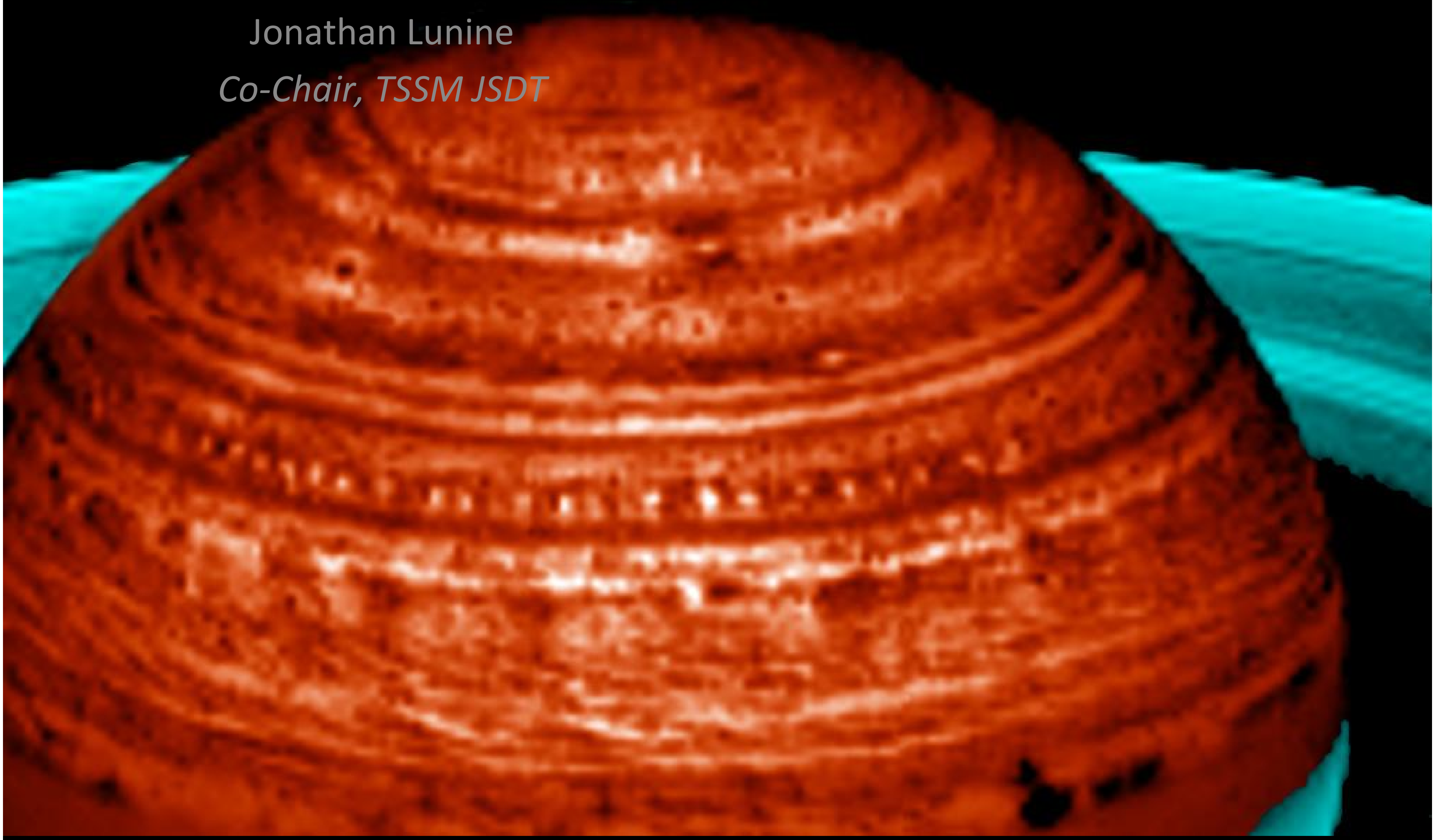
Titan Saturn System Mission:

Jonathan Lunine

Co-Chair, TSSM JSDT



Science Team

Jonathan Lunine, Co-Chair (University of Arizona)
Jean-Pierre Lebreton, Co-Chair (ESA/ESTEC)
Athéna Coustenis, Lead Scientist for ESA Study (Observatoire de Paris-Meudon)
Dennis Matson, NASA Study Scientist (JPL)
Lorenzo Bruzzone, University of Trento
Maria-Teresa Capria (Instituto di Astrofisica Spaziale, Rome)
Julie Castillo-Rogez (JPL)
Andrew Coates (Mullard Space Science Laboratory, Dorking)
Michele K. Dougherty (Imperial College London)
Candice Hansen, NASA Deputy Study Scientist (JPL)
Andy Ingersoll (Caltech)
Ralf Jaumann (DRL Institute of Planetary Research, Berlin)
William Kurth (University of Iowa)
Luisa M. Lara (Instituto de Astrofísica de Andalucía, Granada)
Rosaly Lopes (JPL)
Ralph Lorenz (JHU/APL)
Chris McKay (ARC)
Ingo Muller-Wodarg (Imperial College London)
Olga Prieto-Ballesteros (Laboratorio de Geologia Planetaria, Madrid)
François Raulin (LISA Universités Paris 12 & Paris 7)
Amy Simon-Miller (GSFC)
Ed Sittler (GSFC)
Jason Soderblom (University of Arizona)
Frank Sohl (DLR Institute of Planetary Research, Berlin)
Christophe Sotin (JPL)
Dave Stevenson (Caltech)
Ellen Stofan (Proxemy Research)
Gabriel Tobie (Université de Nantes)
Tetsuya Tokano (Universität zu Köln)
Paolo Tortora (Università di Bologna)
Elizabeth Turtle (JHU/APL)
Hunter Waite (SwRI)

Kim Reh: JPL Study Lead

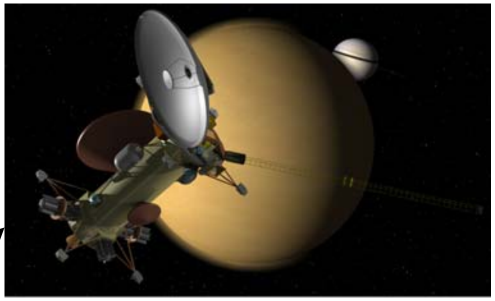
Christian Erd: ESA Study Lead

Pat Beauchamp, Nathan Strange, Tom Spilker, John Elliot,… (JPL)

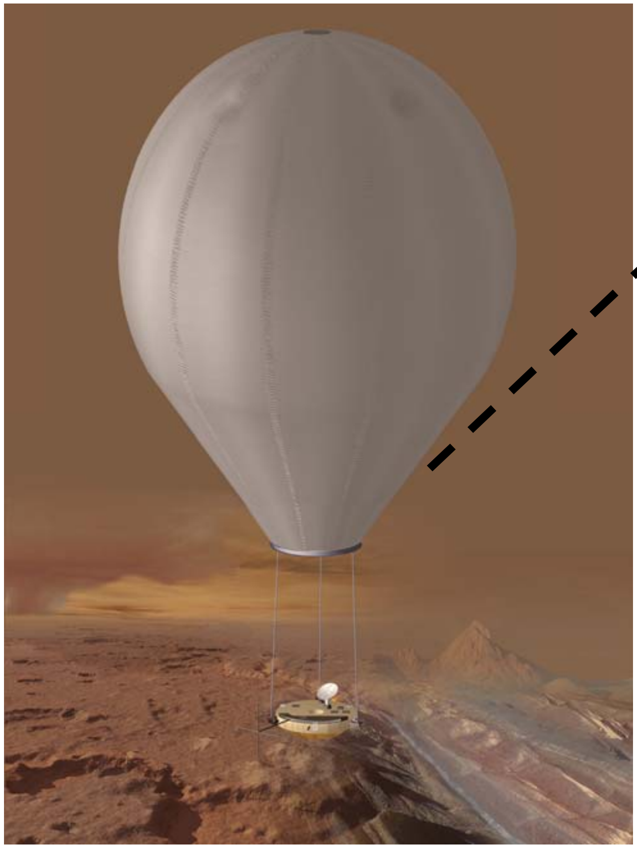
Baseline mission architecture

Combining

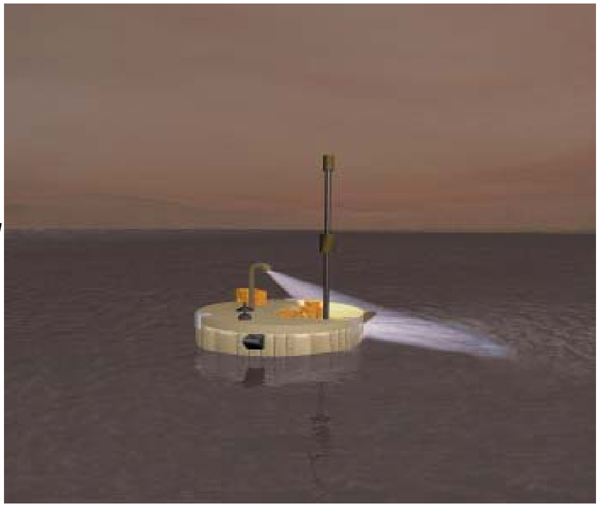
- An orbiter (Titan+Enceladus)
- A hot-air balloon/montgolfière on Titan and one North-pole lake-landing probe



