# ESA's Cosmic Vision Programme: Outer Planet Mission Studies

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**Europa Lander workshop**
**IKI, Moscow, 9-13 February 2009**

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# Outer Planet On-Going Mission

- US-Europe (NASA-ESA-ASI) Cassini-Huygens
  - Prime mission completed (-Jul ‘08)
  - Cassini Equinox Mission (- Sep ‘10)
  - 2nd Extension (-16/17 ?) under study
    - Tour selected in late January
    - Senior Review at NASA/HQ this week

# Missions on their way

- ESA's Rosetta: Comet RV in 2014
  - Philae lander
  - Orbiter
- NASA's New Horizons: Pluto (2014); Kuiper Belt and beyond
- NASA's Dawn:
  - Vesta (Oct '11- May '12)
  - Ceres (Aug '15- Jan '16)

# Missions in development

- NASA's JUNO (Jupiter Polar Orbiter)
  - Launch in Aug. 2011

# Key Earth-based Observatories

- Hubble Space Telescope
- Optical Telescopes (Keck, VLT, Gemini,…)
- Herschel (2009-
- JSWT (2013-
- ALMA (2011?-
- SKA (2020-
  - Operational Capability for OPMs ?

# Outer Planet Mission Studies

- NASA and ESA jointly studied two Outer Planet Missions (Merging of three NASA Flagship concepts and two ESA Cosmic Vision proposals)
  - Europa Jupiter System mission (EJSM)
  - Titan Saturn System Mission (TSSM)
- 10-month intense effort in 2008
- Assessment reports completed on 15 Nov.
- Parallel evaluation in NASA and ESA in Nov-Dec
- Joint down-selection activities in Jan ‘09
- Decision expected to be announced on 12 ? Feb 09
- Programmatic launch date: 2020 (‘18-’22 was explored)

# Study Organization

- Studies conducted under JPL/APL and ESTEC leadership with JSDT support
- International JSDT's
  - EJSM JSDT membership: US, EU and JPN Scientists; RU scientists associated
  - TSSM JSDT membership: US and EU Scientists

# Joint Summary Reports

QuickTime™ and a
decompressor
are needed to see this picture.

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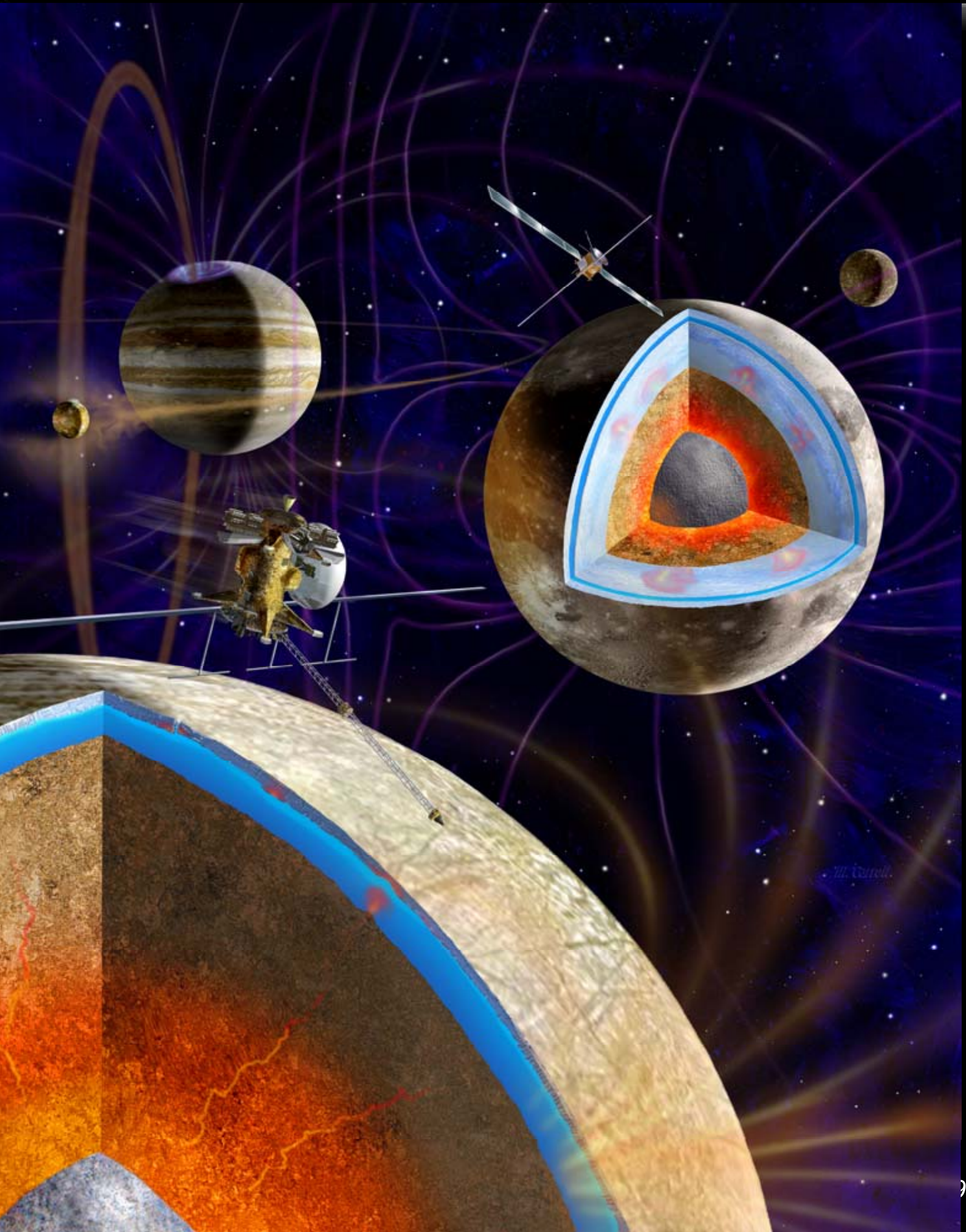
# EJSM Science Objectives (1)

- Characterize and determine the extent of sub-surface oceans and their relation to deeper interior
- Characterize the ice shells and any subsurface water, including the heterogenity of the ice, and the nature of surface-ice-ocean exchange
- Characterize the deep internal structure, differentiation history, and (for Ganymede) the intrinsic magnetic field

# EJSM Science Objectives (2)

- Compare the exospheres, plasma environments, and magnetospheric interactions
- Determine global surface composition and chemistry, especially as related to habitability
- Understand the formation of subsurface features, including sites of recent or current activity, and identify and characterize candidate sites for future *in situ* exploration



