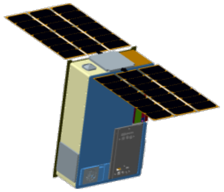
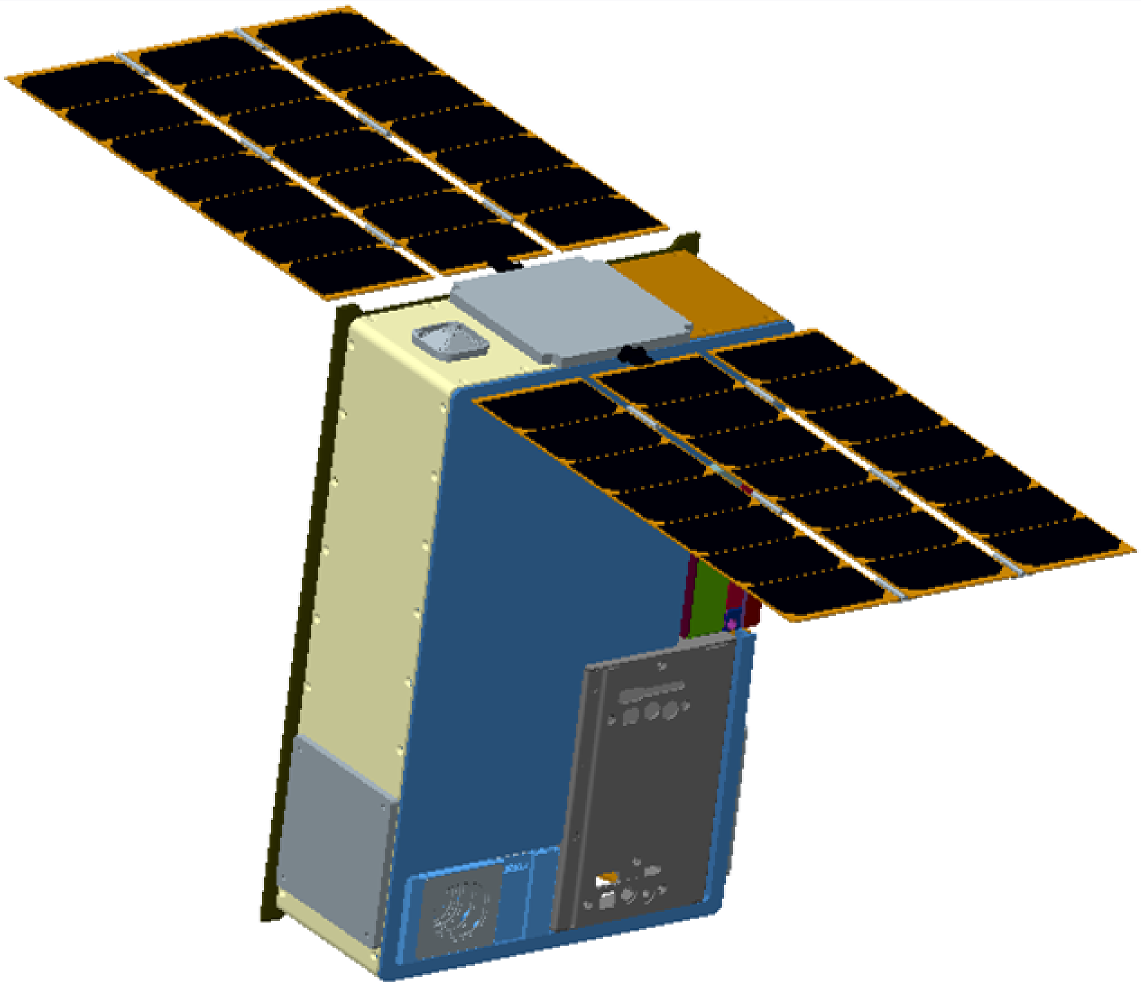
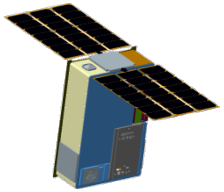


Lunar Water Distribution (LWaDi)

Lunar Water Distribution (LWaDi)-- a 6U Lunar Orbiting spacecraft SSC14-WK-22

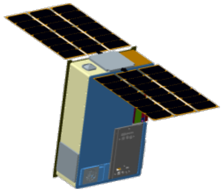
- Pamela Clark, PhD, Planetary Scientist, NASA GSFC and Catholic University
- Walter Holemans, Chief Engineer, PSC (Presenting)
- Wes Bradley, President, Willowhill Precision, Inc.