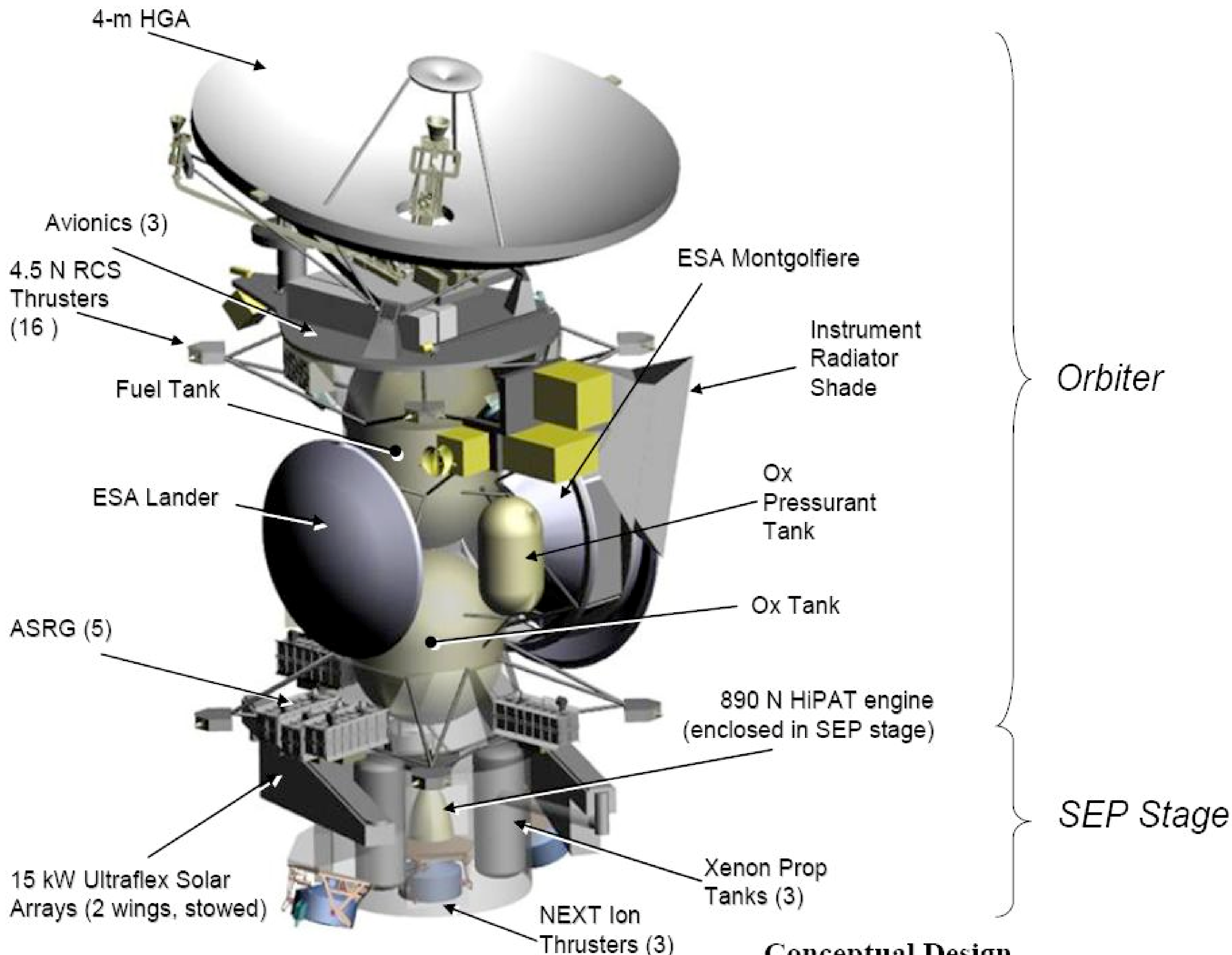
Dedicated Titan orbiter would be used also for relay after several Enceladus flybys



A hot-air balloon (Titan Montgolfière) would float at 10 km above the surface around the equator with some altitude control

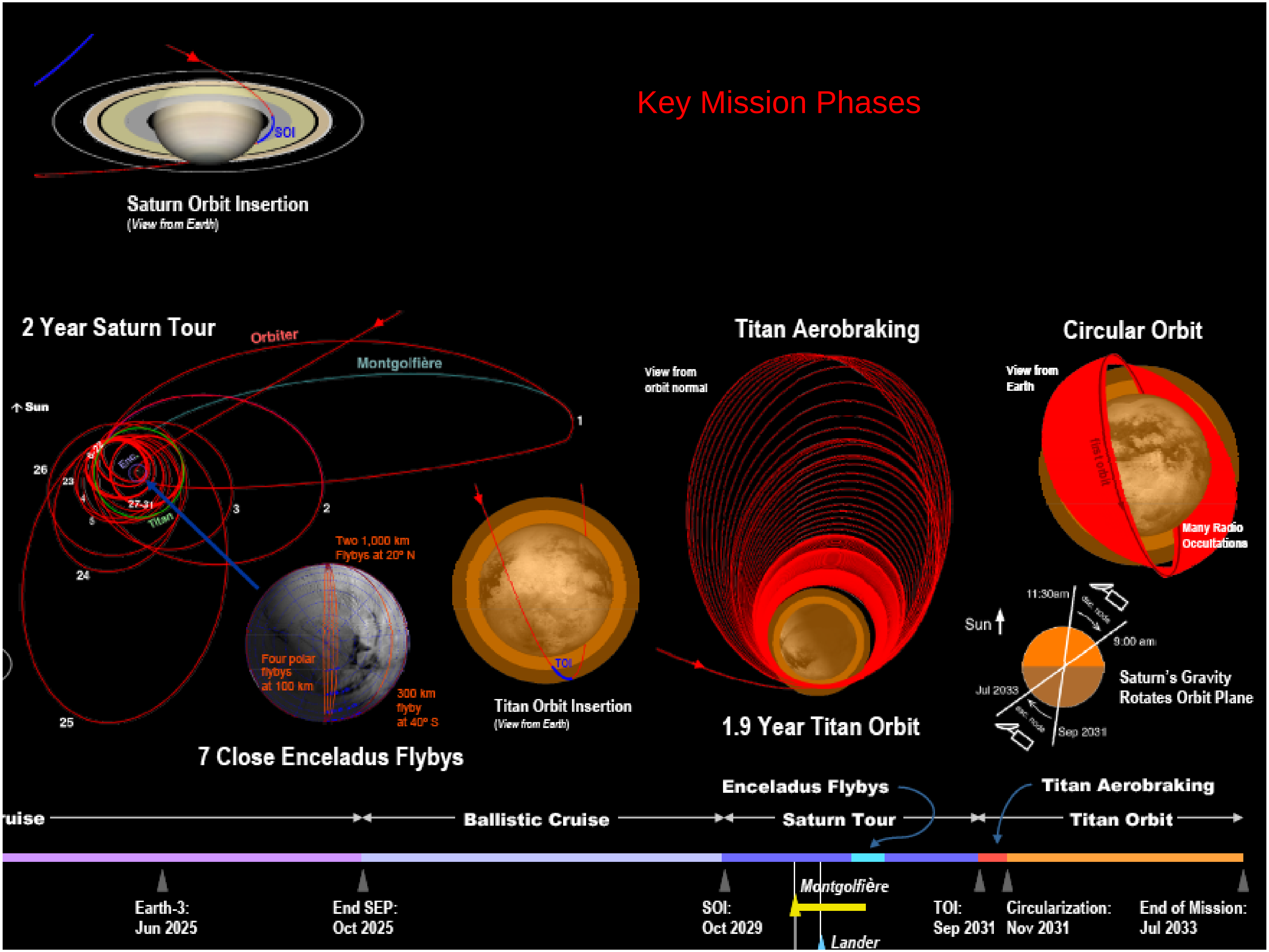


A short-lived Probe/Lander with liquid surface package would land in a northern sea



