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Instrument Constraints and Necessary Science Goals

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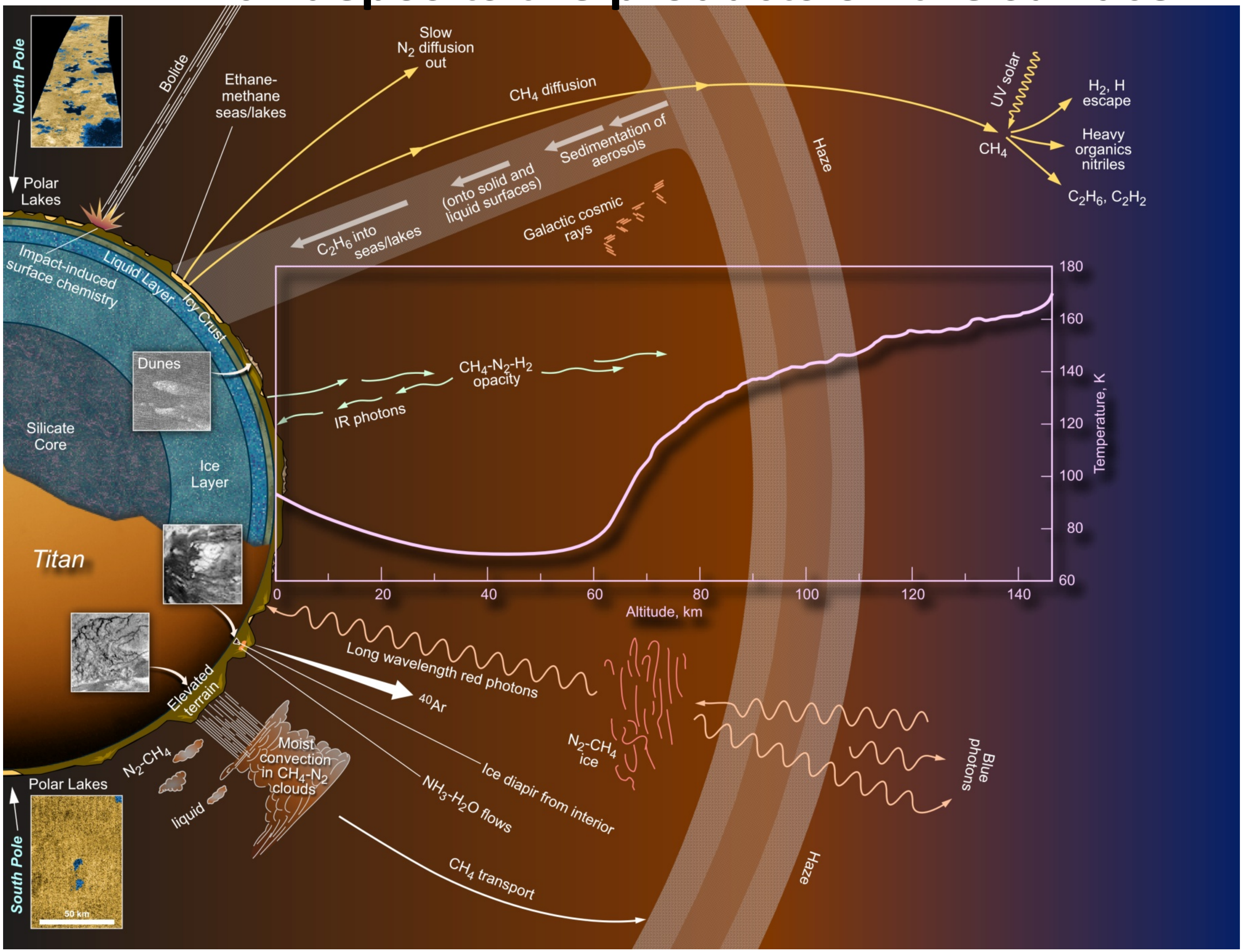
Instruments identified from Titan Studies and Constraints on Potential Future in situ Instruments

Titan Studies

- Many studies conducted over the last decade
- Each study has built upon the last
- NASA appointed Science Definition Teams for the last two studies
- Titan Saturn System Mission is the latest Flagship mission - 2008
- Decadal Survey Study on Titan Submersible conducted 2010

Titan has a complex organic factory in the atmosphere which deposits the products on the surface

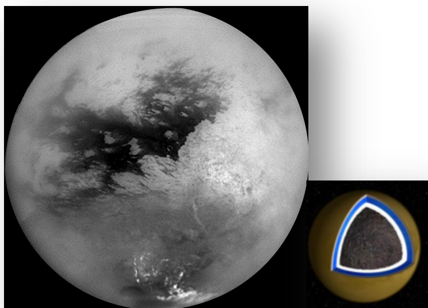


For discussion and planning purposes only.