# Europa & Ganymede

*potentially habitable worlds*
*in the Jupiter system*

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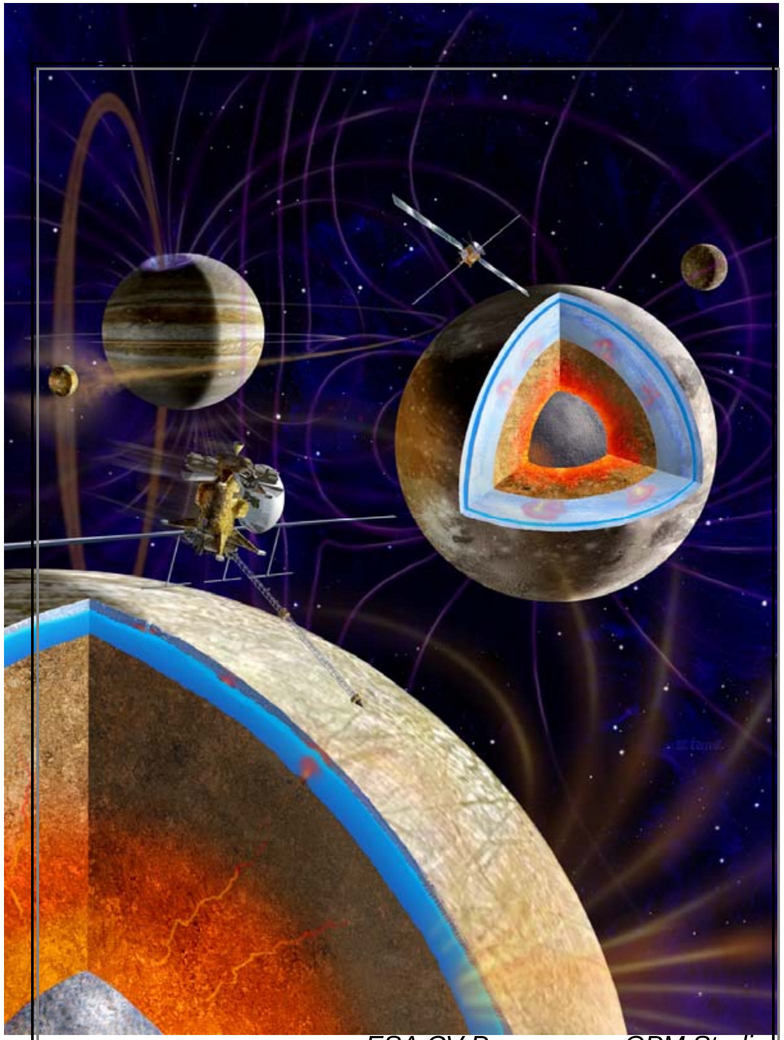
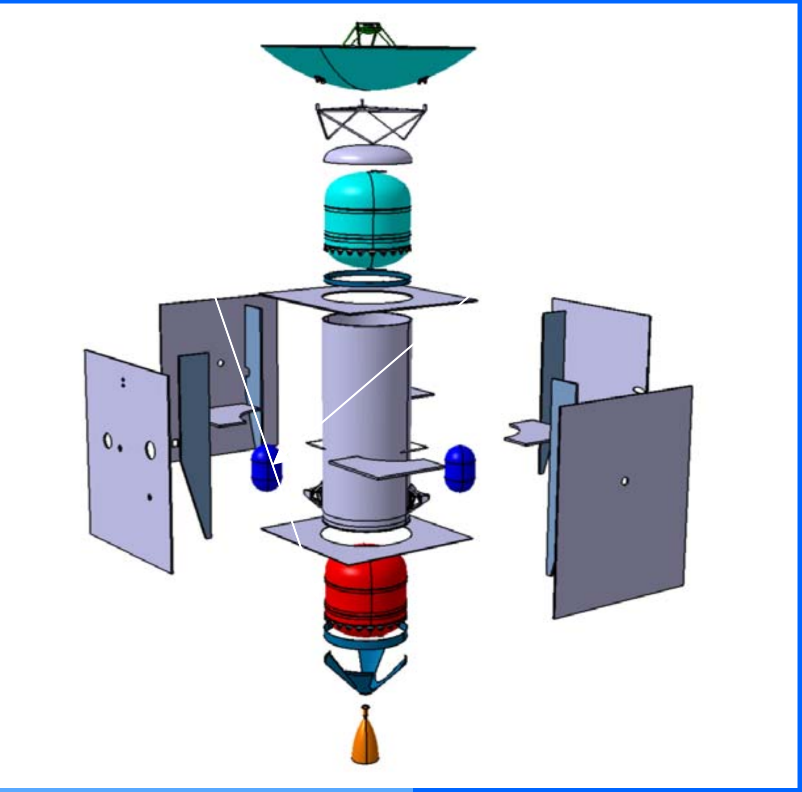
# EUROPA AND JUPITER SYSTEM MISSION



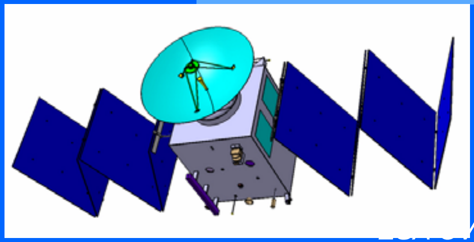
- Reference Mission
  - NASA Jupiter Europa Orbiter
  - ESA Jupiter Ganymede Orbiter
- Potential addition
  - JAXA Jupiter Magnetospheric orbiter
  - Follow-up RSA Europa Lander
  - (UK penetrator ?)

# JGO – Configuration/Structure



*JGO: exploded view*

*JGO: solar panels and HGA*



**Key figures**

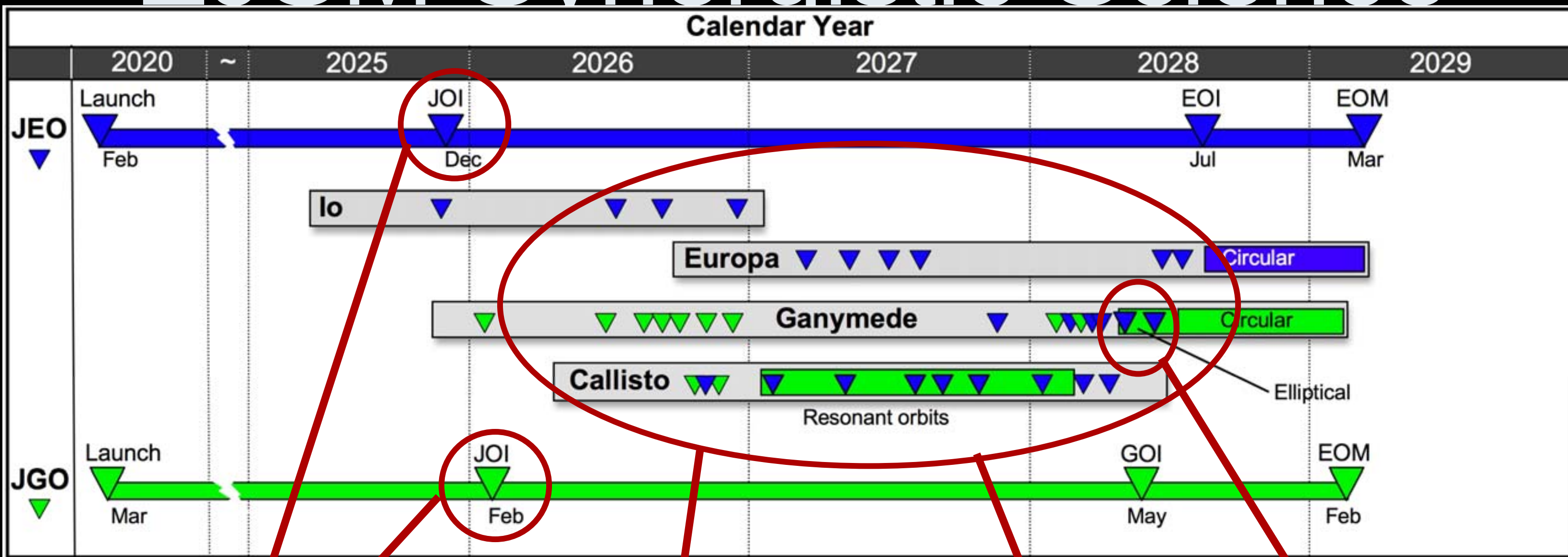
- S/C total dry mass: 1275 kg (payload: 87 kg*, shielding: 80 kg)
- Launch mass: 3493 kg (capacity 4362 kg)
- Delta-V: 2990 m/s
- Propellant: 2027 kg

**Power**

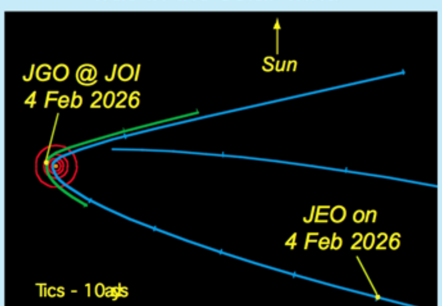
- EOL: **539W** (410 W max. power in Jupiter orbit mode + PCDU inefficiencies + margins)
- Solar cell array: GaAs LILT; 28% efficiency BOL; ~20% degradation in 9 years; Solar arrays: **51m²**, ~253 kg, 4 panels per wing
- Batteries: Sizing case: eclipse mode (270 min); EOL requirement **1534 Wh** → Li-Ion battery of 26 kg

