Planetary Exploration and Balloons

Ralph D Lorenz,

JHU-APL

Ralph.lorenz@jhuapl.edu

NASA Balloon Workshop

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Balloon Niches

Venus

Endurance – can survive for days instead of hours. But requires high altitude.

Or multiple ascents/descents or release of dropzondes

Balloon a critical element in sample return architecture ?

Mars

- Long-track low altitude surveys

- Deployment of networks

Jupiter/Saturn/Uranus/Neptune

- ?? Low M makes challenging. Multiprobes reaching depth preferred to get below cold-trap altitude of O,N,C species

Titan

Long-track low altitude survey. Surface Sampling at Diverse sites

Network Deployment

Altitudes

Balloon Opportunities

Competed Mars Scout

Competed Discovery Missions (Venus)

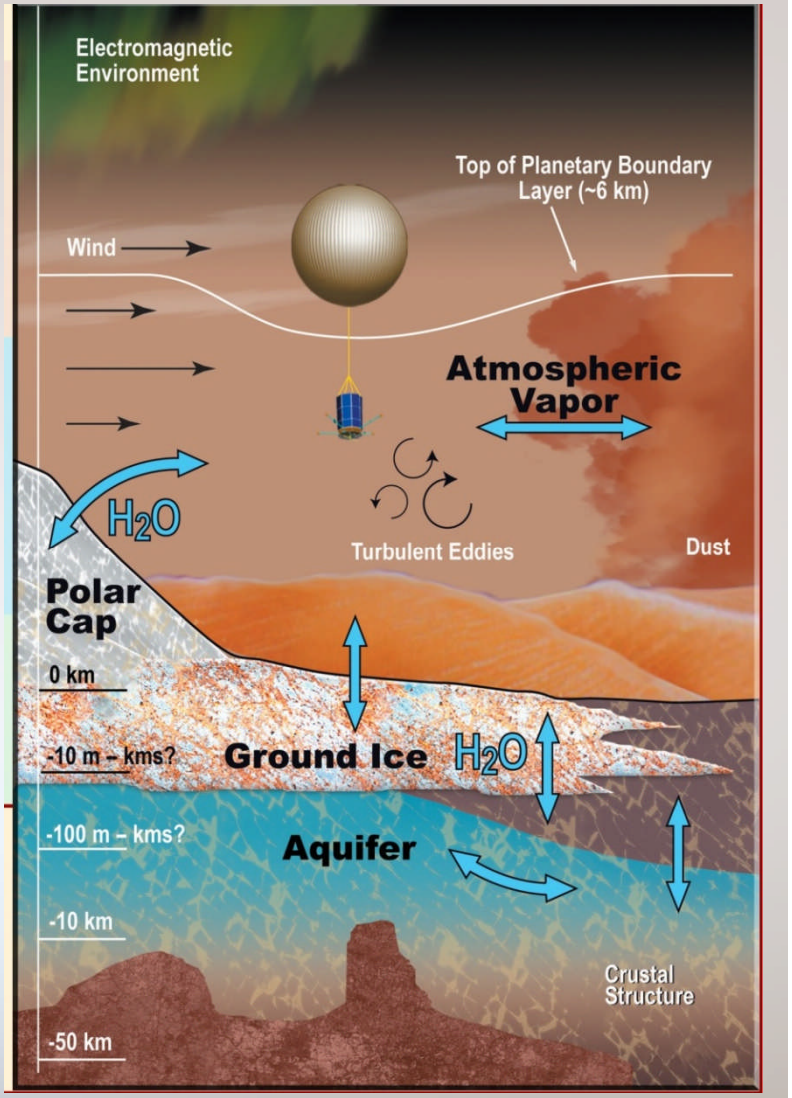
Flagship Mission to Titan

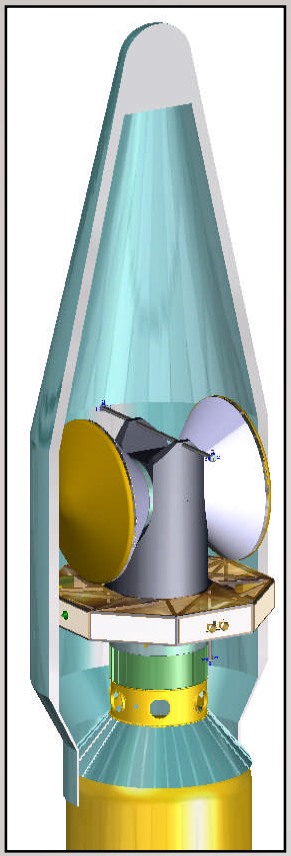
New Frontiers

Courtesy R Grimm SwRI Boulder

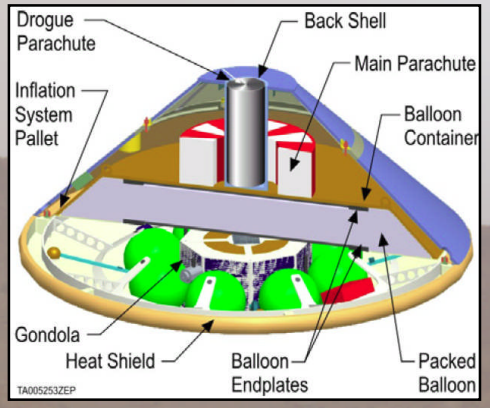
ZEPHYR
SCOUTING WATER ON MARS

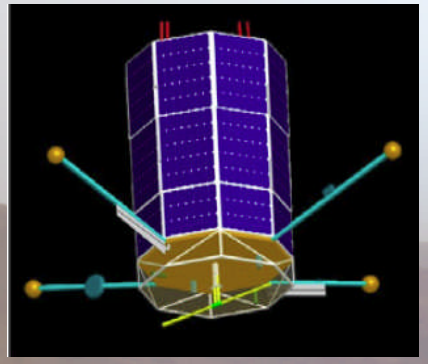
- Determine the distribution, movement, and exchange of water in the atmosphere, surface, and subsurface of Mars.
  - Simultaneous assessment of water on Mars from the deep crust though the lower atmosphere.
  - Fills a critical gap in Mars Exploration Program.
- Required measurements are uniquely enabled by superpressure balloon flight.
  - Meteorological measurements are in the planetary boundary layer “where the action is.”.
