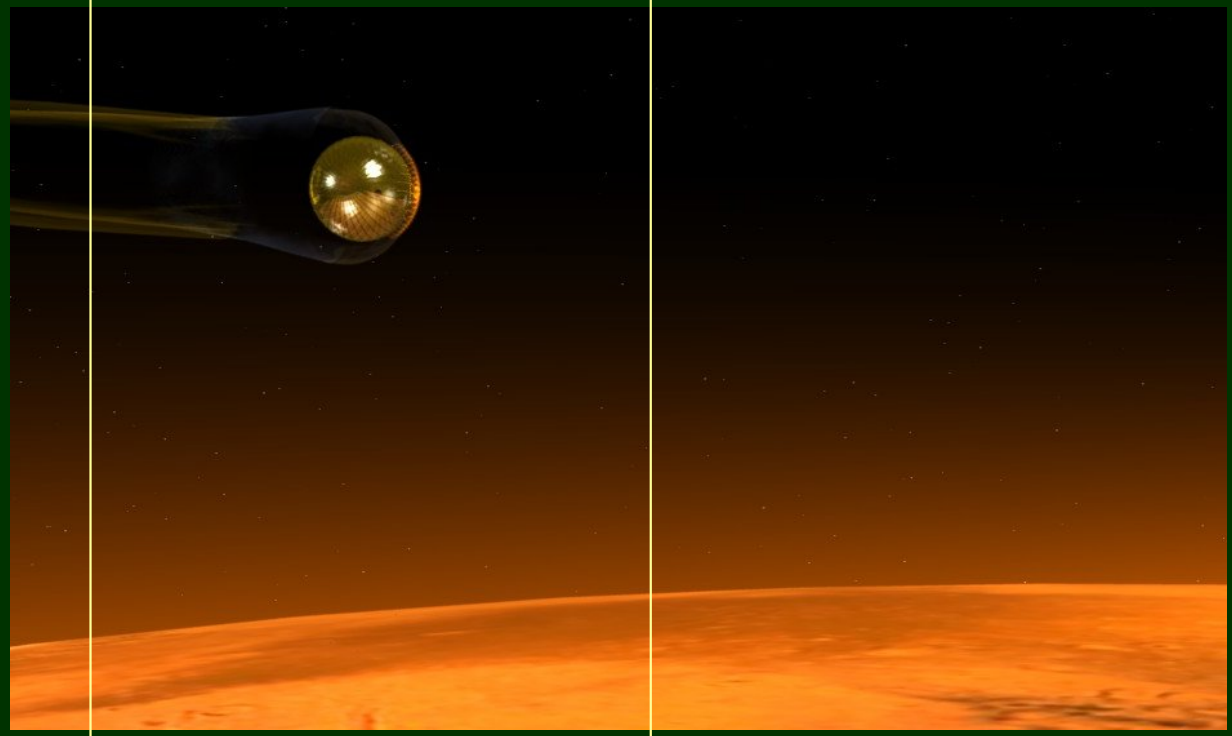
Reaching High Altitudes in Planetary Atmospheres with the