*Note: Masses including margins*
** Instruments 73kg w/o margin*

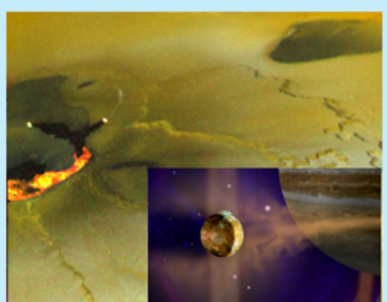
# EJSM Synergistic Science



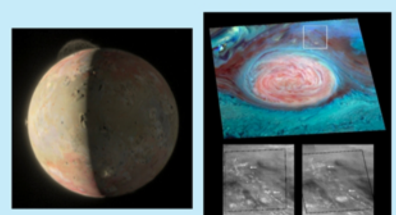

**Jupiter Magnetosphere Studies**



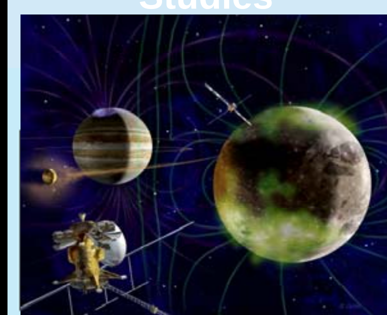

**Io Volcanism & Io Torus Dynamics**

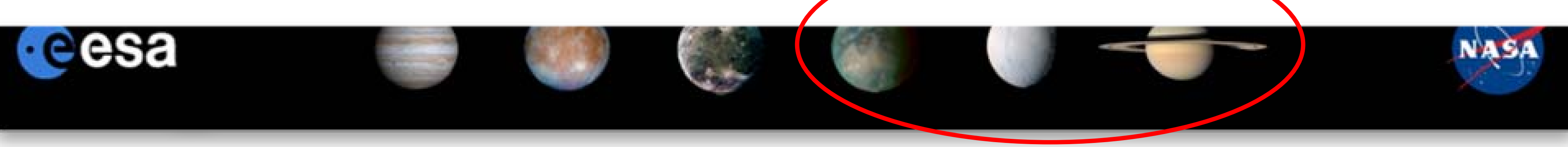


**Satellite/Jupiter Monitoring**



**Ganymede Magnetosphere Studies**



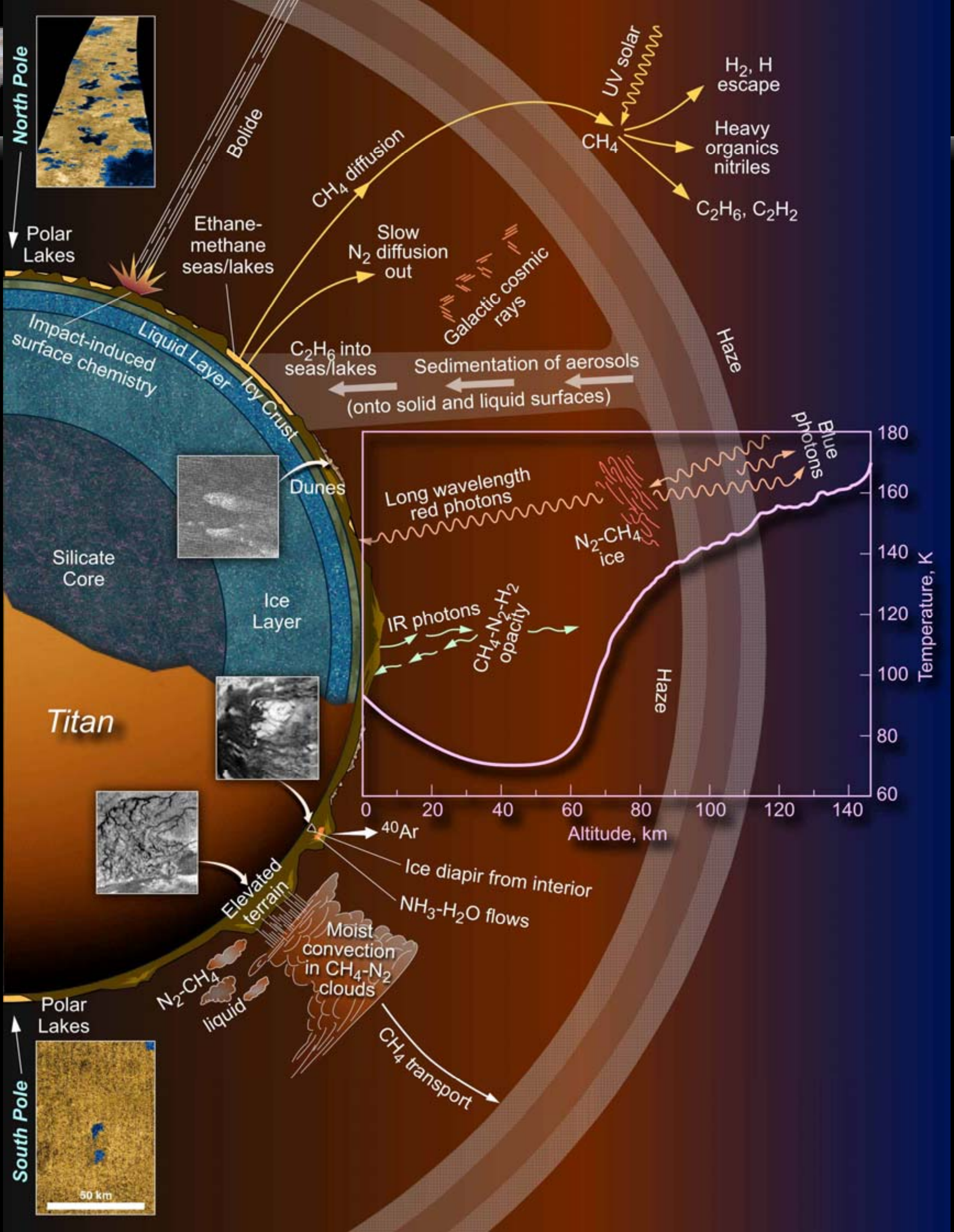


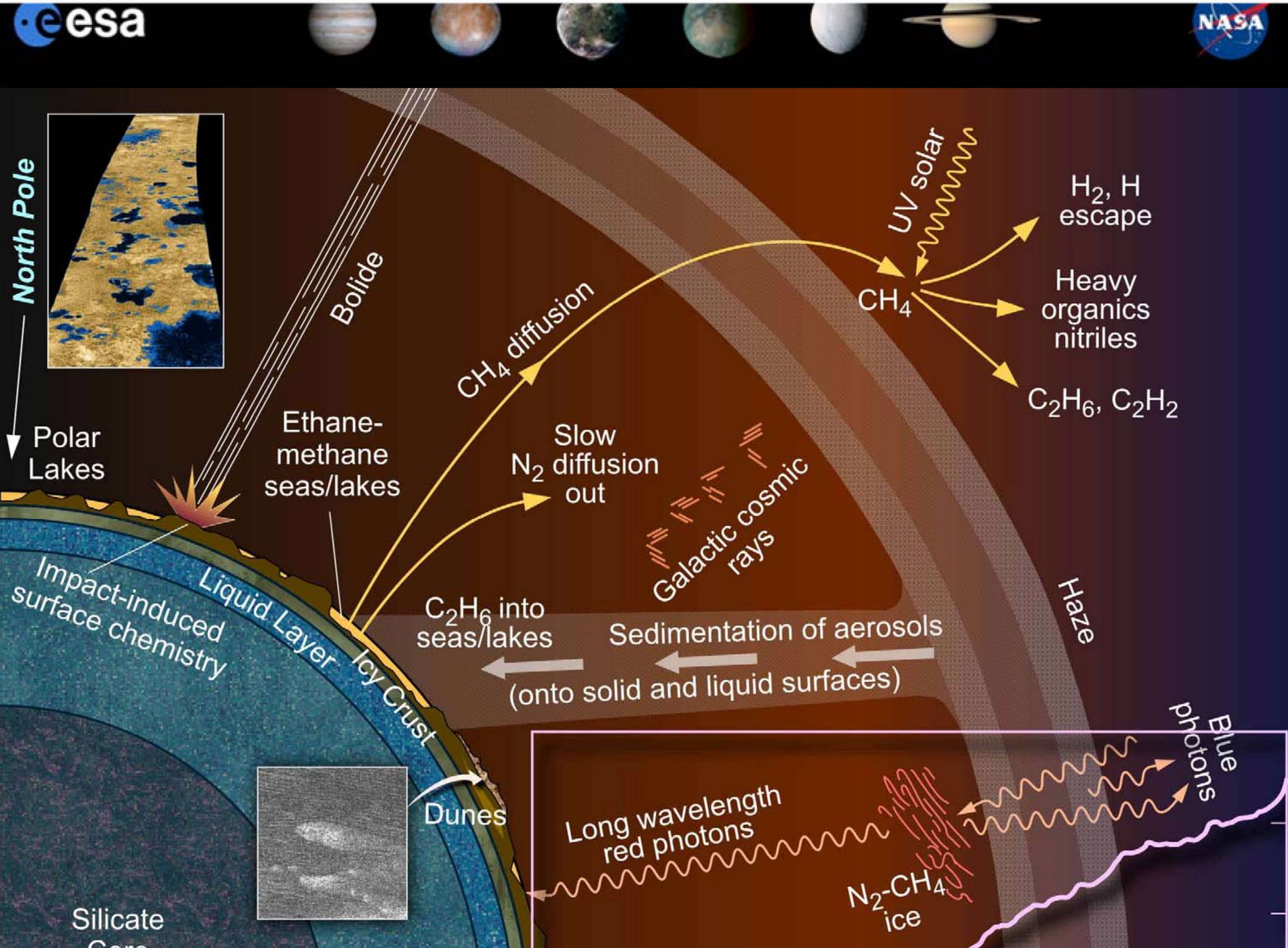

# TSSM Science Goals

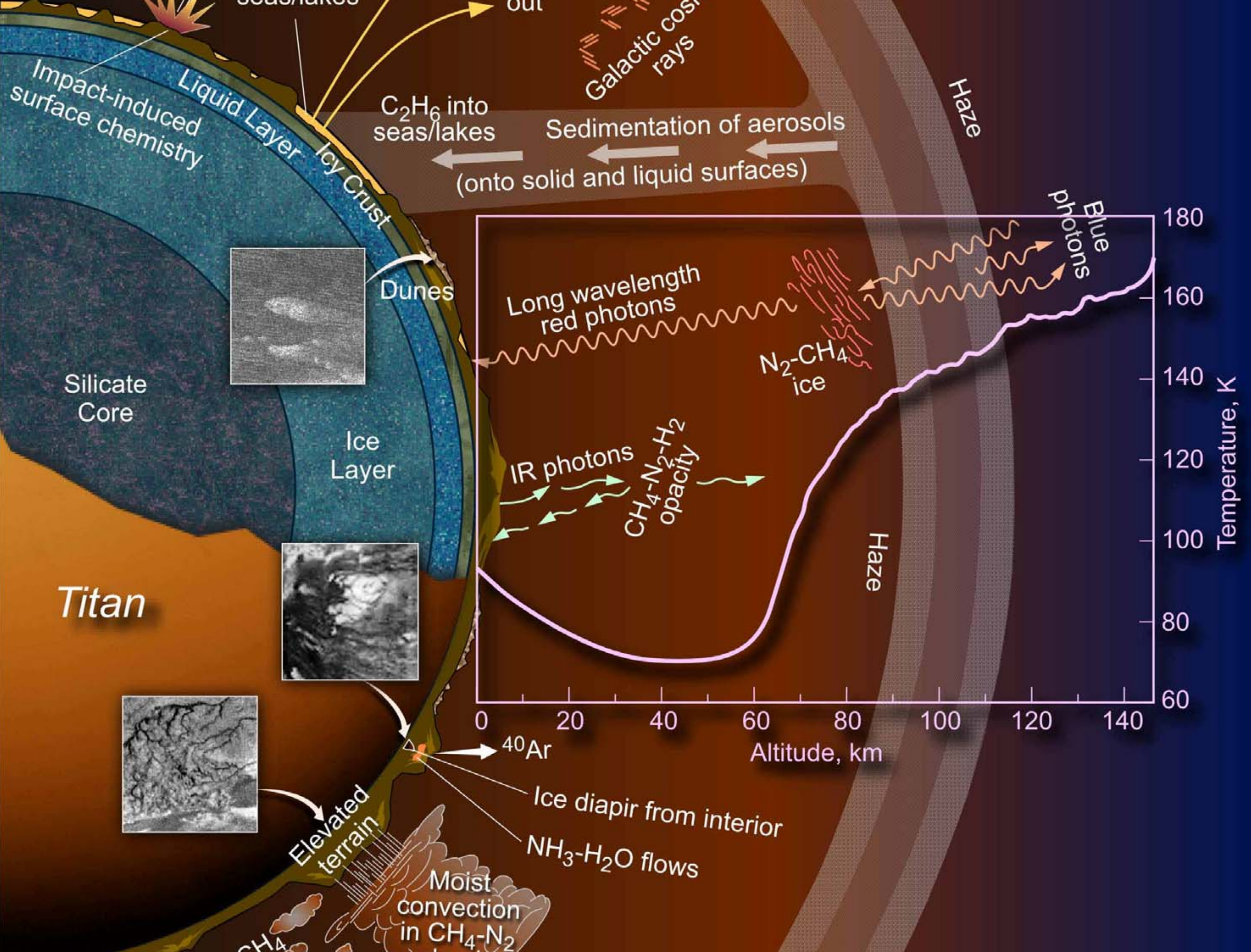
- Goal A: **How does Titan function as a system; to what extent are there similarities and differences with Earth and other solar system bodies?**
- Goal B: **To what level of complexity has prebiotic chemistry evolved in the Titan system?**

  Goal C: **What could be learned from Enceladus and Saturn's magnetosphere about the origin and evolution of Titan?**

Titan as an object is of keen
interest for virtually all areas of planetary science




esa
NASA
