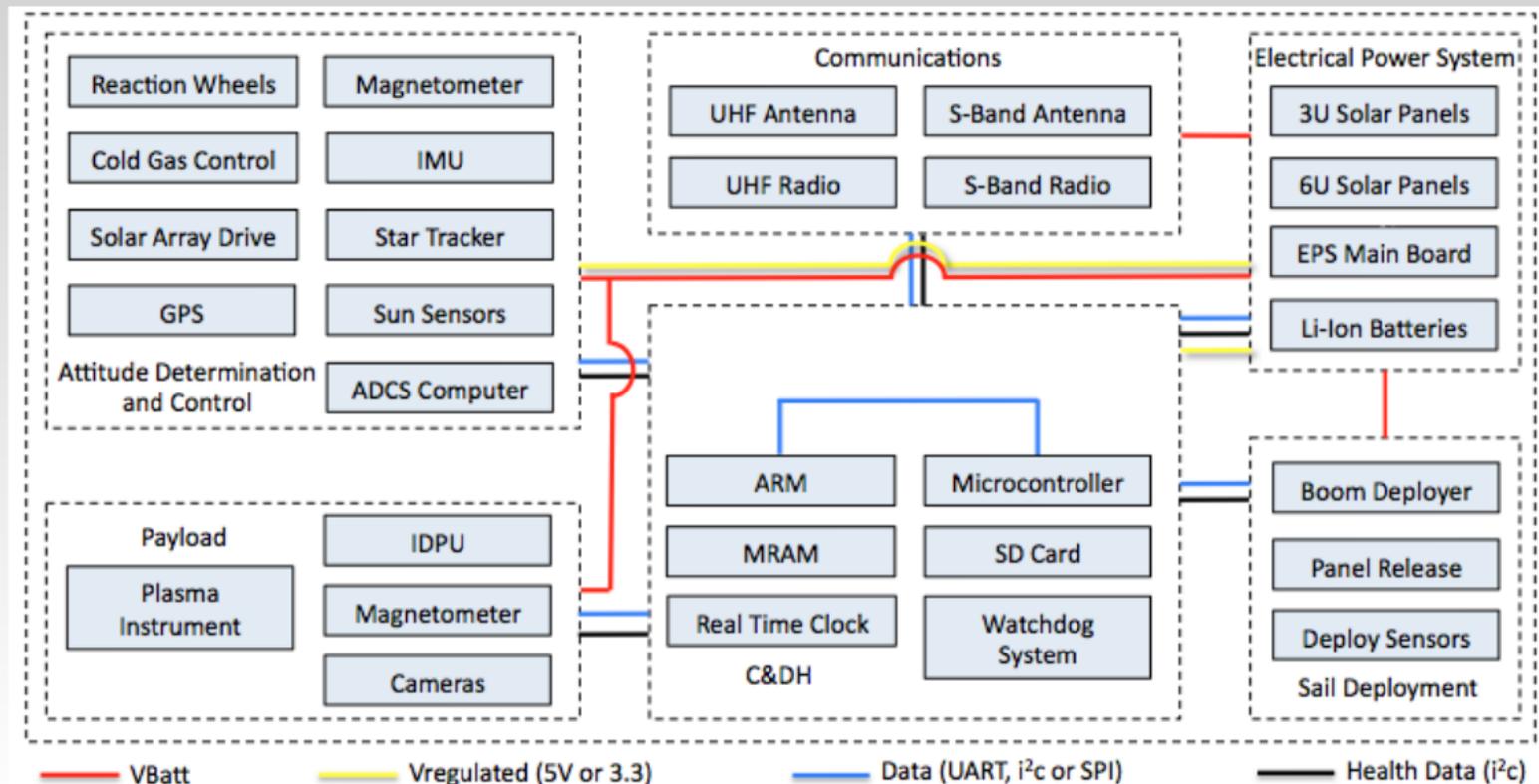
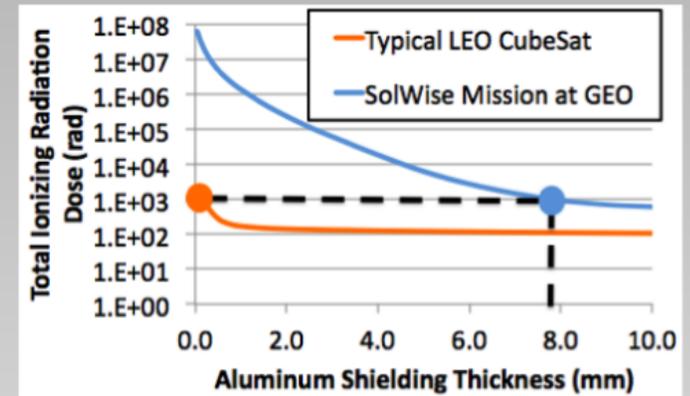