Why the moon?

- It has water
  - To make rocket propellant
  - Support human habitat
- Moon is closest extraterrestrial frontier
  - An ideal ‘test bed’ for
    - Exploring planetary surface processes and origins
    - Validate technologies required for other planetary exploration
- Lunar surface represents a great portion of the entire range of conditions found throughout the solar system due to its
  - Rugged terrain
  - Long diurnal cycle
  - Varying extreme thermal/illumination conditions particularly in polar regions
  - Space radiation environment



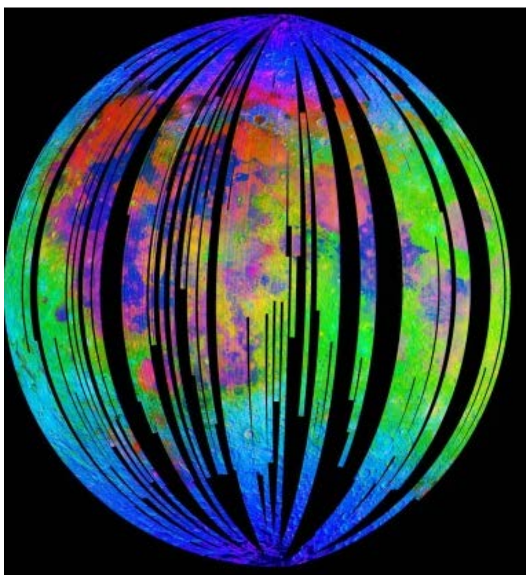
Lunar Water Distribution (LWaDi)

Mission: Determine nature of Lunar water and water component distribution as a function of time of day and latitude

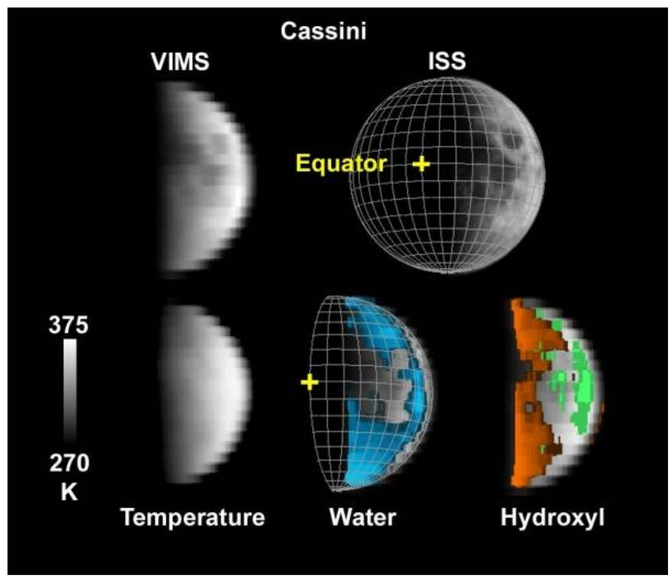
Type of Instrument and Measurement	Near Infrared Spectrometer covering range 1.3 to 3.7 microns,10 nm spectral resolution to detect features (wavelength, band center, band width) associated with water type and component (e.g., OH, water in various forms) near 3 microns. SNR nominally 10 db.
Siting	Highly elliptical, high inclination, equatorial periapsis
Current TRL	Components range (2-6)
Heritage	OVIRS Compact high resolution detector using linear variable filter array under development for OSIRIS Rex; DOD tactical cryocoolers; broad band IR detectors
Mass, Power, Volume	<2 kg, <5W, <2U
Data generation	1.3 to 3.7 microns with 10 nm resolution: 240 channels@12bits/channel for each observation. To maintain 10 km resolution along track, approximately <.3 seconds/observation, observing for tens of minutes out of several hours orbit for sufficient coverage of diverse terrains, or about 1300 observations/orbit for 3-4 orbits per day, for 180 days for complete coverage (27 day cycles convolved with precession rate for overlap) = 240x12x1300x3.5x180 = 2.2Gbits total volume, <10Mbit/day, 10 kbs for 2 hours/day.
Tall Poles/Special Requirements	Compact optical system with adjustable iris. Maintain detector at or below 140K with Compact cryocooler. Additional thermal control for instrument box. Attitude control system with micro-ppts. For 'stand alone' option require in-space propulsion with adequate ISP and DeltaV w/in volume constraints and low energy transfer trajectory.
Operational Modes including duty cycle	Every 24 hour period: take measurements at three latitudes for at least three longitudes (different illumination) over illuminated hemisphere and representative terrains, about 5% duty cycle. Nadir pointing in orbit. Minimum of 6 months at moon plus 3 to 9 months to Moon.
Pointing and orientation	Maintain 10 km spot, km-scale pointing accuracy and 0.1 km knowledge. Control 1 mrad@1000 km, 10 mrad@100 km; knowledge 0.1 mrad@1000 km, 1 mrad@100km
Contamination issues	Protection potentially needed for optical elements (window)
Thermal, mechanical	Special concern optics. Minimize, stabilize, know temperature when measurements are taken.