North Pole
Polar Lakes
Bolide
Ethane-methane seas/lakes
$CH_4$ diffusion
UV solar
$H_2$, H escape
$CH_4$
Heavy organics nitriles
$C_2H_6$, $C_2H_2$
Slow $N_2$ diffusion out
Galactic cosmic rays
Haze
Impact-induced surface chemistry
Liquid Layer
Icy Crust
$C_2H_6$ into seas/lakes
Sedimentation of aerosols
(onto solid and liquid surfaces)
Blue photons
Dunes
Long wavelength red photons
$N_2$-$CH_4$ ice
Silicate Core



out
Galactic
rays
Haze
Impact-induced surface chemistry
Liquid Layer
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$C_2H_6$ into seas/lakes
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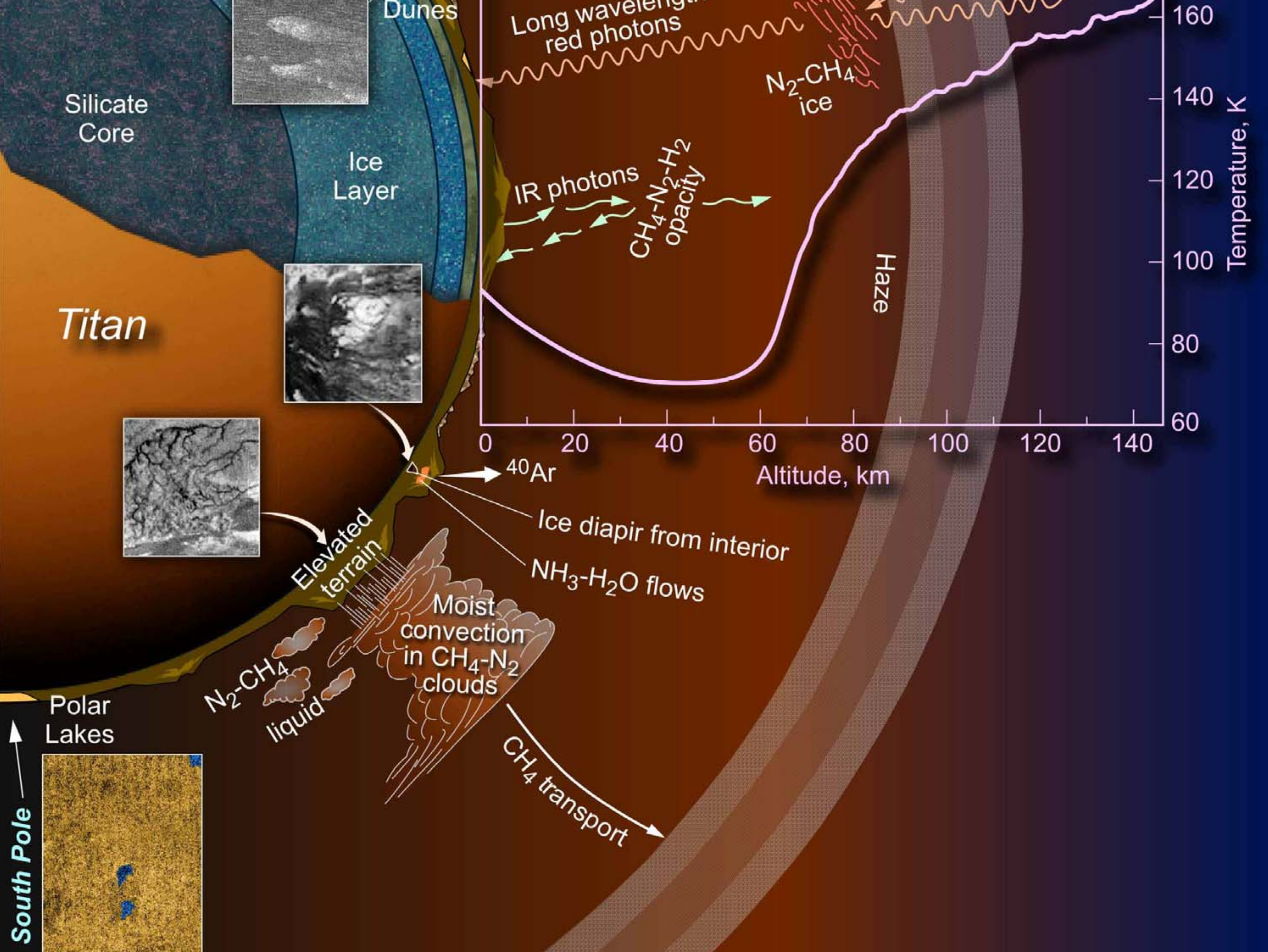
(onto solid and liquid surfaces)
Blue photons
Dunes
Long wavelength red photons
$N_2$-$CH_4$ ice
Silicate Core
Ice Layer
IR photons
$CH_4$-$N_2$-$H_2$ opacity
Haze
Titan
Temperature, K
180
160
140
120
100
80
60
0
20
40
60
80
100
120
140
Altitude, km
$^{40}Ar$
Ice diapir from interior
$NH_3$-$H_2O$ flows
Elevated terrain
Moist convection in $CH_4$-$N_2$