ARCHIMEDES *Hypersonic Drag Ballute*



Hannes Griebel

VEGA Deutschland GmbH

Mars Society Deutschland e.V

ARCHIMEDES Chief Engineer & Programme Manager

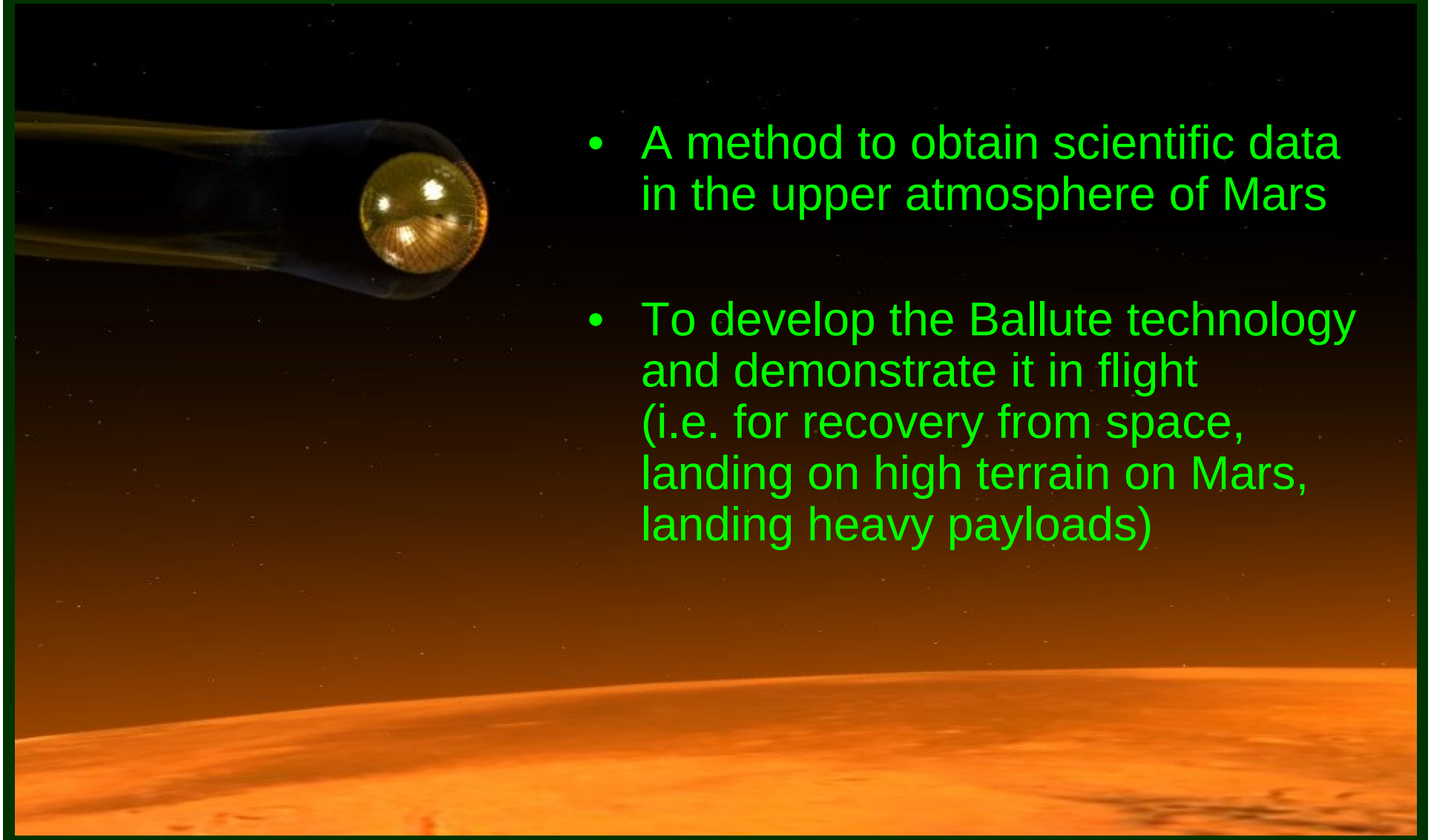
10.06.2010

MARS SOCIETY DEUTSCHLAND E.V.

der Bundeswehr Universität München

Overview

Development Goal

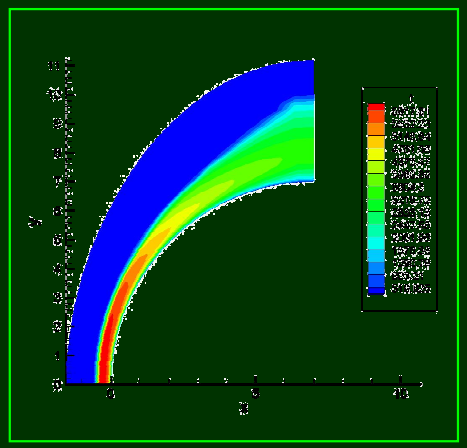


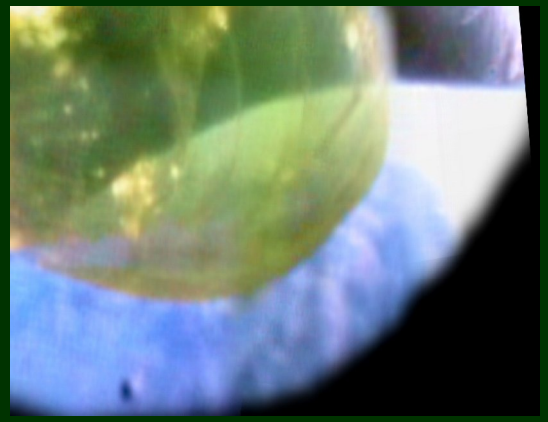
- A method to obtain scientific data in the upper atmosphere of Mars
- To develop the Ballute technology and demonstrate it in flight (i.e. for recovery from space, landing on high terrain on Mars, landing heavy payloads)

