Global L-band Observatory for Water Cycle Studies (GLOWS) mission

Low-cost soil moisture continuity mission

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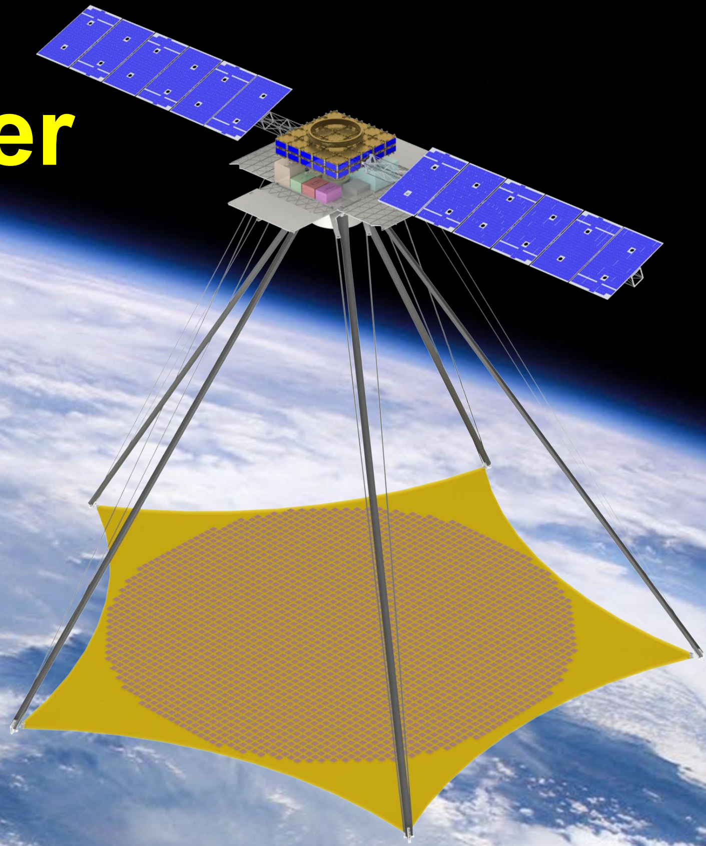
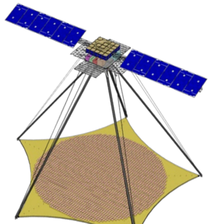
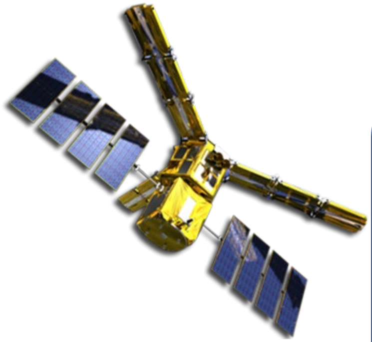


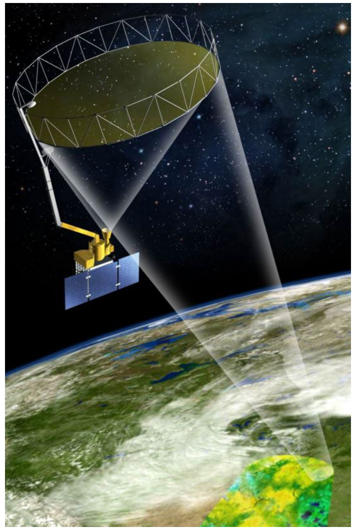
Agile RF Systems LLC



Soil Moisture

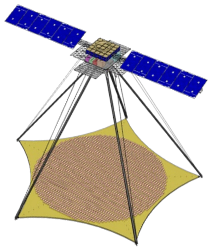
Objective of a Soil Moisture mission is to provide high-resolution and frequent-revisit global maps of soil moisture.





- Provide understanding of the hydrologic cycle
- Understand processes that link the terrestrial water, energy and carbon cycles
- Estimate global water and energy fluxes at the land surface
- Enhance weather, flood and drought prediction
- Improve agricultural forecasts and human health

A number of these science and applications need *longer term* consistent data records at higher *Spatial* and *Temporal* resolutions



Global L-band Observatory for Water Cycle Studies (GLOWS)

Soil Moisture

- High-resolution and frequent-revisit
- Understand processes that link the terrestrial water, energy and carbon cycles
- Estimate global water and energy fluxes at the land surface
- Enhance weather, flood and drought prediction

Ocean Surface Salinity

- Ocean circulation governed by salinity + temperature
- Global water cycle: Salinity reflects balance between precipitation and evaporation
- Freshening due to ice melt in Arctic
- Balance between Atlantic and Pacific
- Changes in coastal salinity due to increased run off

Ocean Surface Winds

- Effective in intense tropical cyclones
- L-band not affected by rain or clouds
- L-band does not saturate with wind speed

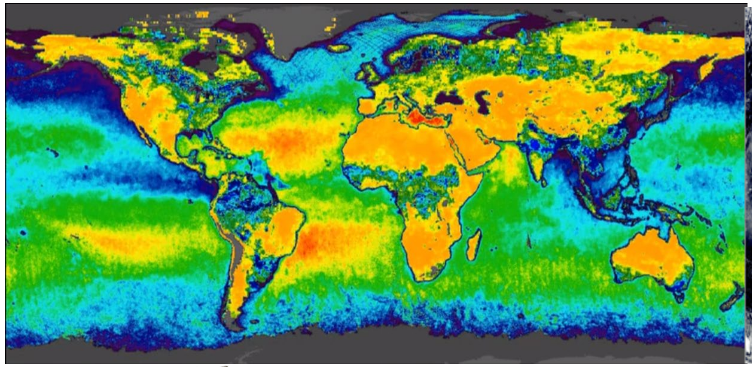
Vegetation Biomass

- Radar observations provide all-weather vegetation biomass
- Microwaves observations saturate at higher biomass
- Food security and agriculture
- Quantify net carbon flux in boreal landscapes

