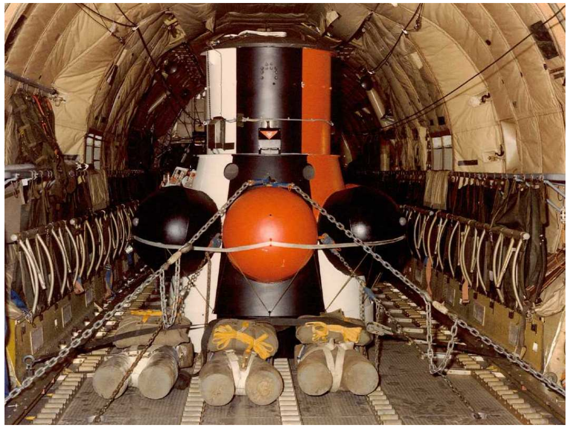
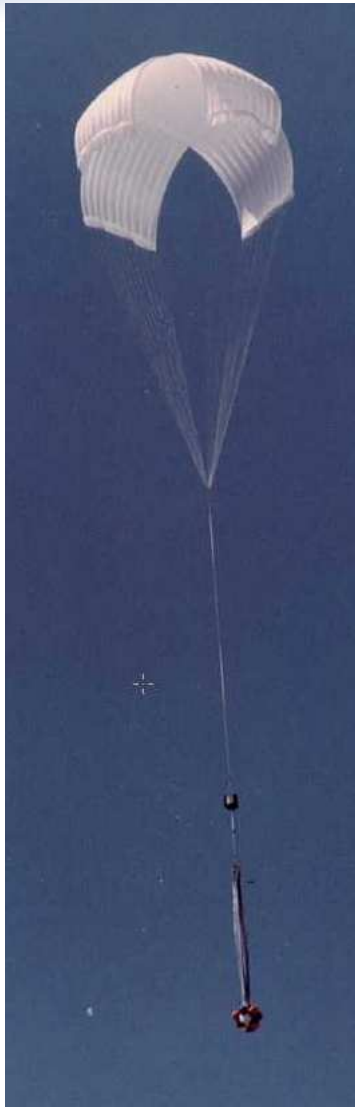
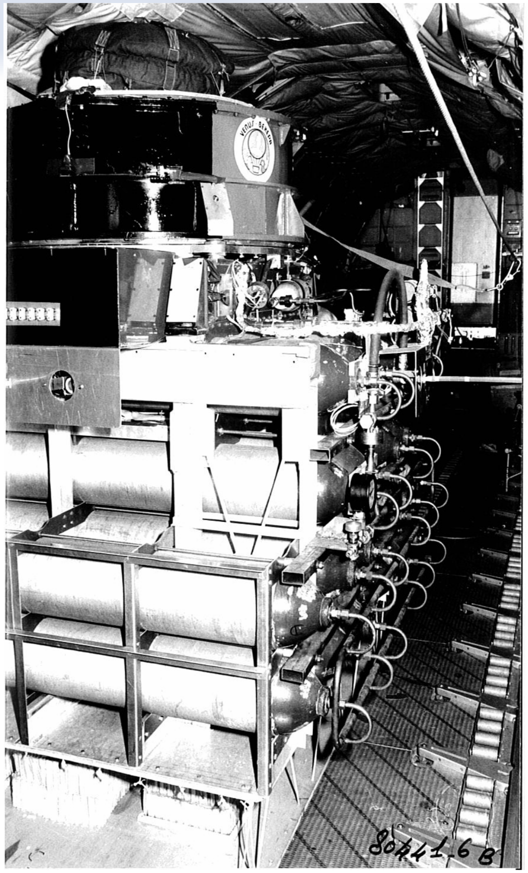
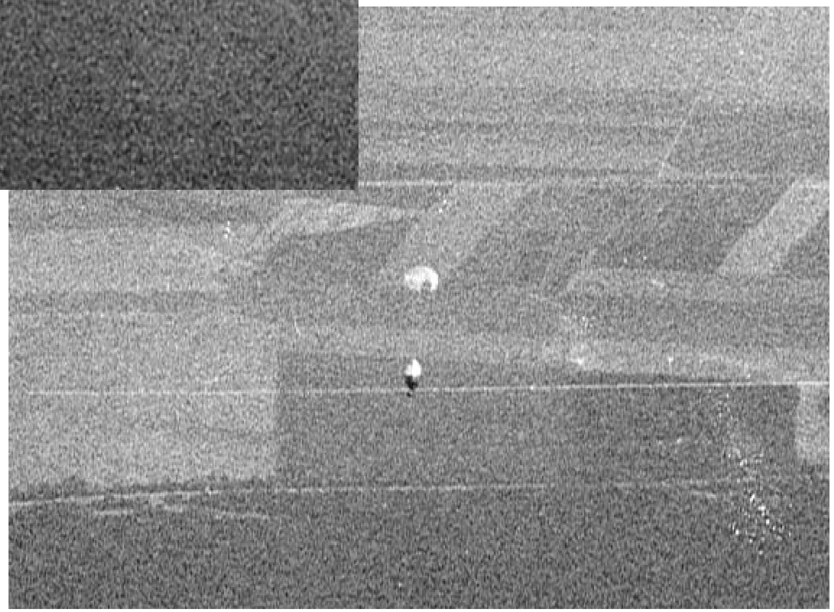
In Flight Deployment of the Venera Balloon





