



# THUNDER: A New Frontiers-class Titan orbiter mission concept from the NASA JPL Planetary Science Summer School

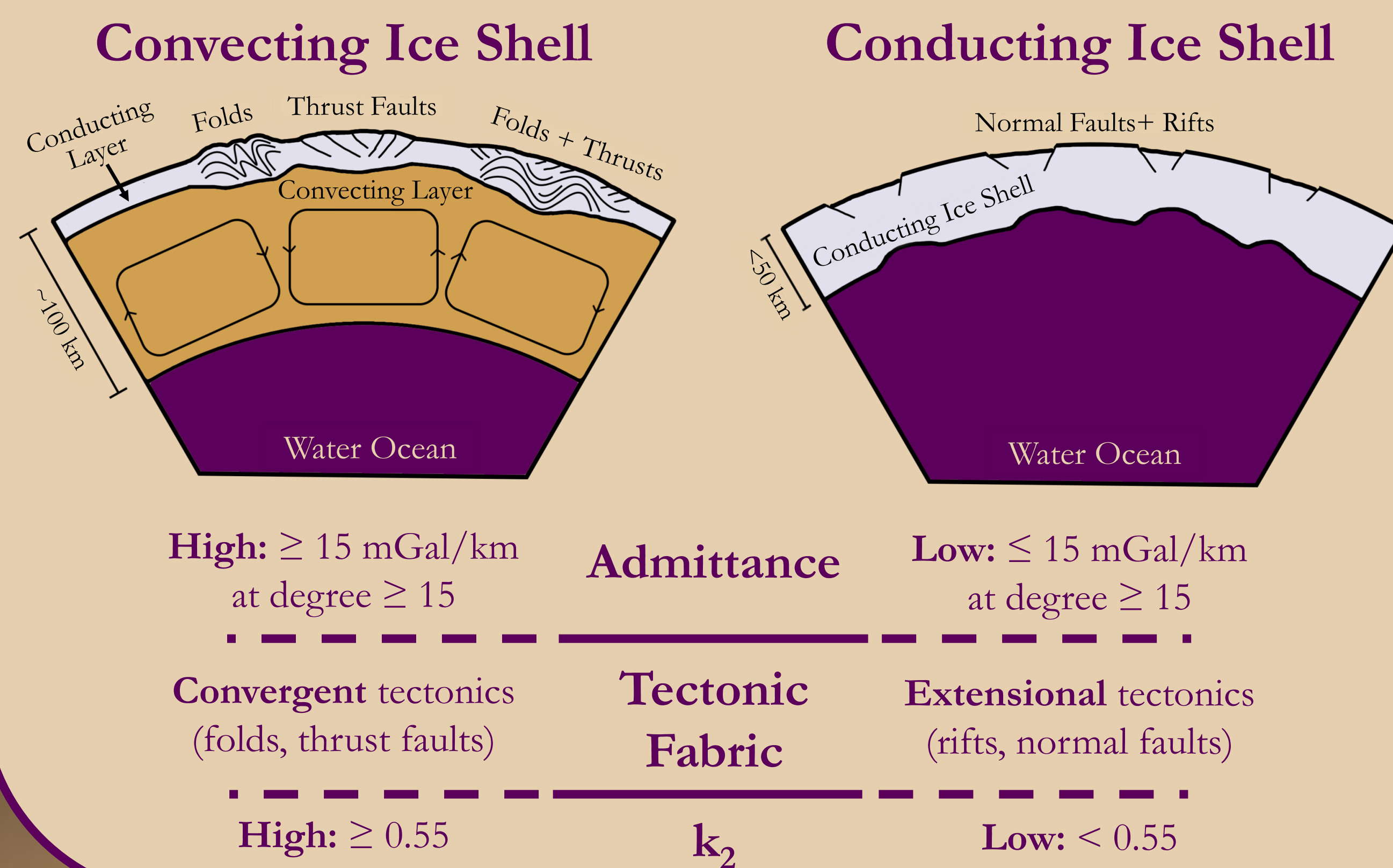