Conceptual Design

Key Mission Phases



Planning Payload

Orbiter

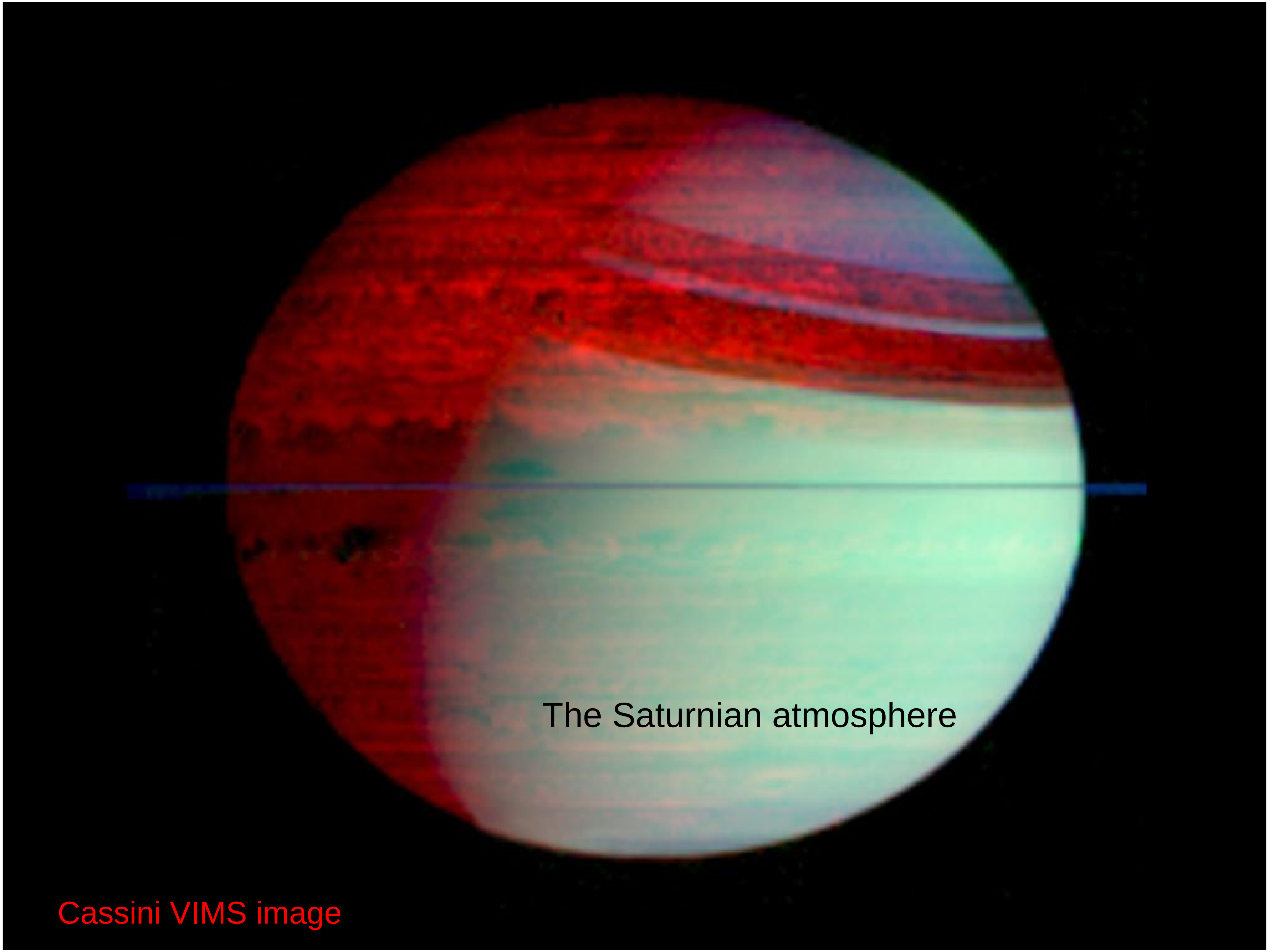
	Orbiter Planning Payload	Instrument Capabilities
HiRIS	High-Resolution Imager and Spectrometer (near IR)	1–6 µm global mapping at 50 m/pixel in three colors. Adjustable spectral editing for surface/atmosphere studies.
TiPRA	Titan Penetrating Radar and Altimeter	>20 MHz global mapping of subsurface reflectors with 10 m altitude resolution in altimetry mode & >10 m depth resolution. Lower data rate sounding mode with ~100 m depth resolution. ~1 km x 10 km spatial resolution.
PMS	Polymer Mass Spectrometer	TOF MS with M /ΔM ~10,000 for masses up to 10,000 Da. From 600 km to upper atmospheric *in situ* analysis of gases and aerosol precursors.
SMS	Sub-Millimeter Spectrometer	Heterodyne spectrometer with scanning mirror. Direct winds from Doppler and temperature mapping from ~200-1000 km altitude; carbon dioxide and nitrile profiles.
TIRS	Thermal Infrared Spectrometer	Passively cooled Fourier spectrometer, 7–333 µm. Organic gas abundance, aerosol opacity and temperature mapping 30–500 km.
MAPP	Magnetometer	Tri-axial fluxgate sensors. Noise level ~11pT$_{rms.}$ Interaction of field with ionosphere: internal and induced field.
	Energetic Particle Spectrometer	TOF Analyzer w/ss detectors to measure magnetospheric particle fluxes, ~10 keV to >MeV with 150° x 15° FOV.
	Langmuir Probe	Swept voltage/current probe. *In situ* electron density and temperature, ion speed constraint, including during aerosampling.
	Plasma Spectrometer	Electrostatic analyzer with Linear electric field TOF MS. Measures ion and electron fluxes at ~5 eV to ~5 keV. M/ΔM~10.
RSA	Radio Science and Accelerometer	All components part of spacecraft telecom system. Lower stratosphere and troposphere T profile. Gravity field.

Montgolfière

Montgolfière Planning Payload (10 km altitude in equatorial region)	
BIS	Balloon Imaging Spectrometer (1–5.6 µm)
VISTA-B	Visual Imaging System for Titan Balloon
ASI/MET	Atmospheric Structure Instrument/ Meteorological Package
TEEP-B	Titan Electric Environment Package
TRS	Titan Radar Sounder (>150 MHz)
TMCA	Titan Montgolfière Chemical Analyzer (1–600 Da Mass Spectrometer)
MAG	Magnetometer
MRST	Radio Science using spacecraft / montgolfière telecom system

Lander

Lake Lander Planning Payload	
TLCA	Titan Lander Chemical Analyzer (GCMS)
TiPI	Titan Probe Imager + Lamp
ASI/MET-TEEP	Atmospheric Structure Instrument/ Meteorological Package + Titan Electric Environment Package
SPP	Surface Properties Package + Acoustic Sensor Package with Magnetometer
LRST	Radio Science using spacecraft/lander telecom system