- 9.7 kg
- 6U undeployed
- 8.8 x 8.8m sail
- > 20 W power
- 1U payload
- 2 driven solar arrays
- S-Band and UHF communication
- Radio nav, GPS (near Earth)
- Gyro, sun sensors, star tracker
- Reaction wheels with solar radiation pressure desaturation, cold-gas de-spin and backup

The SolWise deployed system (with sail, booms and sides hidden) built from high heritage hardware (a) Fixed solar panels, (b) Driven solar arrays (c) ADCS (d) Deployer (e) Cold-gas (f) Star tracker (g) Fluxgate magnetometer (h) Camera (i) Plasma instrument (j) Sail Cavity

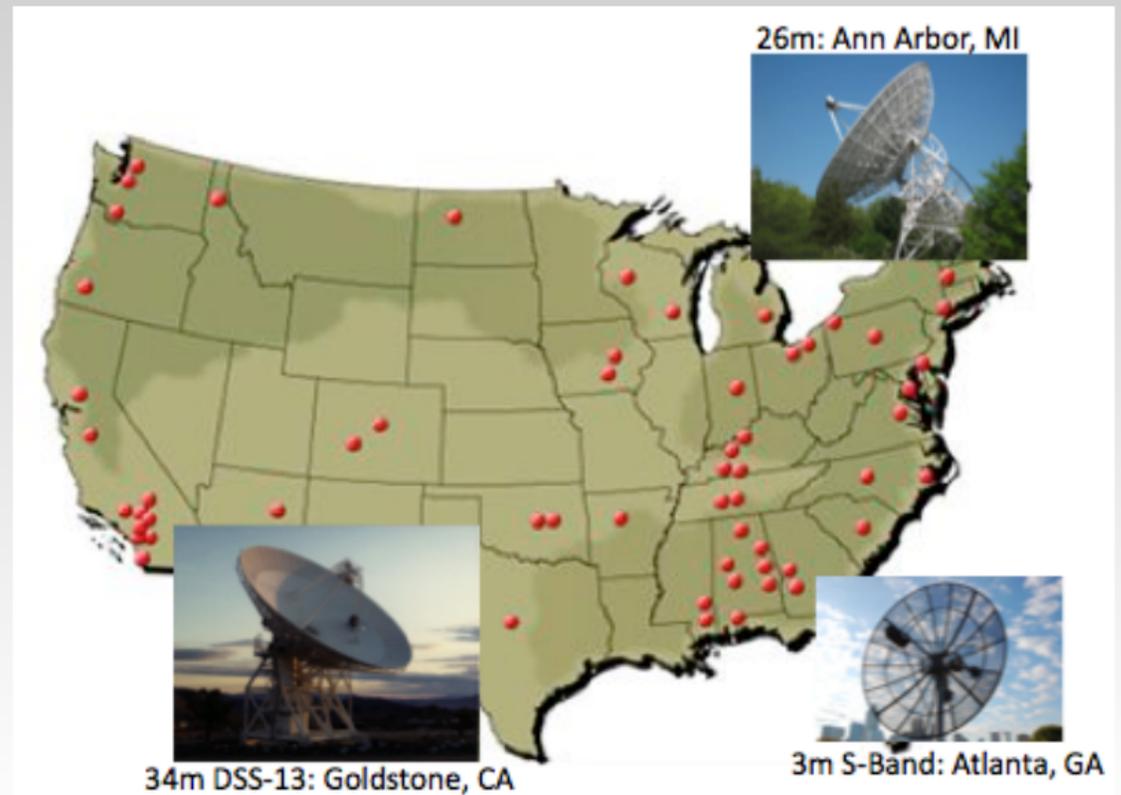
Survivability

- Asymmetric and redundant C&DH
- Flight heritage
- Appropriate shielding (subsystem and spot)
- Radiation sensors (TID and SEU)
- Reboot tolerant (even during deployment events)
- Some parts rad-hard



