TITAN ORBITER AEROROVER MISSION (TOAM)

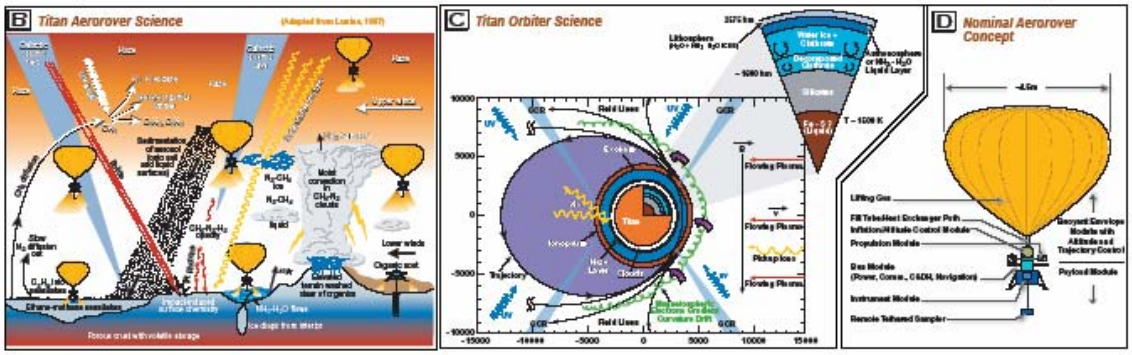
E. C. Sittler Jr., J. Esper, H. Niemann, P. Mahaffy, J. Brasunas, J. F. Cooper, J. Nuth, J. Green, F. Raulin, F. Robb, B. McKibben, D. J. McComas, Eastwood Im, and Mark Allen

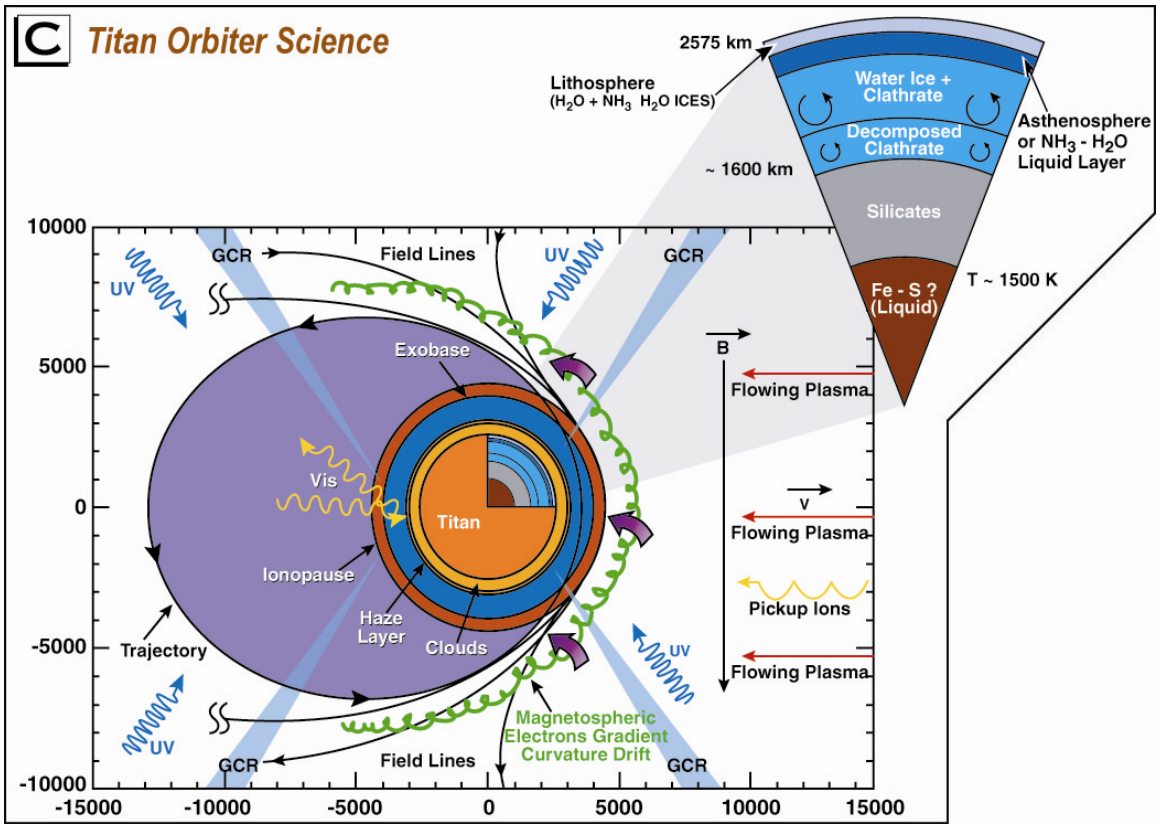
We propose to develop a new mission to Titan called Titan Orbiter Aerorover Mission (TOAM). This mission is motivated by the recent discoveries of Titan, its atmosphere and its surface by the Huygens Probe, and a combination of in situ, remote sensing and radar mapping measurements of Titan by the Cassini orbiter. Titan is a body for which Astrobiology will be the primary science goal of any future missions to it. TOAM is a multi-faceted mission with launch using a Delta IV Heavy for high C3 interplanetary orbit injection, possible Jupiter flyby, Solar Electric Propulsion (SEP), orbit injection via aerobraking at Titan, probe entry with balloon technology (i.e., Aerorover phase) and finally a landing phase. The cruise phase can last between 5-9 years, orbiter reconnaissance phase of ~ 6 months, Aerorover global reconnaissance phase ~ 6 months, Aerorover global surface science phase ~ 6 months and Aerorover landing phase ~ 6 months, with possibility of an extended mission. The orbiter will be powered by 3 MMRTGs and Aerorover by a single MMRTG. The Aerorover will probably use a hot air balloon concept using the waste heat from the MMRTG ~ 500-1000 watts, but other concepts may be considered. Our strategy to use an orbiter is contrary to some studies using just a single probe with balloon. Autonomous operation and navigation of the Aerorover around Titan, which will include descent near to the surface to collect surface samples for analysis, is in itself a very complex process and will require nearly continuous tracking and navigation updates. Only an orbiter can provide this capability as a relay station and GPS role so that the Aerorover will be able to navigate safely within Titan's environment, while maintaining nearly continuous communication with ground stations. Although very complex, our goal is to keep the Aerorover as simple as possible in order to enhance the likelihood of success. Experience has shown that such complex missions will develop unexpected problems, for which a balloon concept allows for it to safe itself by going to high altitudes and thus allow teams on the ground the necessary time needed to work around such problems. New technologies will need to be developed and miniaturization will be required to maintain functionality while controlling mass, power and cost. Duty cycling will be used. The orbiter will combine radar altimetry, radio science and remote sensing instruments to measure the global topography, sub-surface structure and atmospheric winds during its recon phase so that the Aerorover can use this information to navigate safely around Titan and identify prime sites for surface sampling and analysis. In situ instruments will sample the upper atmosphere which may provide the seed population for the complex organic chemistry on the surface. The Aerorover will have all the instruments needed to sample Titan's atmosphere, surface, possible methane lakes-rivers, use multi-spectral imagers for recon phase of surface and take close up surface images and during landing phase take core samples and use seismometers. During the landing phase we may even have a Sojourner class robot that was previously used for Mars.