In Flight Deployment & Inflation of Venera Balloon



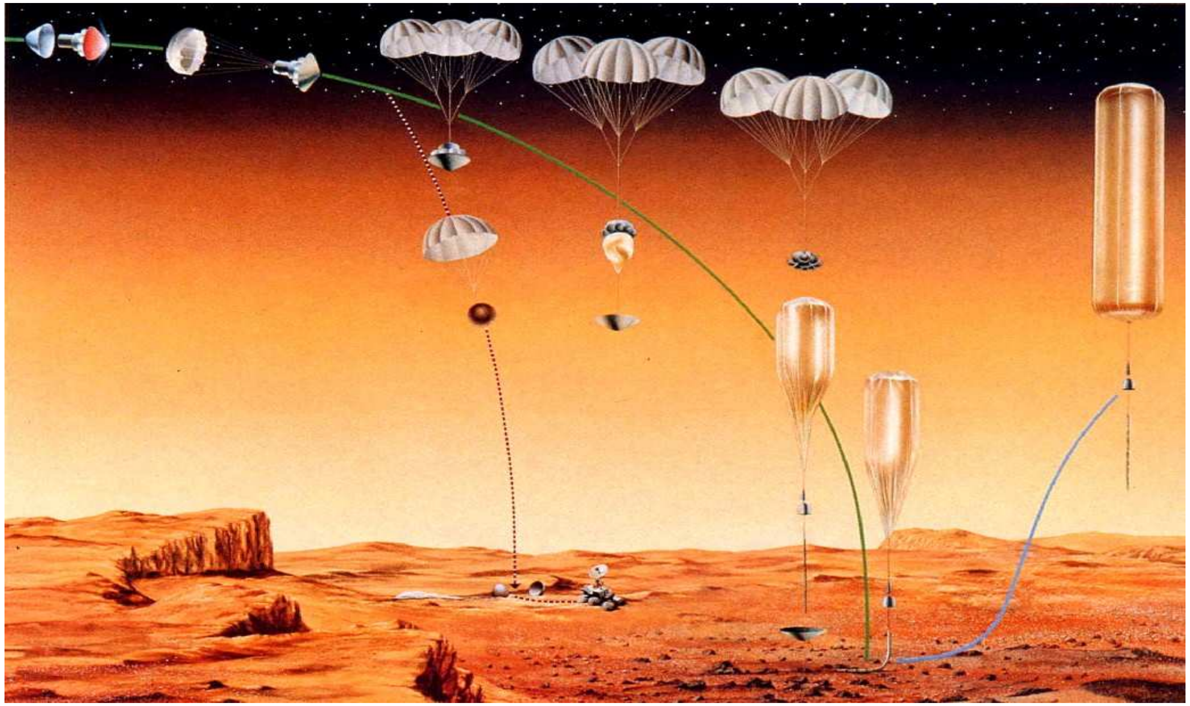


Mars 96 : Russian – French Collaboration for a Mars Balloon

- From 1989 à 1995, within the frame of the Russian - French mission Mars 94 – 96, CNES developed a planetary balloon with a guiderope (GR)

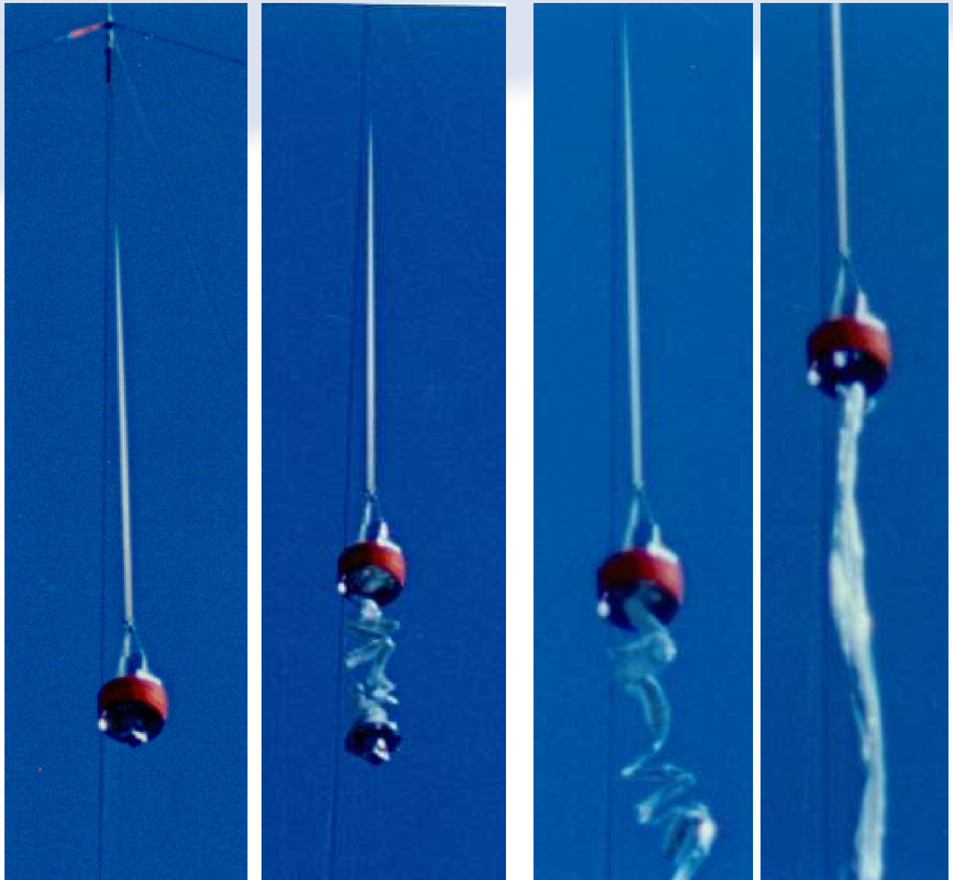
- **Basic characteristics** :