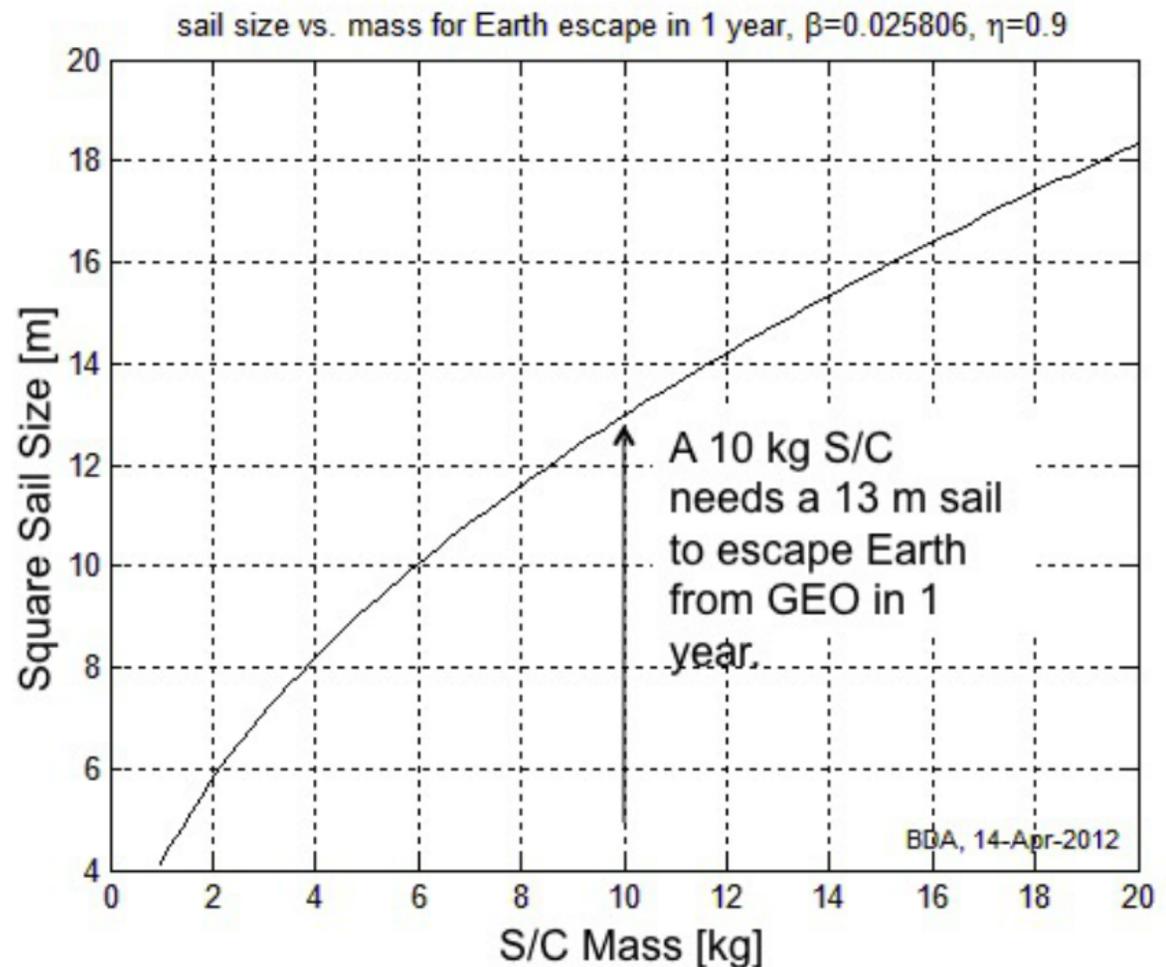
Telecommunications

- S-Band primary - can transmit data from 0.2 AU at 10 bps
- UHF backup (link closes at 1 kbps through lunar distance)
- Partnered with GAVRT to provide mission operations and science opportunities to students
- Operations run from U. Michigan, with backup operation sites at G. Tech and Goldstone DSN



Navigation

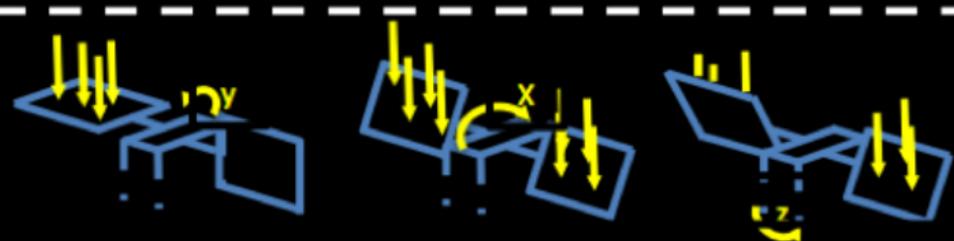
- GPS for near-Earth navigation, calibration, and training
- One-way radio navigation - Doppler, ranging, differential Doppler
- Students collaborating with JPL engineers
 - Trajectory generation
 - Navigation



Attitude Control