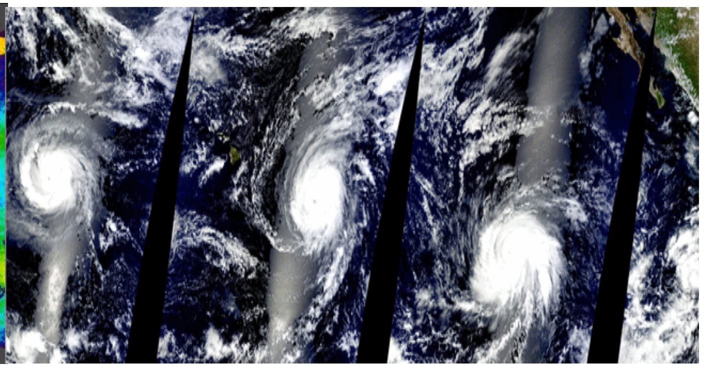
Thin Sea Ice

- Sea ice thickness up to 0.5 m
- Complementary observations to altimeter - thin sea ice
- Summer melt of sea ice and ice sheets can cause fresh water lenses

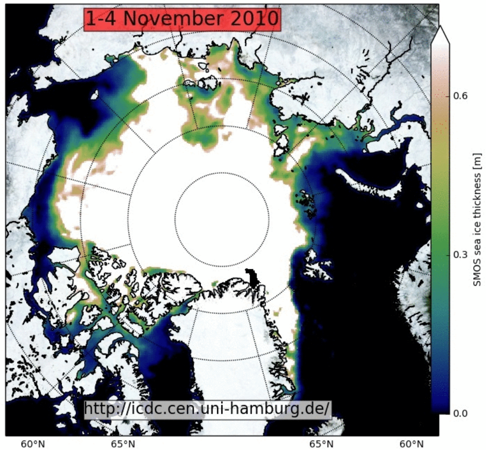
Soil Moisture and SSS from SMAP

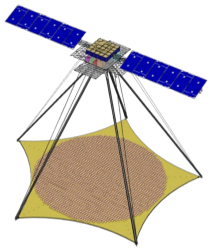


Ocean Winds using L-band



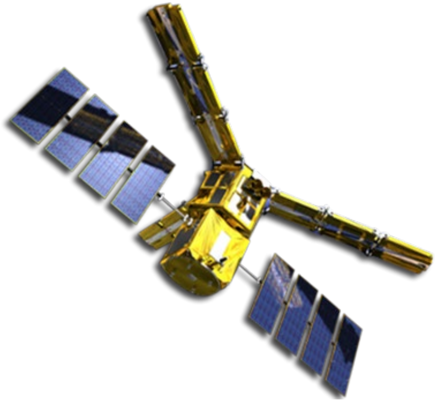
Sea Ice





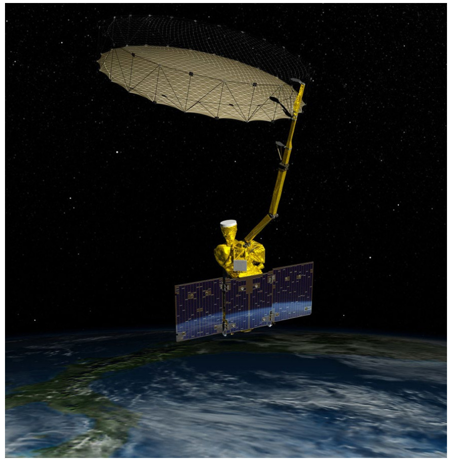
SMOS

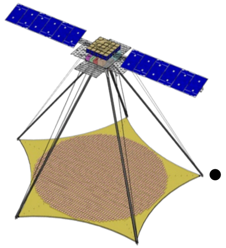
- Launched Nov 2009
- 2D-synthetic aperture
  - Multiple incidence angles at every location [0^o-65^o]
- Sun Synchronous orbit with an ascending orbit of 6:00 AM
- Spatial resolution 40 km
- Swath – 1400 km
- 3 day global coverage



SMAP

- Launched Jan 2015
- Conically Scanning Real aperture
  - Constant incidence angle of 40^o
- Sun Synchronous orbit with a descending orbit of 6:00 AM
- Spatial resolution 40 km
- Swath – 1050 km
- 3 day global coverage
- 8 day exact repeat





Global L-band Observatory for Water Cycle Studies (GLOWS)

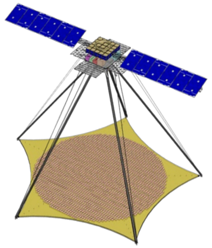
- SMOS, Aquarius and SMAP missions have shown the advantages of L-band observations to provide improved soil moisture (greater accuracy and estimates over greater vegetation levels) and SSS retrievals from space
  - Use of low frequency for secondary applications has also been demonstrated (Sea Ice, Ocean Surface Winds)

- Active and Passive L-band observations provide an opportunity for integrated land surface observations using a remote sensing platform

- Low frequency L-band missions can address a wide range of science objectives from different disciplines (soil moisture, ocean salinity, freeze-thaw, sea ice, ocean winds)

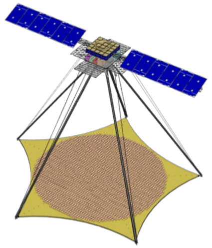
- Unfortunately, there are no current plans for a future U.S. L-band mission because low frequency missions have been traditionally too expensive due to the need for a large antenna

- Need for soil moisture observations to provide data continuity for operational applications
  - Weather forecasting (NWP)
  - Agriculture
  - Disaster (floods, droughts)
  - Land surface hydrology



GLOWS objectives

- Create SMAP-like capability
  - Science (resolution/swath/etc.)
  - Radar and radiometer
  - CONOPS
  - Design Life
- Stow within a rideshare volume
  - Use deployable high gain meta-material Lens
  - Use multi-element patch array feed
  - Reduce mass and volume
  - Leverage SOA commercial radar technologies
- Enable an Earth Venture Class mission