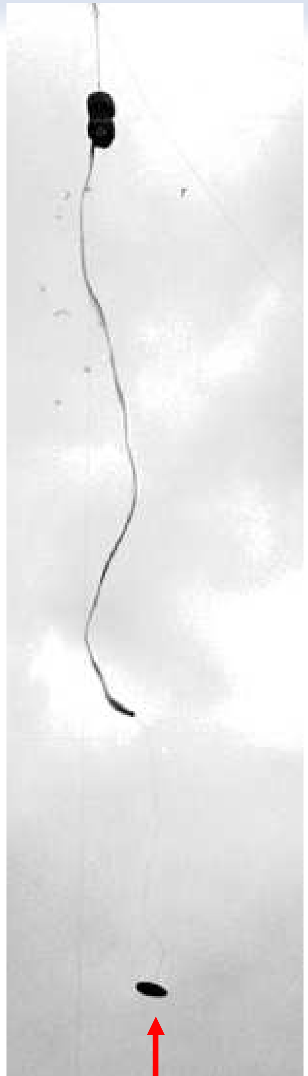
Balloon mass : 30 kg
Gondola mass : 15 kg
Guide rope mass : 13 kg
Floating mass : 65 kg
Balloon volume : 5500 m^3
Balloon height : 42 m
Balloon diameter : 13,5 m
Riser lengths:
 - Balloon – Gondola : 20 m
 - Gondola - GR : 25 m
Lifetime : 10 days

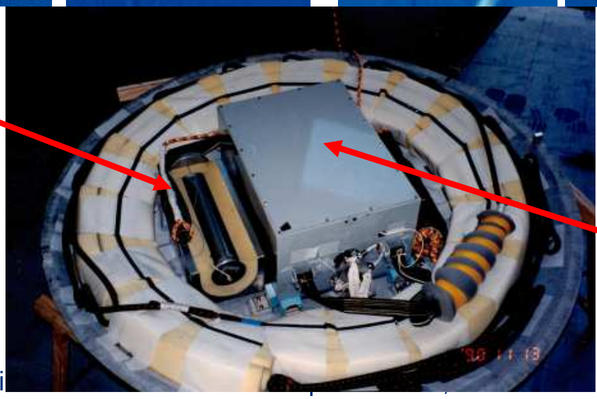


Mars 96 : Gas Leakage Testing

Mars 96 : Static Deployment Testing





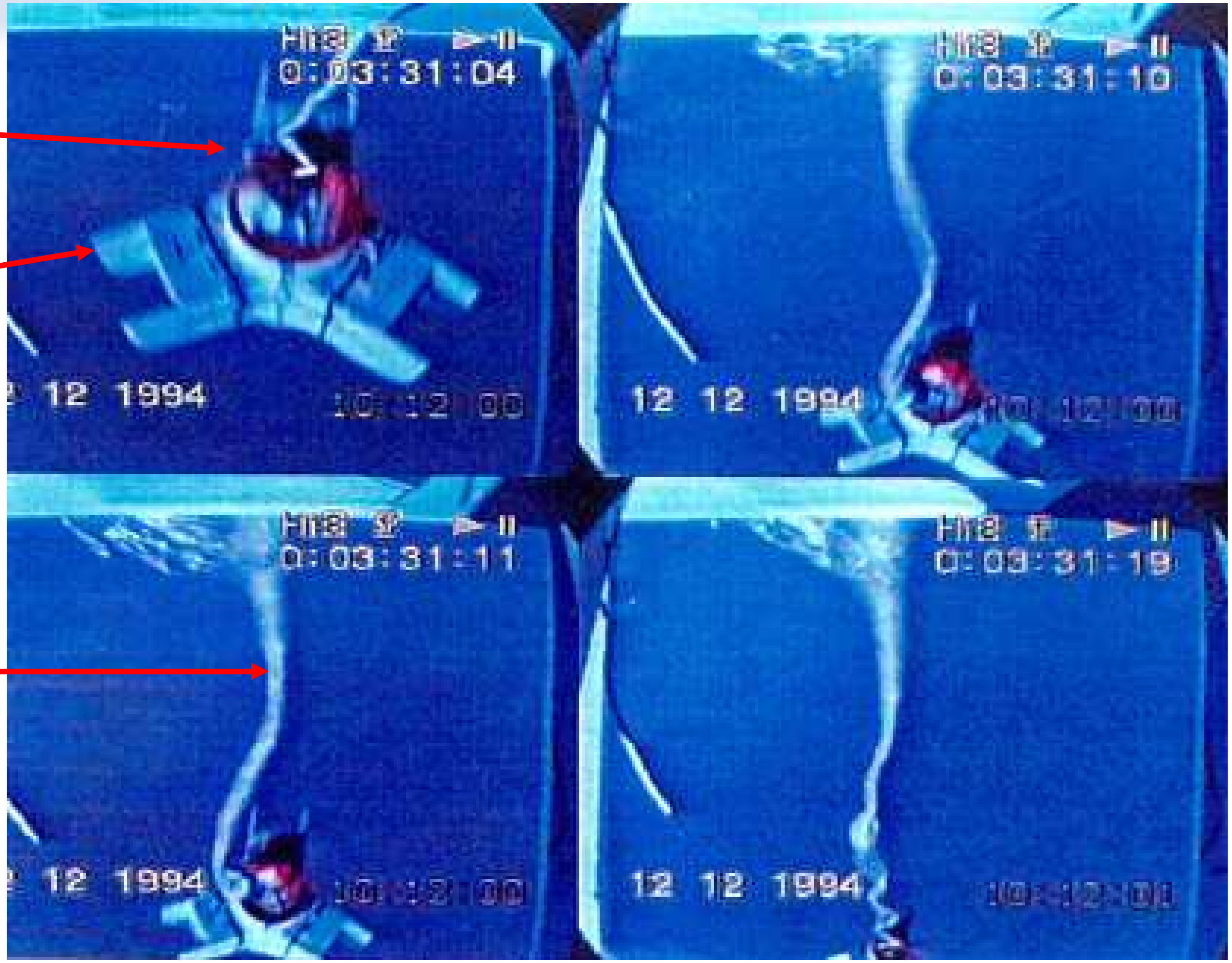


In Flight Deployment Testing (Scaled Balloon)