Present indication of water on moon

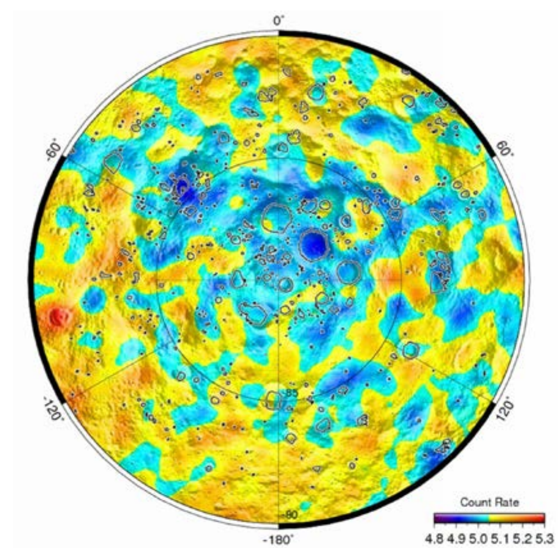
- The presence of water and complexity in its distribution has been indicated from several recent sources
  - LRO
  - CASSINI
  - Chandrayaan M3
  - LCROSS



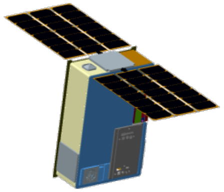
LRO LEND: solid water in blue