Development Programmes

- ARCHIMATTER: material science
- ARCHYFLOW: Aerothermodynamics and flight dynamics
- CLEOPATRA: Space operations and flight testing

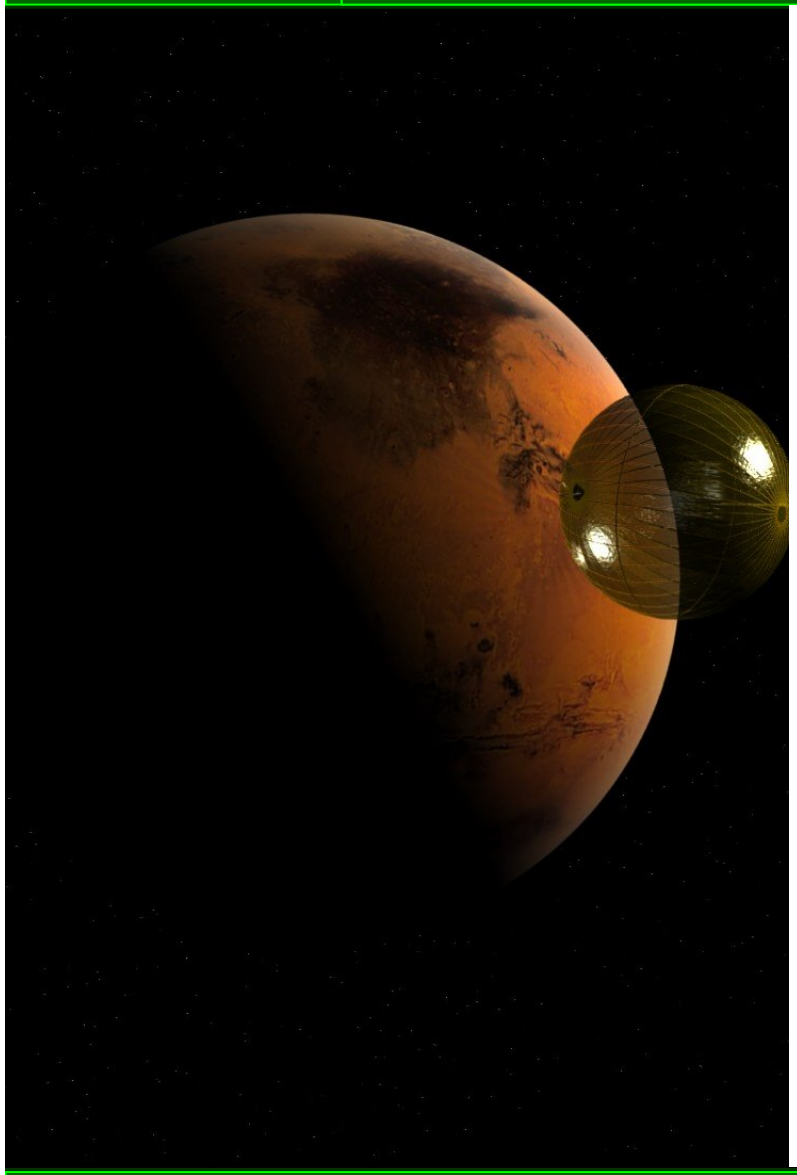
- Supported by:
  UBW, Lohmann Tapes Neuwied, IABG Ottobrunn, DLR MORABA