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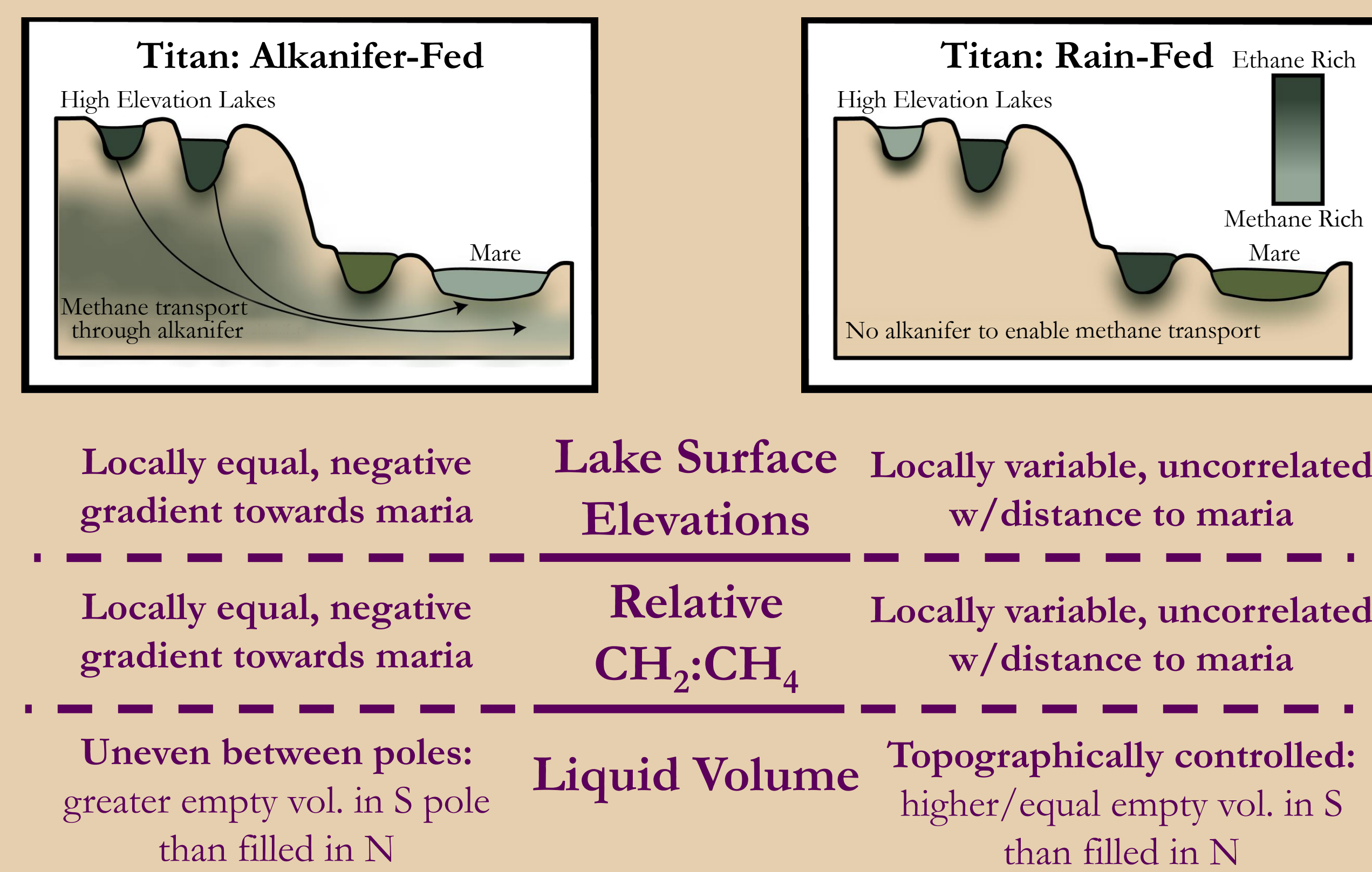
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## Mission Objectives

