Cross Cutting & Related Technologies: *Planetary Balloons*

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Topics

- Overview
- Aerobot Exploration of the Solar System
- Balloon Envelope Materials and Structures
- Buoyancy and Positional Control
- Landing and Recovery Systems
- Deployment and Inflation
- Design Modeling and simulation

Overview

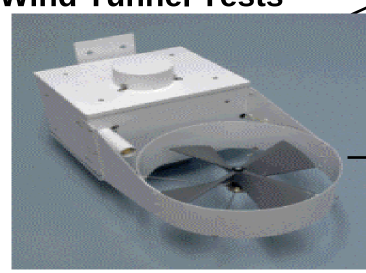
- Planetary Aerobot program at JPL is developing and demonstrating the enabling technology for the exploration of Mars, Venus and Titan with lighter-then-air vehicles
- There are a number of technologies that are common between Planetary Aerobots and the use of scientific balloons in the Earth's stratosphere
- This emphasis of this presentation is on the common elements as defined by JPL and Wallops Flight Facility staff

Visit the Planetary Aerobot Program website at
http://robotics.jpl.nasa.gov/aerobot

AEROBOT EXPLORATION OF THE SOLAR SYSTEM

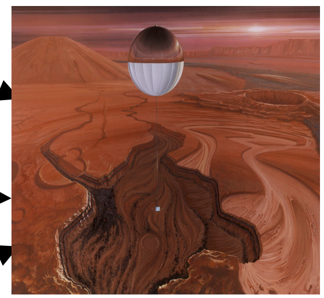
Freeflight Atmospheric Tests

Wind Tunnel Tests

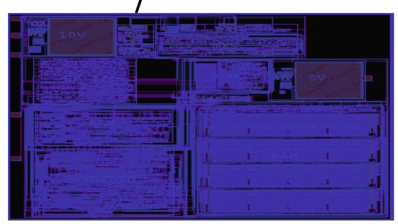


Test payloads

Mars Balloon Microlander

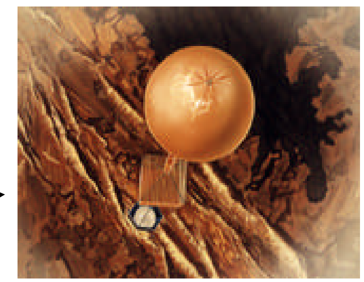


Mars Aerobot Technology Experiment



Miniaturized Electronics

Mars Geoscience Aerobot



Venus Geoscience Aerobot

Titan Biological Explorer

MARS BALLOON VS ULDB

PARAMETER	MARS BALLOON	ULDB
PAYLOAD	2-5 kg	1600 kg
ALTITUDE	5 km 35 km Earth Equivalent	35 km
PRESSURE AT FLOAT	3-8 mbar	4-6 mbar
MATERIAL DENSITY	<10 g/m2	62 g/m2
SIZE	Spherical 10-12 m diameter	Oblate 79 m high 128 m diameter
DEPLOYMENT/INFLATION	AERIAL	GROUND
INFLATION TIME	60-100	NOT LIMITED
LIFE TIME	7-100 days	100-300 days

BALLOON ENVELOPE MATERIALS AND STRUCTURES
Technology Needs

- High strength to weight composite envelope materials suitable for fabrication into balloon vehicles
- Materials tolerant of a wide range of environmental conditions including extreme temperatures, intense UV environment and acidic environments for planetary balloon applications
- Efficient and cost effective balloon envelope seaming fabrication and inspection techniques
- Techniques for contamination and sterilization of planetary balloon materials to meet planetary protection requirements
- Advanced balloon designs - spherical and oblate

Advanced Balloon Envelope Technology

Projected performance gains

ITEMS	STRATOSPHERIC BALLOONS			PLANETARY AEROBOTS MARS		
	Today	5 yrs	10 yrs	Today	2 yrs	10 yrs
Payload Fraction						
Zero Pressure	70%	Same	Same	NA	60%	80%
Superpressure	40% (ULDB)	50%	70%	NA	30%	50%
Lifetime (days)						
Zero Pressure	2-20	Same	Same	NA	2-5	Same
Superpressure	100	200	1000	NA	100	500

Material and Fabrication Development
Potential breakthrough technologies

- Composite materials technology - this technology has applications to both earth and planetary superpressure balloons
- Precision fabrication techniques - highly accurate cutting and assembly methods
- Advances in materials - the use of high strength materials such as Kevlar and PBO - for example as part of these composites.

Buoyancy and positional control
Technology Needs:

Buoyancy control methods involving no consumables and low mass renewable power systems to

limit balloon diurnal altitude excursions

limit temperature/differential pressure fluctuations

provide an altitude control capability

Latitude trajectory control techniques using altitude control and other active devices for exploiting variations in wind velocity with altitude

Parametric wind models derived from Global Circulation Models and large data sets for use in simulation and real time control and enable global reconnaissance of the planets.