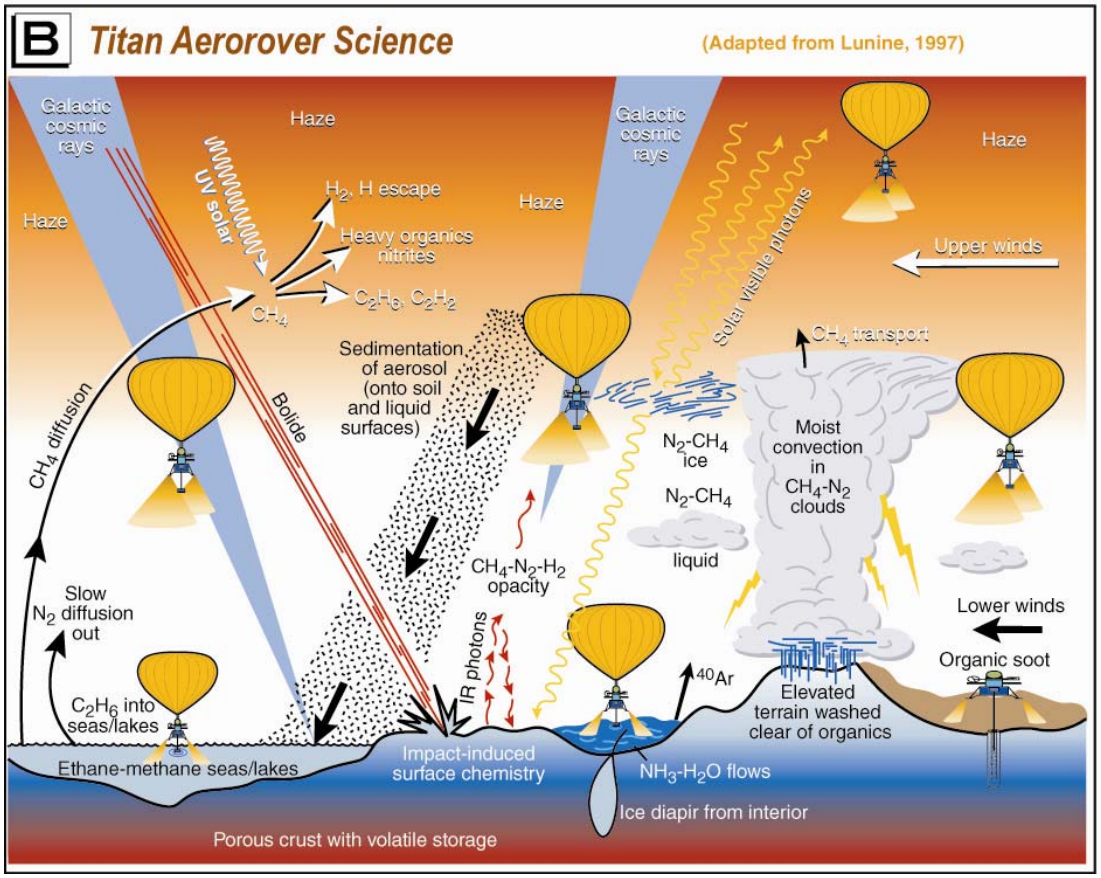
Titan Orbiter Aerorover Mission (TOAM)

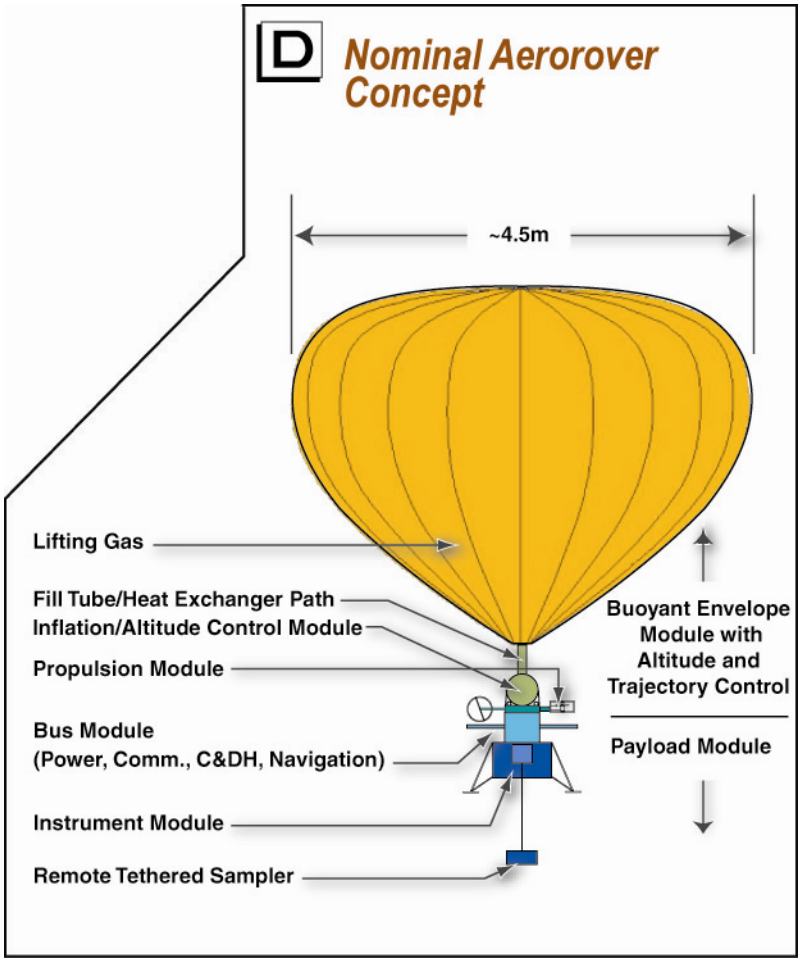
A Requirements Flowdown

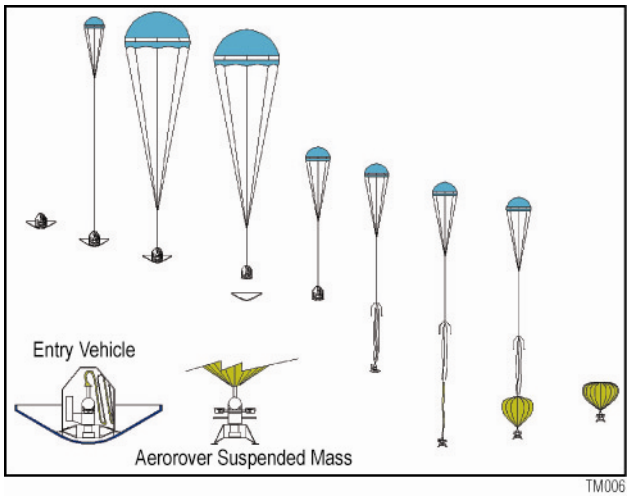
Decadal Study Theme	Science Objective	Measurement	Candidate Orbiter Instruments	Candidate Aerorover Instruments
The First Billion Years of Solar System History	1. What is the origin of Titan's atmosphere?	• Provide composition measurements of Titan's atmosphere • Measure D/H ratio, and ^{14}N/^{15}N abundance and other elemental isotope abundances. • Measure Titan's atmospheric density, temperature, and pressure from the exosphere to the surface	Ion Neutral Mass Spectrometer (INMS) Langmuir Probe (LP) Thermal Infrared Spectrometer (TIRS) Titan Radio Science (TRS) Titan Submillimeter Limb Sounder (TSLS)	Aerosol Collector Pyrolyzer (ACP) Atmosphere Properties Unit (APU) Gas Chromatograph Mass Spectrometer (GCMS)
Volatiles and Organics: The Stuff of Life	2. Are there liquid bodies on Titan's surface? 3. What is the origin, chemical composition, and significance of the aerosols?	• Sample aerosols in situ from the stratosphere down to the surface • Map the atmospheric composition and surface characteristics from microwave, infrared, to near infrared wavelengths and provide information on the composition and size distribution of aerosols • Define the character of energetic particle and cosmic ray radiation reaching Titan • Perform in situ analyses to obtain comprehensive and sensitive molecular and elemental assays, particularly of volatile organics of atmosphere and oceans	Hyperspectral Imager for the Titan Science (HITS) Ion Neutral Mass Spectrometer (INMS) Radiation Environment of Titan Investigation (RETI) Thermal Infrared Spectrometer (TIRS) Titan Submillimeter Limb Sounder (TSLS)	Aerosol Collector Pyrolyzer (ACP) Aerosmer Hyperspectral Imager for Titan Science (AHITS) Gas Chromatograph Mass Spectrometer (GCMS) Ocean Properties Unit (OPU) Siphon Sampling Unit (SSU) Titan Aerosmer Radiation Monitor (TARM) Titan Ice and Dust Experiment (TIDE)