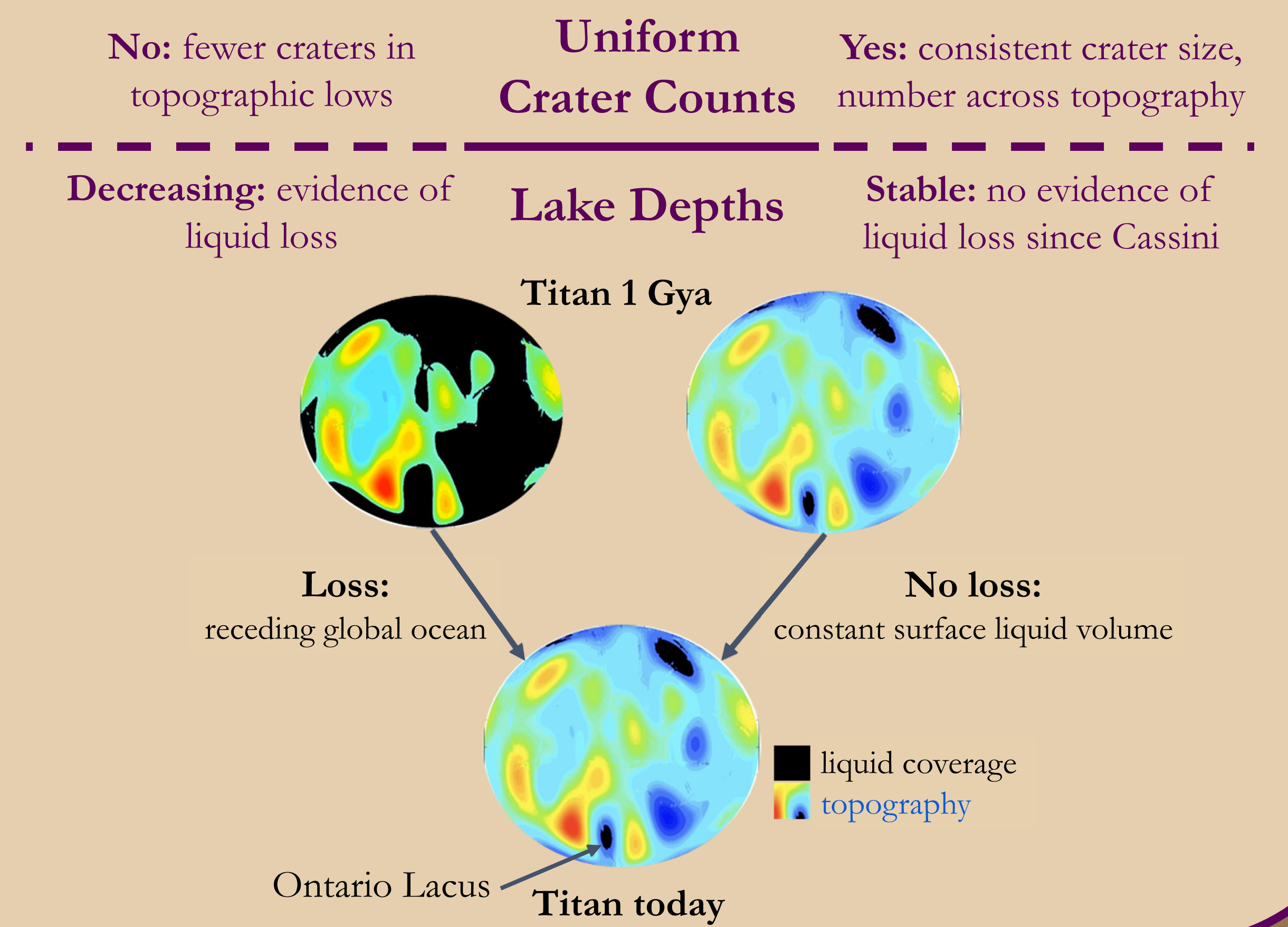
**Objective 1:** Determine if Titan's ice shell has a convective layer that can facilitate material transport between the surface and ocean.



**Objective 2:** Determine whether Titan's major liquid hydrocarbon bodies are connected and exchanging material with each other through a subsurface reservoir.