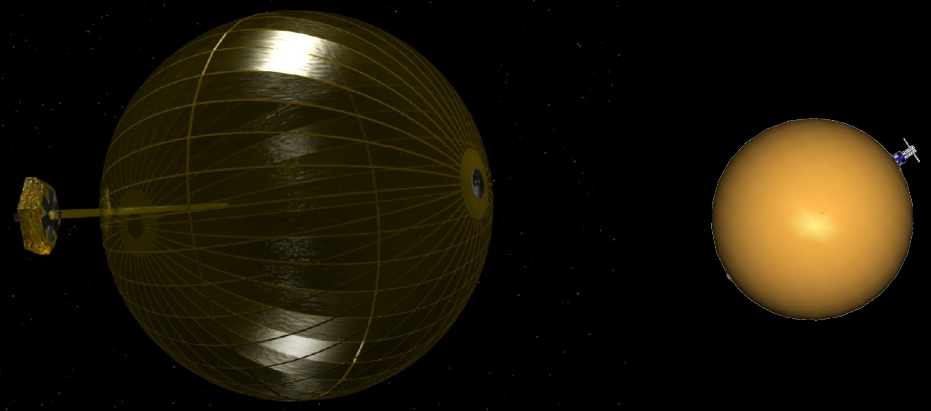
System & Mission Design

Archimedes Overview



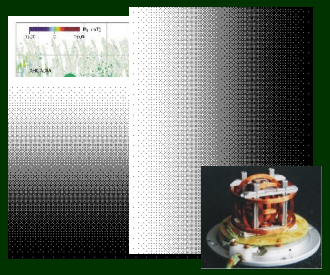
- Hypersonic drag balloon (BALLUTE) for atmospheric sounding
- Designed for Mars, but works on other planets as well…
- Technology demonstrator
- International cooperation between Mars Society Germany, University of the Federal Armed Forces.

System Design
(MIRIAM & ARCHIMEDES)

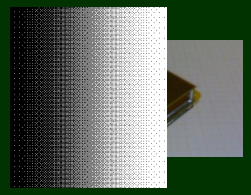


Item	ARCHIMEDES Mars Mission	MIRIAM Earth Test	Relation
Mass Instrument Pod [kg]	ca. 18.3	2.9	1 : 6.3
Mass Ballute [kg]	ca. 15.1	2.6	1 : 5.8
Mass EV [kg]	ca. 33.2	5.4	1 : 6.1
Pod : Ballute [-]	ca. 1.21	1.12	1 : 1.08
Ballist. Coeff. [kg / m²]	ca. 0.54	0.59	1 : 0.92
Ballute Diameter [m]	ca. 10	ca. 4	1 : 2.5

ARCHIMEDES: Suggested Payload

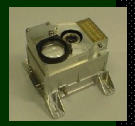


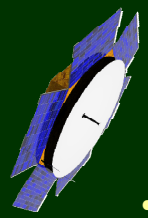
- Magnetic field / Solar Wind Interaction
  IGEP, TU Braunschweig
  K.H. Glassmeier



- Environmental Sensors
  Finnish Meteorological Institute
  A.-M. Harri, J.Polkko

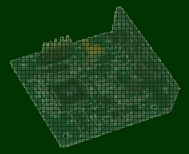
- High Resolution Camera
  Institut für Planetenerkundung, DLR Berlin
  H.Hoffmann



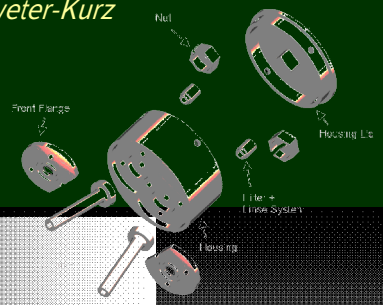


- Tracking & Radio Science
  AMSAT Deutschland e.V., Inst für Raumfahrttechnik, UBW