Science Traceability to Instrument Specification Matrix

Science Objectives	Scientific Measurement Requirements	Instrument Functional Requirements	Mission Functional Requirements
Understand processes that link the terrestrial water, energy and carbon cycles; Estimate global water and energy fluxes at the land surface; Quantify net carbon flux in boreal landscapes; Enhance weather and climate forecast skill; Develop improved flood prediction and drought monitoring capability.	Soil Moisture: ~4% volumetric accuracy in top 5 cm for vegetation water content < 5 kg m^{-2}; Hydrometeorology at 10 km; Hydroclimatology at 40 km	L-Band Radiometer: Polarization: V, H, U; Resolution: 40 km; Relative accuracy*: 1.5 K L-Band Radar: Polarization: VV, HH, HV; Resolution: 10 km; Relative accuracy*: 0.5 dB for VV and HH Constant incidence angle** between 35° and 50°	DAAC data archiving and distribution. Field validation program. Integration of data products into multisource land data assimilation.
	Freeze/Thaw State: Capture freeze/thaw state transitions in integrated vegetation-soil continuum with two-day precision, at the spatial scale of landscape variability (3 km).	L-Band Radar: Polarization: HH; Resolution: 3 km; Relative accuracy*: 0.7 dB (1 dB per channel if 2 channels are used); Constant incidence angle** between 35° and 50°	
	Sample diurnal cycle at consistent time of day Global, 3-4 day revisit; Boreal, 2 day revisit	Swath Width: 1000 km Minimize Faraday rotation (degradation factor at L-band)	Orbit: 670 km, circular, polar, sun-synchronous, ~6am/pm equator crossing
	Observation over a minimum of three annual cycles	Minimum three-year mission life	Three year baseline mission***

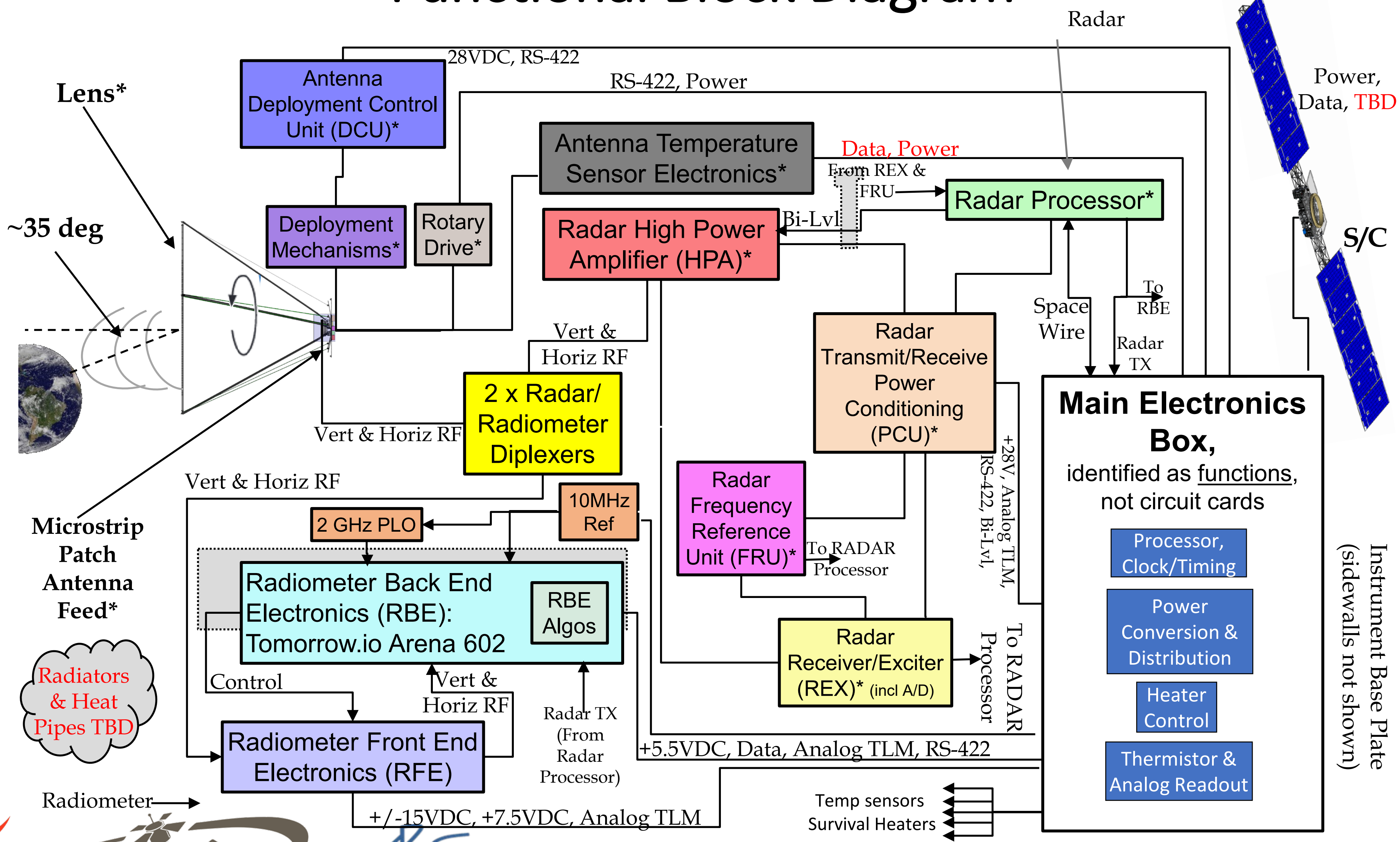
* Includes precision and calibration stability, and antenna effects