- 1) Despin with RWs & cold gas thrusters
- 2) Deploy panels and sail
- 3) For GEO departure, induce y-axis spin s/c to 180 deg/day. Change y-axis spin rate slightly to achieve best acceleration
- 4) Use driven solar arrays for SRP desat

SolWise Attitude Control Strategy

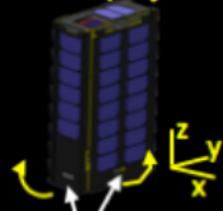


Creating Torques with Solar Radiation Pressure (SRP)

SolWise Control Authority		
System	Momentum Storage (Nms)	Number of desaturations available
Cold Gas Reaction Wheels	1.2	102 over mission lifetime
SRP	11.8e-3	N/A
	1.77e-3	1 / week

Undeployed

Deployed

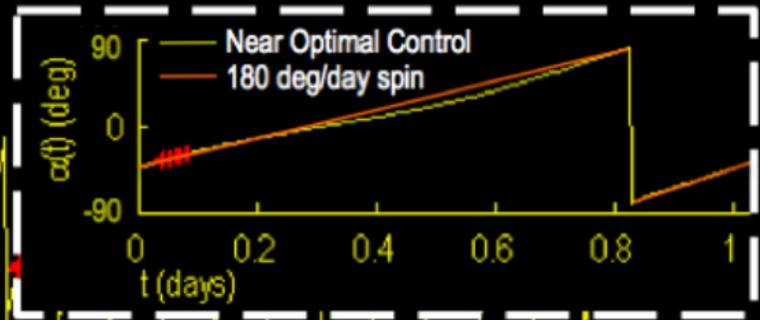
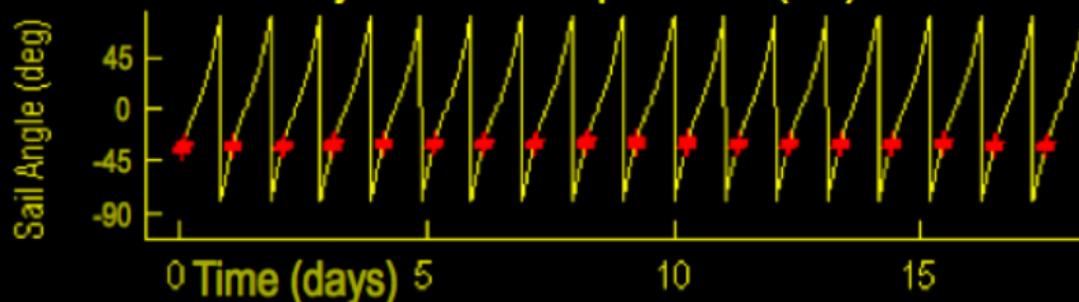