Dunes
Long wavelength red photons
N2-CH4 ice
Silicate Core
Ice Layer
IR photons
CH4-N2-H2 opacity
Haze
Titan
160
140
120
100
80
60
Temperature, K
0
20
40
60
80
100
120
140
Altitude, km
40Ar
Ice diapir from interior
NH3-H2O flows
Elevated terrain
Moist convection in CH4-N2 clouds
N2-CH4 liquid
CH4 transport
Polar Lakes
South Pole

# TM Road from Goals to Instruments

*Table 2.3-1. Science traceability matrix: orbiter, cont'd.*

| MISSION GOALS | SCIENCE OBJECTIVES | SCIENCE INVESTIGATIONS | REQUIRED MEASUREMENTS/ DETERMINATIONS | PLANNING MEASUREMENT APPROACH | PLAN INSTR. | DATA PRODUCTS | MISSION REQUIREMENTS |
|---|---|---|---|---|---|---|---|
| **Goal A**: How does Titan function as a system; to what extent are there similarities and differences with Earth and other solar system bodies? | **O8**: Determine the state of internal differentiation, whether Titan has a metal core and an intrinsic magnetic field, and constrain the crustal expression of thermal evolution of Titan's interior. | **I1**: Map interior structure of Titan. | **M1**: Global gravity field to at least degree six. Doppler accurate to 50 µm/s with 60 s integration periods. | **A1**: Relative velocity between the spacecraft and ground station determined from Doppler tracking with an accuracy up to 50 µm/s with 60 s integration periods. (Ka-band link stability $\sim 10^{-15}$ after all calibrations including accelerometer for non-gravitational forces). | RSA | Coefficients of spherical harmonic expansion of gravity field for further analysis and interpretation in terms of internal structure. The static degree-two gravity field will lead to constraints on the global density structure of the interior. Time variations of the degree-two field will lead to investigating the tidal response of the satellite and constraining its viscoelastic structure and crustal structure. | Prefer mapping phase orbit height of 1500 km |
| | | **I2**: Determine whether Titan has a dynamo. | **M1**: Detect or set limits on the intrinsic magnetic field of Titan. Measure vector magnetic field perturbations of order a few nT (with a resolution of order 0.04 nT).Thermal and magnetospheric plasma measurements will provide supportive role with regard to external currents from magnetospheric measurements. | **A1**: Vector Magnetometry (part of a combined instrument). | MAPP | Magnetic field vector at 1 s resolution from both sensors Ion and electron thermal and suprathermal velocity moments of density, temperature and magnetosphere-ionosphere winds. | Continuous measurements, globally distributed at varying altitudes. Knowledge of orbiter attitude and location, and a rigid magnetometer boom. Consideration of magnetic cleanliness requirements vs. boom length. |
| **Goal B**: To what level of complexity has prebiotic chemistry evolved in the Titan system? | **O1**: Determine the processes leading to formation of complex organics in the Titan atmosphere and their deposition on the surface. | **I1**: Assay the speciation and abundances of atmospheric trace molecular constituents. | **M1**: Abundances of monomer and polymer organic species and inorganic species with a detectability of $<1$ ppb and an accuracy of better than 3% over an altitude range from 30–1500 km. | **A1**: Passive Thermal-infrared Fourier Transform spectrometry, in the region from 30–1400 wavenumbers (7–333 µm); resolution 0.1–3.0 wavenumber. | TIRS | Thermal and compositional maps and profiles of the stratosphere (50–450 km) with altitude and latitude | Limb and nadir viewing on polar orbit, rotation in |
| | | | | **A2**: Submillimeter sounding at 540–640 GHz with resolution 300 khz and 10% precision in retrieved abundances. | SMS | Alt/lat maps of selected organics | Limb viewing from polar orbit, in-track and off-track orientation |

# Montgolfiere Science Traceability Matrix flows from the three goals to measurements

| MISSION GOALS | SCIENCE OBJECTIVES | SCIENCE INVESTIGATIONS | REQUIRED MEASUREMENTS/ DETERMINATION | PLANNING MEASUREMENT APPROACH | PLAN. INSTR. | DATA PRODUCTS | MISSION REQUIREMENTS |
|---|---|---|---|---|---|---|---|
| | | | **M2:** Global electric circuit and fair-weather electric field in the range from 0–10 kHz. With a height resolution of 1 km | | | | |
| | | | **M3:** Extra low and low frequency (ELF-VLF) magnetic components of the atmospheric | | | | |
| | | | | optical sensors | B | spectra | |
| | | | | **A1:** Relaxation probe to measure the conductivity of all charged species | TEEP-B | Time series of conductivity (all charged species) | Time series of conductivity (all charged species) |
| | | | | **A2:** Mutual impedance probe which measures the conductivity of electronics only | TEEP-B | Amplitude and phase of electric signal | Amplitude and phase of electric signal |
| | | | | **A1:** Use the infrared images at different incidence angles to | BIS | Infrared maps of the surface between 1 and 5.6 μm with a spectral sampling of 10.5 | Adapt the observation strategy to the motion of the montgolfière. Coordination with VISTA-B for |

| SCIENCE OBJECTIVES | SCIENCE INVESTIGATIONS | REQUIRED MEASUREMENTS/ DETERMINATION | PLANNING MEASUREMENT APPROACH | PLAN. INSTR. | DATA PRODUCTS | MISSION REQUIREMENTS |
|---|---|---|---|---|---|---|
| **O5:** Characterize the amount of liquid on the Titan surface today. | **I3:** Determine surface composition that might reveal the presence of liquids. | **M1:** Optical maps in the methane windows at 2.5 m resolution | **A1:** Use the infrared images at different incidence angles to determine the nature of the surface (liquid or solid) | BIS | Infrared maps of the surface between 1 and 5.6 μm with a spectral sampling of 10.5 nm. | Adapt the observation strategy to the motion of the montgolfière. Coordination with VISTA-B for context is required. |
| | | **M2:** Precipitation rate, solid or liquid nature of precipitation | **A1:** *In situ* monitoring of T and P conditions with reference to the altitude level | ASI/ MET | T and P time series | 1 km and 5° attitude knowledge of montgolfière |
| | | | **A3:** *In situ* observations at all wavelengths. | VISTA-B | 1360 x1024 multispectral images 48°FOV | Precise location of montgolfière to 1 km and 5° attitude knowledge of montgolfière |


| SCIENCE OBJECTIVES | SCIENCE INVESTIGATIONS |
|---|---|
| **O5:** Characterize the amount of liquid on the Titan surface today. | **I3:** Determine surface composition that might reveal the presence of liquids. |

| REQUIRED MEASUREMENTS/ DETERMINATION | PLANNING MEASUREMENT APPROACH | PLAN. INSTR. | DATA PRODUCTS | MISSION REQUIREMENTS |
|---|---|---|---|---|
| **M1:** Optical maps in the methane windows at 2.5 m resolution | **A1:** Use the infrared images at different incidence angles to determine the nature of the surface (liquid or solid) | BIS | Infrared maps of the surface between 1 and 5.6 μm with a spectral sampling of 10.5 nm. | Adapt the observation strategy to the motion of the montgolfière. Coordination with VISTA-B for context is required. |
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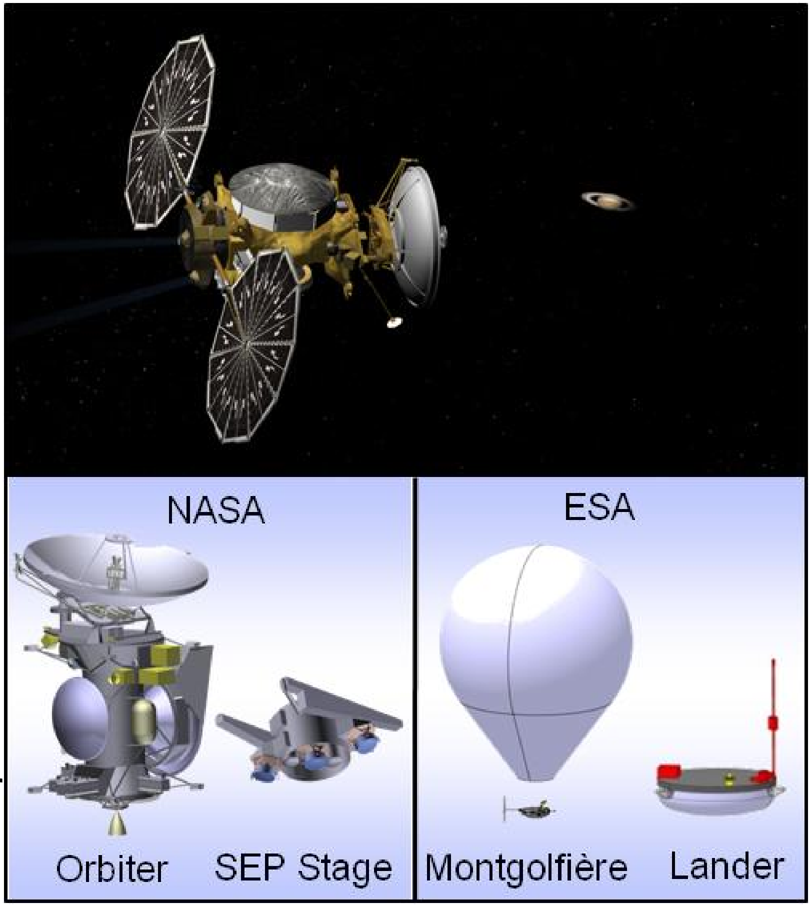
QuickTime™ and a
decompressor
are needed to see this picture.