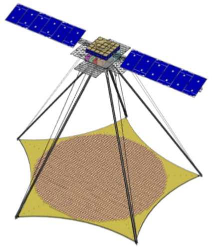
** Defined without regard to local topographic variation

*** Includes allowance for up to 30 days post-launch observatory check-out

Global L-band Observatory for Water Cycle Studies (GLOWS)

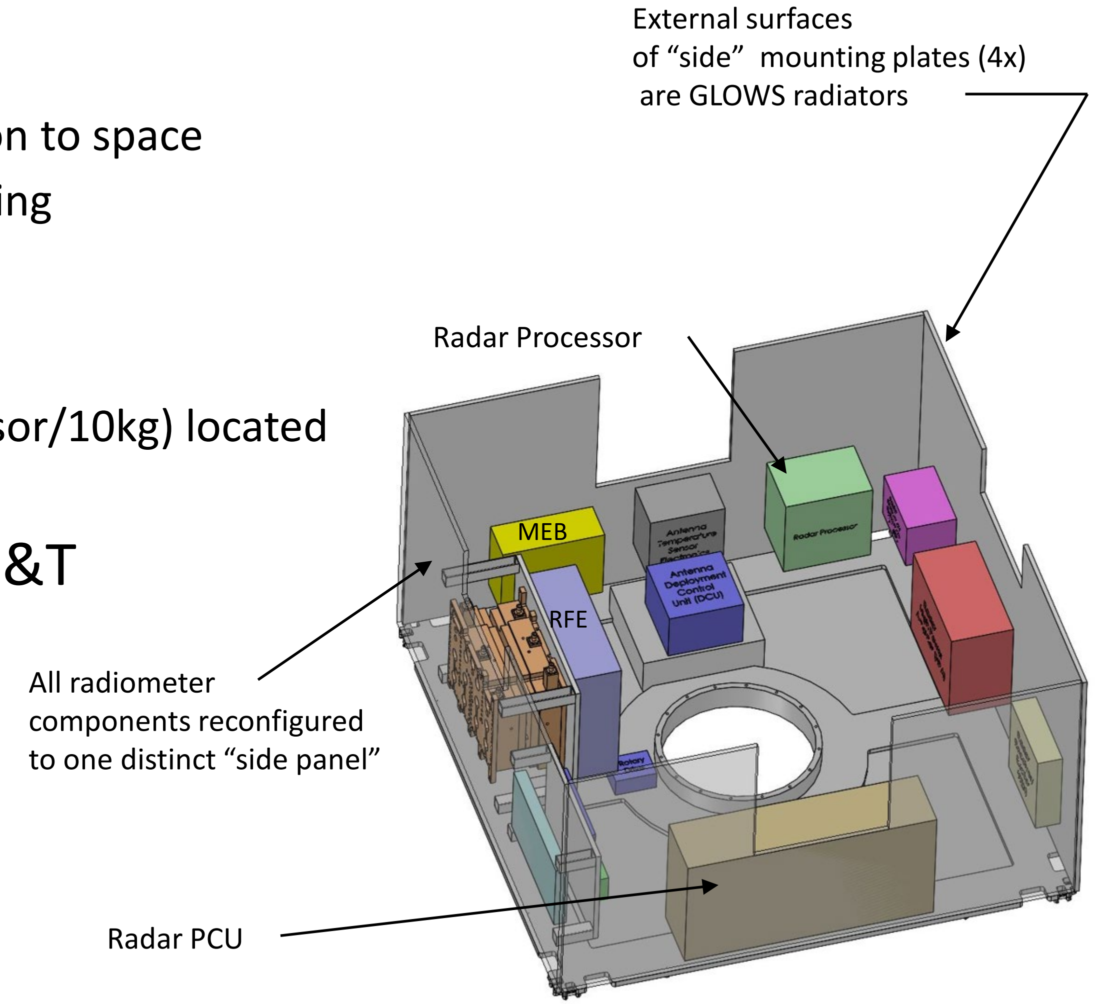
Functional Block Diagram

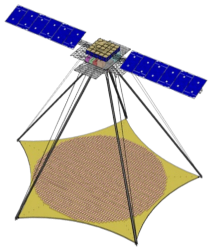




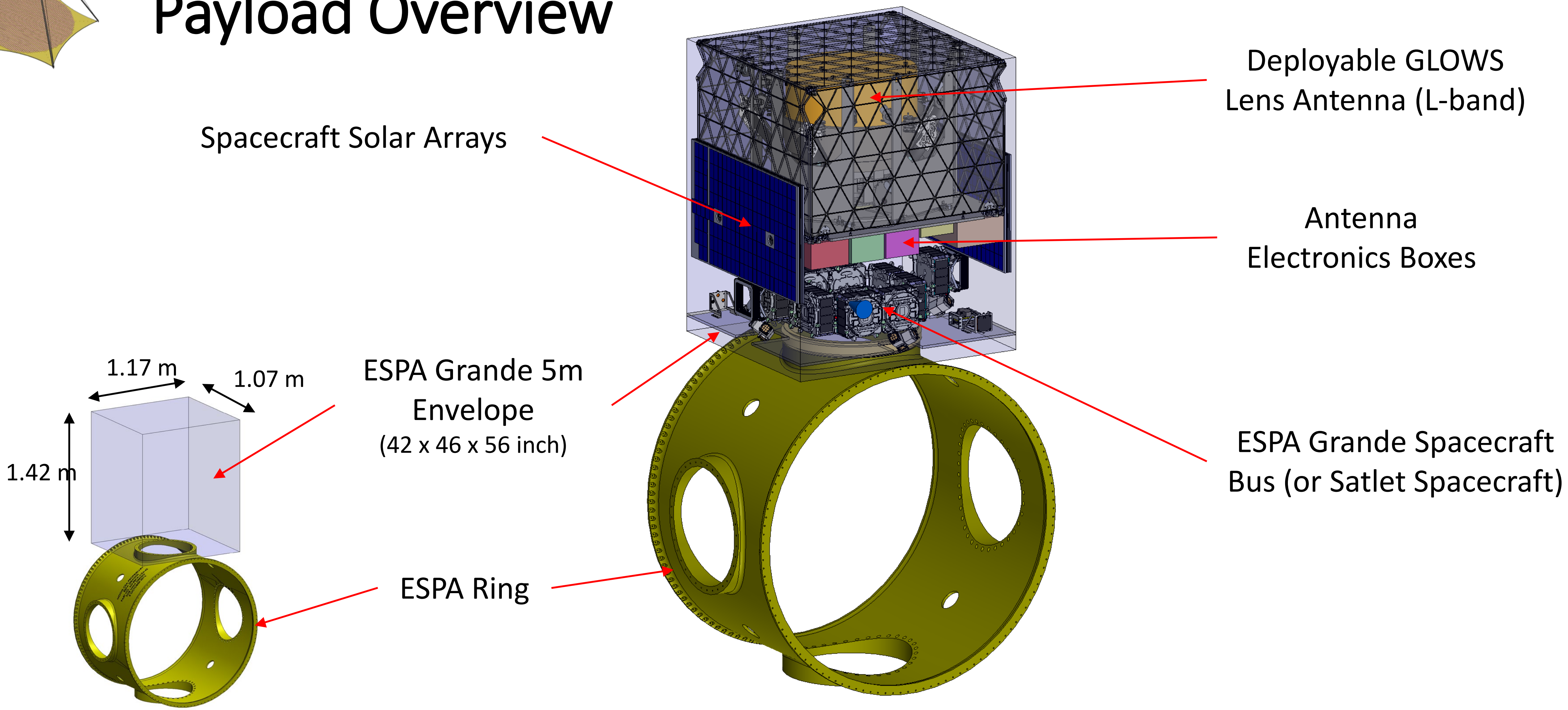
GLOWS Electronics

- Thermal:
  - Components located on "side panels" for efficient radiation to space