In Situ Measurements

- Lakes
- Atmosphere
- Dunes
  - Physical properties
  - Geophysical properties
  - Chemical composition
  - Geological measurements
  - Etc.

High Priority Science Questions (established by joint science definition team)

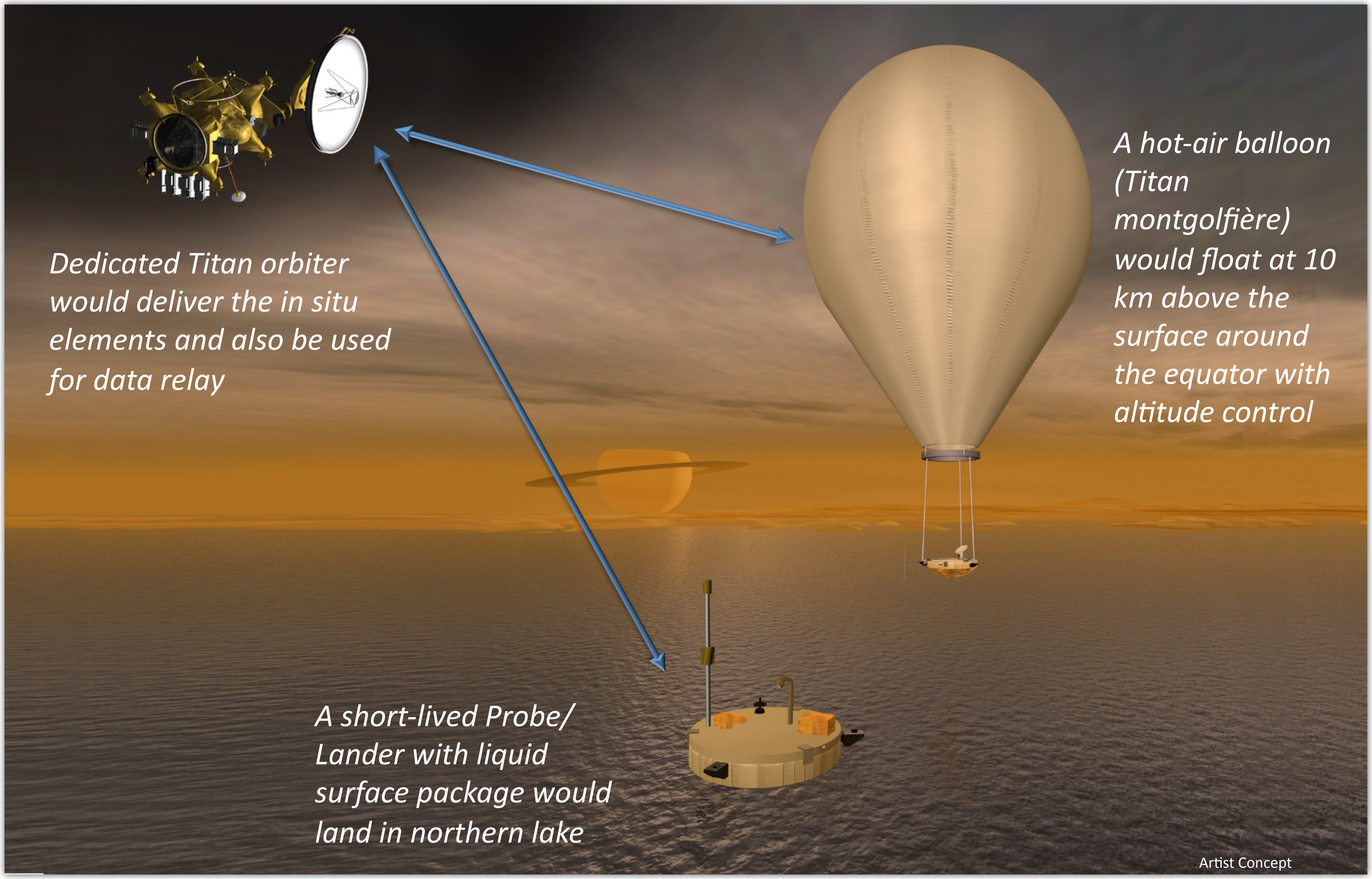


- Goal A: Explore Titan, an Earth-Like System
  - What is Titan's climate like?
  - How does it change with time?
  - What can it teach us about Earth's climate?