BALLON CONTAINER

HEAT SHIELD
(mock-up)

DEPLOYED BALLOON

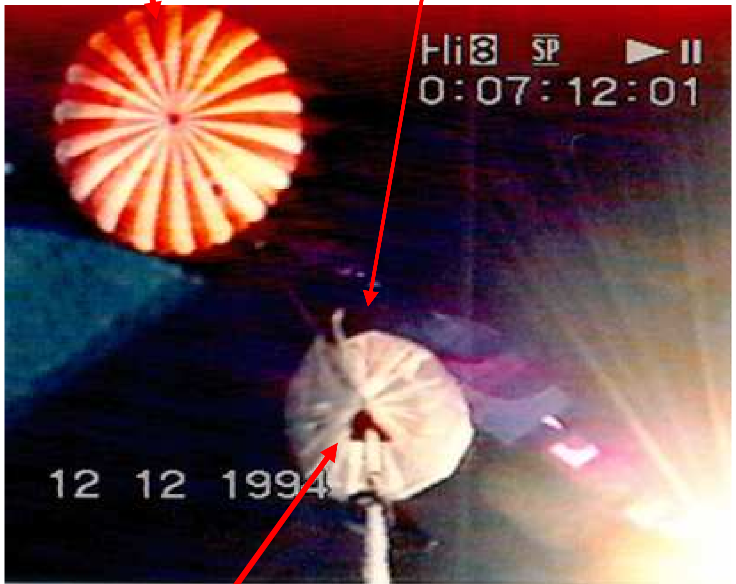


(TOP VIEW)

In Flight Deployment & Inflation Testing (Scaled Balloon)

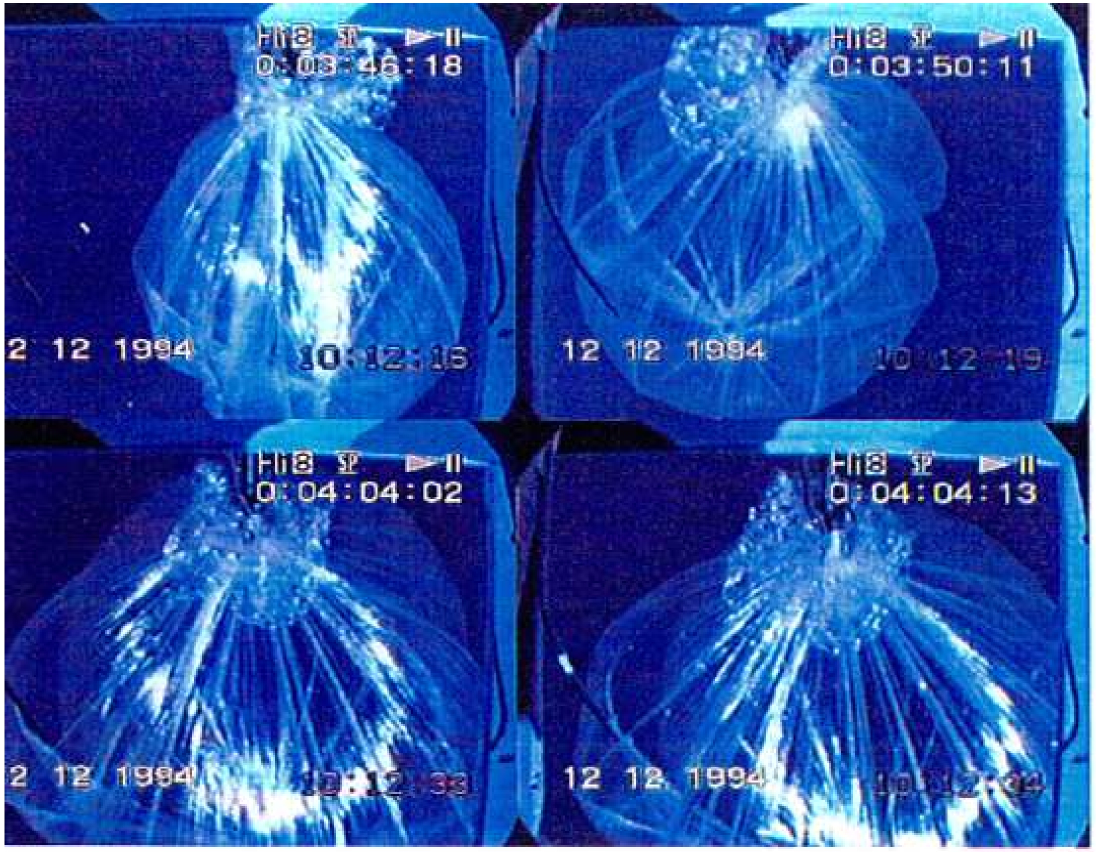
PARACHUTE

INFLATION SYSTEM
(hidden by balloon)



BALLOON

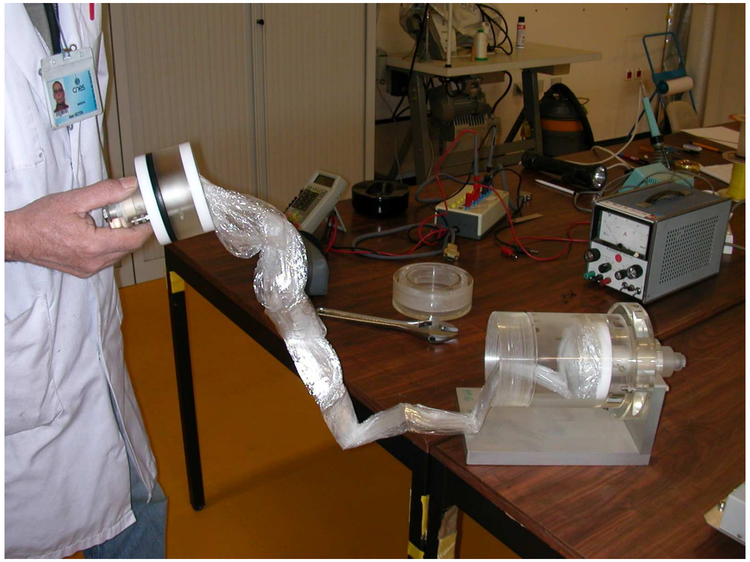
(BOTTOM VIEW)