CASSINI fly by: water and hydroxyl

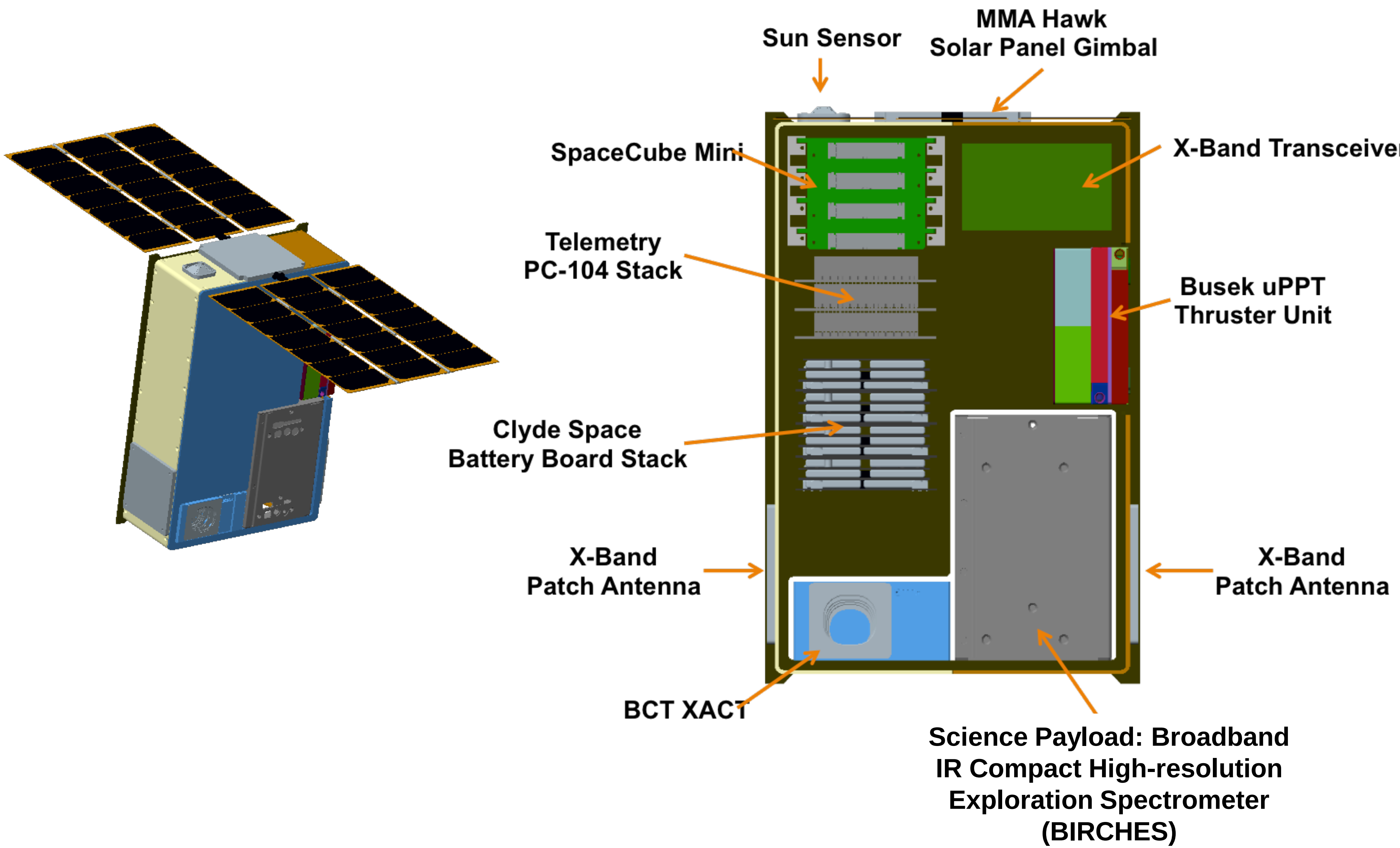


Chandrayaan M3: water in blue



Lunar Water Distribution (LWaDi)

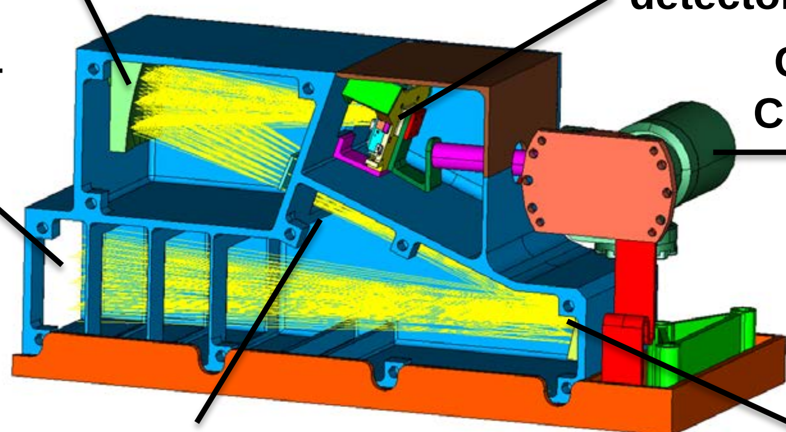
6U Spacecraft: 0.37 x 0.24 x 0.11 m; 11.5 Kg



Lunar Water Distribution (LWaDi)

Science Payload (BIRCHES)