- Goal B: Examine Titan's Organic Inventory—A Path to Prebiological Molecules
  - What kind of organic chemistry goes in Titan's atmosphere, in its lakes and seas, and underground?
  - Is the chemistry at the surface mimicking the steps that led to life on Earth?
  - Is there an exotic kind of life—organic but totally different from Earth's—in the methane/ethane lakes and seas?

- Goal C: Explore Enceladus and Saturn's magnetosphere—clues to Titan's origin and evolution
  - What is the source of geysers on Enceladus?
  - Is there life in the source water of the geysers?

Relationship between key mission elements



Model instruments in the planning payload on the montgolfière

Instrument	Description	Science Contributions
BIS	Balloon Imaging Spectrometer (1–5.6 µm).	Mapping for troposphere and surface composition at 2.5 m resolution
VISTA-B	Visual Imaging System with two wide angle stereo cameras and one narrow angle camera	Detailed geomorphology at 1 m resolution
ASI/MET	Atmospheric Structure Instrument and Meteorological Package	Record atmosphere characteristics and determine wind velocities in the equatorial troposphere
TEEP-B	Titan Electric Environment Package	Measure electric field in the troposphere (0–10 kHz) and determine connection with weather
TRS	>150 MHz radar sounder	Detection of shallow reservoirs of hydrocarbons, depth of icy crust and better than 10 m resolution stratigraphic of geological features
TMCA	1–600 Da Mass spectrometer	Analysis of aerosols and determination of noble gases concentration and ethane/methane ratios in the troposphere
MAG	Magnetometer	Separate internal and external sources of the field and determine whether Titan has an intrinsic and/or induced magnetic field
MRST	Radio Science using spacecraft telecom system	Winds from tracking the montgolfière

Model instruments in the planning payload on the lander

Instrument	Description	Science Contributions
TLCA	Titan Lander Chemical Analyzer with 2-dimensional gas chromatographic columns and TOF mass spectrometer. Dedicated isotope mass spectrometer.	Perform isotopic measurements, determination of the amount of noble gases and analysis of complex organic molecules up to 10,000 Da.
TiPI	Titan Probe Imager using Saturn shine and a lamp	Provide context images and views of the lake surface
ASI/MET-TEEP	Atmospheric Structure Instrument and Meteorological Package including electric measurements	Characterize the atmosphere during the descent and at the surface of the lake and to reconstruct the trajectory of the lander during the descent
SPP	Surface properties package	Characterize the physical properties of the liquid, depth of the lake and the magnetic signal at the landing site
LRST	Radio Science using spacecraft telecom system	Winds from tracking the lander

Concepts for a Titan Lake Probe Mission

As stated in the initial Study Questionnaire document:

The purpose of the study is to determine the technical feasibility and cost of a lake probe mission both as an element of a future Titan flagship mission and as a standalone New Frontiers mission. A secondary objective is to identify the technology developments required to make such a mission possible in the next decade

This study was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

Science Goals

SGa: To understand the formation and evolution of Titan and its atmosphere

SGb: To study the lake-atmosphere interaction in order to determine the role of Titan's lakes in the methane cycle

SGc: To study the target lake as a laboratory for pre-biotic organic chemistry in both water (or NH3 enriched water) solutions and non-water solvents

SGd: To understand if Titan has an interior ocean

Science Instrumentation

- **SGa: Atmospheric Evolution**
  - Lake Composition Analyzer **(LCA)**
- **SGb: Lake/atmosphere interaction**
  - Other Properties **(OP)**
  - Meteorological Package **(MP)**
- **SGc: Lake chemistry**
  - Lake Composition Analyzer **(LCA)**
  - Lake Properties Package **(LPP)**
  - Other Properties **(OP)**
- **SGd: Interior structure**
  - Lake Properties Package **(LPP)**

OP

- Dielectric constant
- Speed of sound sensor
- Temperature sensor
- Pressure sensor
- Refractive index
- Turbidimiter
- Densitometer
- Accelerometer

MP

- TDL spectrometer
- Temperature sensors
- Wind speed and direction sensors
- Cameras – Descent, Surface and Zenith
- Atmospheric pressure
- Radar altimeter
- Rain gauge
- Spectral radiometer