# TSSM Baseline Overview

- NASA Orbiter with ESA in situ elements
  - Orbiter – ASRG power (also MMRTG compatible
  - Solar Electric Propulsion (SEP)
  - Lake Lander – battery powered
  - Montgolfière Balloon – MMRTG powered
  - NASA provided Launch Vehicle and RPS
- Mission Design
  - 2020 Gravity Assist SEP trajectory
  - 9 years to Saturn arrival
  - SEP stage released ~5 yrs after launch
  - Balloon released on 1st Titan flyby, Lander on 2nd Titan flyby
  - ~4 year prime mission: 2 year Saturn tour, 2 mo Titan aerosampling; 20 mo Titan orbit



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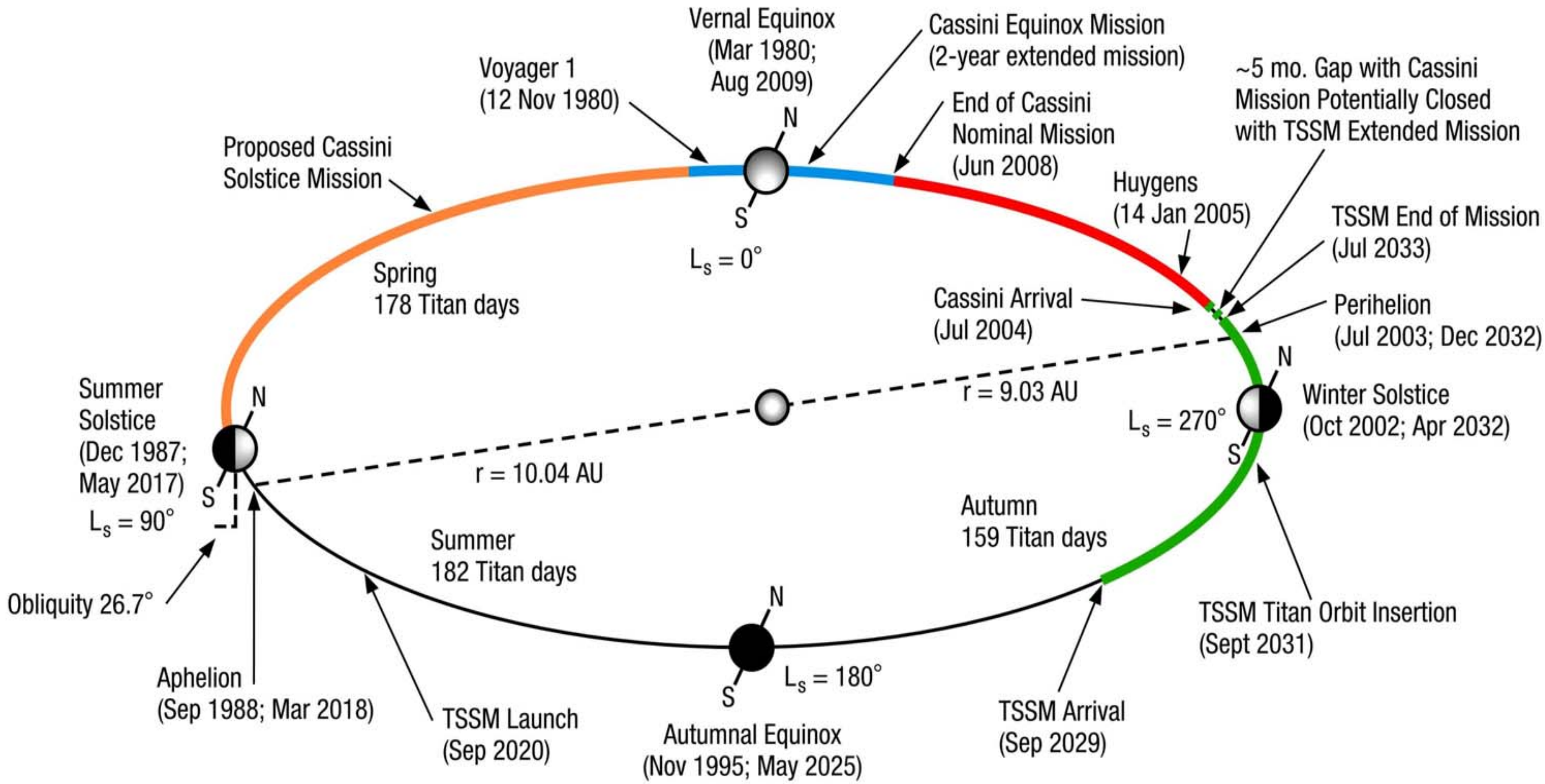
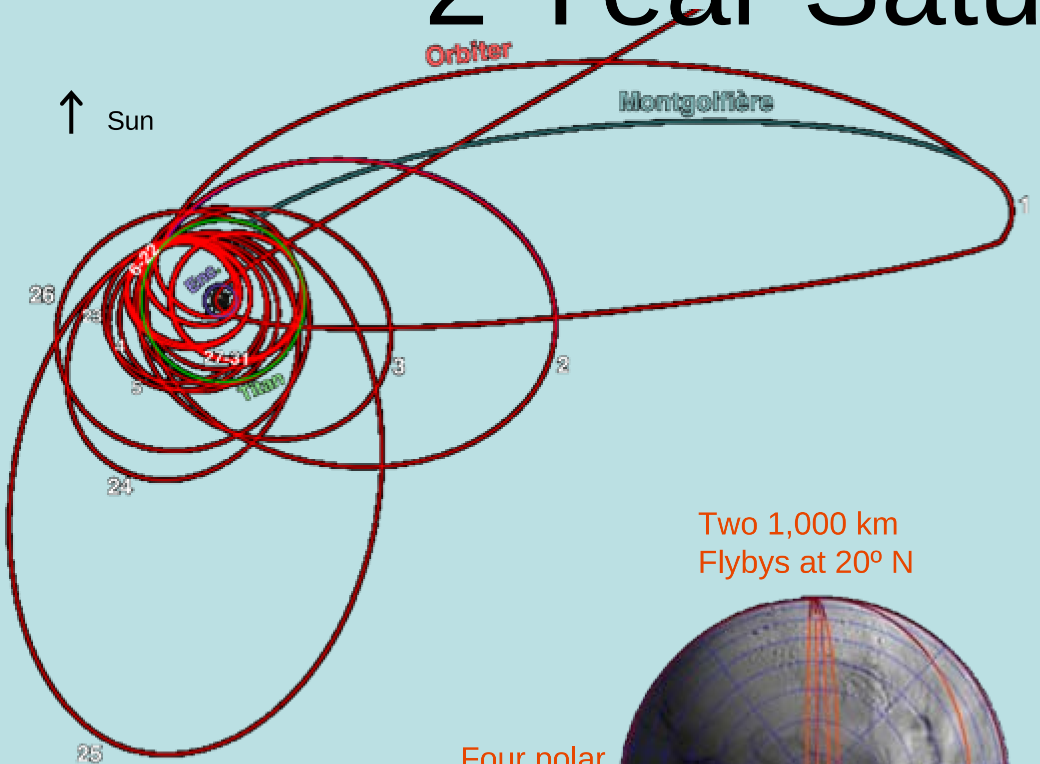
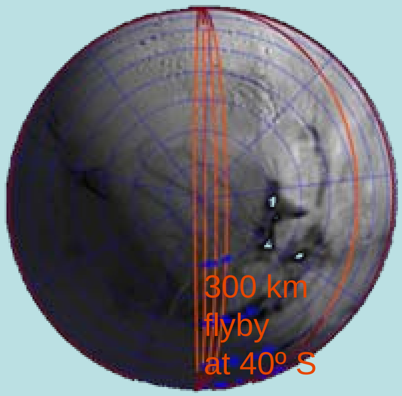
# Titan seasonal cycle: exploration coverage




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.