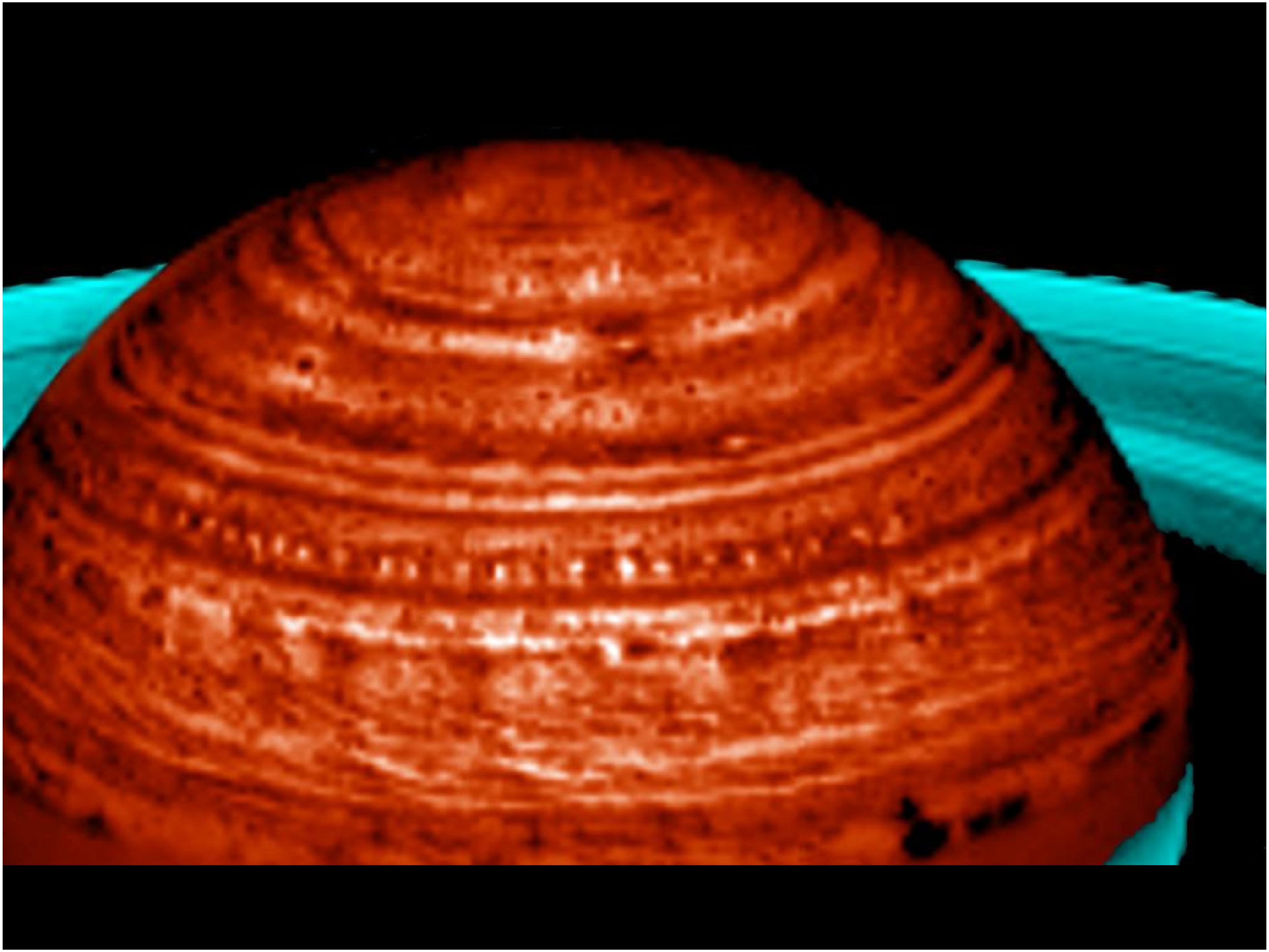

The Saturnian atmosphere
Cassini VIMS image

Saturn Atmospheric Science

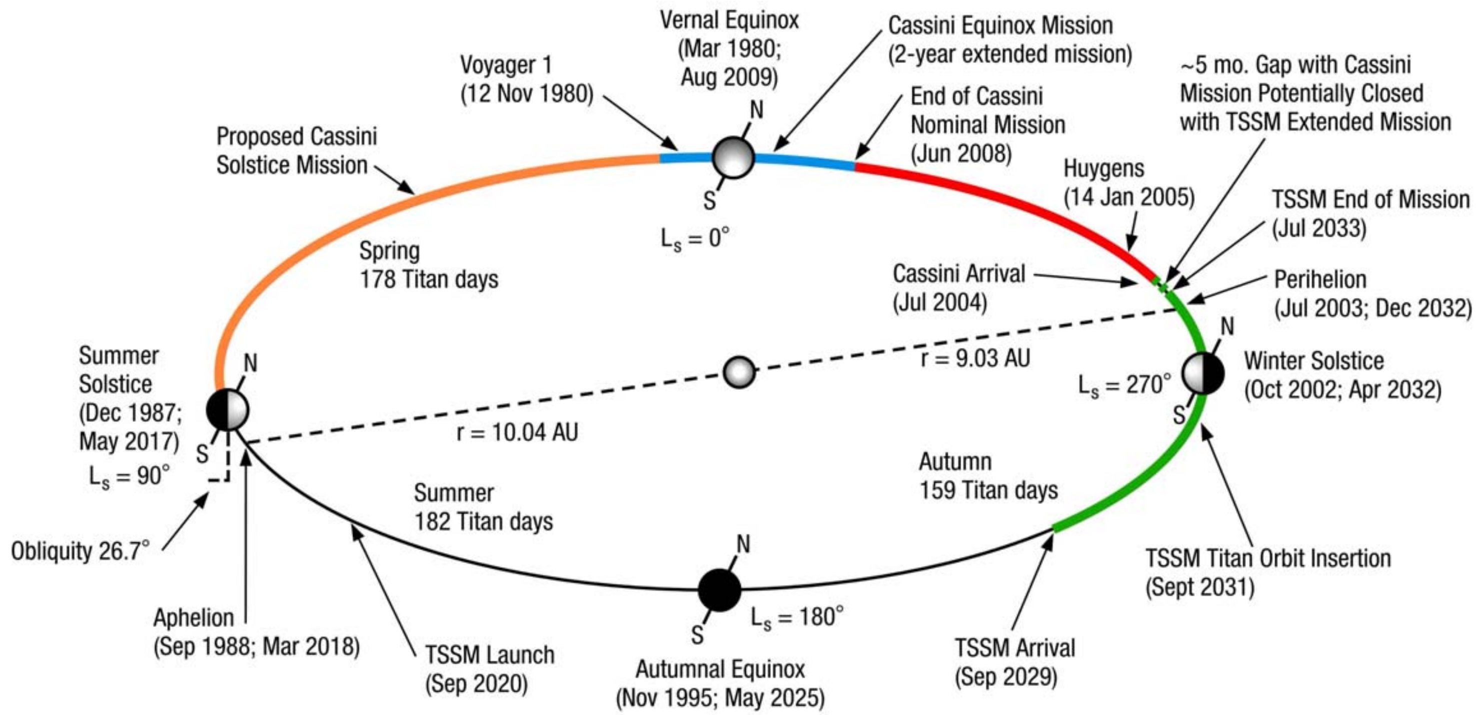
•Observations of Saturn by TSSM could provide new information on unusual features seen in the 2-3 bar level atmosphere at a season different from that observed by Cassini.

- •annular clouds (“donuts”) at temperate northern latitudes
- •string of pearls” of approximately 2-dozen regularly-spaced, westward-drifting cloud clearings extending over one quarter of Saturn’s circumference near 33 degrees N. latitude
- •the solar system’s largest and most powerful vortices at both poles
- •Unusual convective storm systems: bright clouds similar to some found on Jupiter and near-IR-dark clouds that reveal materials dredged up from deep within the atmosphere by thunderstorms.

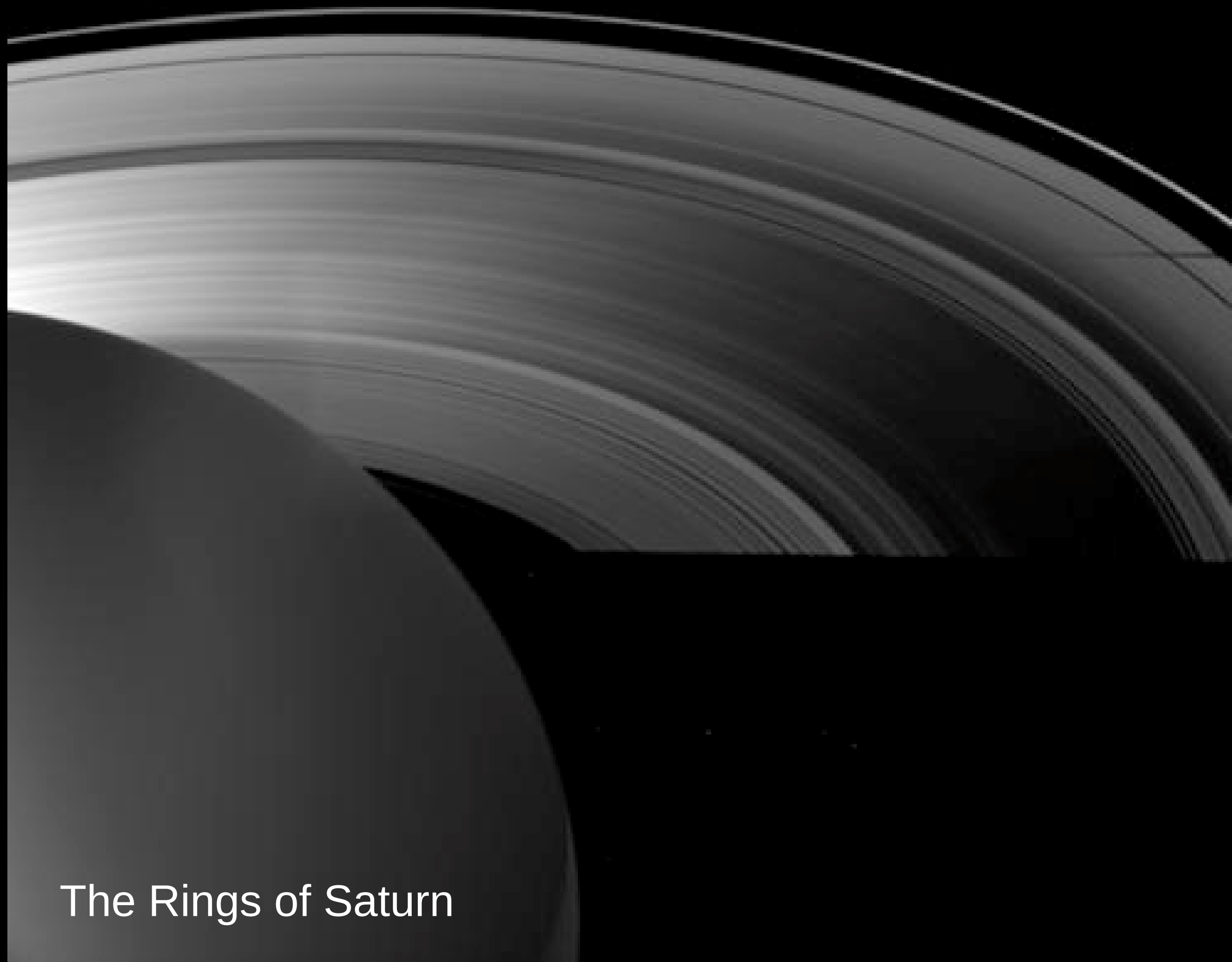
•Higher sensitivity near-IR spectrometer operating out to nearly 6 microns would provide better vertical and spatial resolution on storms systems.