LCA

- GC x GC MS
- FTIR spectrometer

LPP

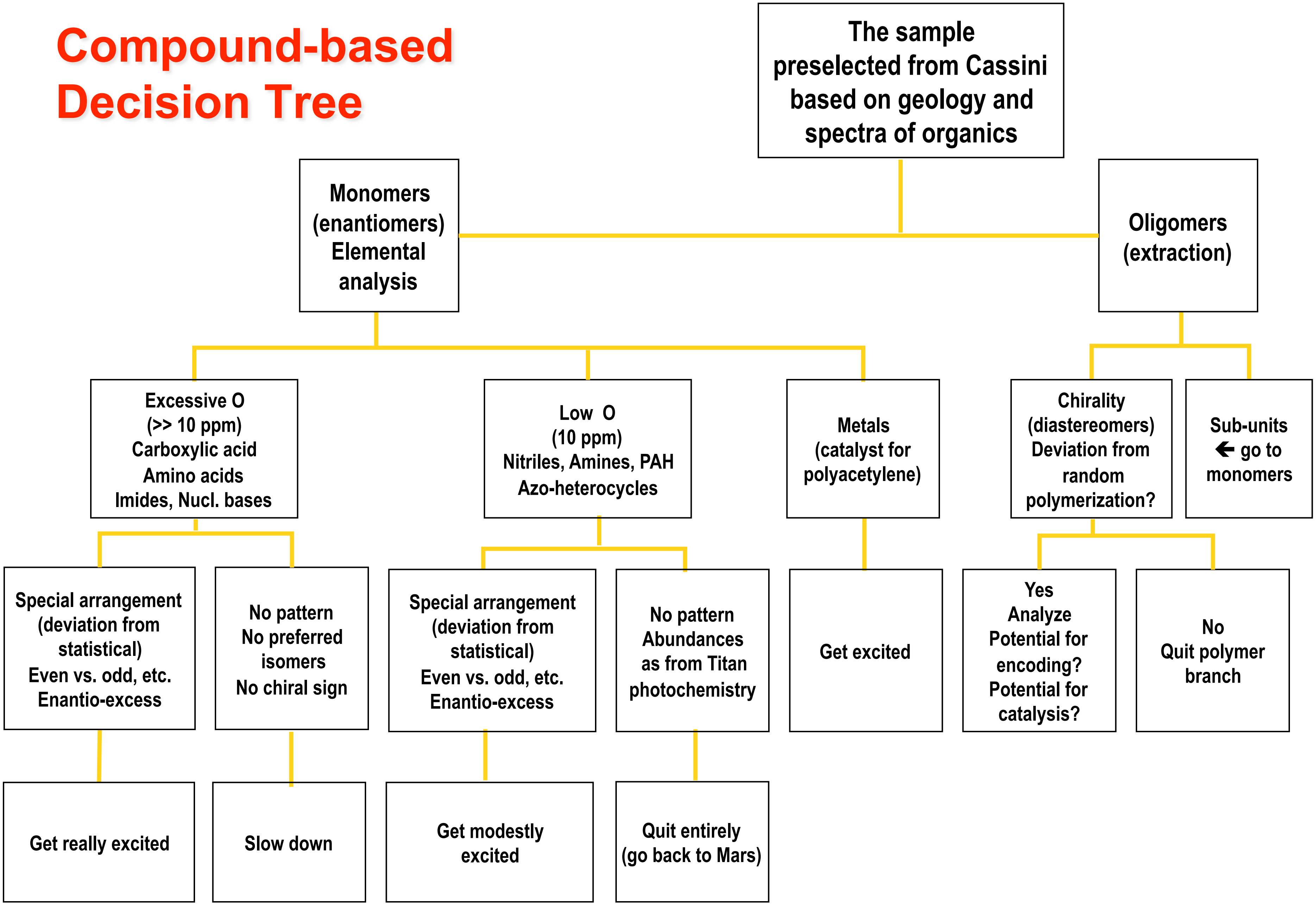
- GC x GC MS
- Temperature sensor
- Refractive index
- Speed of Sound sensor
- Turbidimeter
- Permittivity meter
- Echo sounder
- Refractive index
- Accelerometer
- Magnetometer