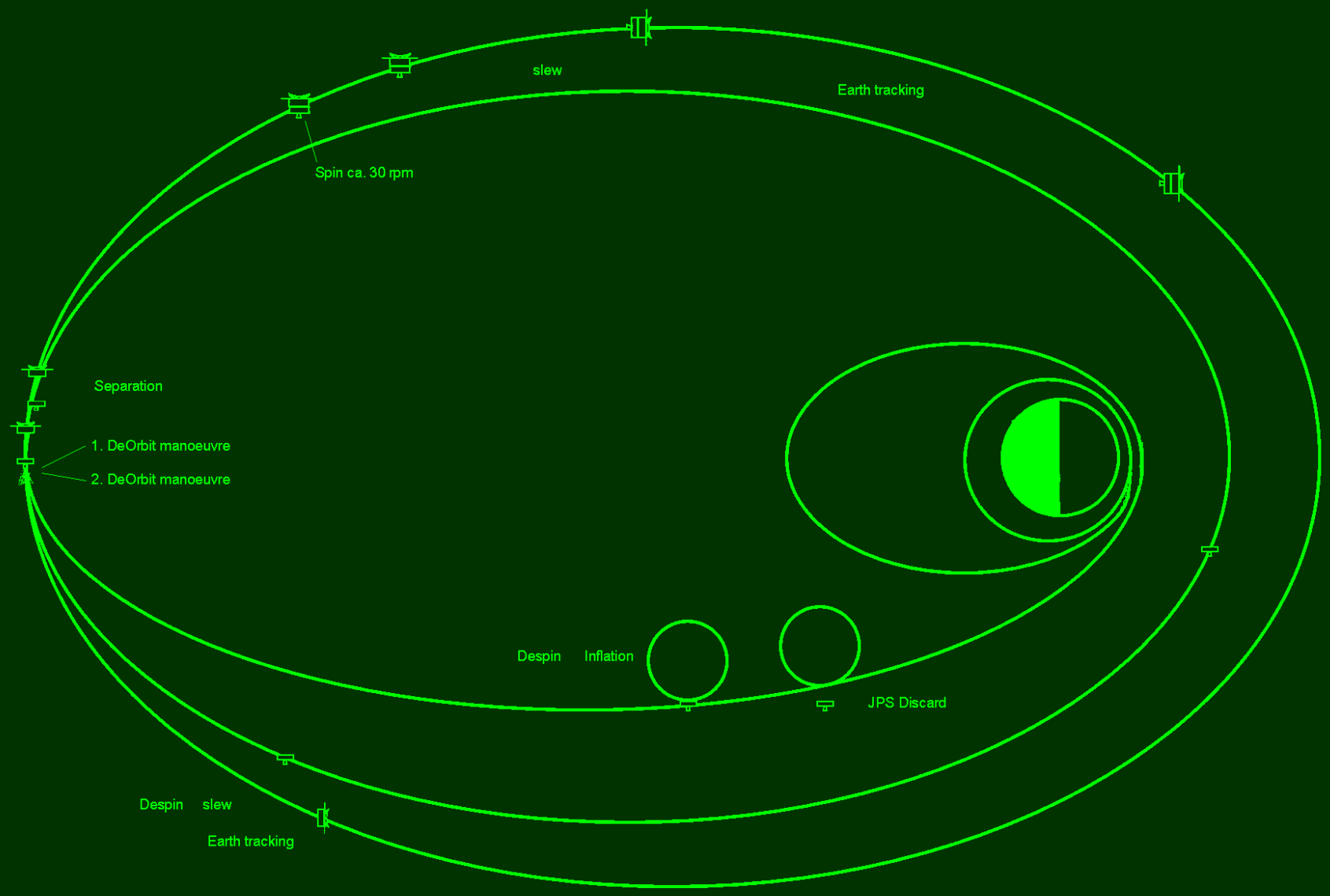
- Accelerometric Measurement System
  TU Iasi & TU Pitesti, Romaia
  H.N.Teodorescu, S.Ionita



- COMPARE Entry Experiment
  Institut für Raumflugsysteme, TU Stuttgart
  G.Herdrich, M.Auweter-Kurz