Cold Gas Thruster for Secondary Desaturation of Reaction Wheels

Driven Solar Arrays for Primary Desaturation of Reaction Wheels

After spinning s/c to reach 180 deg/day rate about y-axis, vehicle must slow to ~6 deg/day by the time it reaches the moon

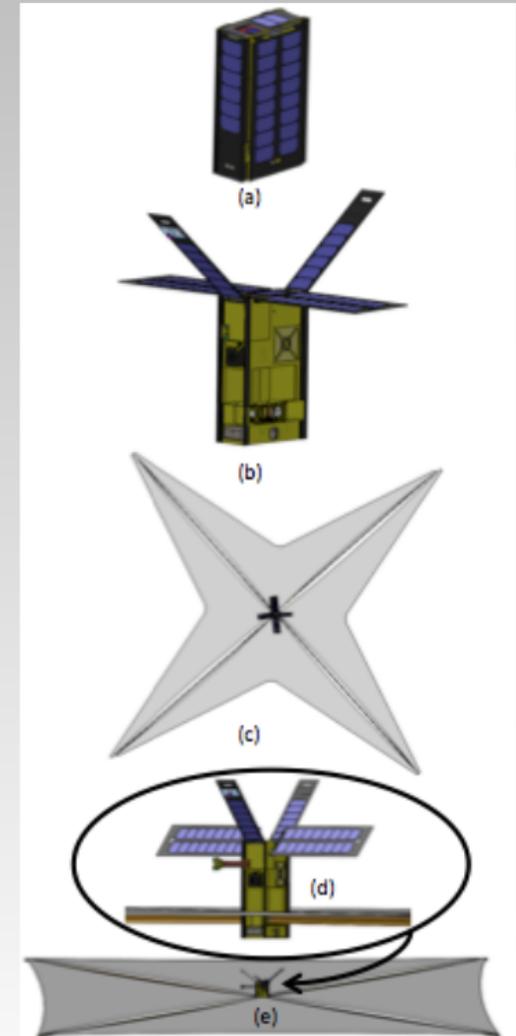
Near optimal attitude control for GEO departure with 90% reflectivity and short eclipse times (red)