Buoyancy and Positional Control
MISSION BENEFITS

- Stratospheric Balloons
  - Limiting the environmental stresses on the balloon may be a more cost effective means of extending lifetime or payload fraction than employing advanced materials
  - Control of latitude, which can be enabled by buoyancy control can avoid overflight of certain geographic areas
  - Control of altitude as well as latitude also makes it possible to sample the atmospheric properties in different air masses
  - Increased duration and trajectory control could enable balloon-borne interferometry missions.
- Solar System Exploration
  - As for Earth missions PLUS
  - Overfly desired targets
  - Deploy probes to surface targets

Buoyancy and positional control
Technology Approaches

Ballonets - here the requirement is for more efficient pumps to optimize the use of energy in altitude control.

Solar heated hot air balloons using venting - likely important in planetary applications

Lifting or drag bodies attached to tethers - can be effective on planets with low gravity and high wind shear.

Lifting gas replenishment systems

Variable radiative property materials

Phase change materials

Landing and recovery systems
Technology Needs

- Parafoil and decelerator systems for
  - recovery of terrestrial ballooncraft
  - earth testing of planetary aerobot concepts
- Balloon systems for soft landing of fragile payloads
- Parachute and parafoil systems for precision targeting of terrestrial payloads and of planetary probes and sondes.

Details covered in companion presentation

Aerial Deployment and Inflation
Technology Needs

Robust deployment and inflation of balloon envelopes
- Low turbulence diffuser systems
- Innovative envelope deployment systems

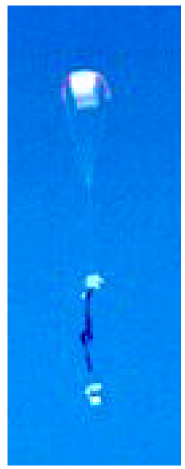
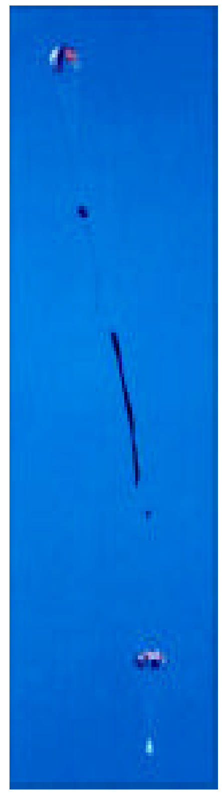
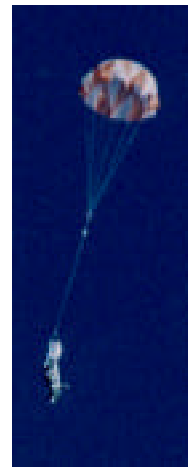
Lightweight inflation systems for planetary exploration which are a factor of two lighter and more compact than current brassboard systems

Ultra-lightweight inflation system components
- Miniaturization of valves and tanks
- Lightweight pressure regulators
- Innovative gas generators

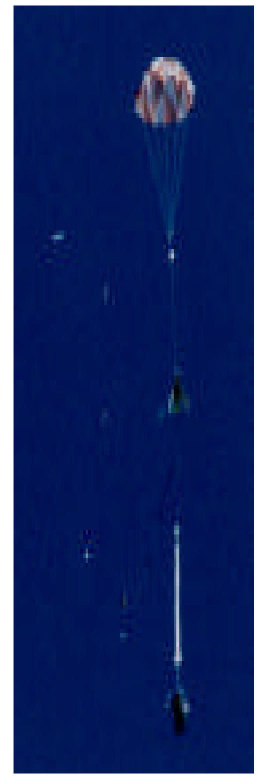
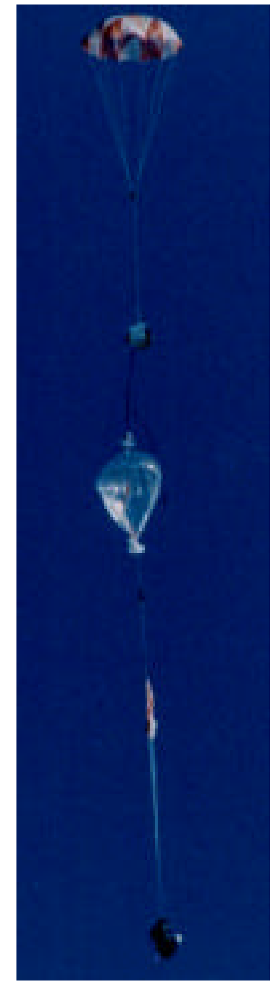
No direct ULDB Benefit

PLANETARY AEROBOT
DEPLOYMENT AND INFLATION TESTS

HELICOPTER LIFTING PAYLOAD

TEST 2
DEPLOYMENT LOAD TESTS

TEST 3
DEPLOYMENT & INFLATION

Design, modeling and simulation
Technology Needs

- System trade models for balloon systems and aerobots
- Structural modeling of fabrics
- Detailed thermodynamic models of balloon inflation systems
- 3 D CFD models of deployment and inflation of balloons
- Improved radiative and convective transfer models
- New, more meaningful material testing methods
- Non-intrusive strain and temperature measurement devices

Summary

- Robotic balloons will play a key role in NASA's in situ exploration of the planets
- New technology is key to developing aerobots with high payload fractions
- Synergy with ULDB program and other terrestrial scientific balloon efforts is the key to rapid technology insertion
- JPL encourages industry involvement at all phases of the technology readiness cycle