ARCHIMEDES Mission Scenario



Basics

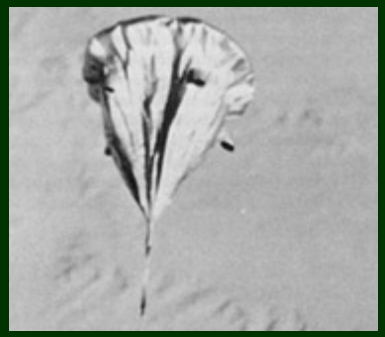
Technology Roots

ECHO
Inflatable passive communication satellite

+

IRDT
Inflatable Heatshield

+



Inflatable Hypersonic Decelerator

+

Stratospheric Balloon

=

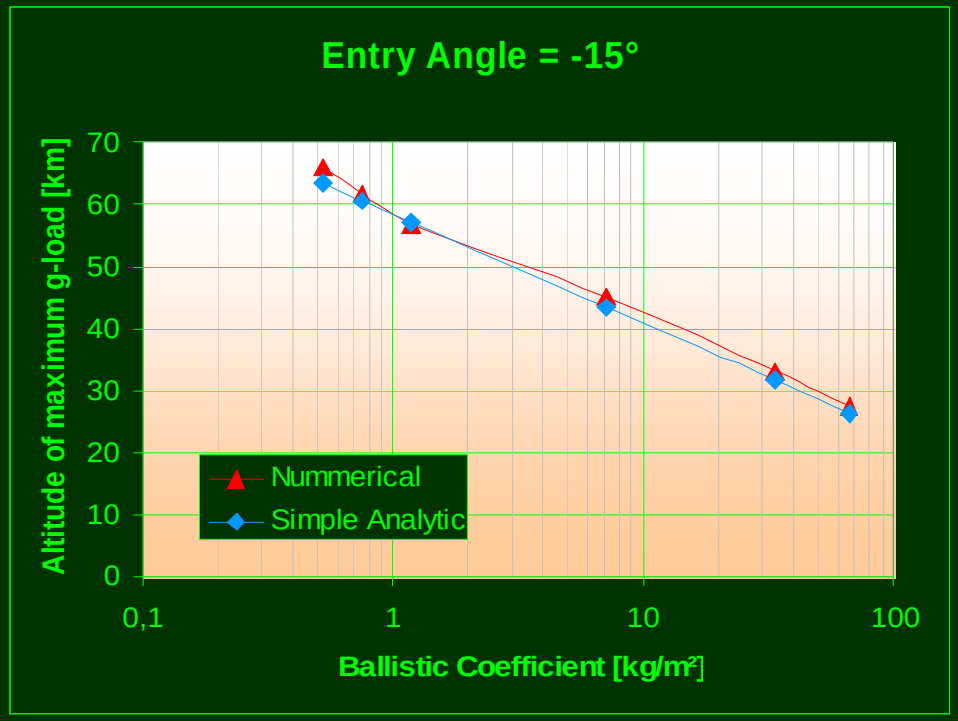
Ballute Probe for high Altitude Atmospheric Sounding

Determination Of the Desired BC: Min. Alt of Max-g

- May be a requirement
- Unrelated to actual feasibility!

$$h_{a,max} = H_0 \cdot \ln\left(\frac{H_0 \rho_0}{\beta \sin\gamma}\right)$$

$$\beta_{design} = \frac{H_0 \rho_0}{\sin\gamma} e^{-\frac{h_{a,max,design}}{H_0}}$$