Propulsion

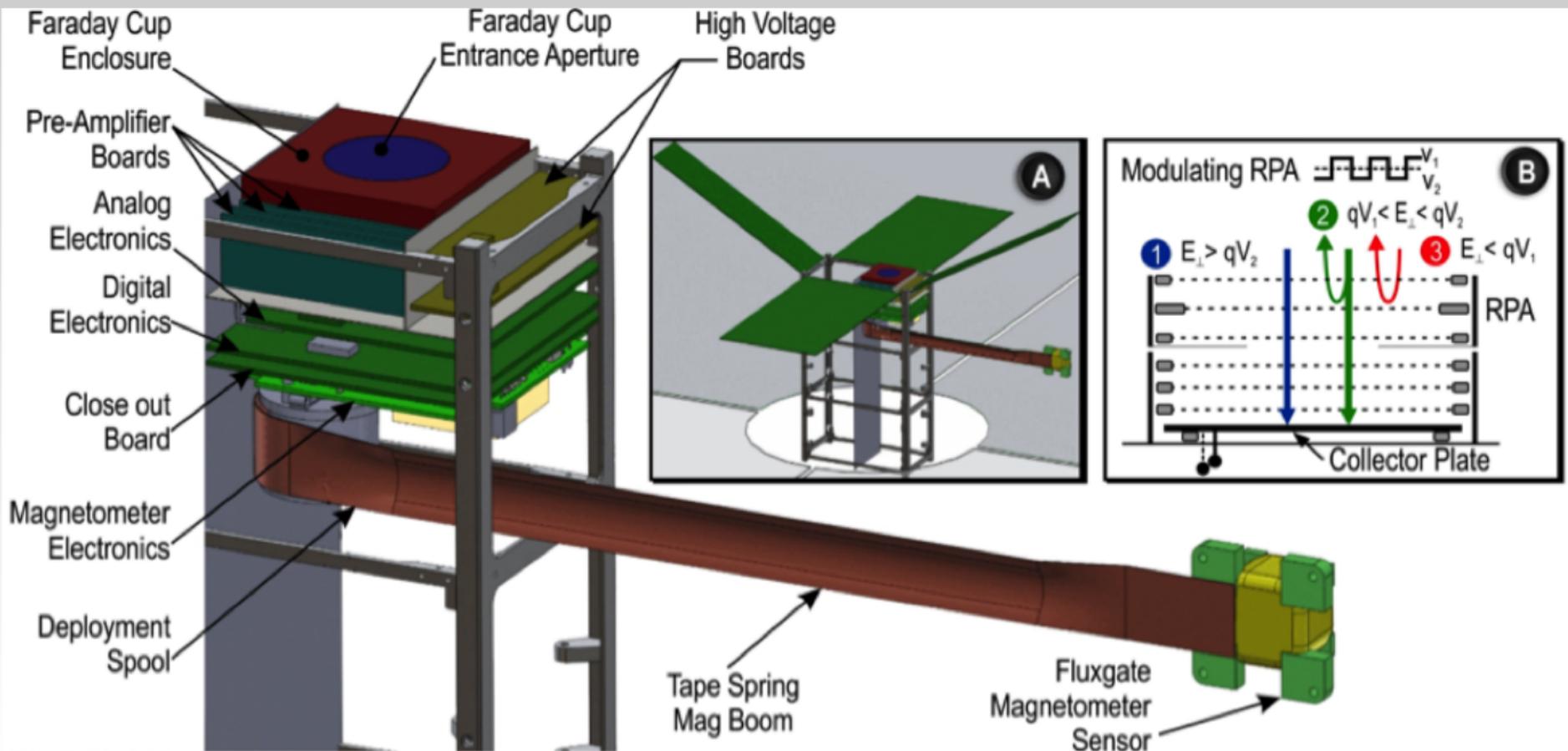
- 8.8 x 8.8m sail with TRAC booms based on LightSail-1
- Ratchet deployment of booms over 3 minute period