  - Geophysical measurements are favorably “low and slow:” high resolution and SNR due to ground proximity and integration time.

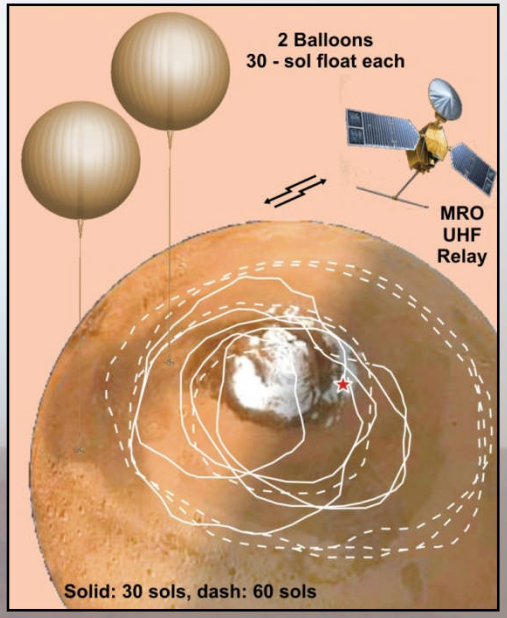




- Two entry vehicles (balloons) with carrier S/C on Atlas V.
- MER aeroshell, two-stage parachute, balloon air launch.
- >30-sol floats, >30,000 km traverses for each balloon.
- Phoenix site preferred for 2011 opportunity– tie missions together.
- Selection declined for 2011 due to perceived risk in separation of 2 probes from carrier and in entry, descent, and balloon inflation.








VALOR
VENUS AEROSTATIC-LIFT
OBSERVATORIES for in-situ RESEARCH
Dr. Kevin H. Baines, Principal Investigator
GSFC
THE UNIVERSITY WISCONSIN MADISON
Step 1
April 5, 2006
JPL
Ball
^{20}Ne / ^{21}Ne / ^{22}Ne
^{15}N / ^{14}N
HDO / H_2O
SO_2
^{34}S / ^{33}S / ^{32}S
Xe / Kr
^{3}He / ^{4}He
^{40}Ar / ^{36}Ar
4.5 Gyr
Formation
4.2 Gyr
Evolution
Present
^{129}Xe / ^{130}Xe
^{36}Ar / ^{38}Ar

VALOR

VENUS AEROSTATIC-LIFT OBSERVATORIES for in-situ RESEARCH

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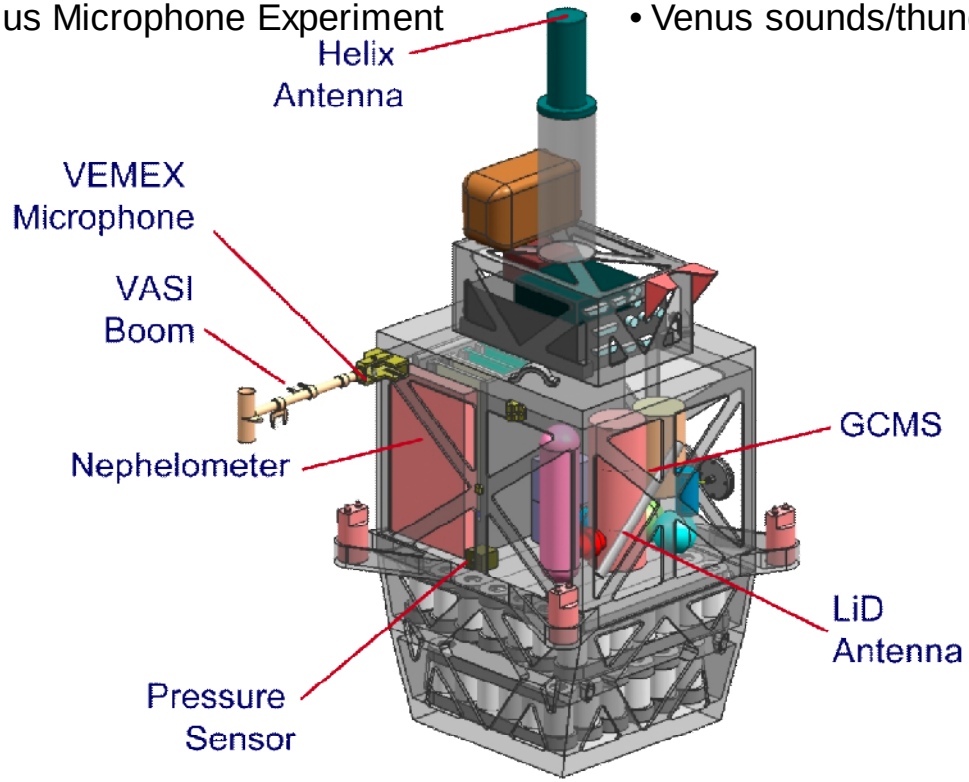
GSFC | THE UNIVERSITY of WISCONSIN MADISON | Step 1 April 5, 2006 | JPL | Ball

Primary Science Objectives

A 2-day, *in-situ*, balloon-borne high- and low-latitude reconnaissance to directly sample the com-position and dynamics of Venus to elucidate the origins and evolution of the inner solar system and present-day processes on Venus. A 6-day Bonus Phase option samples dynamics at all longitudes.