The Origin and Evolution of Habitable Worlds	5. Are organic or prebiotic chemical processes occurring in the subsurface water-ammonia ocean? 6. What is the nature of Titan's cryogenic surface organic and prebiotic chemistry?	• Detect proteins, DNA, and other life-forming building blocks in surface and oceans • Perform detailed surface sampling, collection, and composition analyses • Detect subsurface oceans	Hyperspectral Imager for the Titan Science (HITS) Titan Radio Science (TRS) Titan Synthetic Aperture Radar and Altimeter (SARA)	Aerosmer Hyperspectral Imager for Titan Science (AHITS) SAR Ocean Sampling Unit (SOSU) Gas Chromatograph Mass Spectrometer (GCMS) Microarray Assay for Titan Exploration (MATE) Sample Acquiring Unit (SAU) Siphon Sampling Unit (SSU)
Processes: How Planets Work	4. What are the energy sources driving the chemical processes on Titan?	• Perform mapping of topography, surface properties, and subsurface stratigraphy • Measure atmospheric winds from the surface to the thermosphere • Examine Titan for lightning spheric signals, optical flash, and radio beam • Provide temperature and composition mapping of the surface and atmosphere, resolve CO_2 ice line, CO_2, and water vapor lines • Study Titan's gravity field • Measure the magnetospheric plasma interaction with Titan • Measure the chemistry profiles for Titan's ionosphere from above and below • Determine Titan's surface-elemental composition, mineralogy, density, layering, and subsurface liquid water • Measure the intensity, vertical profile, and changing properties of radiation from the top of the atmosphere to the surface • Measure the chemistry of possible liquid methane and ethane oceans, the speed of sound, the depth of