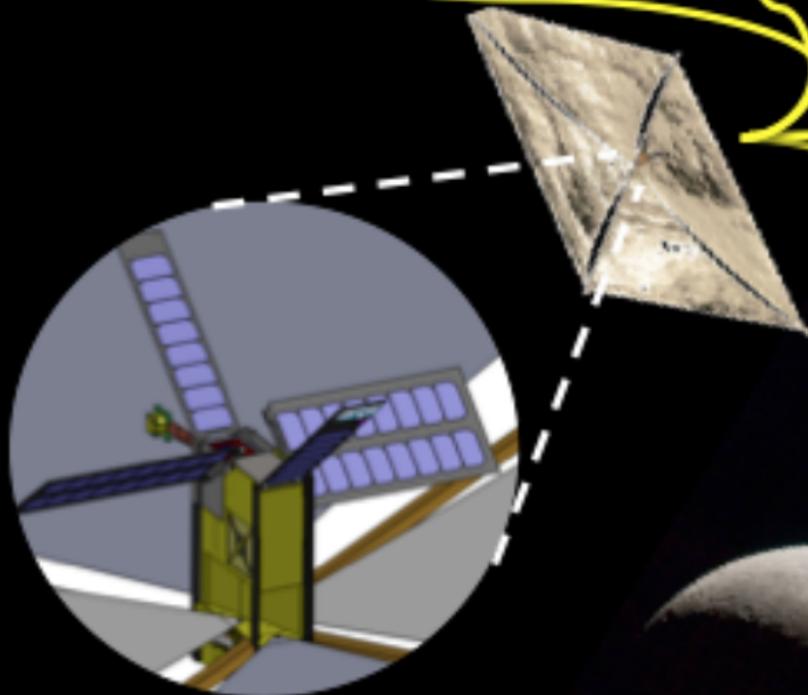
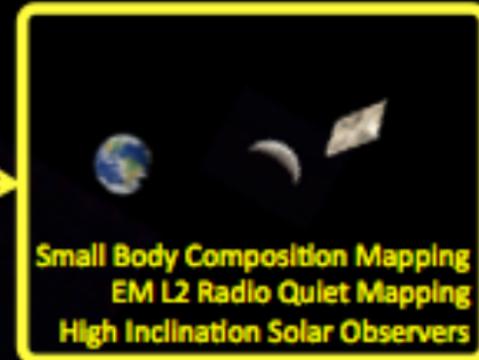
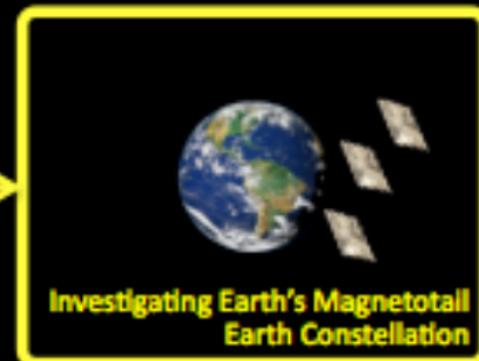
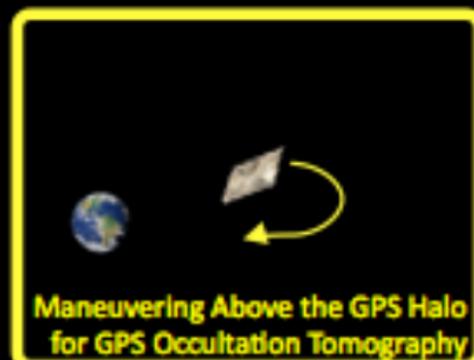
	IKAROS	L'Garde TDM	NanoSail-D	LightSail-1	SolWise
System Mass	315 kg	31 kg (+81kg stage)	4 kg (3U)	5 kg (3U)	9.7 kg (6U)
Size	200 m ²	1200 m ²	10 m ²	31.36 m ²	78 m ²
Characteristic Acceleration	0.005 mm/s ²	0.33 mm/s ²	0.02 mm/s ²	0.05 mm/s ²	0.068mm/s ²
Mission	Interplanetary	Interplanetary	De-orbit	Sail Demo	Interplanetary
Sail Material	Kapton	Kapton	Mylar	Mylar	Kapton
Booms	None (Spinner)	Inflatable	TRAC	TRAC	TRAC
Attitude Control	Cold Gas and LCD Panels	3-axis Vanes	-	Single RW	3-axis RW with SRP desat
Sail Environment	Dust Density and Polarimeter	Navigation Magnetometer	-	-	Plasma Instr / Fluxgate Magnetometer
Lifetime	1+ years	1 year	Weeks	Months	1+ years
SolWise Team			CubeSat Formfactor		



Mission Capable

- Solar sails may interfere with scientific measurements due to interaction with surrounding plasma
- Mission capability established after evaluation of environmental interaction
- 1U payload with Faraday Cup plasma instrument and deployable fluxgate magnetometer





Demonstrating: Interplanetary CubeSat Solar-Sail Propulsion
Enabling: Fuel-less SmallSat Exploration of Solar System
Engaging: Small Businesses and New Investigators

Reality?



- In the next several years, **NanoSats will reach escape orbits.**
- SolWise is a mission **ready to be built** with high-TRL technology and **capabilities that feed forward** to highly desired missions.
- Looking for partners to **enable** this mission, and future missions, **to boldly go where no CubeSat has gone before..**

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