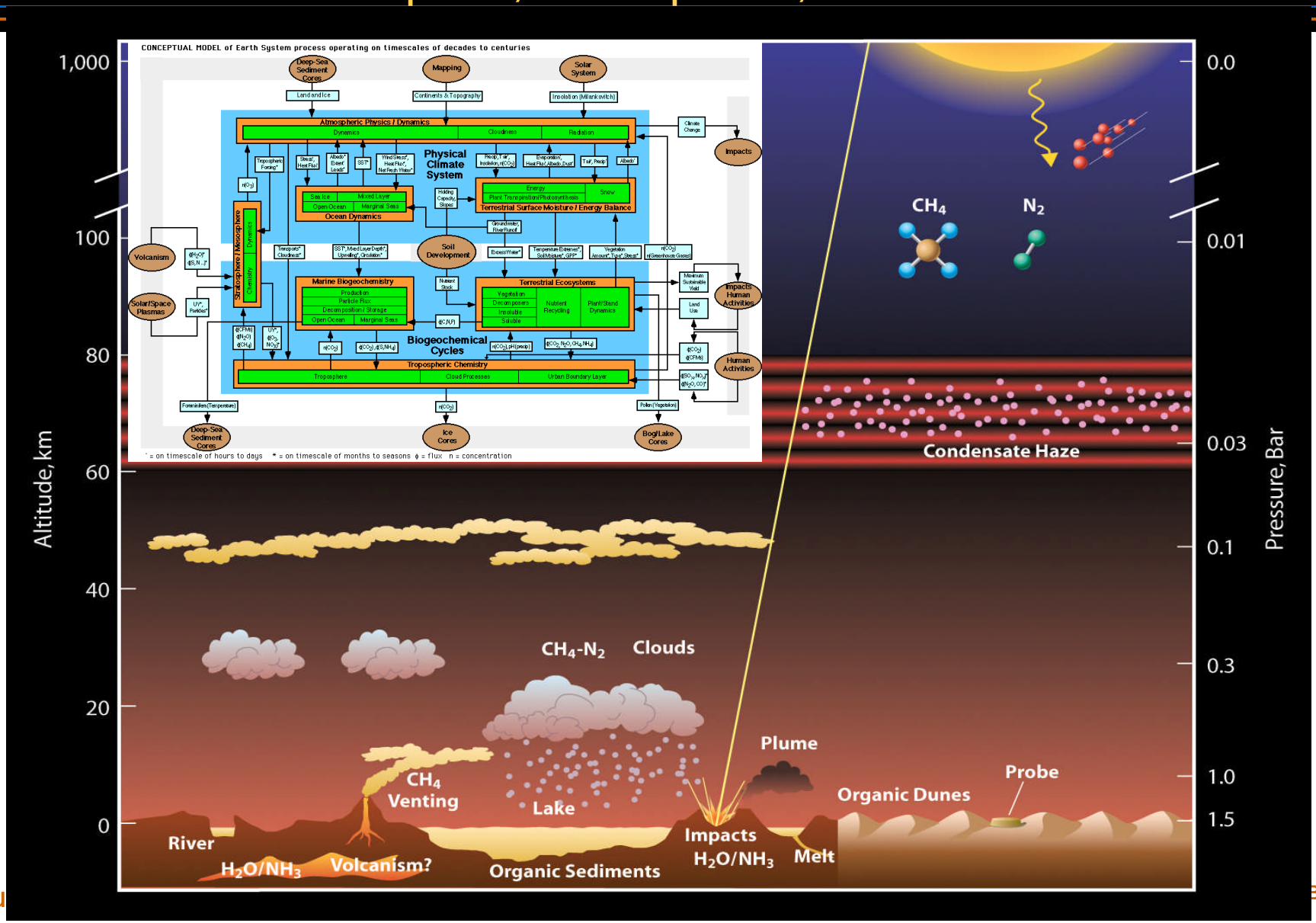
Twin balloon-borne aerostats at 55.5-km altitude (Performance Floor consists of one aerostat, without LiD and nephelometer experiments).