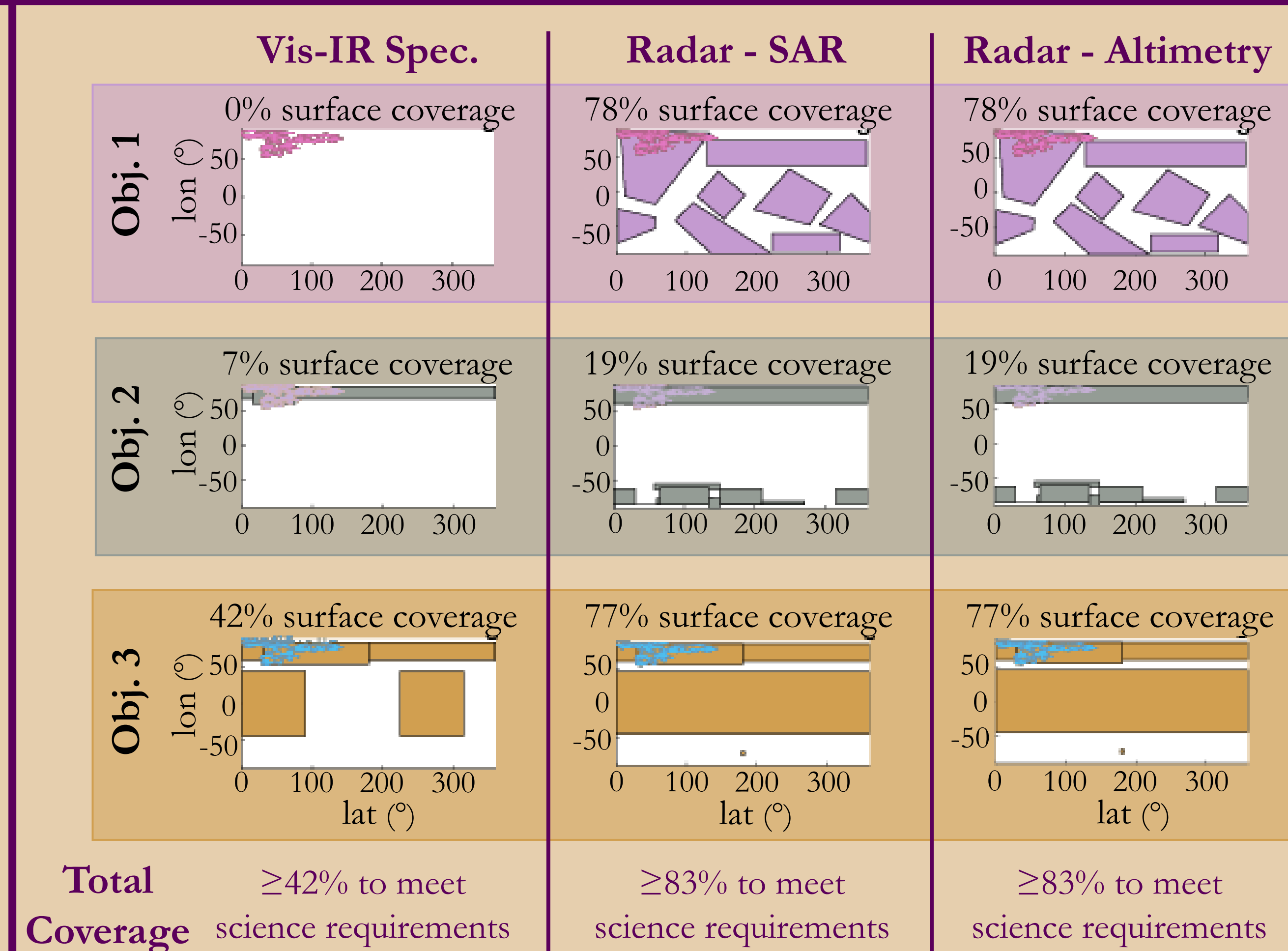
**Objective 3:** Determine if Titan is losing its atmosphere and surface liquids.