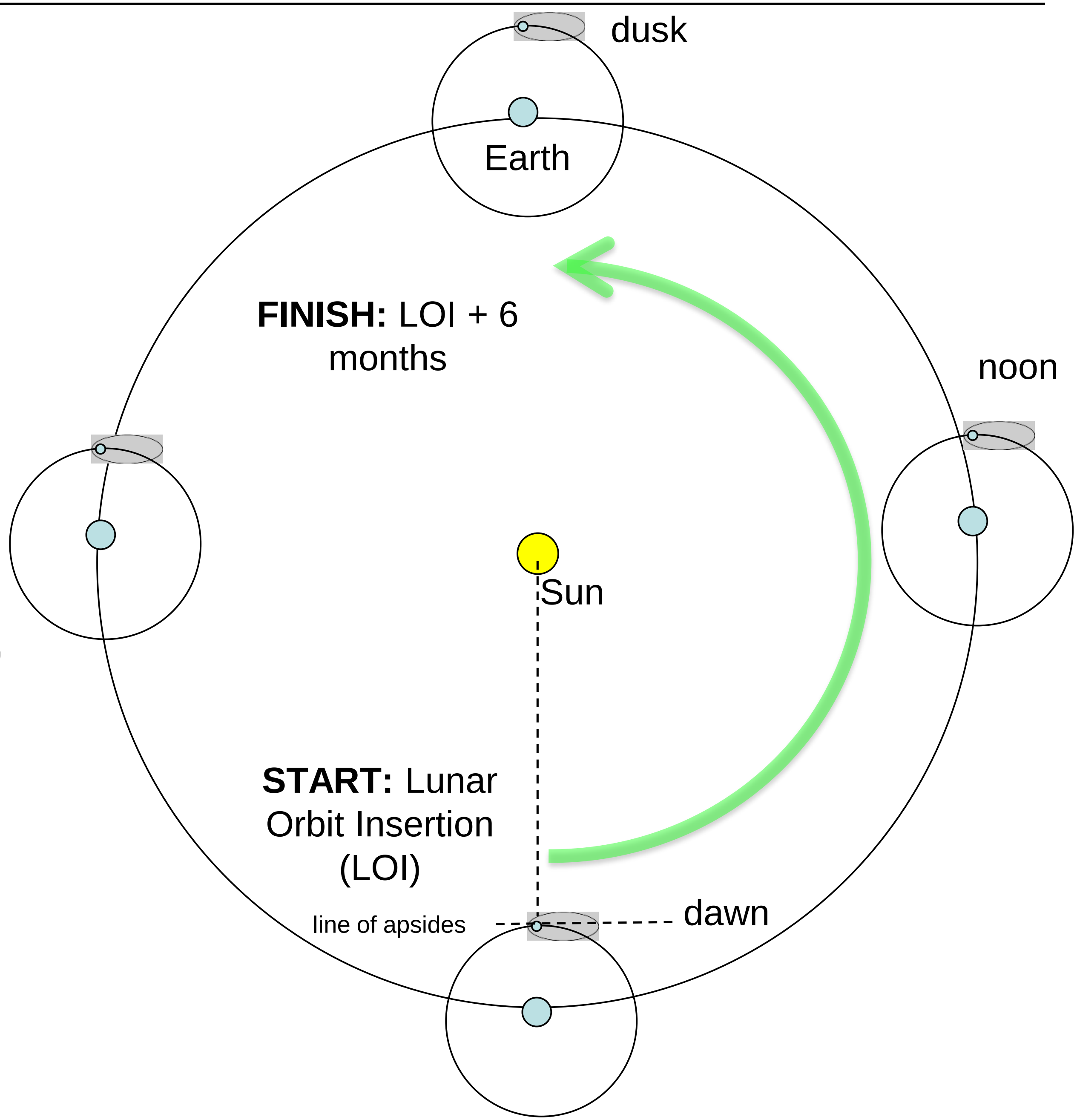
- Broadband IR Compact High-resolution Exploration Spectrometer (BIRCHES)
- 640 x 512 HgCdTe detector with a linear variable filter
- Two off-axis paraboloid mirrors separated by a field stop (adjustable square iris)
- 10 x 10 km footprint (regardless of altitude)

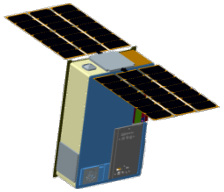


Water State Component	Reported Feature Wavelengths (microns)
Water Vapor	2.66, 2.74
Liquid Water	1.4, 1.9, 2.85, 2.9, 3.1
OH attached to mineral	2.2 to 2.3, 2.7 to 3.4,
Bound Water	2.85, 2.95, ~3, 3.14
Adsorbed Water	2.9-3
Solid Water	1.5, 2, 3.05-3.07