Instruments	Measurements
GCMS (Gas Chromatograph Mass Spectrometer)	• Noble gas abundances • Isotopic abundances • Chemically-active trace species abundances
VASI (Venus Atmospheric Structure Investigation)	• Pressure • Temperature • Vertical wind • Particle size/density
ART (Aerostat Radio Tracking)	• 3-D winds
LiD (Lightning Detector)	• Lightning rate/strength
Venus Microphone Experiment	• Venus sounds/thunder



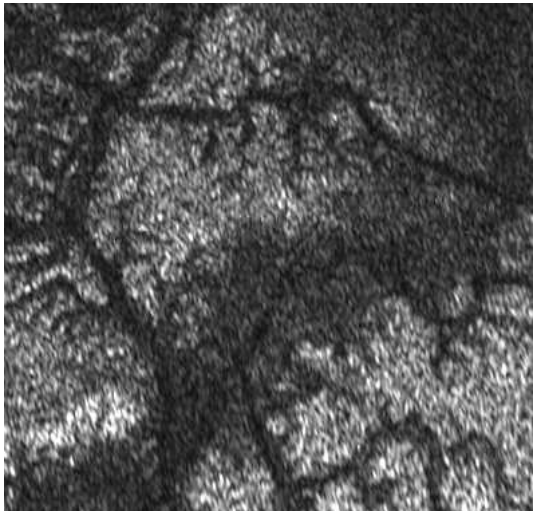

APL
JPL
TITAN EXPLORER
NASA
NASA
Titan Flagship
Mission Study
NASA
07-01121

Titan System Science: Like Earth, Titan is an active world with exchanges of matter and energy between space, atmosphere, surface and interior

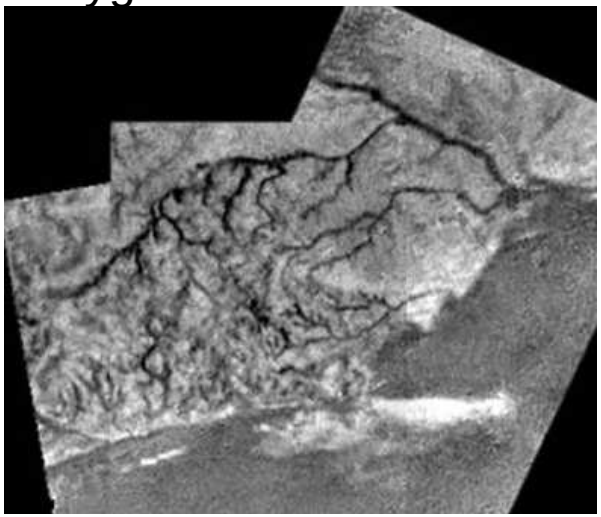


Orbiter – Balloon – Lander: A Multiscale Architecture for Exploring a Diverse Multiscale Surface