  - Components grouped on panels according to thermal zoning
  - RFE requires specific thermal stability
- CG balancing:
  - Heaviest components (Radar PCU/15kg and Radar Processor/10kg) located near the center
- I&T: Dedicated radiometer panel allows easier I&T
- Proximity Considerations
- Efficient Cable Feed sequence





Payload Overview



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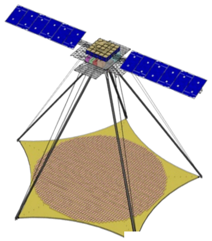
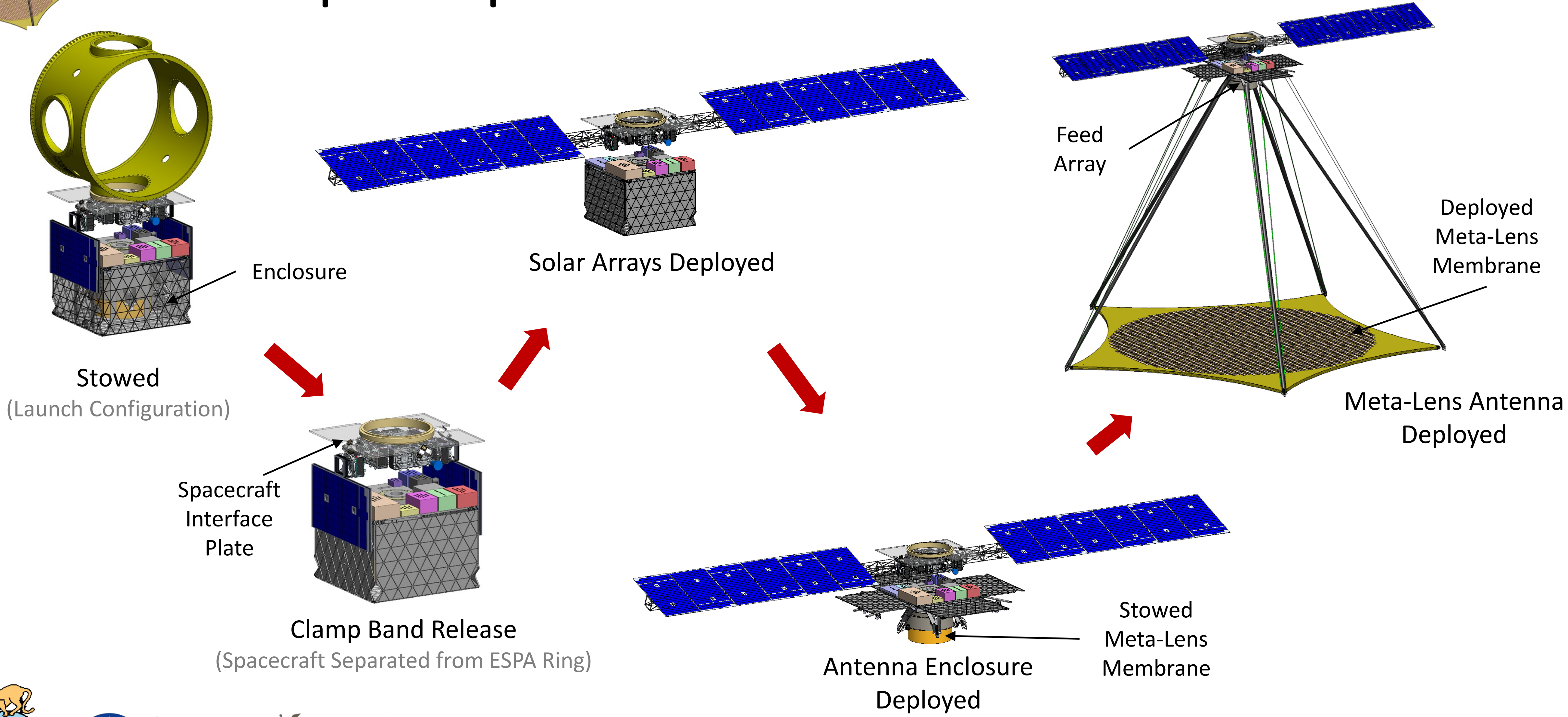
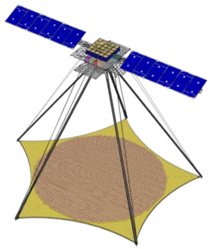