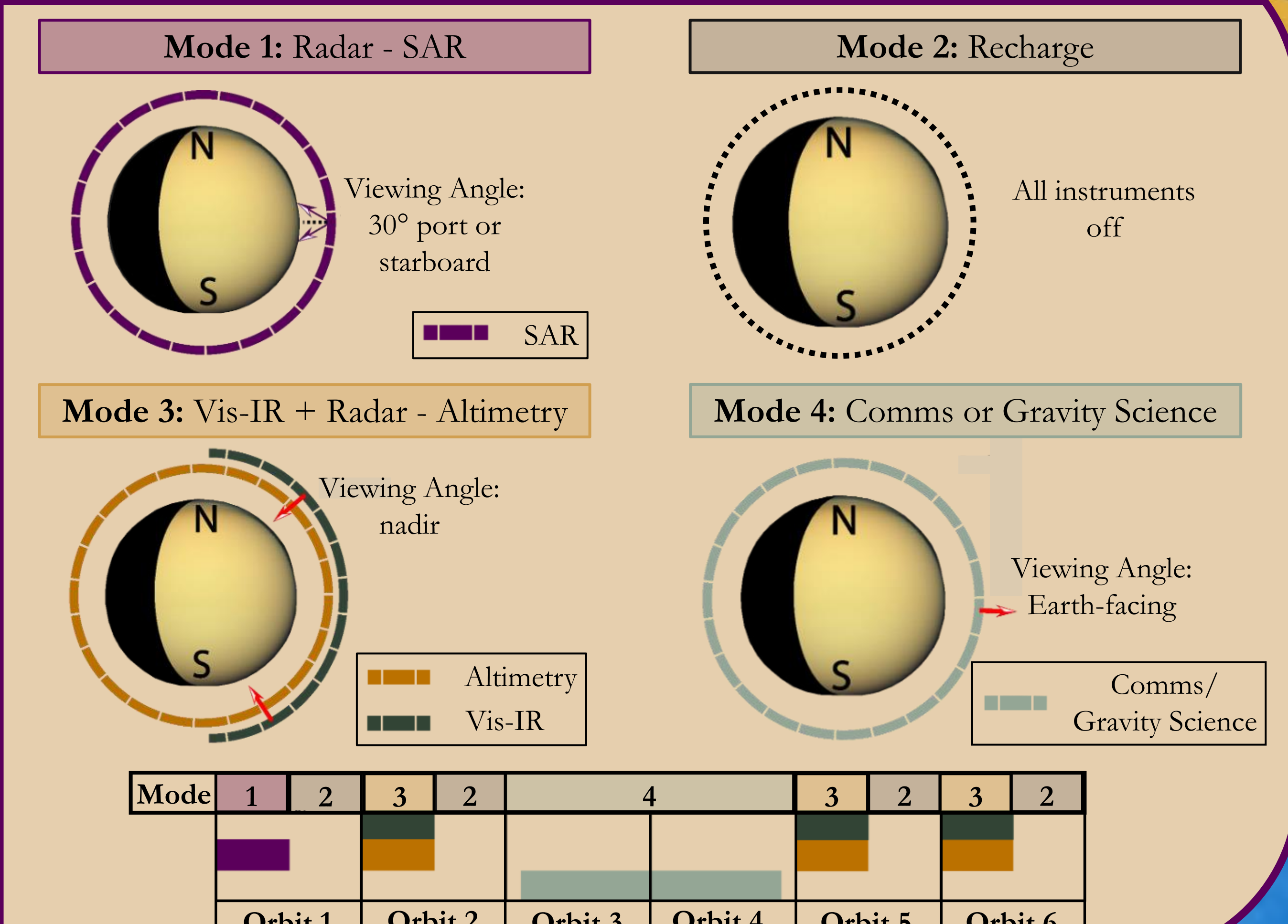
## Instrument Suite

Instrument		Science Requirement	Instrument Capability
Vis-IR Spectrometer	Spatial Resolution	$\leq 10$ km	5 km
	Spectral Bandwidth	0.93 – 3.2 $\mu$ m	0.4 – 4.3 $\mu$ m
	Spectral Resolution	$\leq 25$ nm	10 nm
	SNR/wavelength	$\geq 30:1$	$\geq 45:1$
Radar – SAR Mode	Spatial Resolution	$\leq 125$ m	100 m
	Swath Width	$\geq 20$ km	31 km
Radar – Altimeter Mode	Sensitivity	-20 dB	-26 dB
	Vertical Precision	$\leq 1$ m	20 cm
	Along Track Resolution	$\leq 500$ m	300 m
	Swath Width	$\leq 10$ km	6.0 km
Radar – Radiometer Mode	Sensitivity	-20 dB	-22 dB
	Spatial Resolution	149 km	124 km
Gravity Science	Spherical Harmonic	Degree $\geq 15$	Degree $\geq 15$