the ocean, the temperature, permittivity, refractive index of the liquid, and ocean wave properties • Measure coastal image/erosion, surface stiffness, uniformity, and granular structure	Hyperspectral Imager for the Titan Science (HITS) Magnetometer (MAG) Radio and Plasma Wave Science (RPWS) Radiation Environment of Titan Investigation (RETI) Titan 3D-Plasma-Ion Composition Spectrometer (T3DPICS) Titan Ion Plasma Spectrometer (TIPS) Titan Infrared Spectrometer (TIRS) Titan Orbiter Radio Sounder (TORS) Titan Radio Science (TRS) Titan Synthetic Aperture Radar and Altimeter (SARA) Titan Submillimeter Limb Sounder (TSLS)	Aerosmer Hyperspectral Imager for Titan Science (AHITS) Atmosphere Properties Unit (APU) Ocean Properties Unit (OPU) Surface Properties Unit (SPU) Titan Aerosmer Radiation Monitor (TARM) Titan Aerosmer Radio Sounder (TARS) Titan Mission Plasma Ray Instrument (TMPR)






B
Titan Aerorover Science
(Adapted from Lunine, 1997)
Galactic cosmic rays
Haze
UV solar
H_2, H escape
Heavy organics nitrites
C_2H_6, C_2H_2
CH_4
Haze
Galactic cosmic rays
Haze
Solar visible photons
Upper winds
CH_4 transport
Sedimentation of aerosol (onto soil and liquid surfaces)
CH_4 diffusion
Bolide
N_2-CH_4 ice
N_2-CH_4 liquid
Moist convection in CH_4-N_2 clouds
CH_4-N_2-H_2 opacity
IR photons
Slow N_2 diffusion out
C_2H_6 into seas/lakes
^{40}Ar
Elevated terrain washed clear of organics
Lower winds
Organic soot
Ethane-methane seas/lakes
Impact-induced surface chemistry
NH_3-H_2O flows
Ice diapir from interior
Porous crust with volatile storage


D
Nominal Aerorover Concept
~4.5m
Lifting Gas
Fill Tube/Heat Exchanger Path
Inflation/Altitude Control Module
Propulsion Module
Bus Module
(Power, Comm., C&DH, Navigation)
Instrument Module
Remote Tethered Sampler
Buoyant Envelope Module with Altitude and Trajectory Control
Payload Module


Entry Vehicle
Aerorover Suspended Mass
TM006