(TOP VIEW)

Long Duration Storage of Packed Balloon

- **In March 2005, unpacking of a Mars 96 small scale balloon**
  - **polyester balloon of 6 µm thickness**
  - **stored in the early 90's**



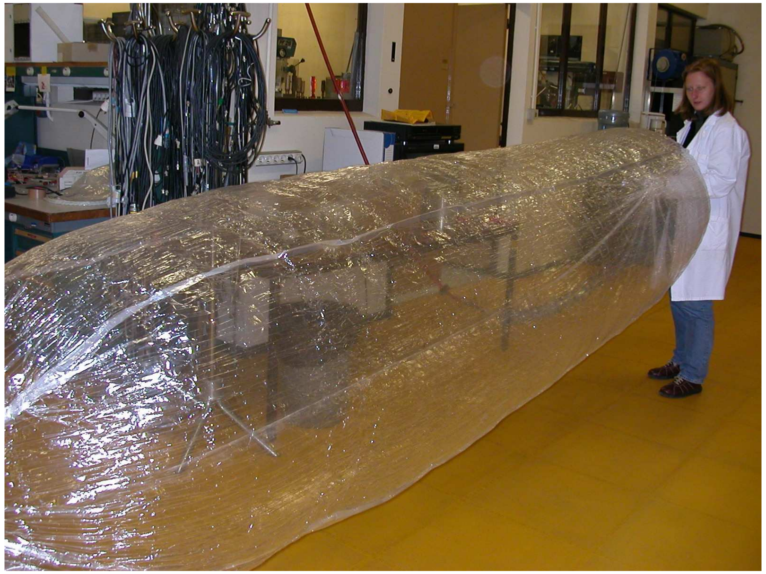
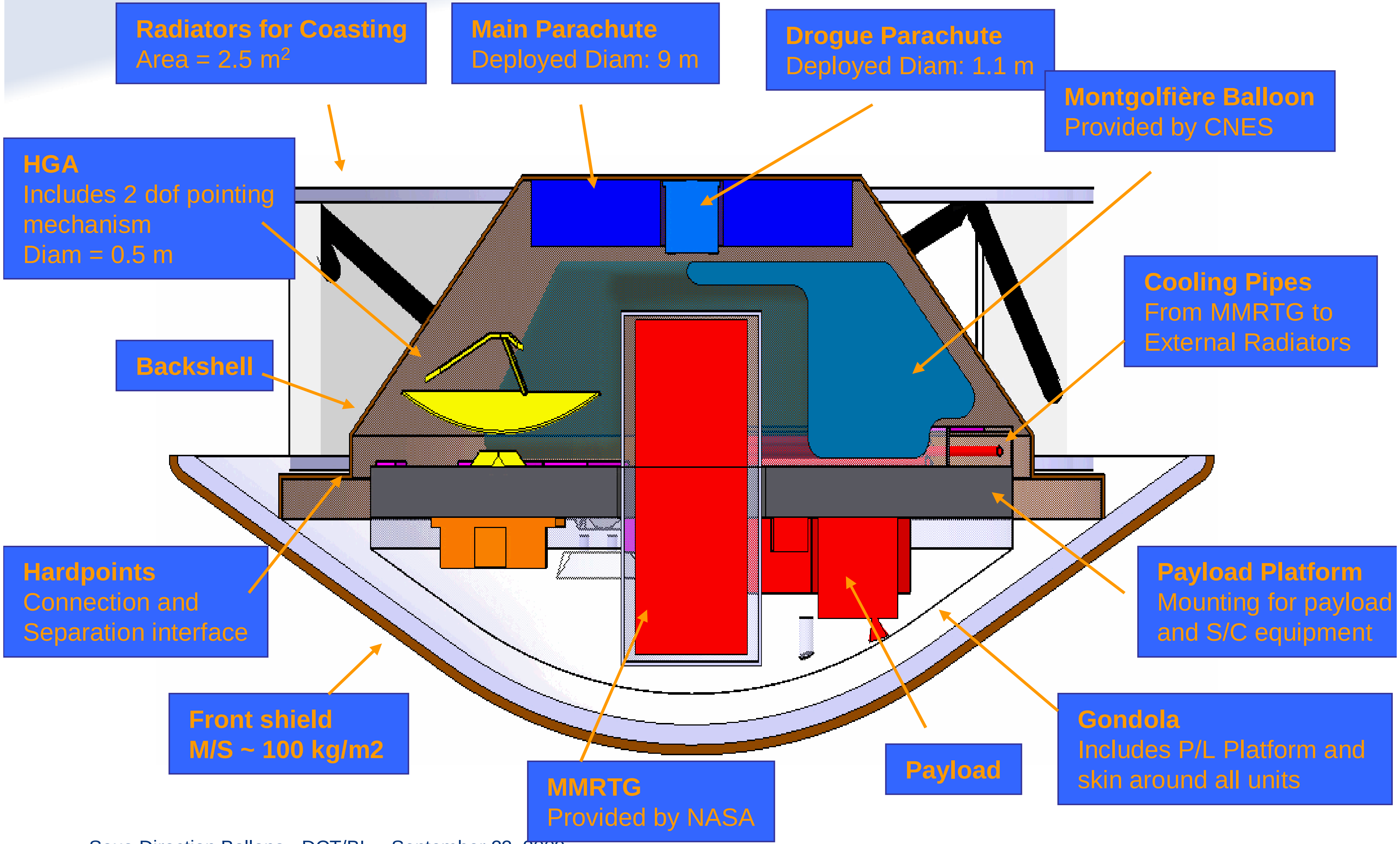