TSSM seasonal coverage of the Saturn atmosphere meshes very well with that of Cassini assuming a launch in 2020.



Orbital motion of Titan and Saturn around the Sun during one Saturn year. L_s denotes the Kronocentric (Saturnicentric) orbital longitude of the Sun that characterizes the season.



The Rings of Saturn

Ring Science

•TSSM's Saturn orbit insertion trajectory is on the lit side of the rings and is 3 to 4 times closer to the B and C rings than Cassini's SOI trajectory.

•For the outermost A ring, TSSM is only 1,000 km away, about 7 times closer than Cassini, providing near-IR resolution better than 20 meters.

•

•The closer flyby distance, combined with the lit-side viewing of the rings, opens up the possibility for direct imaging of the A and B ring gravitational wakes.

•The closer flyby distance will also enhance in situ measurements of the ring atmosphere.


Properties of the Saturnian moons

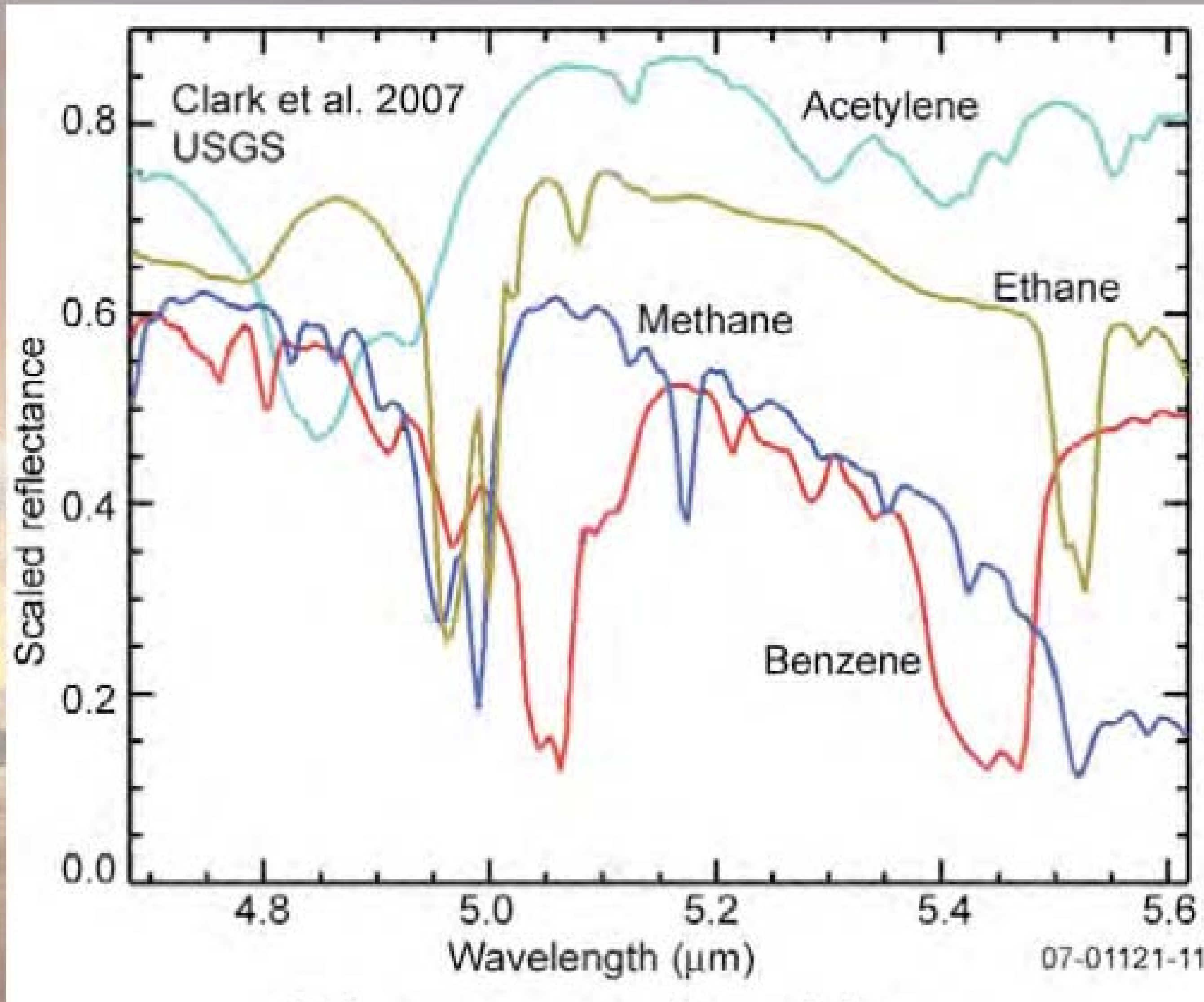
Satellite Science

- Ground-penetrating radar instrument provides structural information to a depth of many km (up to 50 km at Enceladus).

- Near-IR studies out beyond 5 microns (to between 5.6-6 microns) provides better diagnostics of organics on the surfaces of the satellites.

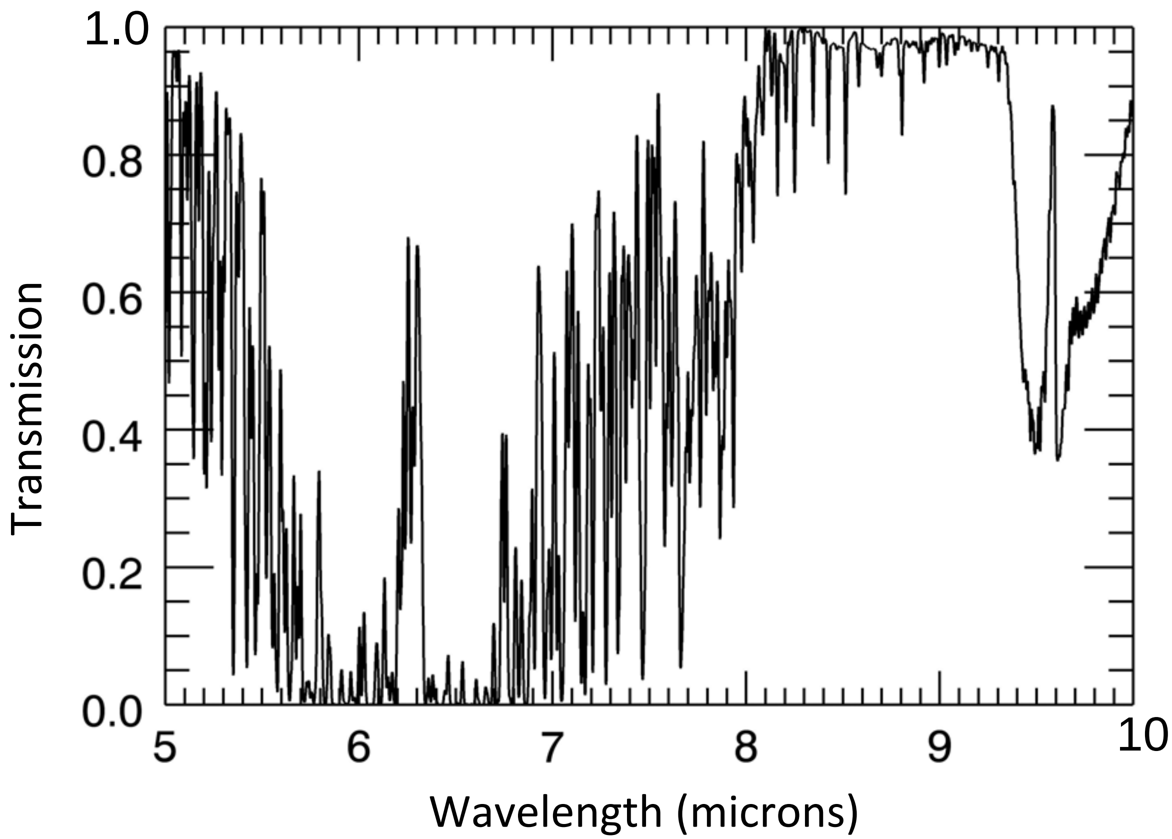
- More sensitive and higher resolution thermal infrared mapping will permit better temperature diagnostics of the plume sources on Enceladus, and searches for more subtle activity on other icy satellites.