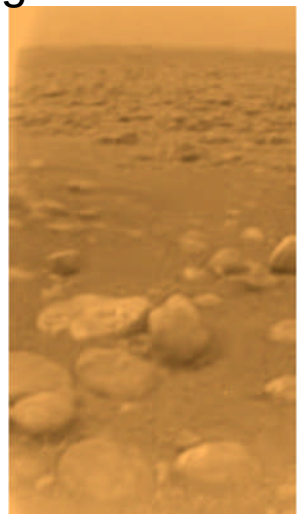
T28 SAR ~ 35km



Huygens DISR ~4km



Huygens DISR ~ few m

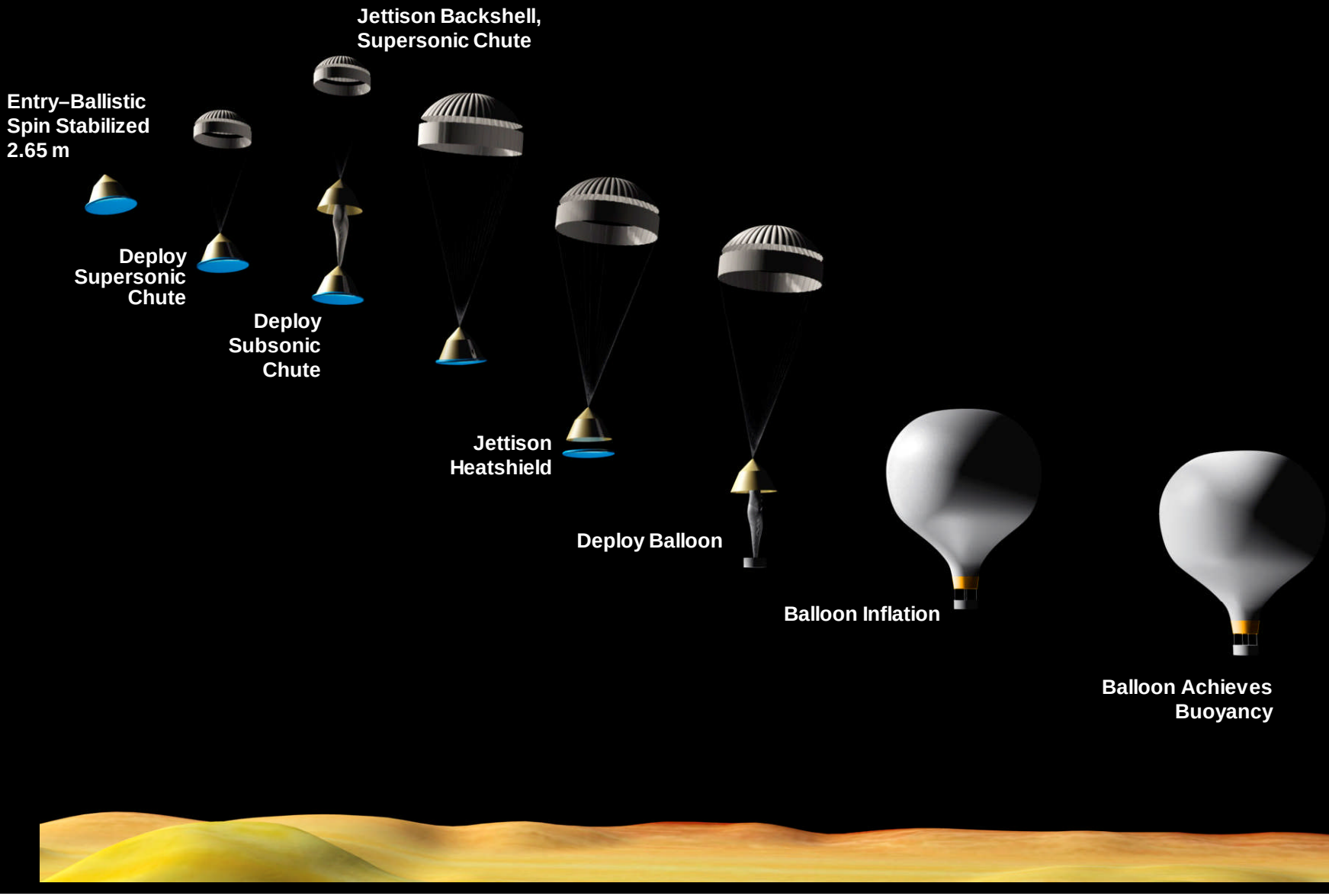


To understand the processes shaping Titan needs information on all scales – e.g. for fluvial processes need large-scale networks and topography, mid-scale observations to understand e.g. runoff threshold and floor fill, and small scale to characterize sediment itself.

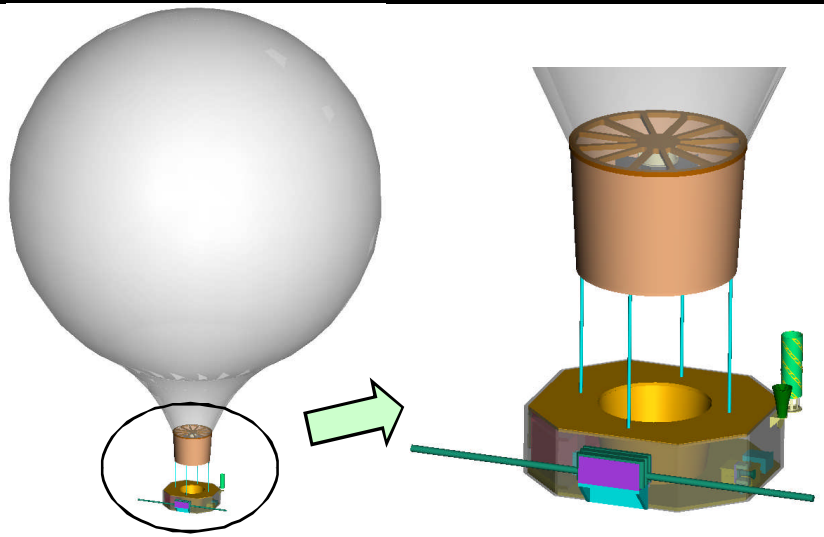
Atmosphere (via optical scattering and enforced high altitude of orbiter) makes mid-scale (~1-10m resolution) difficult to acquire e.g. by HiRISE-type instrument. Lander would not see wide diversity of terrain during descent.

An aerial platform like a balloon bridges the scale gap – wide coverage at high resolution. Reduces risk for future lander missions by characterizing terrain hazards.

Entry, Descent and Deployment



Titan Aerial Vehicle



- One year aerial operations; drift with Titan winds at < 10km
- Power allocation = 128 W EOL (14 yrs)
  - Power system margins: ≥31%
- Science relay rate = 1.2 kbps CBE; 4 Gbits CBE total data
  - Relay margin: 25% DL time; 30% rate
- Power system single fault tolerant*
- Comm relay to orbiter – UHF, Electra 5.5W RF
- 12m diameter double walled balloon
- Conservative approach for balloon and gondola thermal management and power decoupling
  - ASRG in gondola for primary power, gondola thermal source
  - MMRTG inside balloon for buoyancy, supplemental power
  - Higher fidelity analyses, experimental work to further assess
- Valve in top of balloon for altitude control
- Key technology: Balloon system, deployment

6 Science instruments: Met package, TDL spectrometer, visible imager, near IR spectrometer, subsurface radar, altimeter

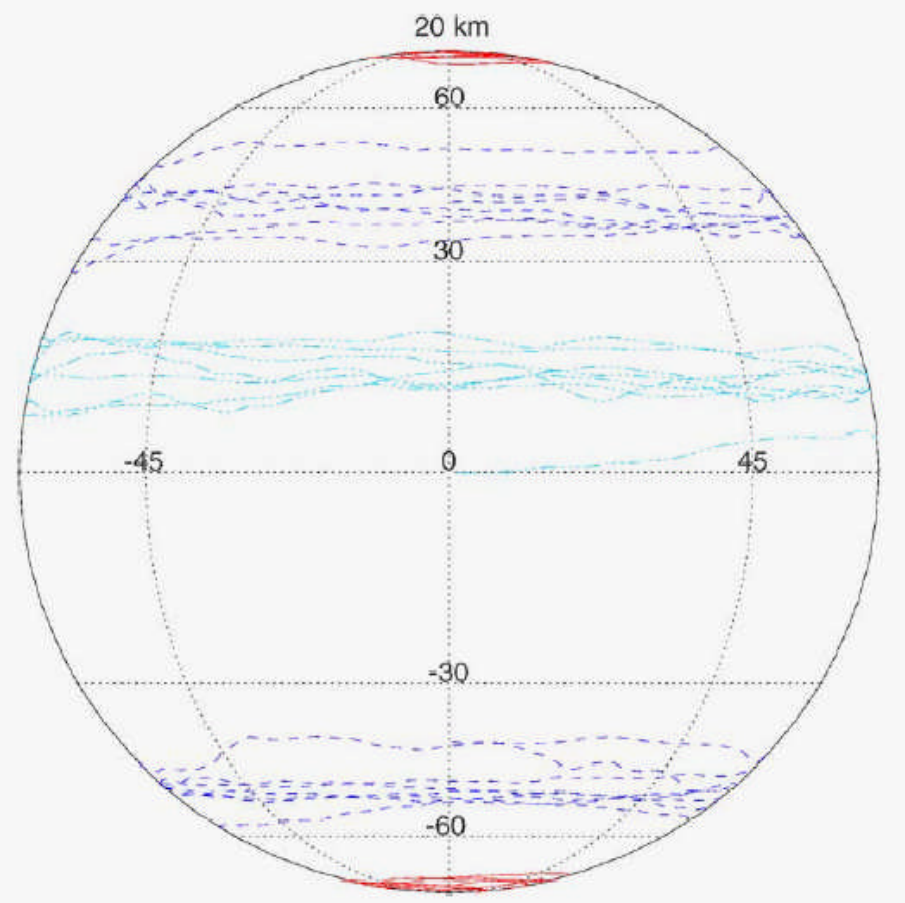
EDL instrumentation: heatshield pressure and temperature instrumentation