Table of Content

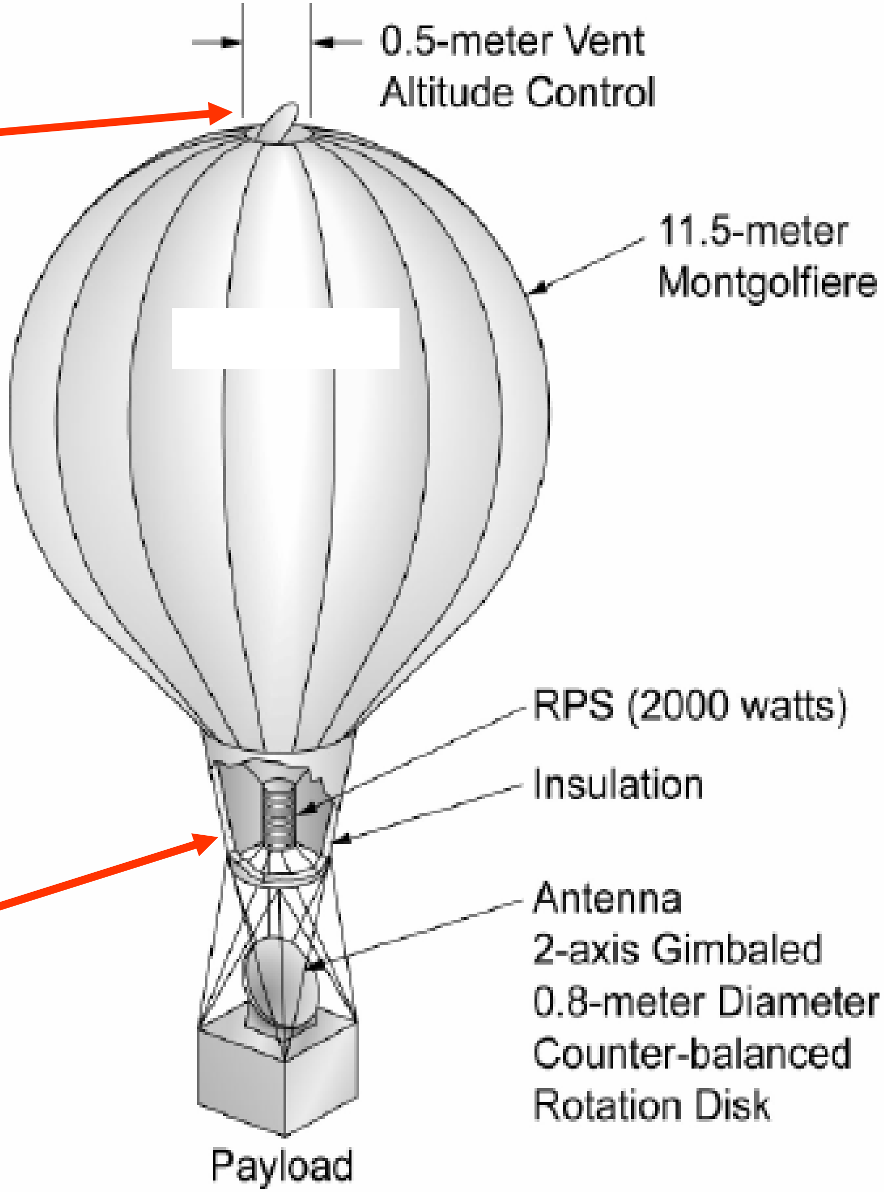
Montgolfière Probe – Overall Configuration



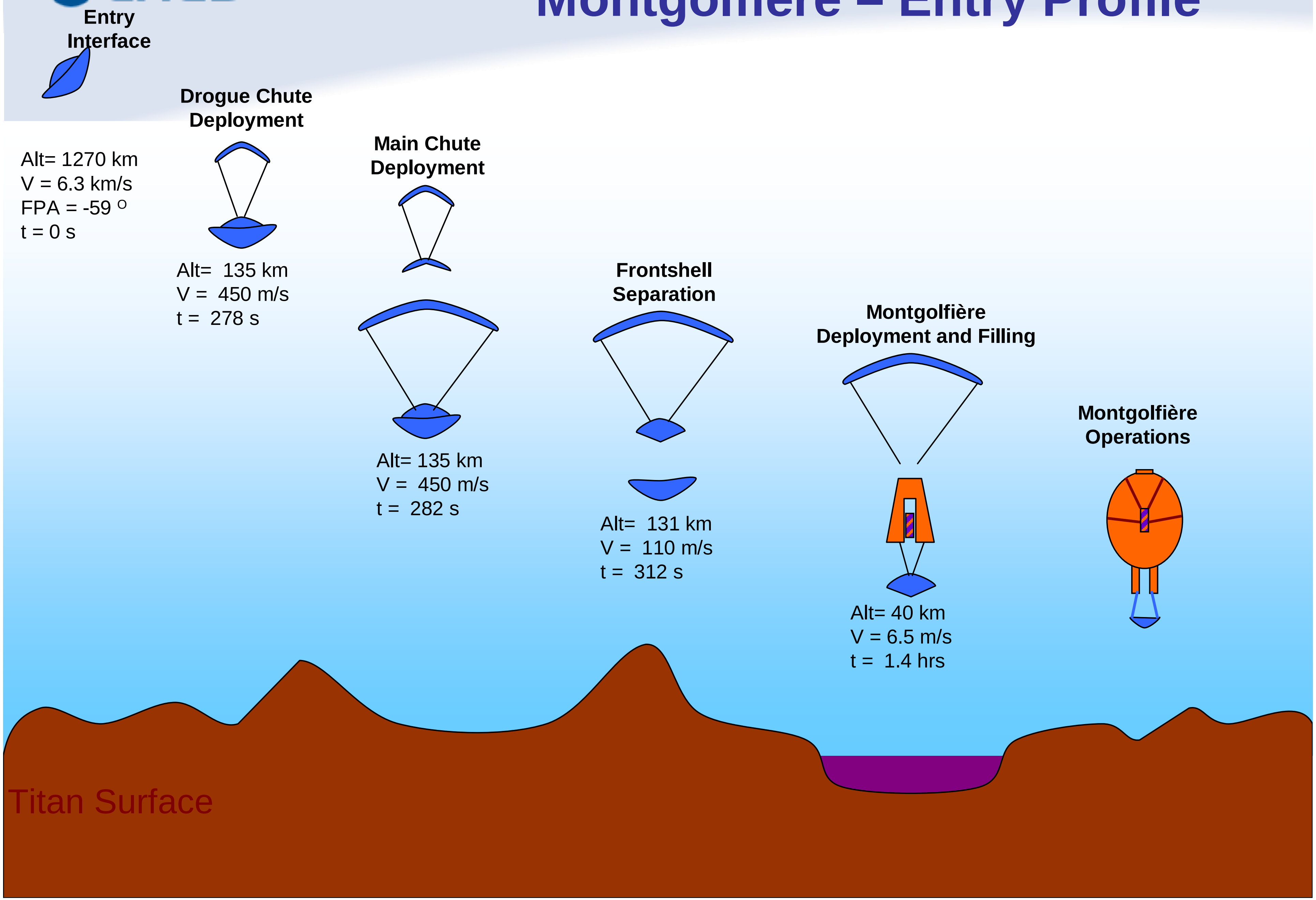
Preliminary Design of Montgolfière Balloon