Six Month Mission

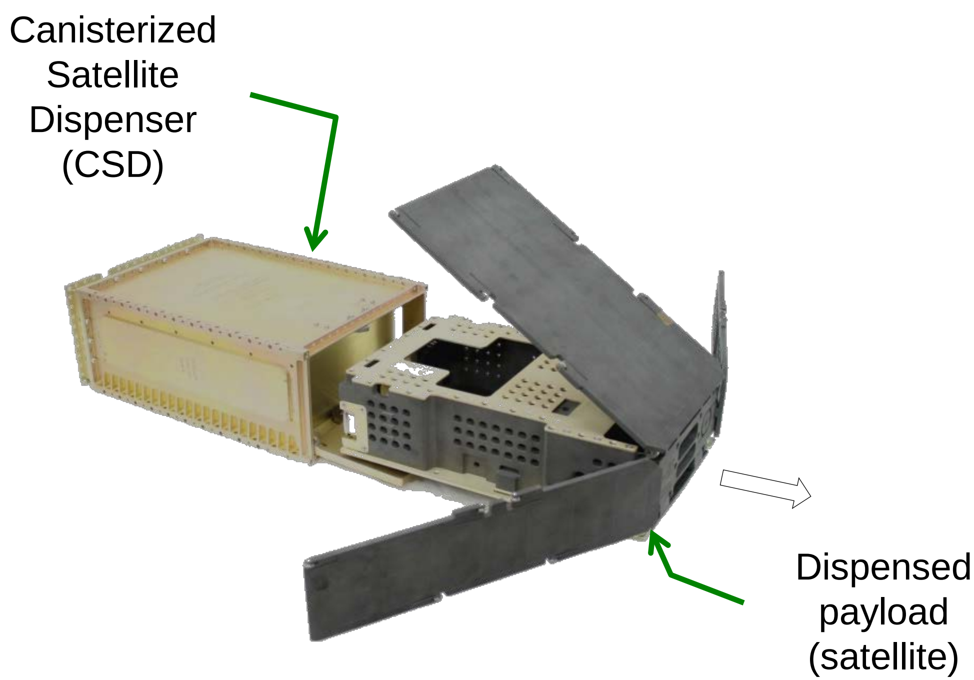
- At LOI the line of apsides orthogonal to the Sun line
  - Perilune in Sunlight for 6 months.
  - Revisit same representative (in latitude, composition, structure) features at different times of day during 6 lunar cycles
- To keep perilune in Sunlight beyond 6 months, need to rotate the line of apsides

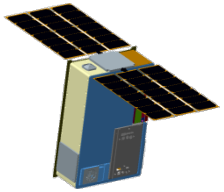




Why 6U size and using CSD?

- In comparison to a 3U only paying an extra ~$200K in launch cost for 2X more volume and mass
  - Larger optics and easier packaging
- Canisterized satellite dispenser (CSD) preloads the spacecraft creating a model able load path
  - Engineers can accurately predict detrimental loading on sensitive and expensive science instruments
  - Avoid exposing a $5M spacecraft to random vibration without being certain of success

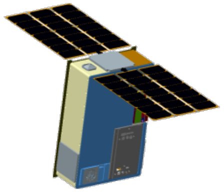




Lunar Water Distribution (LWaDi)

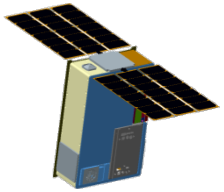
Mass, Volume and Power

System	Description	Heritage	Mass [kg]	Volume [U]	Power [W] (peak)
ACS/Propulsion	Star tracker, sun sensor, Momentum Wheels, uPPTs	BCT RWA, sun sensor, star tracker, GWU ucat or MIT PETA microthrusters	1	1.5	4/40 (min)
C&DH/ Processing	Science and engineering management, processing	SpaceCube mini	0.5	0.5	7
Thermal/ Radiation	Passive Shielding, Passive cooling	In-house	1	0.5	4
Structures/ Mechanisms	Frame, deployer, deployables (Gimballed, stowable Solar panel array, antennas)	PSC 6U deployer, MMA Design Ehawk gimballed solar panels	4	-	70
Comm	Antenna, transceiver	INSPIRE Dual X-band patch antennas, transceiver	1	1.0	10
Power	Electrical system, conversion, regulation, batteries	GOM batteries, rest in-house	1.5	1.0	5
Instrument	Detector, optics, associated electronics, cryocooling	Teledyne 1-4u HgCdTe, tactical cryocooler	2.5	1.5	7
Total w/out propulsion (WOP)	Costs Dependent on WHERE bus development and testing done. Instrument development cost estimated to be 1 to 2 million.		11.5	6.0	32



Enabling technologies

- We wish the following were TRL 9 now:
  - RF communications
    - >10kb/sec at lunar distance
    - Cost <<$100K
    - Volume 1/2U
    - Power < 20W
  - Laser communications
    - 1 Mbit/sec from lunar distance
    - Cost <$100K
    - Volume 1U
    - Power < 40W
  - Electric propulsion
    - 1U form factor for moon, 2U for other planets
    - 1.5 Km/sec deltaV for moon
    - Isp > 1,500 seconds
    - thrust > 3.25 mN
    - supplied power < 180W