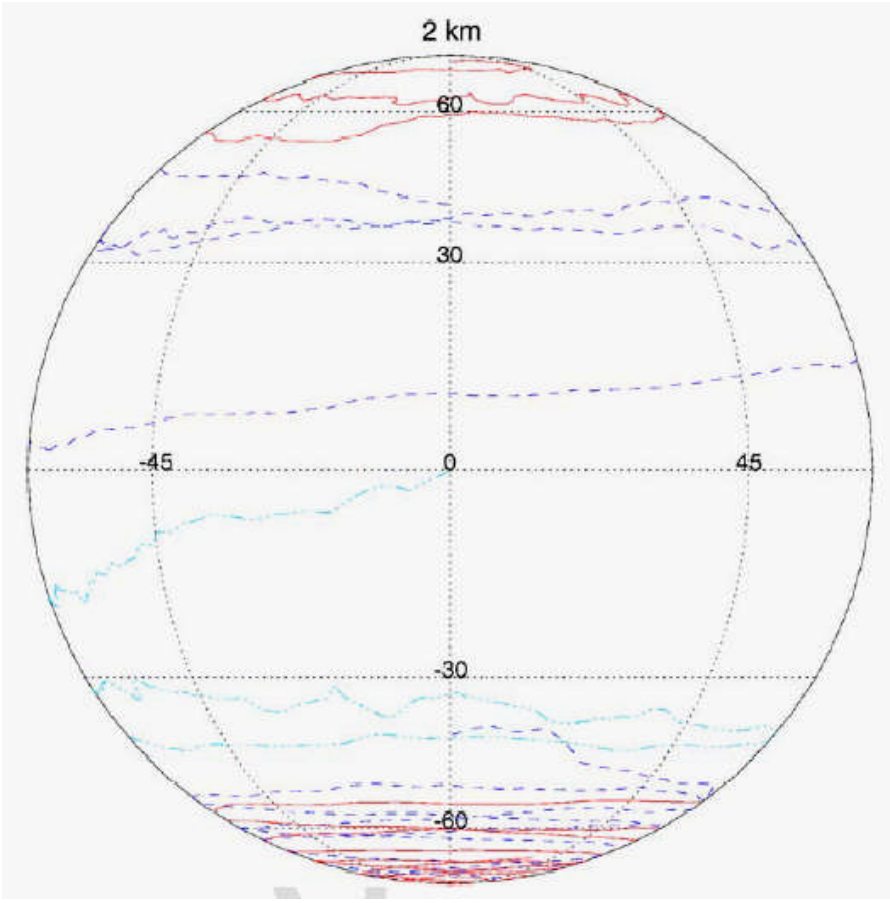
Mass (kg)	CBE	CBE+Contin
Payload	25	29
Bus	393	476
S/C Mass	418	(20.8%) 505
System Margin	16.5%	83
Launch Alloc.		588

Entry, descent and deployment system:

- Huygens heritage entry, descent system
- 2.65m diameter entry aeroshell
- Two disk gap band parachutes
- 2nd parachute deploys balloon
- Balloon inflates with entrained air
- Balloon buoyancy attained through MMRTG heating of entrained air
- EDD comm relay to cruise stage/orbiter

*future work to trade additional fault tolerance





Because the tidal wind introduces a significant periodic meridional component to the wind, balloons do not drift just E-W, but sail across a band of latitudes.

Tokano and Lorenz, GCM Simulation of Balloon Trajectories on Titan, *Planetary and Space Science*, **54, 685-694, 2006.**

Balloon Challenges

Balloon-borne science has to be compelling as such – perceived as a riskier platform. Emphasis in NASA balloon program on large exceptionally flimsy-looking balloons is not helpful.

-Why fly a balloon for days/weeks when a rover can last for years ? Measurement at altitude needs justification

- Heavier-than-air vehicles pose challenge in some applications (e.g. Mars survey - Balloons do not have a monopoly on flight)

- Why accept a couple of circumnavigations if an orbiter can give global coverage? (Late 1990s, Mars balloon filled resolution gap – no longer the case…)

- Bandwidth. Balloon information-gathering-capability far exceeds telemetry capability.