Main characteristics of the Montgolfière balloon :

- Venting valve (sky pole) to monitor the balloon altitude
- Montgolfière balloon :
  - Double wall balloon
  - Diameter : 11,5 m
  - Envelope material : 55 g/m²
  - Balloon mass : ~ 70 kg
- Gondola :
  - Total mass : ~ 155 kg (incl. 24 kg payload)
- MMRTG :
  - Inside the balloon (lower half)
  - Suspended from the sky pole
  - Mass : ~ 45 kg
- Total Mass : 270 kg

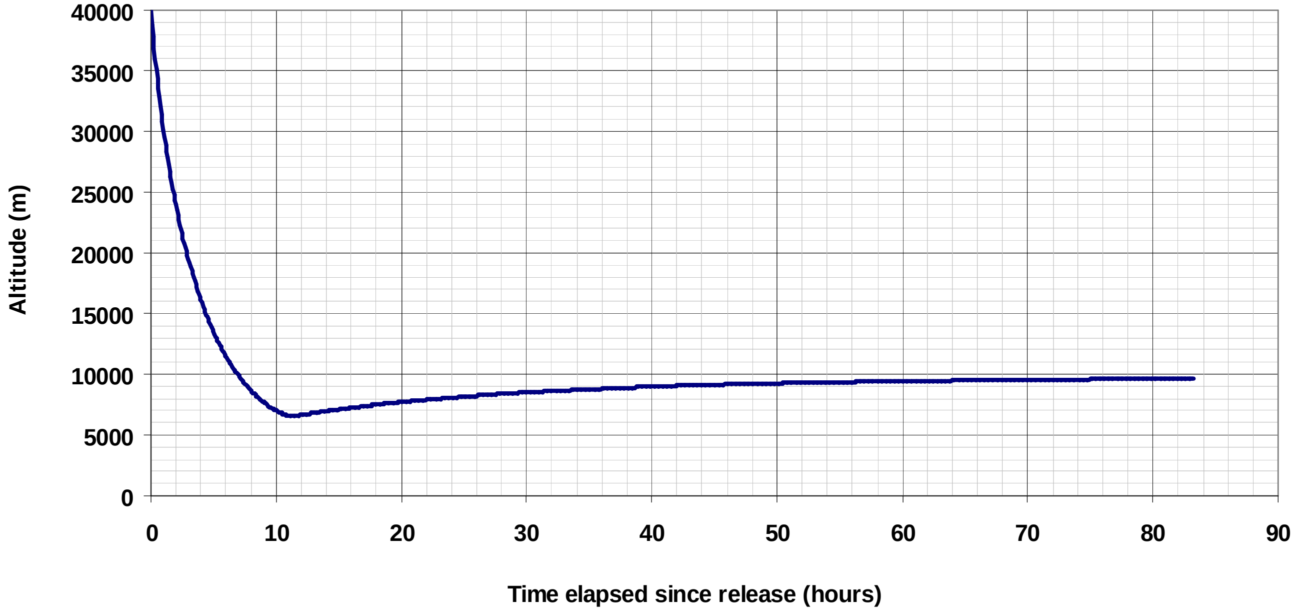


Montgolfière – Entry Profile



Montgolfière Balloon Mission Profile

- Beginning of the balloon deployment
  - Altitude : ~ 40 km
  - Velocity : ~ 5 m / s
- About 10 hours of descent before ascent at flight level
- Montgolfière nominal operations at ~10 km above surface
- Montgolfière drift provided by winds (passive system)
- Mission lifetime: 6 months (goal: extension to 1 year)



CNES Support to the Titan Montgolfière

- **Provision of balloon system**
  - Montgolfière Balloon with valve for altitude control
  - Balloon container with deployment devices
- **Support of feasibility study w.r.t. critical points**
  - Engineering work for flight physics analysis with Computational Fluid Dynamics tools (cross checking with JPL)
  - Development of balloon fabrication techniques
  - Fabrication of prototypes of balloon systems
  - Fabrication and demonstration of packaging technique
  - Demonstration of the deployment and filling feasibility