Concept of Operations





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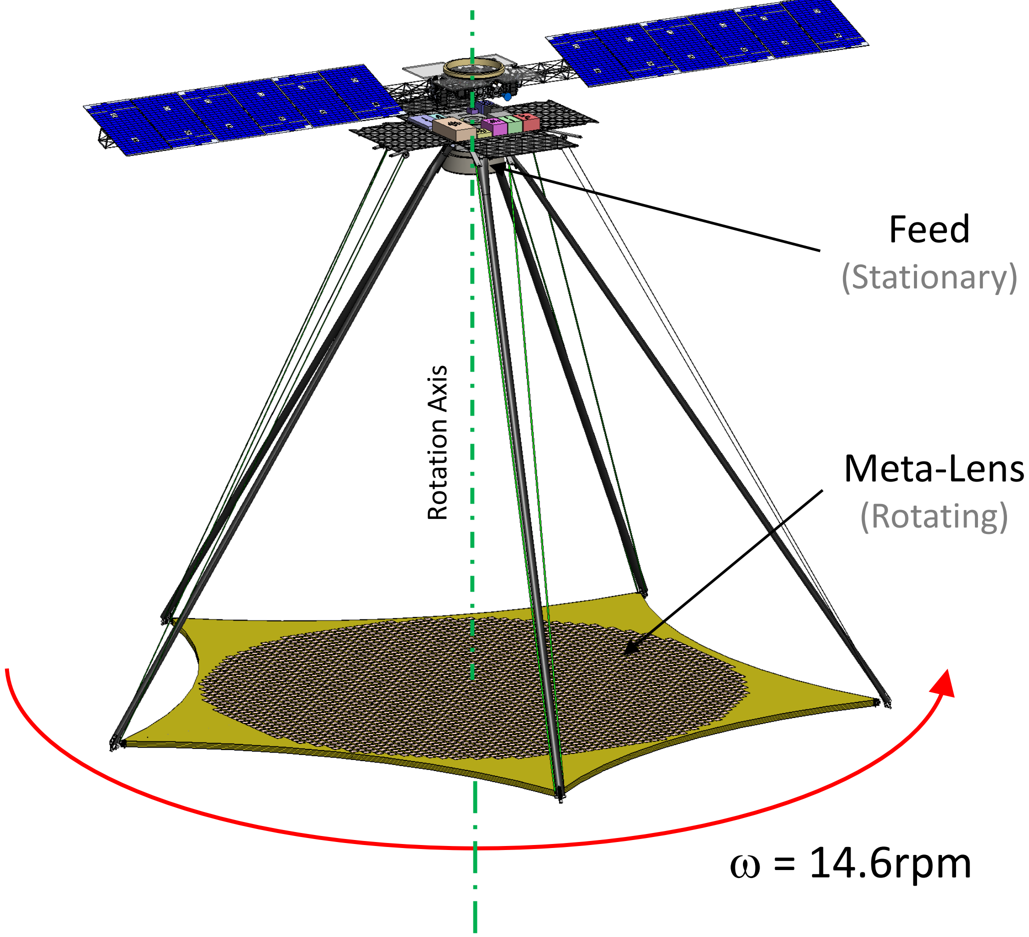
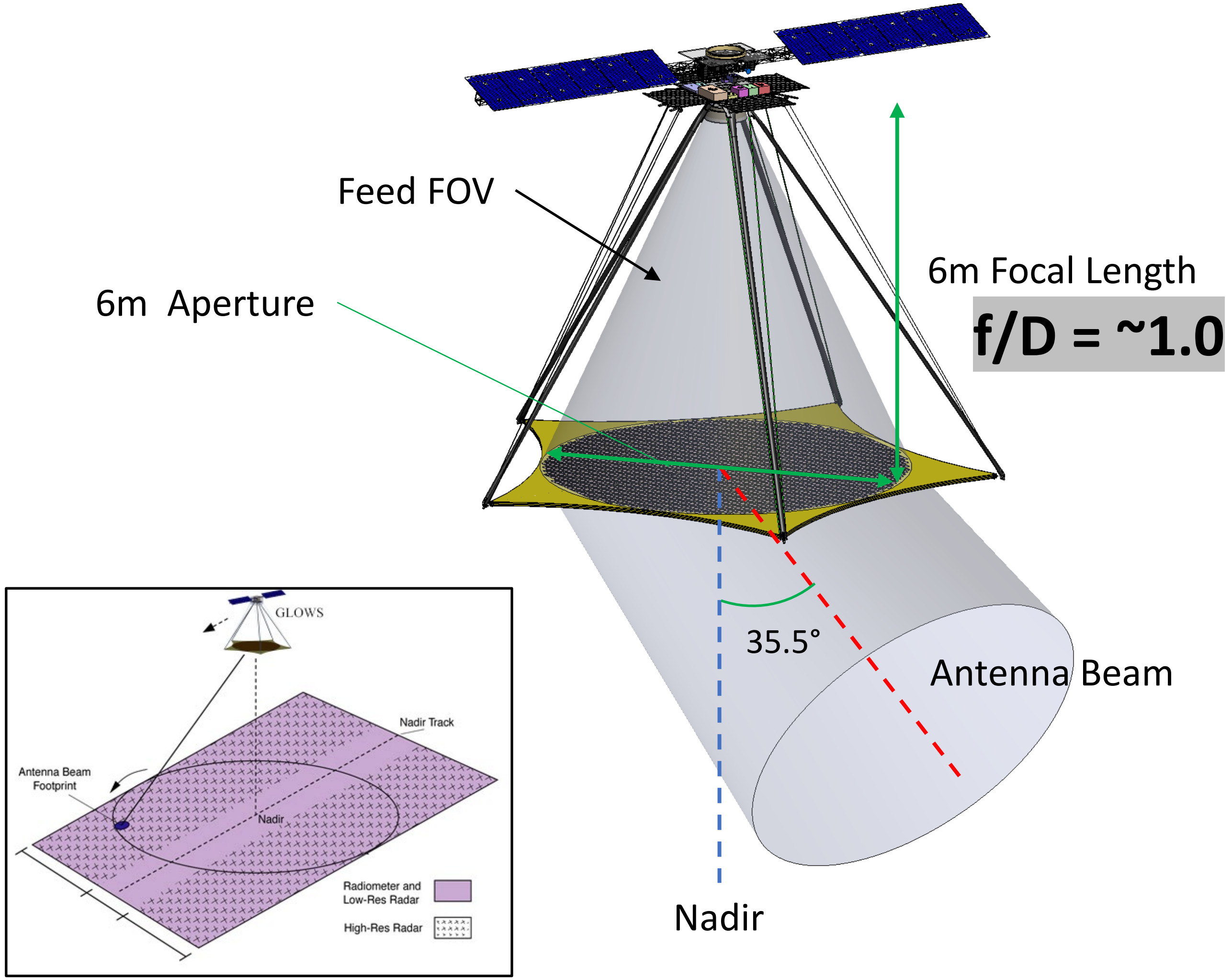
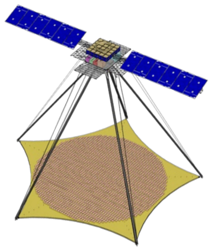
GLOWS Meta-Lens Antenna