Satellite Science beyond 5 microns



Reflectance spectra of organic ices

The 5-6 micron region is difficult from the ground



Atmospheric transmission at Gemini North site, 1 PMM water, airmass =1

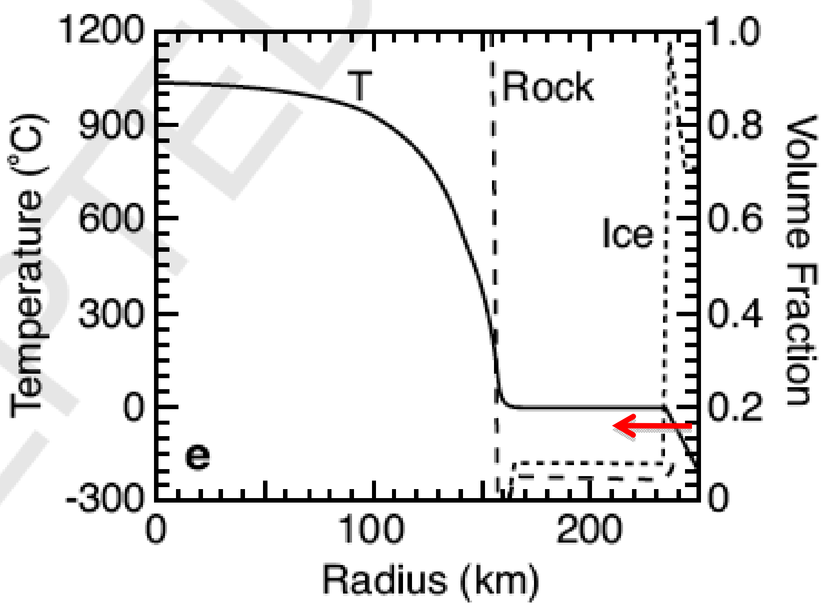
Magnetospheric Science

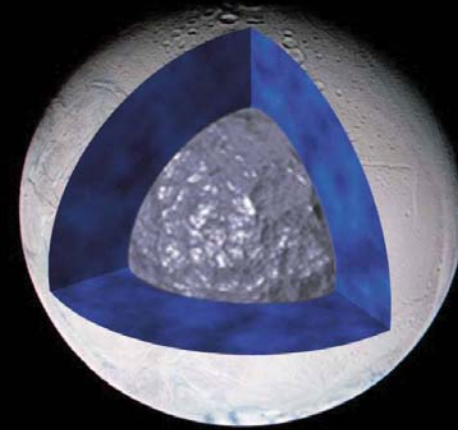
- Exploration of various phenomena including magnetospheric plasma convection patterns, various roles played by reconnection, etc.

- Exploration of the Saturnian magnetosphere at a different phase of the solar cycle.

- Investigation of the transport mechanisms of O and possibly OH from Enceladus to Titan.

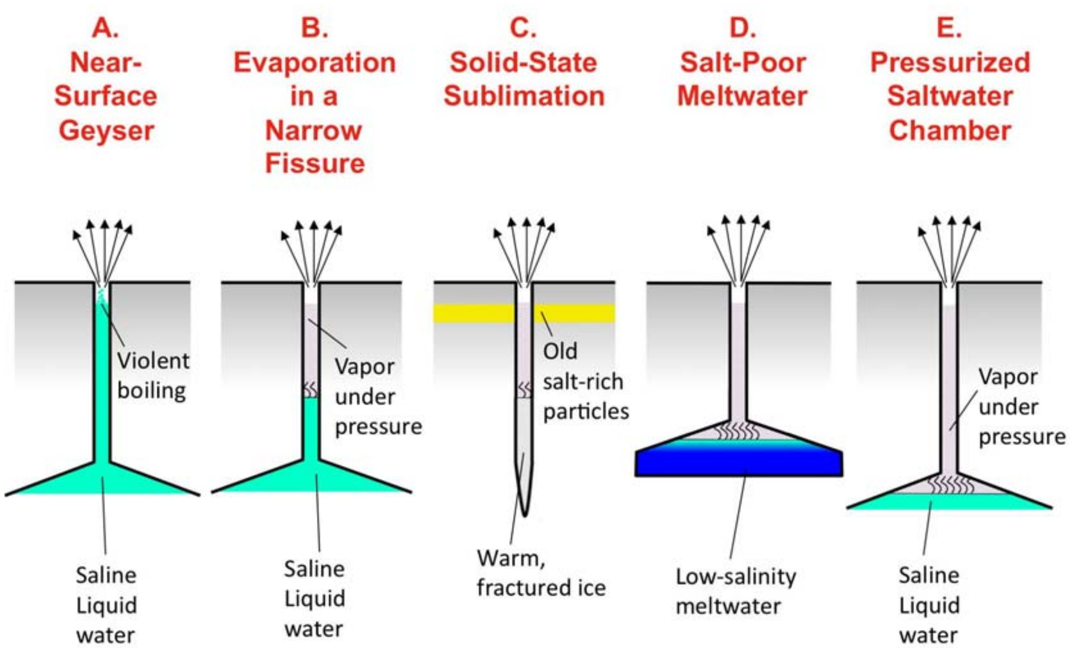
Ground-penetrating radar on Enceladus





Schubert et al 2007. Superposed arrow indicates maximum radar penetration depth

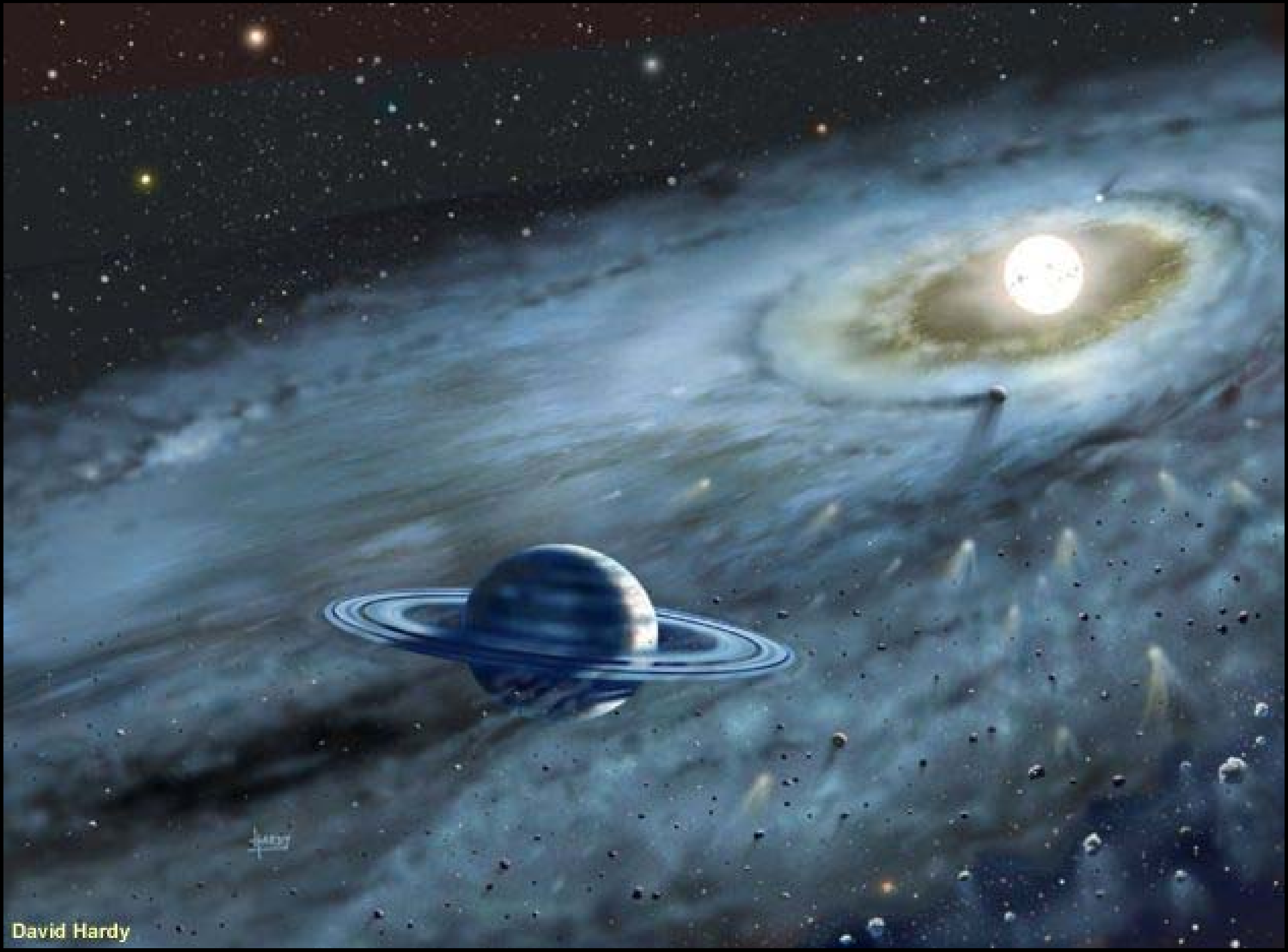
Plume Vent Models (SWRI)