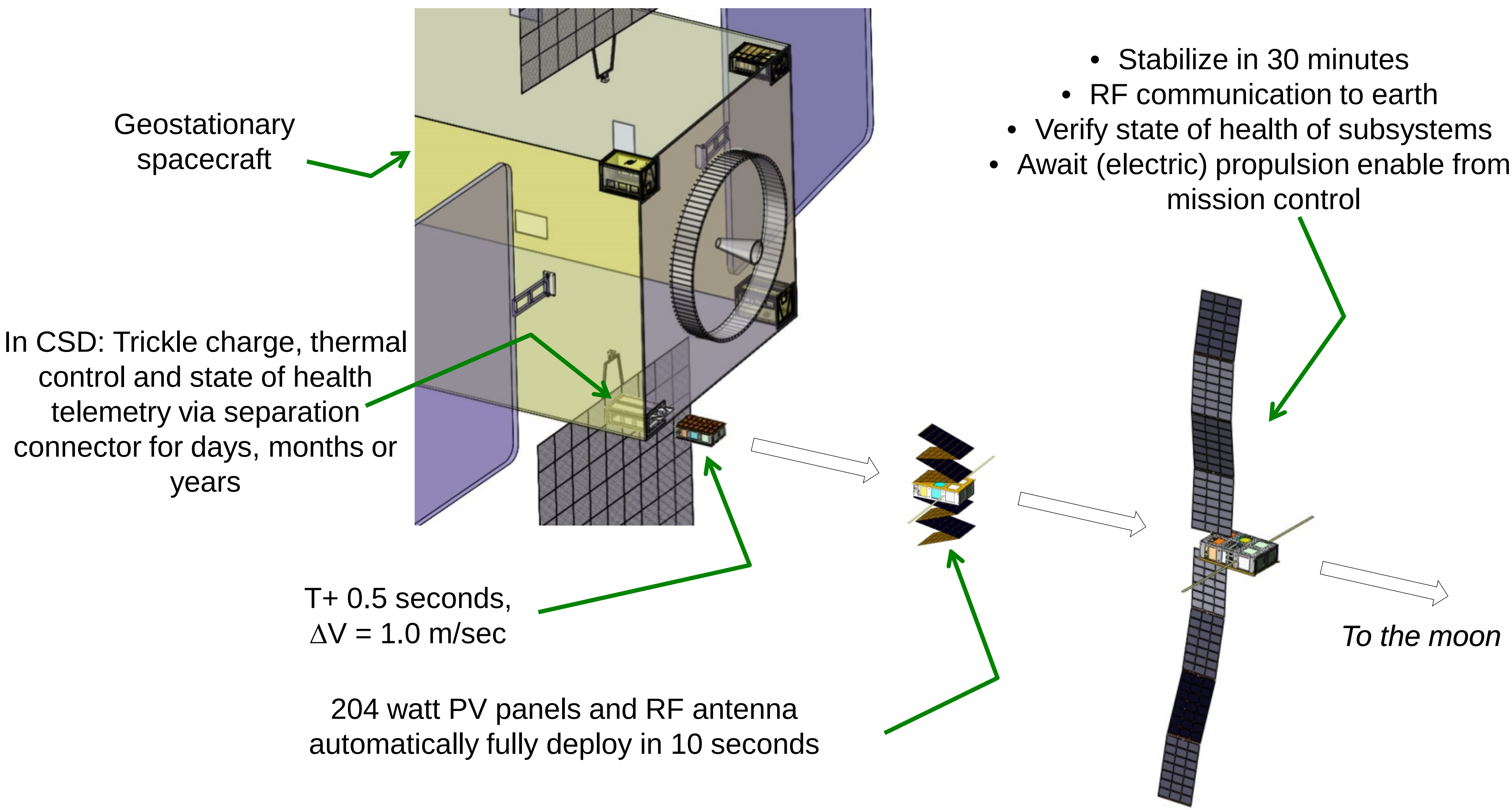
Launch Opportunities

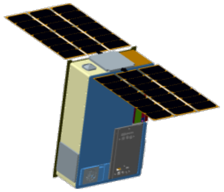
- SLS Launches after EM1 (requiring NASA SMD PSD slots)

- Google X Prize Team (Moon Express, Astrobotic) landers (from orbit prior to landing)

- As hosted payload from GeostationarySecondaries on Launches to GEO/GTO/Earth Escape