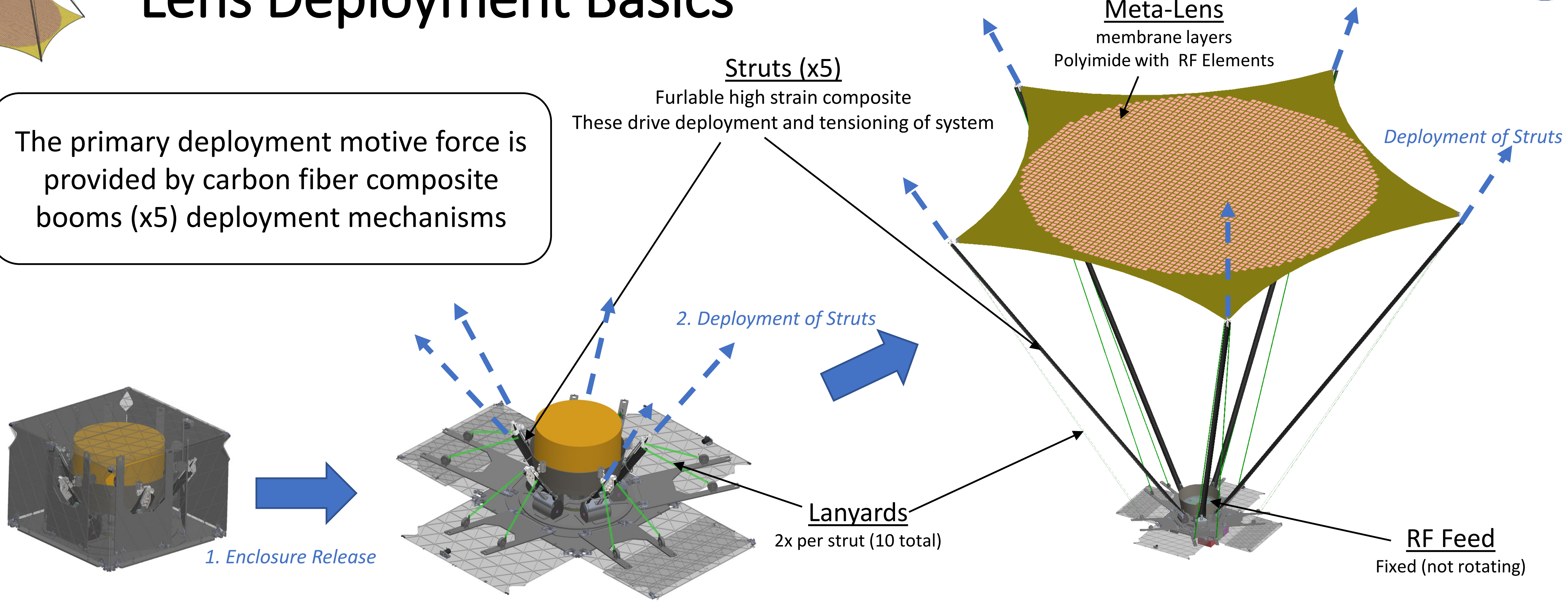


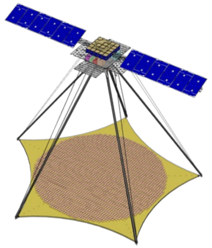




Lens Deployment Basics

The primary deployment motive force is provided by carbon fiber composite booms (x5) deployment mechanisms





Global L-band Observatory for Water Cycle Studies (GLOWS)