Empirical Observation :

NO PLANETARY BALLOON FLIES ALONE

VEGA balloons were adjunct to landers (piggybacked en route to P/Halley)

MARS-96 Balloon was part of larger architecture (penetrators, small stations etc.)

Scout/Discovery efforts at standalone missions have not been successful – science/risk ?

Balloon element in a Titan Flagship a promising opportunity?

What can the balloon program do for us ?

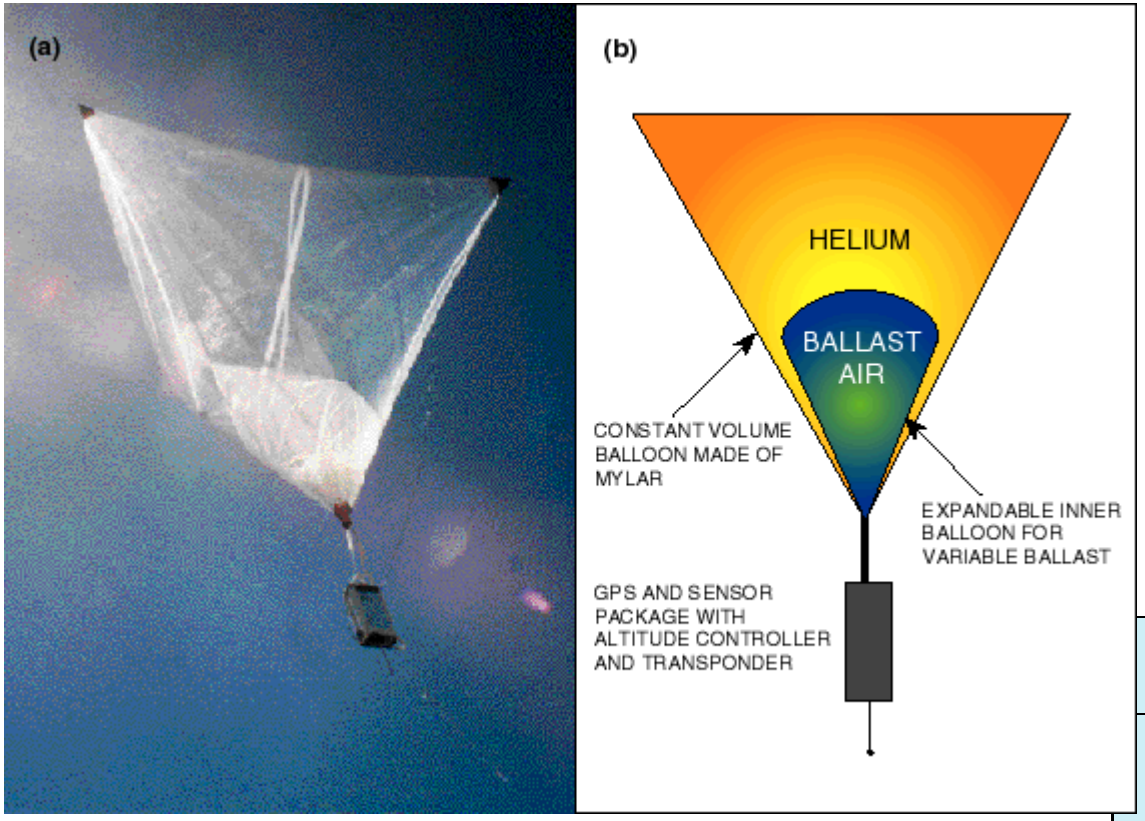
1. Planetary astronomy opportunities (see LCANS talk)
2. Pathfinder for In-Situ Planetary Balloons

Get the message out. Run some terrestrial balloon flights as if they were planetary. This means small!
Multi-balloon missions?

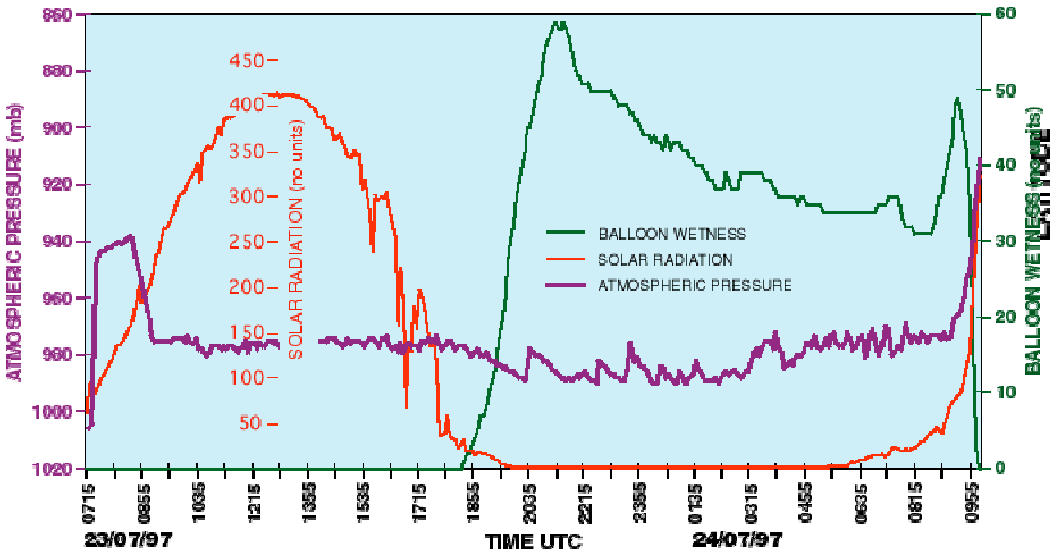
Aerial deployment (drop from a balloon? Aircraft?)
Commercial/tourist high-altitude flight opportunities – more affordable than traditional sounding rockets?