# 2 Year Saturn Tour



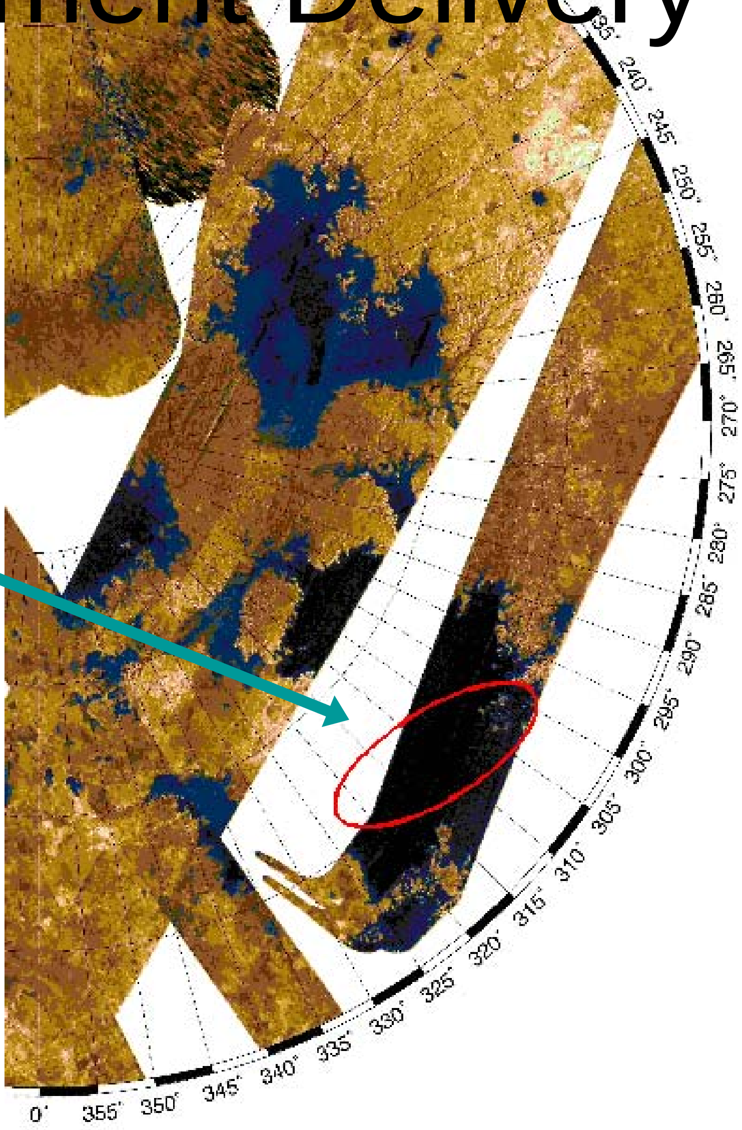




7 Close Enceladus Flybys

# TSSM In Situ Element Delivery

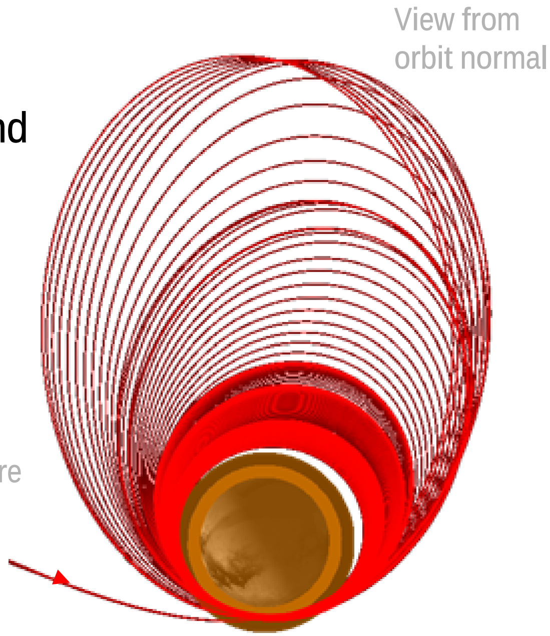
- Lake Lander would be released at 2nd Titan flyby and targeted to land in a northern polar lake – Kraken Mare

- Montgolfière would be released at 1st Titan flyby and targeted to ~20 deg N. The balloon would circumnavigate Titan.

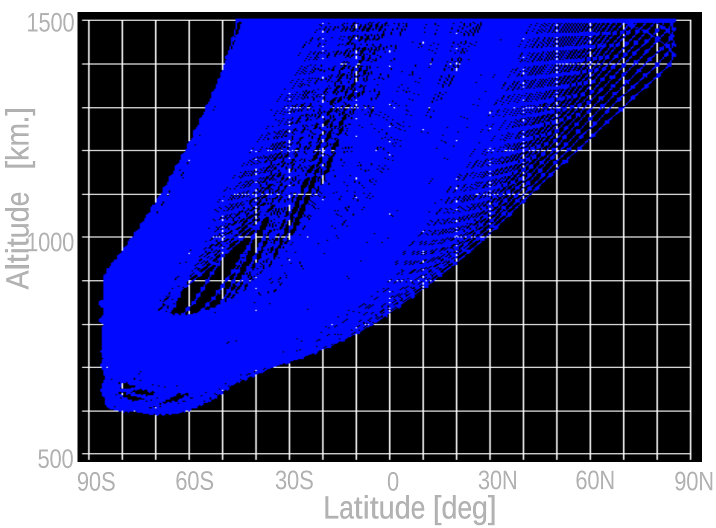


# TSSM ~ 2 Year Titan Orbit

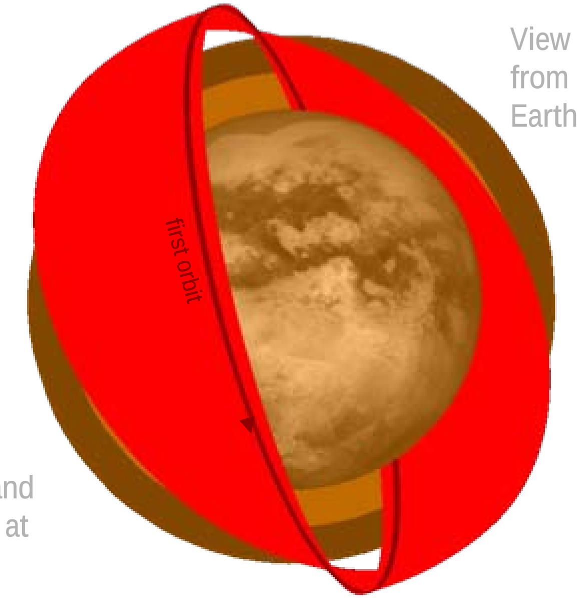
2 Months Aerobarking and Aerosampling



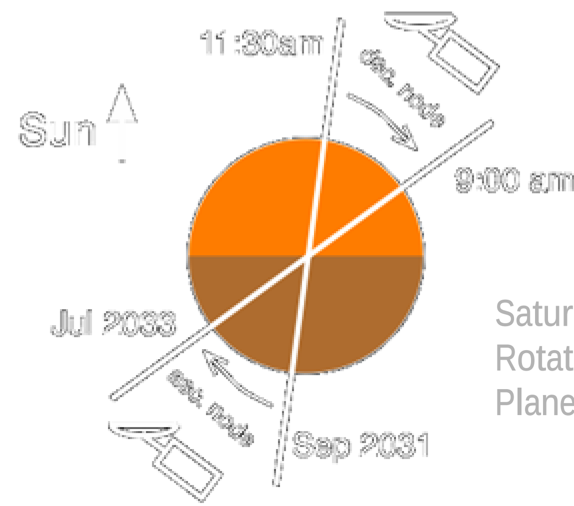

In situ sampling of Titan's entire southern hemisphere below 1,000 km.