Plume reservoirs should be accessible via the ground-penetrating radar.

(Verification using detailed models to be done).

Origin of the Saturnian system



Mousis et al, 2009

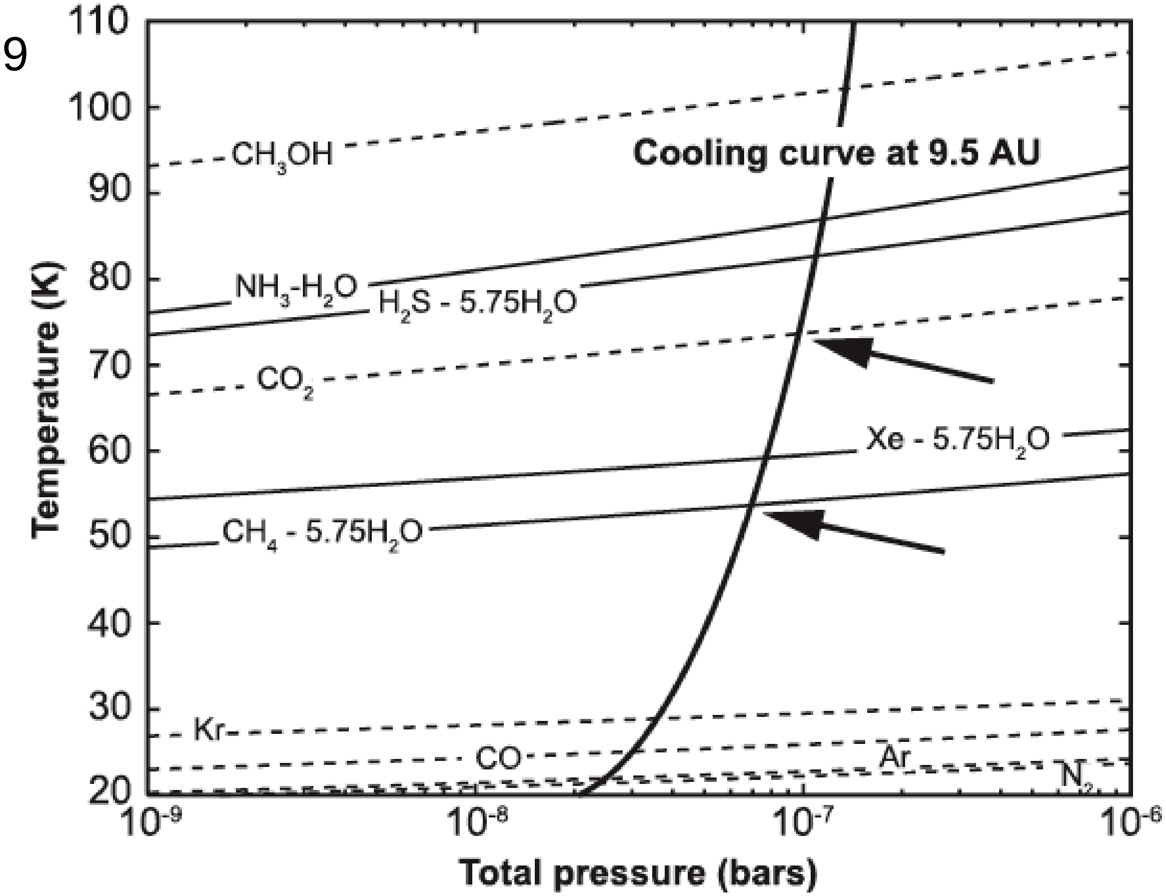
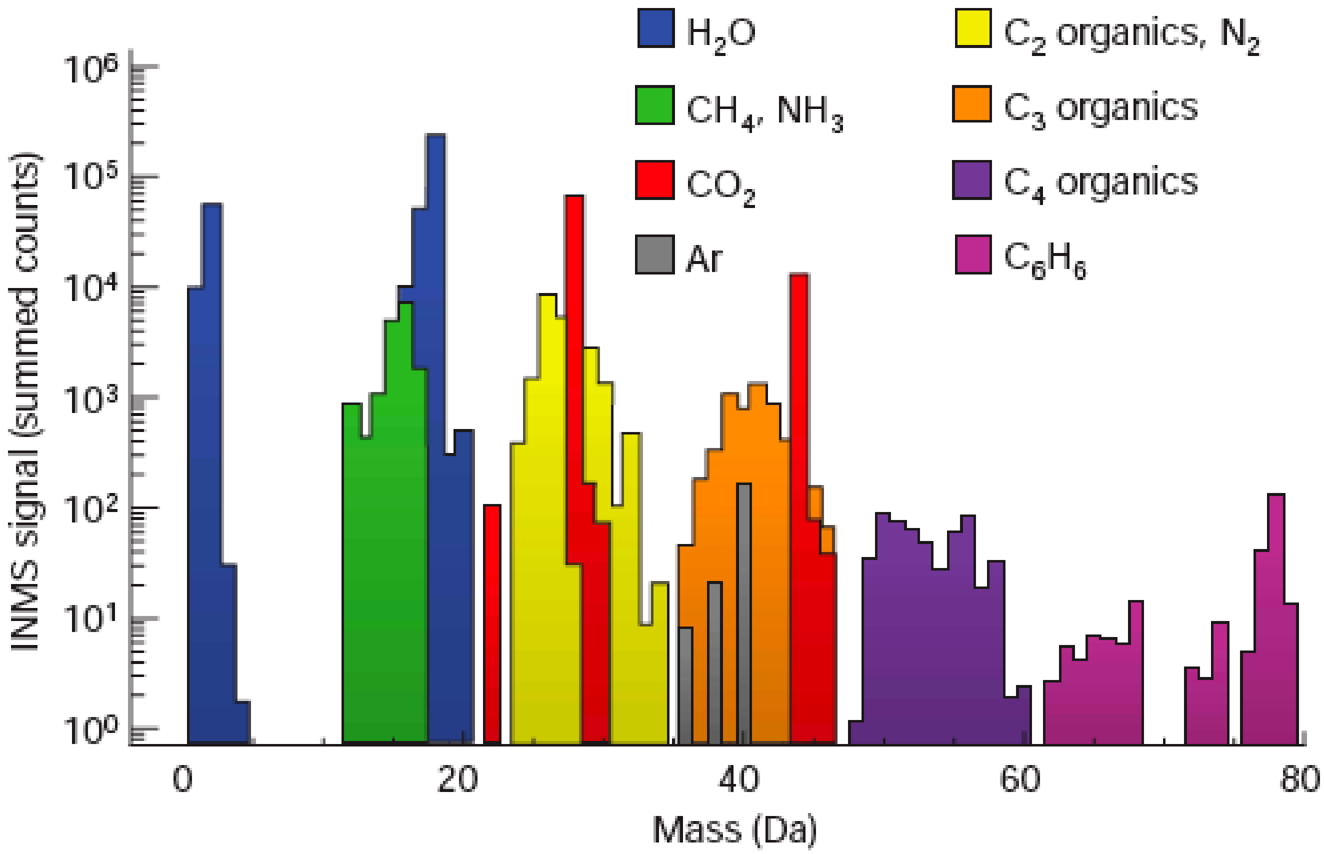
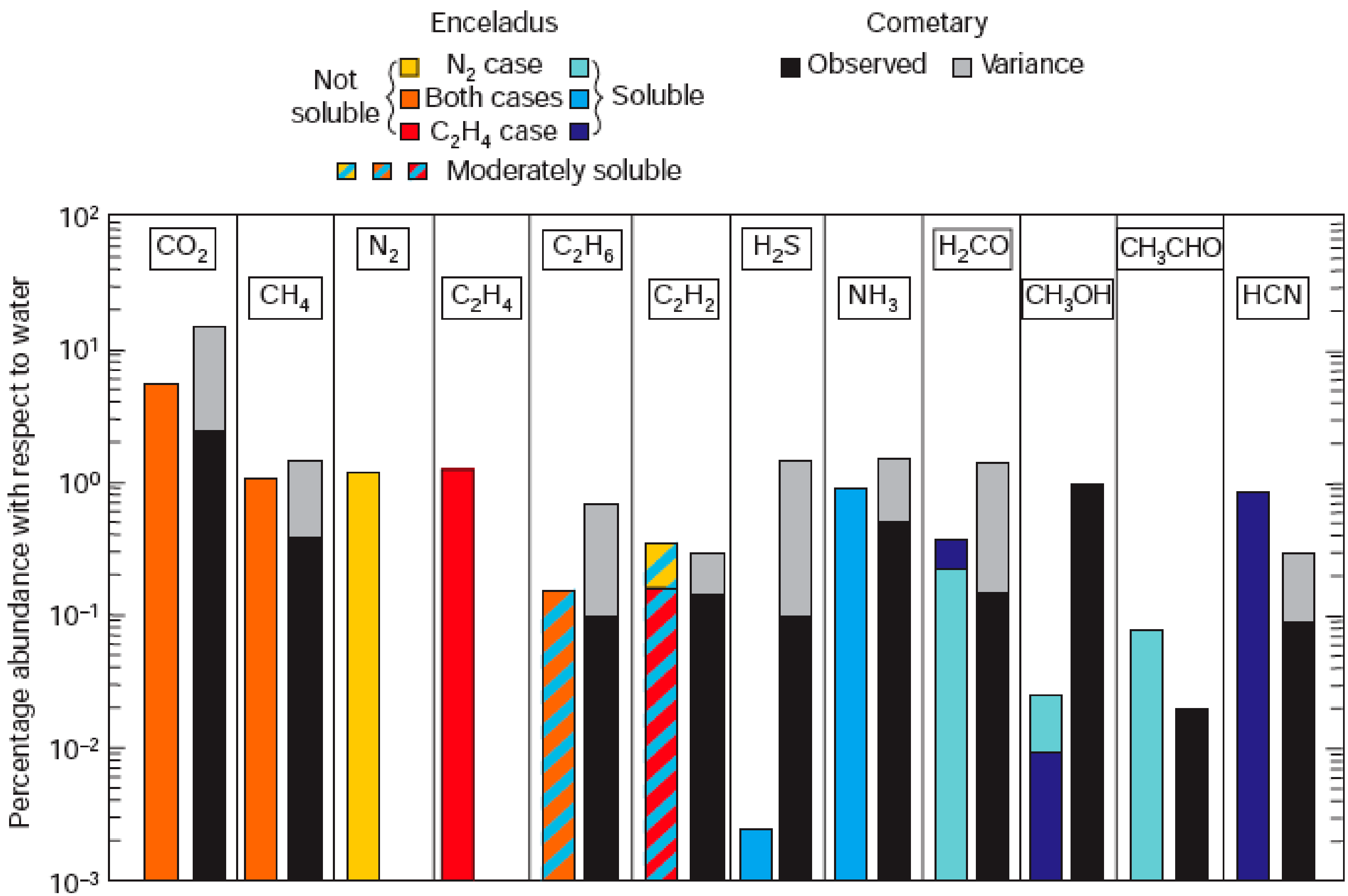