Ways to think of translating the science to instruments

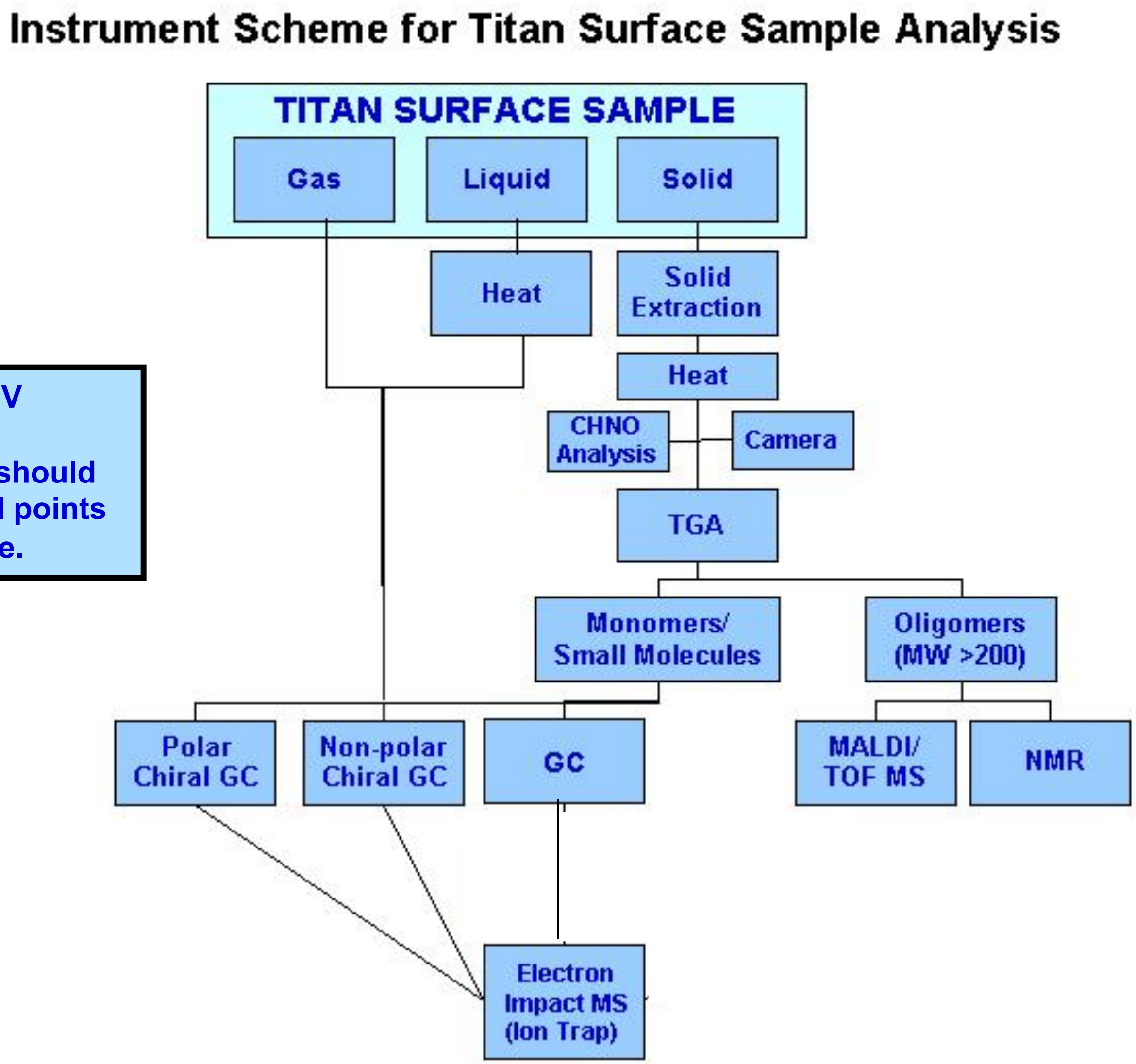
Traceability Matrix is the road from goals to instruments

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 ~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 form-ation 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

Compound-based Decision Tree



Conceptual Scheme for Comprehensive Analysis of Organics and Accompanying Gaseous Phases on the Surface of Titan



Capability for IR/Vis/UV spectroscopy and fluorescence studies should be provided at several points in the analysis scheme.

Constraints on Titan in situ instrument systems

- Low Mass
  - Cryogenic mechanisms
  - Electronics that can survive Titan ambient (~94K)
  - Dual purpose structures
  - Reduction in harnessing
  - Etc.
- Low Power
- Low volume
- High resolution
- High sensitivity
- Provide representative data (operations /miniaturization)
- Autonomy required
- High reliability

Constraints on Titan In situ instrument systems (Continued)

- Long lifetime (could be as long as 15 years including cruise)
- Manageable data rate
- Easily calibrated
- Must have compatible sample handling mechanisms
- Able to withstand extreme environments
- Able to withstand launch loads
- Accommodates Planetary Protection and Contamination Control requirements
- Space-flight qualifiable
- Thermally stable
- May have to withstand thermal cycling
- Flexibility
- KISS