Balloon Design Issue Assessment (1/3)

- **Balloon design (JPL & CNES)**
  - Science requirement : payload mass and float level
  - Envelope material requirements
  - Gas heating performance during deployment
  - Balloon requirements : bottom hole, valve, double wall,…
  - Mechanical interfaces with gondola & EDS
- **Envelope material requirements :**
  - Balloon packing (vacuum / residual air) with electrical cable (valve activation) & MMRTG attachment lines
  - Envelope sterilization by irradiation (planetary protection) - TBC
  - Long duration (10 years) storage phase (risk of sticking)
  - Impact of MMRTG radiation (neutrons)
  - Thermal shock at deployment
  - 80 to 90 K atmosphere temperature during flight

cnes

Balloon Design Issue Assessment (2/3)

- Design of the balloon
  - Positioning / connection of the two envelopes
  - Design of the inlet ring for the inner / outer envelopes
  - Design of the balloon sky pole including the MMRTG lines
  - Design of the gondola attachment lines
- Manufacturing of the balloon : adaptation of the assembly machine as required
- Valve design for operation at very low temperature
- Design of the balloon container :
  - ‘rip-stitch’ straps for damping the envelope mechanical load at deployment shock
  - ‘Separation nuts’ for container opening
  - Separation device between sky pole and the container

Balloon Design Issue Assessment (3/3)

- **Validation of balloon deployment / filling phase**
  - Balloon deployment with MMRTG positioning within the balloon (lower half)
  - Deployment and filling of the double wall structure
  - Efficiency of gas heating during deployment
- **Strategy for validation of deployment / filling phase**
  - No facility available for full scale (deployed / filled) balloon testing in temperature
  - Development of a deployment model for validate cinematic and assess mechanical loads in the balloon system
  - Ground and in flight tests (similarity criterion Titan / Earth) to validate cinematic and mechanic loads with small scale and full scale balloons
  - Mechanic test of material in Titan thermal shock conditions to assess impact on material tensile strength
  - Heating efficiency validated with small scale balloon tested in Titan temperature condition (Raleigh & Reynolds numbers appropriate)

Proposal for CNES Phase A studies (1/2)

- The development, to be carried out in Phase A of Titan Montgolfière design, are split in 2 steps over 2 calendar periods
- Step 1 (2009-2010) : studies are focused on feasibility of the most critical issues identified in the JPL / ESA/ CNES TandEM study :
  - Validation of the heating performance of the balloon by the radioactive source MMRTG
  - Development of balloon material and fabrication technique
  - Validation of storage, deployment and filling concepts with a small scale balloon (ground testing)
- Step 2 (2011-2013): studies will focus on baseline architecture selected in Step 1 :
  - Fabrication of a full scale balloon prototype system
  - Validation of storage, deployment and filling with full scale balloon (in flight testing)
  - Validation of models from experimental data
- Phase A must demonstrate TRL 5-6 for balloon system

Proposal for CNES Phase A studies (2/2)

	Risk Reduction Tasks 2010 - 2011
Balloon material	Procurement & testing (cyclic stress, ability to stick, irradiation, ..) of potential materials for envelope Storage of samples in vacuumed containers for later examination after unfolding
Assembly technique	Gore assembly technique and assembly performance testing Prototype assembly for double wall envelope
Packing concept	Fabrication of sub-scale models of the envelop & container Packing design (folding the balloon in the container)
Deployment system	Development systems for on ground deployment tests (crane)
Balloon valve	Verification of design principle at low temperature (cryogenic technique)
Engineering	Numerical simulation of deployment of balloon system Numerical & experimental simulation of gas heating in the balloon (descent & at float) Mechanical design of the packing system (container, attachment lines, ..) Thermal analysis of the packed configuration
Balloon fabrication	Development of a sub-scale balloon system (envelope, container, ..)
Environment testing	Packing of the sub-scale balloon Vacuum tests for the packed balloon
Deployment	Ground deployment tests (crane) of the sub-scale balloon
Deployment & Filling	Ground deployment and filling tests in vertical wind tunnel
I/F with gondola	Preliminary definition of I/F with gondola
I/F with EDS	Preliminary definition of I/F with EDS

Verifications Foreseen in Phase A (1/2)

■ Before balloon deployment in Titan atmosphere

Design Issue	Cnes relevant Background	Phase A
Balloon packing under vacuum	Earth super pressure balloons (BPS) are packed in containers but with a lower level of vacuum Folding of Mars balloon (light : polyester) and Venera balloon (strong : Kevlar)	Step 1 & 2
Launch environment (vibrations, ..)	BPS packed are transported throughout the world	No tests
Aging of the balloon envelope phase MMRTG radiation effect on balloon material and associated equipments	Aging, in Earth standard atmospheric conditions, of Mars 96 & Venera balloon material (> 10 years) Experiments on Mars 96 balloon material : 7 Mrad without degradation	Step 1
Thermal environment of balloon during probe atmospheric entry	Experience on maximum temperature limit for polyester based material (BPS)	Requirement TBD

Verifications Foreseen in Phase A (2/2)

- **After balloon deployment in Titan atmosphere**

Design Issue	Cnes relevant Background	Phase A
Balloon deployment and filling	Deployment of Mars 96 and Venera balloons Inflation (not filling) of both Mars & Venus balloons (partly relevant because of inflation by gas injection)	Step 1 & 2
Balloon heating during atmospheric descent	CDF/Thermal unsteady modeling of Earth Infrared Montgolfière and validation against flight data	Step 1 & 2
Valve operation reliability during balloon flight operation	Mechanism for Mars 96 balloon and for Earth stratospheric balloons (valve)	Step 1