20 Months in Circular Polar Orbit



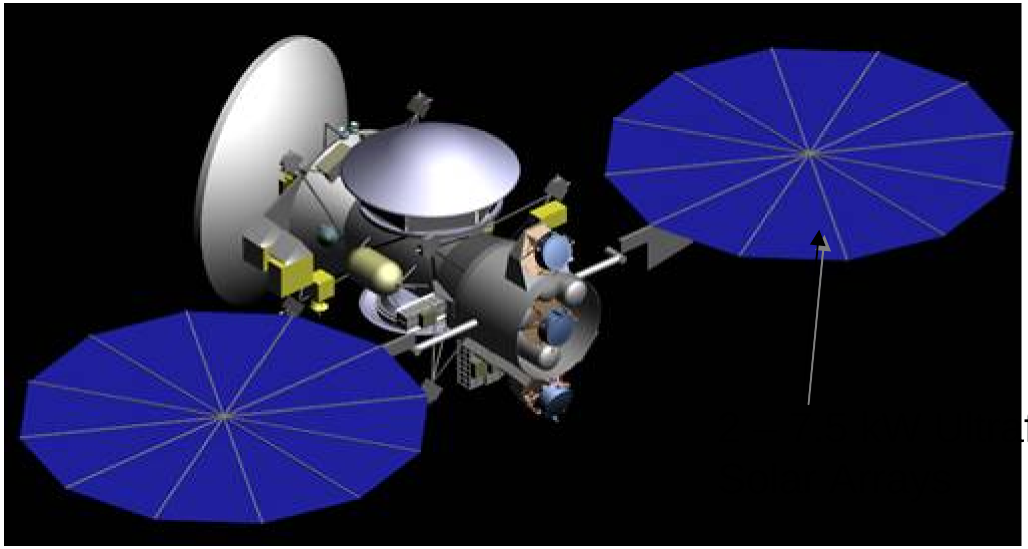

2.5 hr. Variation in LST time of orbit and radio occultations at wide range of latitudes.




Saturn's Gravity Rotates Orbit Plane

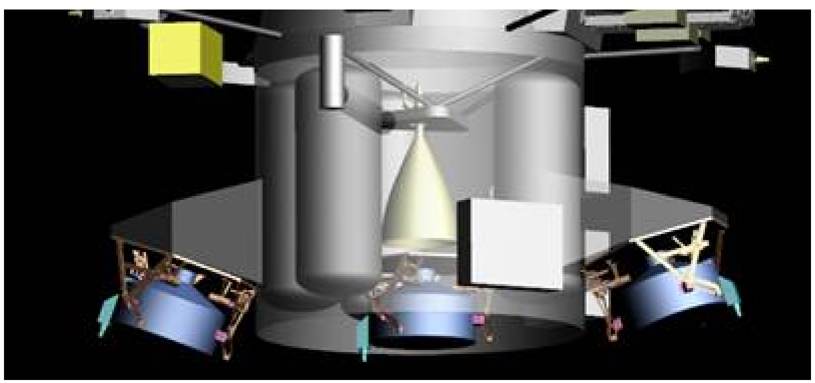
# TSSM with SEP Stage Configuration

Flight Configuration

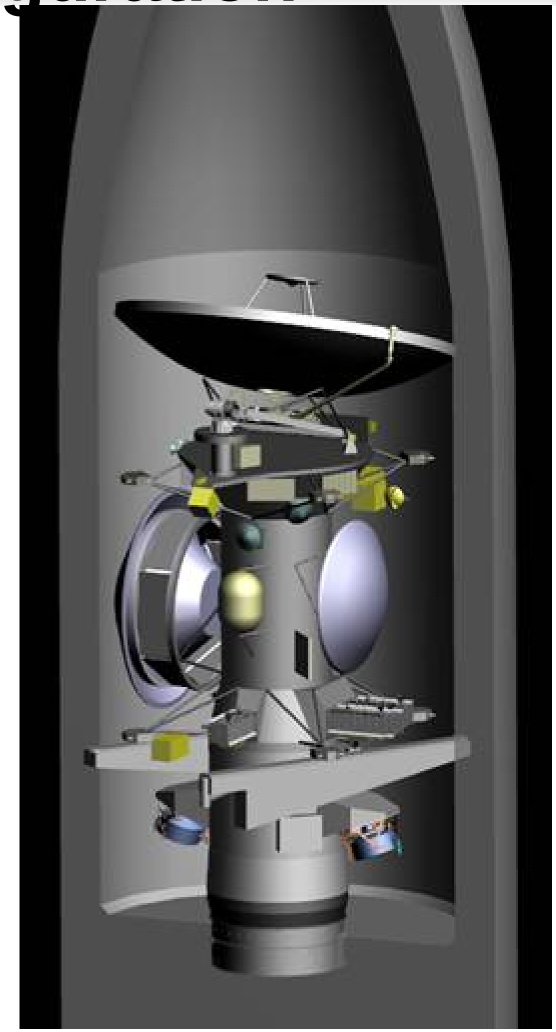


flex

Stage includes SEP integrated into LV adapter

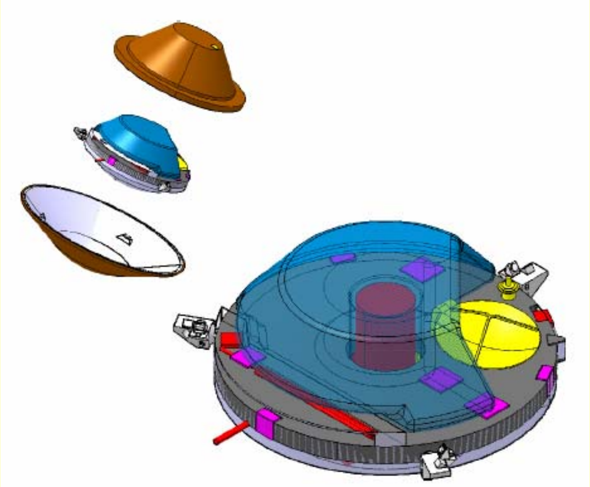


Integrated Stage fits around Orbiter Engine



SEP Option Stowed Configuration in Atlas V Fairing

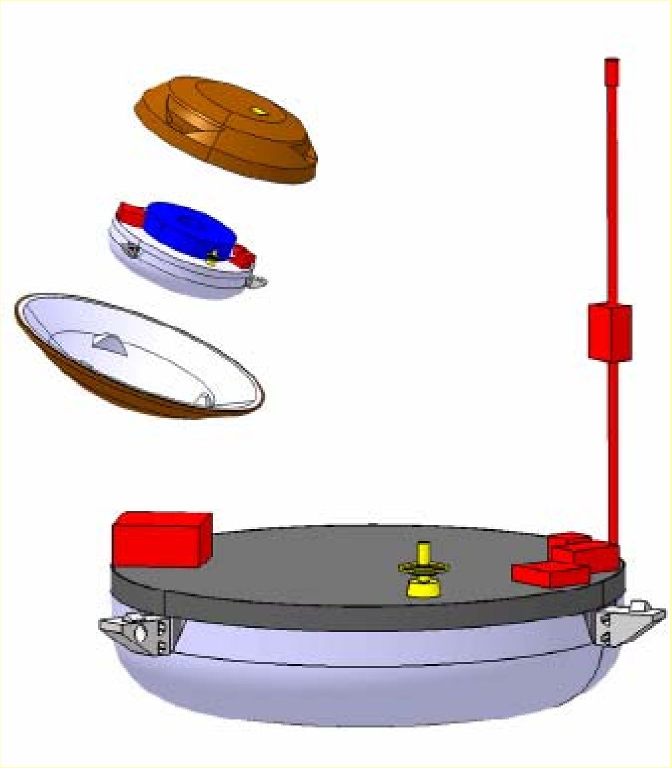
# Montgolfière



Conceptual design
of the Montgolfière

montgolfière floating over the
equatorial region of Titan

# Lake lander



Conceptual design of the lander in floating configuration

Lander in deployed configuration as it would be floating in Kraken Mare

# Around Titan in 80 days

QuickTime™ and a
decompressor
are needed to see this picture.

[Video](#)

QuickTime™ and a
H.264 decompressor
are needed to see this picture.

# ESA CV L-Class Mission – schedule

| Date \ Time frame | Action |
|---|---|
| **January 2009** | **Joint ESA/NASA down-selection;** confirmation of down-selection by the ESA Science Programme Committee (SPC) on 4 Feb. 2009 |
| **1st quarter 2009** | - Preparation for Invitation to Tender (ITT) for 2 parallel industrial studies.<br>- Call for instrument studies (Declaration of Interest for national funded studies) for the down-selected mission |
| **Spring 2009** | Issue of ITT |
| **June 2009 – June 2010** | 2 Competitive industrial studies; nationally funded instrument studies in parallel |
| **September 2010** | **Due date for L-Class assessment report** |
| **Late 2010** | **Selection of 2 of the remaining 3 L-class missions for launch in 2020**: Candidates: Outer Planet Mission, IXO (Xeus), LISA |
| **1st quarter 2011 to mid 2012** | **Industrial studies** (start of phase B1) – Definition Phase |
| **End 2012** | **Selection of 1 L-class mission for launch in 2020 →** mission moves into phase B2 (12 months) |
| **May 2015 – Nov. 2016** | Phase C (30 months) |
| **Nov. 2016 – Nov. 2019** | Phase D (36 months) |
| **2020** | Launch |

# Selection process