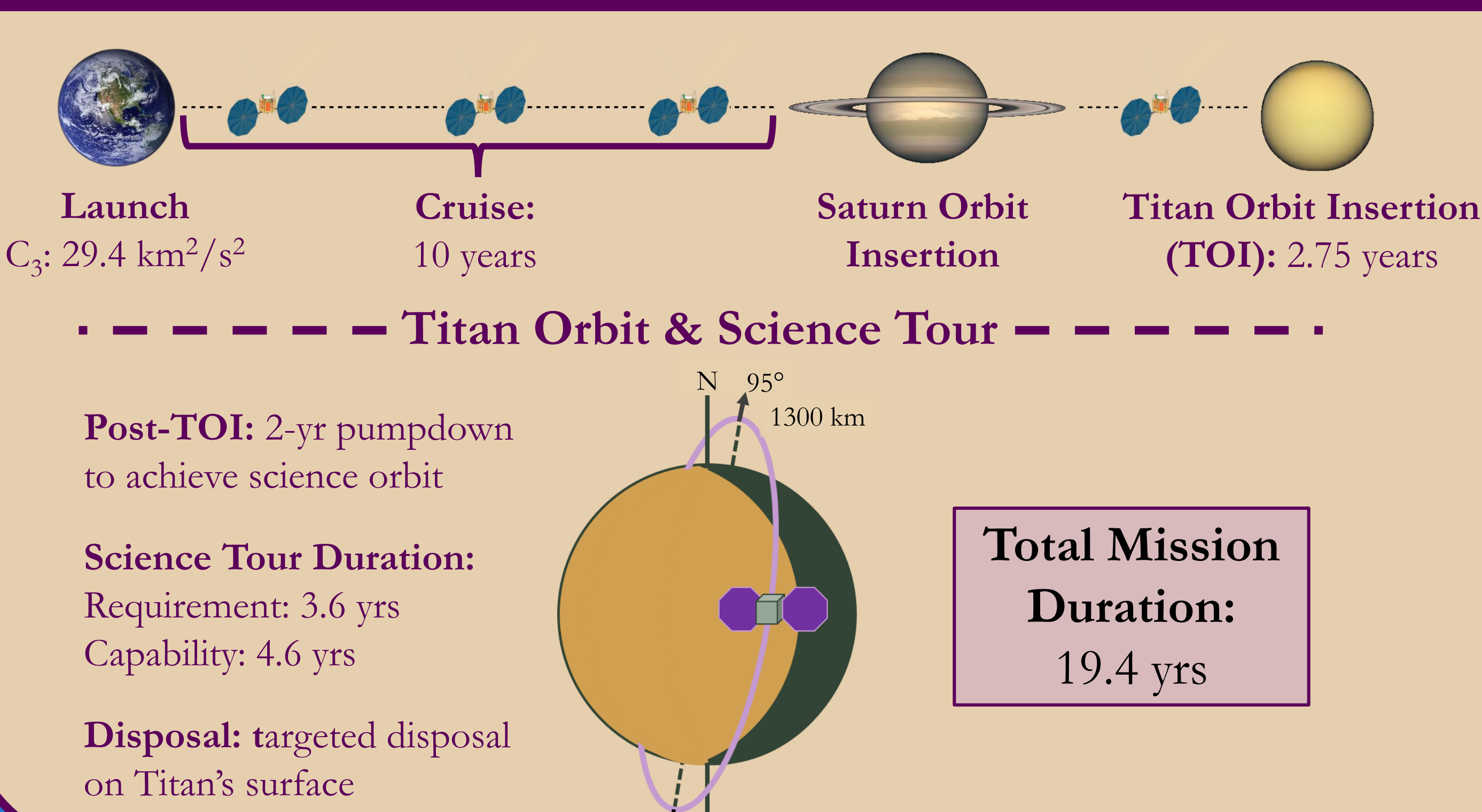
## Minimum Coverage by Objective & Instrument