MMA Design

NASA GLOWS

Antenna for Global L-band Active/Passive Observatory for Water Cycle Studies

accomplish MORE

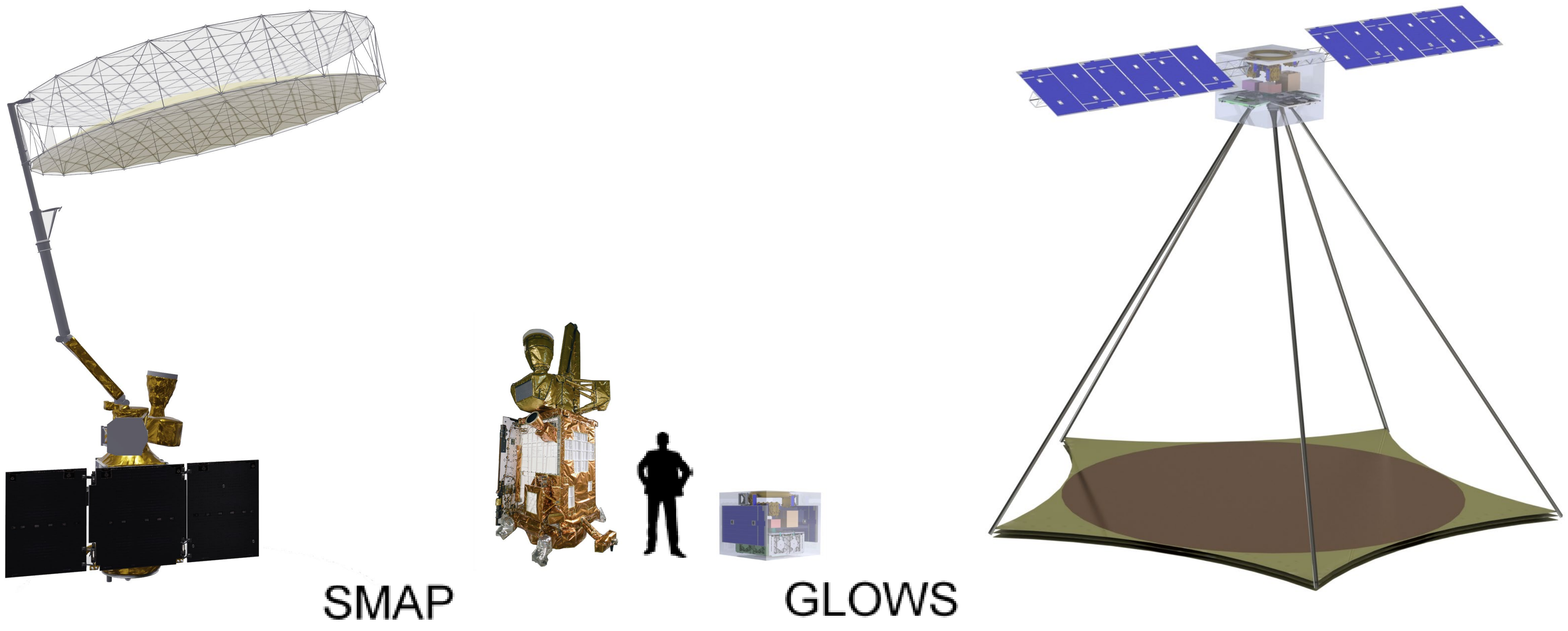
BRIGHAM YOUNG UNIVERSITY MICROWAVE EARTH REMOTE SENSING

NASA

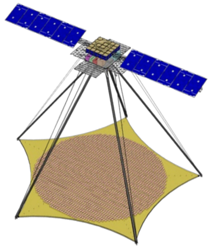
MMA Design

ARS Agile RF Systems LLC

GLOWS - Comparing GLOWS and SMAP



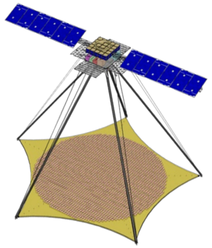
MICROWAVE EARTH REMOTE SENSING BRIGHAM YOUNG UNIVERSITY
NASA
MMA Design
ARS Agile RF Systems LLC



GLOWS - Comparing GLOWS and SMAP

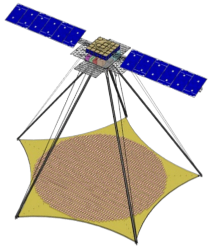
- Similarities
  - Active (Radar) and passive (Radiometer) share a common aperture
  - Same orbit (685 km 6am/6pm)
  - 6-meter aperture
  - Same L-band frequencies for both radar and radiometer
  - 14.6 rpm rotation motor that creates a rotational swath pattern on the earth
  - Same on-orbit calibration plans/maneuvers
  - Same 3-year mission objective

- Differences
  - **Flat multi-layer membrane Meta-lens(TR) vs. Canted mesh reflector**
  - Nadir deployed aperture with 5 symmetrical supports vs. Zenith deployed hoop on single deployed boom support
  - Instrument aperture obscuration of data downlink window vs. Solar illumination and GPS
  - Electrical Disconnect after deployment vs slip rings/rotary joints
  - Lens temperature sensors vs. no sensors
  - Multi-element Patch Feed vs. Feed Horn



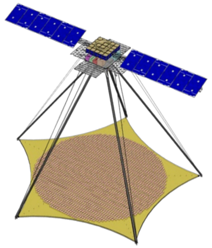
GLOWS - Comparing GLOWS and SMAP

MASS	SMAP	GLOWS	Reduction
Instrument	356 kg	199 kg	45%
Spacecraft	686 kg	183 kg	73%
Propellant	80 kg	21 kg	74%
Total	1122 kg	403 kg	**-60%**
VOLUME	**SMAP**	**GLOWS**	**Reduction**
Launch Volume	15.5 m^3	1.54 m^3	**-90%**



Summary

- SMOS and SMAP have demonstrated the value of L-band radiometer observations - Large set of science and applications addressed
- L-band radiometer missions have been challenging due to the aperture size required to make high resolution observations - cost perception
- GLOWS project demonstrated the ability to make L-band observations (consistent with SMAP resolution) using a smallsat – soil moisture continuity
- Reduced mass and volume compared to SMAP – lower cost
- Ability to do big science with smallsat – cost effective
- Further work needed to increase the TRL and mature the GLOWS mission concept



Thanks

Questions?