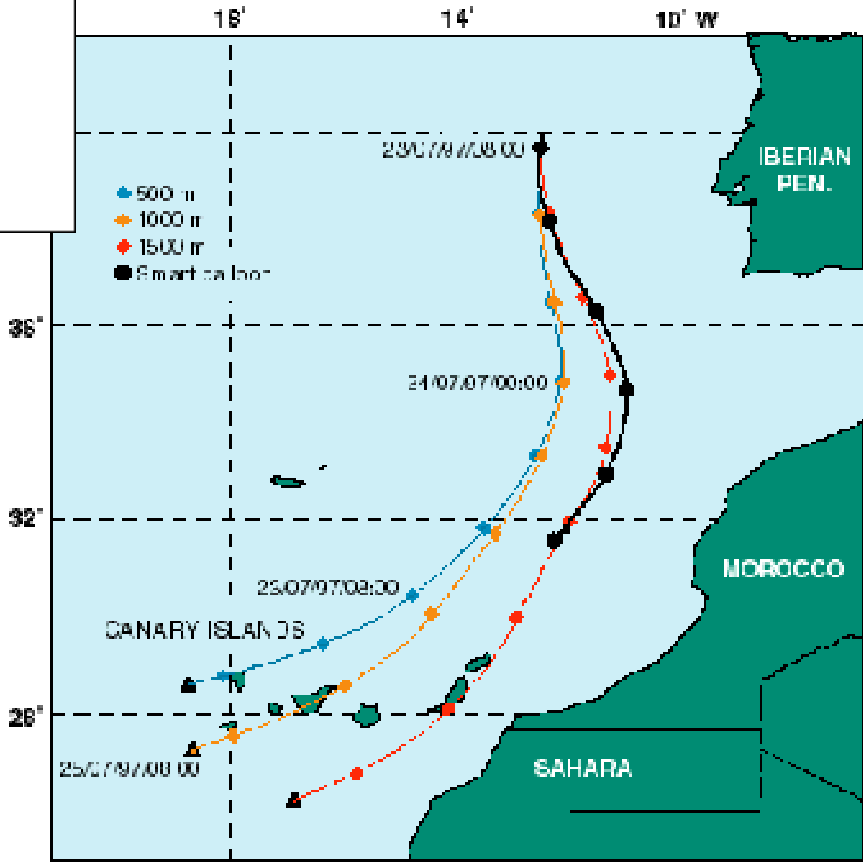
Send lots of pictures! Iridium / TDRS ?

Find some worthwhile science to do.



'Smart Balloon' (tetroon) campaign by Businger et al. http://www.soest.hawaii.edu/MET/Faculty/businger/poster/balloon/





Backup material

A Titan Aerobot Menu

R. D. Lorenz 2/18/07

PASTA	PASsive TitAn balloon	Few kg. Helium. Released from descent probe or lander. No power, instrumentation or communication. Tracked via foil radar reflector or passive transponder (RFID) Could use condensible gas for altitude regulation.
ZORBA	ZOnal Recon BAlloon	~50kg. One RPS (~100W). Montgolfiere or buoyant gas. Omnidirectional comm (DTE and relay) Payload ~5kg : USO for groundbased tracking. Simple camera system. Altimeter. Meteorology (Sky brightness, Pressure, Temperature, Methane humidity) Minimal (no?) commanding.
TABI	TitAn Balloon Investigation	~100kg Montgolfiere. Active altitude control. 1-2 RPS 30kg payload? Camera system, ground-penetrating radar. Aerosol collector and analysis laboratory. Meteorology.
TABASCO	TitAn BAlloon Survey and Collection of Organics	Similar to 2005/6 JPL 'TiPEX' study ~200kg floating mass 2 RPS double-wall Montgolfiere. Active altitude control Steerable antenna for data relay Tether/penetrator sample acquisition system and organic analysis laboratory. IR spectrometer, camera system, gound penetrating radar, meteorology, etc.
TALE	Titan Airship Latitude Excursion	Similar to 2005 JPL and Langley Visions studies. Buoyant gas airship with propulsion giving capability to traverse to different latitudes. 2 RPS. Steerable antenna for data relay Tether/penetrator sample acquisition system and organic analysis laboratory. IR spectrometer, camera system, gound penetrating radar, meteorology, etc.

Helium Balloon at Titan

Advantages

Helium or hydrogen offer much higher lift / volume than hot air.

Envelope can be much smaller. Inflation probably more straightforward.

Light gas balloons are the only effective way of attaining high altitudes (e.g. 80kg payload at 60km altitude requires 13m dia balloon 202kg float mass ; 296kg delivered mass)*

Disadvantages

-For low altitudes especially, helium mass required is not small (dominates over envelope mass). Situation is exacerbated by tankage required for gas. (e.g. 80kg payload at 8km requires 4.2m balloon ; float mass 127kg ; delivered mass 191kg)*

- While low temperatures will lead to slower diffusion, helium balloon is ultimately doomed by loss of gas via diffusion and/or leaks

- No possibility of commandable altitude control (some limit-cycling by condensible fluid could be achieved)

* 0.1 kgm^{-2} envelope. 2kg/kg Tankage