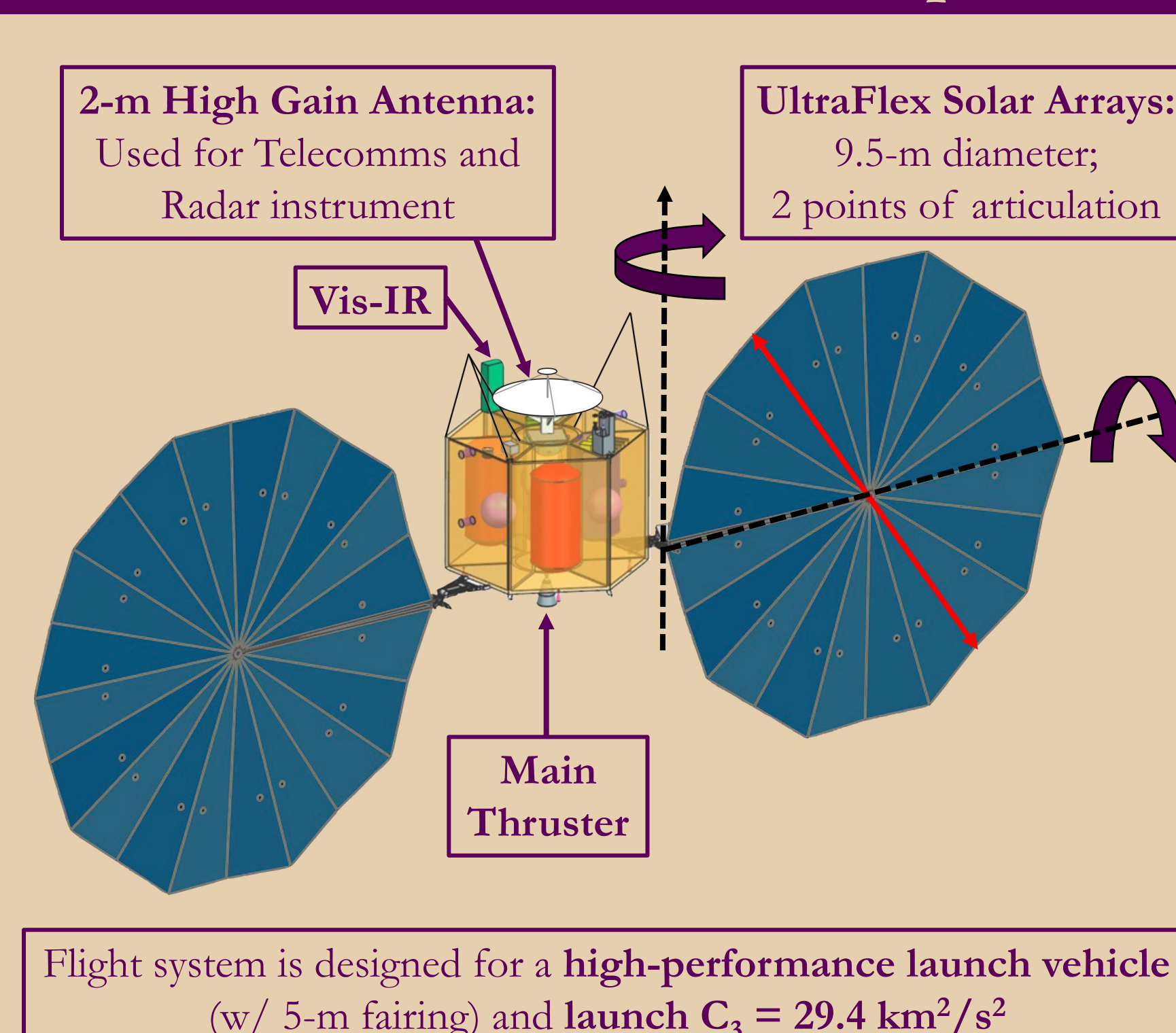
## Concept of Operations



## Mission Timeline



## Spacecraft Design



Subsystem	Key Features
Propulsion	Segmented fuel system: only one heated tank during science tour to save on heating power
Thermal	Loop heat pipe system to handle opposing temp. extremes during Venus flyby and Titan orbit
Power	Solar-powered: required to operate radar instrument for total mission duration Lithium-ion battery for power storage
Attitude Control	Spacecraft is three-axis stabilized Reaction Wheel Actuators (RWAs) + backup Reaction Control System (RCS) thrusters
Command & Data Handling	64 Gbits storage (>100 days worth of science data: 370 Mbits/day) Onboard data compression
Flight Software	F Prime software (55% reuse from past missions)
Mechanical	Avionics embedded around prop system for improved thermal management Radiation Shielding: 50 krad
Telecomms.	High-rate science downlink: 12 kbps (@ 11 AU) Dual frequency (up/down): X- and Ka-bands

## Mission Significance

**Titan's Hydrocarbons: Uncovering New Dimensions of Evolutionary pROcesses (THUNDER)** is a dedicated geology and geophysics mission to trace Titan's hydrocarbons from the inside out, assessing whether hydrocarbons move through Titan's water ice bedrock to cycle from the subsurface ocean to the atmosphere. This Titan orbiter will use surface mapping (via radar and spectrometry) and gravity science to advance geophysical expertise for Saturn's most Earth-like moon.

### THUNDER Team:



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