Launched as a Hosted Payload from a Geostationary bus

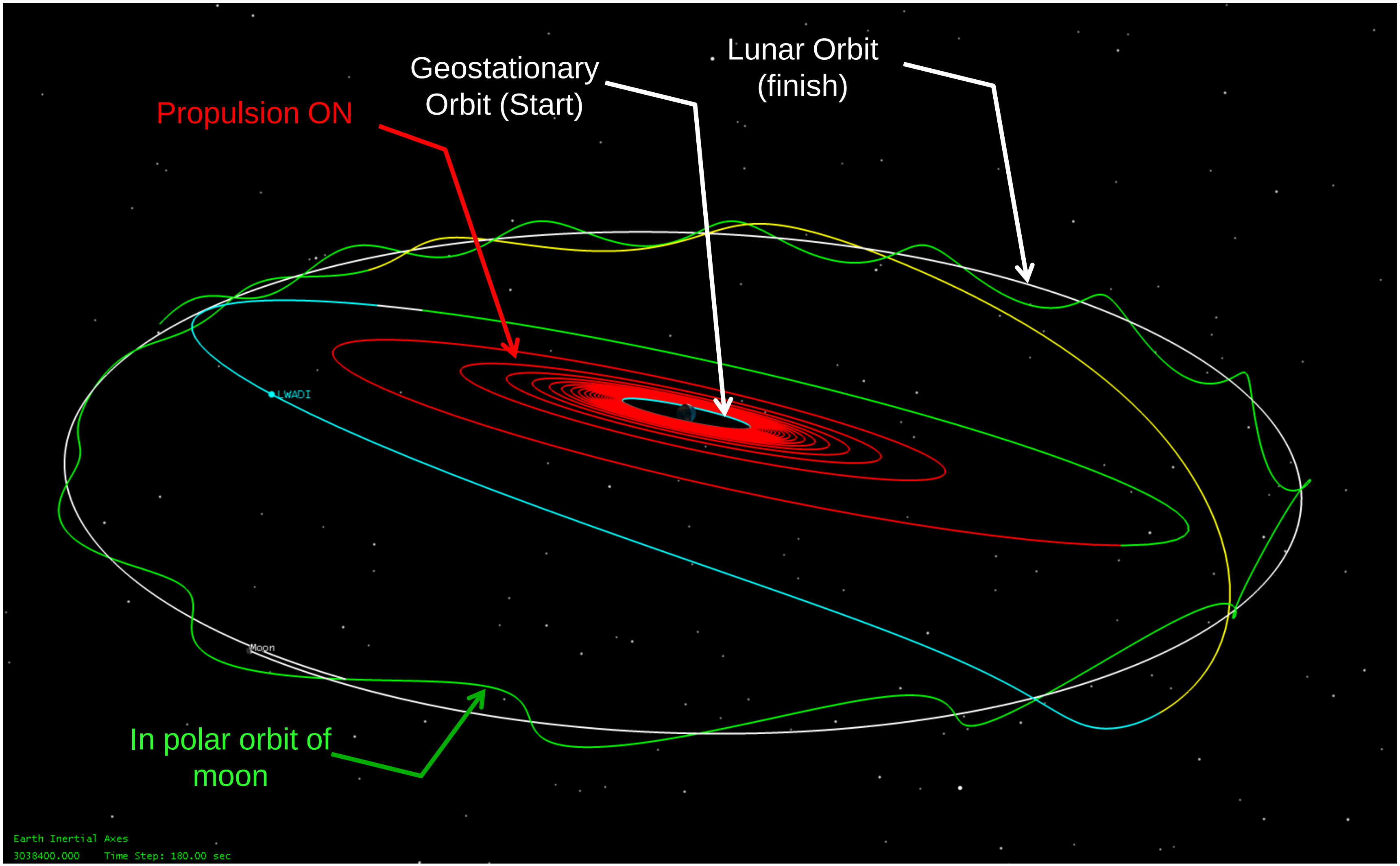




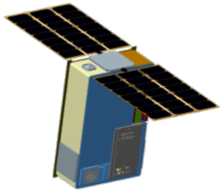
Lunar Water
Distribution
(LWaDi)

From Geostationary to Lunar orbit

- Need 1.6 km/sec from Geostationary to lunar orbit
- 89 days at Isp = 1,500 seconds and power = 180 W

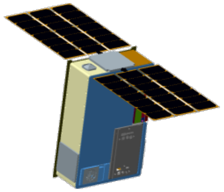


Video of Orbit



Next Steps

- Test Prototype for BIRCH instrument in simulated environment (2014-2015)
- Seek NASA SMD PSD funds for BIRCH instrument development (2015-2017)
- Test breadboard for LWaDi (LunarCube) bus (2014-2015)
- Build and test prototype for LunarCube bus (2015-2017)
- Bring LWaDi to TRL 5-6 by 2017



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