Figure 1. Formation sequence of the different ices in Saturn's feeding zone. Equilibrium curves of ammonia monohydrate, clathrates (solid lines), and pure condensates (dotted lines), and cooling curve of the solar nebula at the heliocentric distance of 9.5 AU, assuming a clathration efficiency of 25%. The bottom and top arrows designate, respectively, the maximum temperatures at which the building blocks of Enceladus can be heated during their migration within the Saturn's subnebula if methane observed in the plumes is primordial or if it is produced in the satellite.



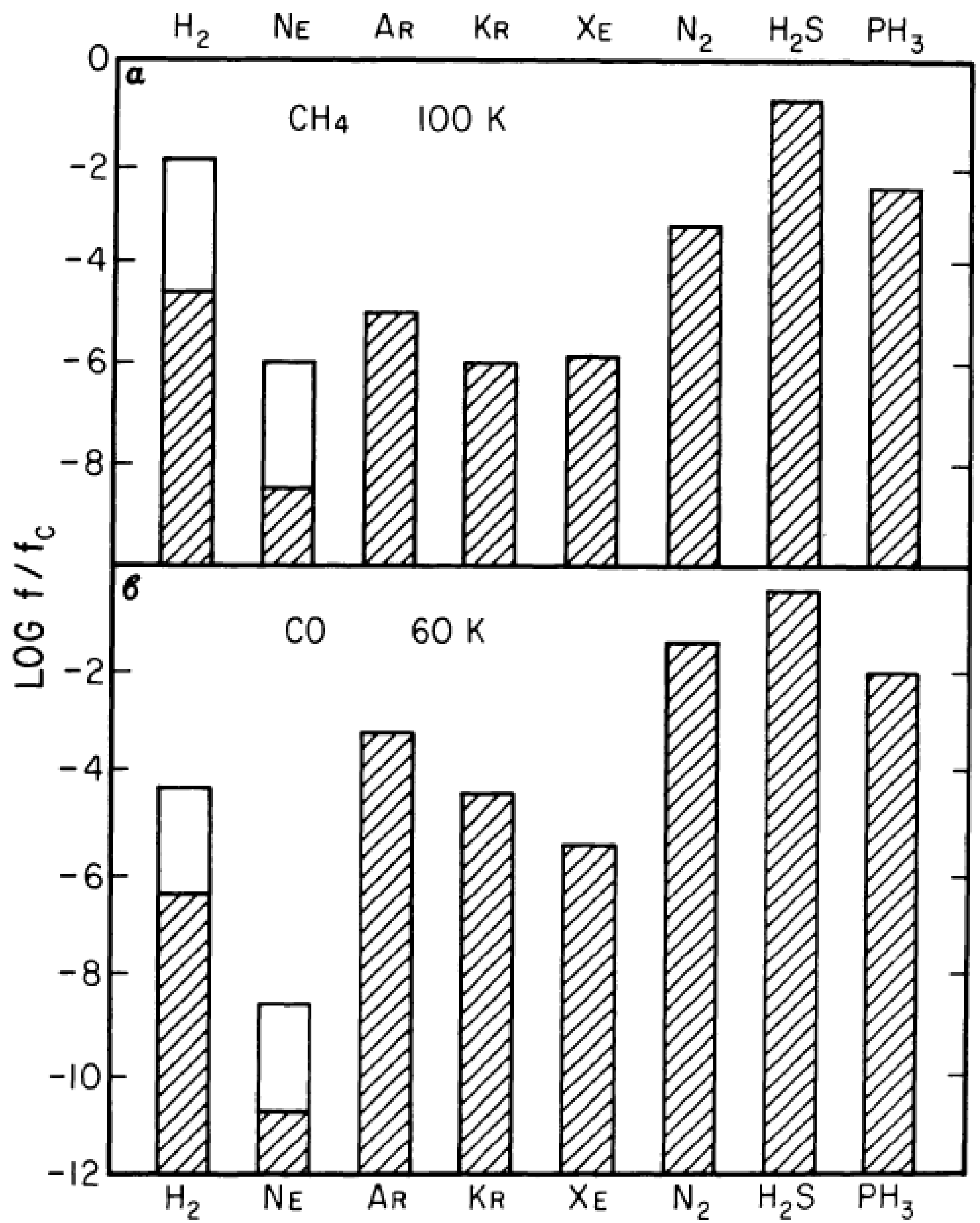
Waite et al., 2009



Waite et al., 2009

Use noble gas ratios to diagnose oxidation state of the material which delivered volatiles to Enceladus.
This requires a more advanced mass spectrometer than is carried by Cassini.

Lunine and Stevenson, 1985



Conclusion

Although TSSM's primary mission is the detailed exploration of Titan, the notional payload for the Orbiter provides new types of observations and capabilities that will enable the mission to address first-order science questions about the rest of the Saturn system.