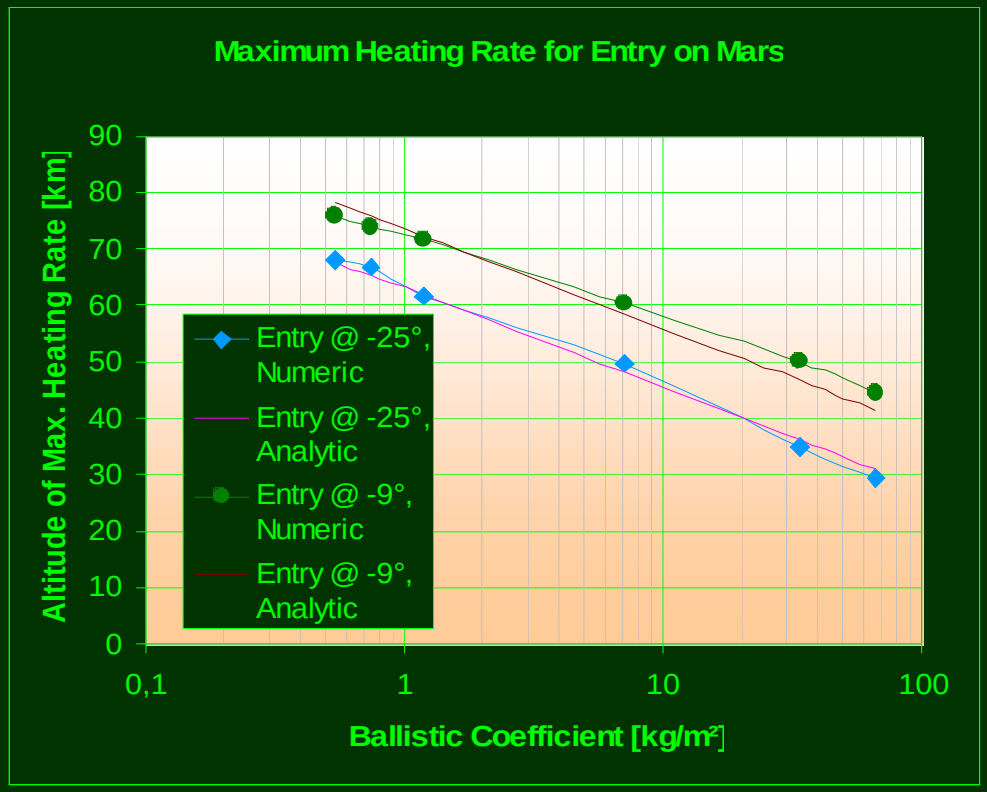


Determination Of the Desired BC: Max. Heat Influx

- May be a requirement
- Based on Sutton & Graves

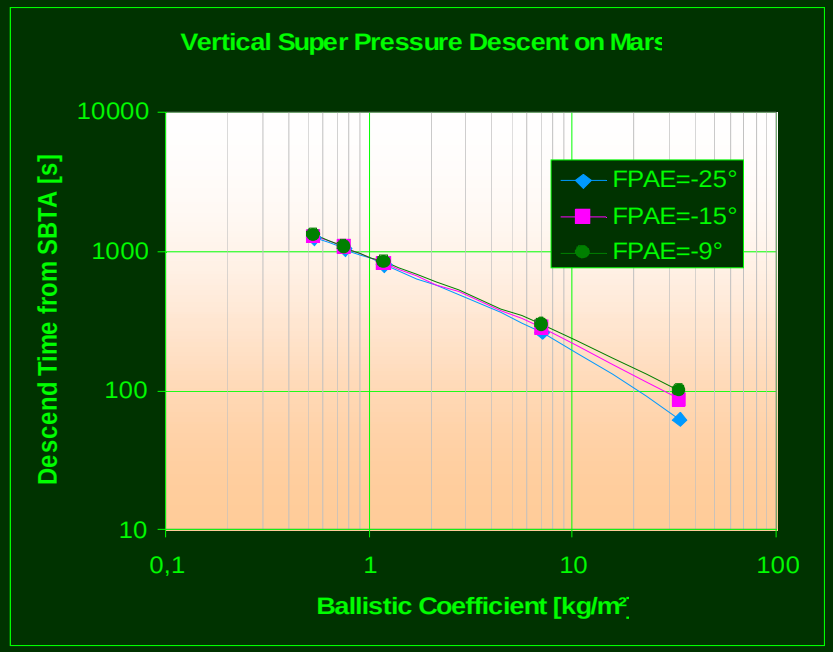
$$h_{c,max} = H_0 \cdot \ln\left(\frac{3 H_0 \rho_0}{\beta \sin\gamma}\right)$$

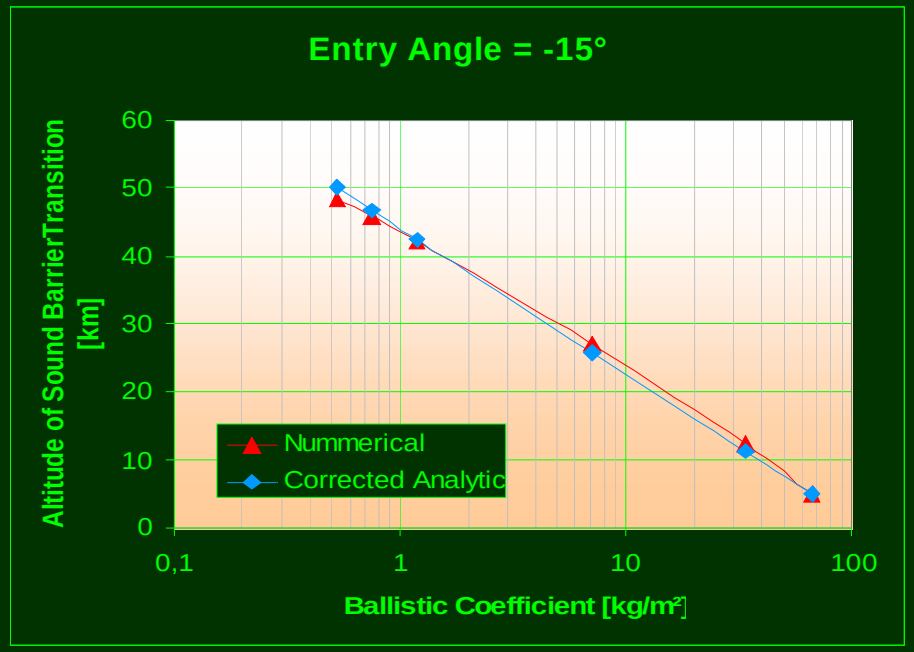
$$\beta_{design,max} = \dot{q}^2_{c,max} \cdot \frac{3e\,10^{10} H_0 R_N}{v_E^6\, \tilde{k}^2 \sin(\gamma)}$$



Determination Of the Desired BC: Mach-1 Transition

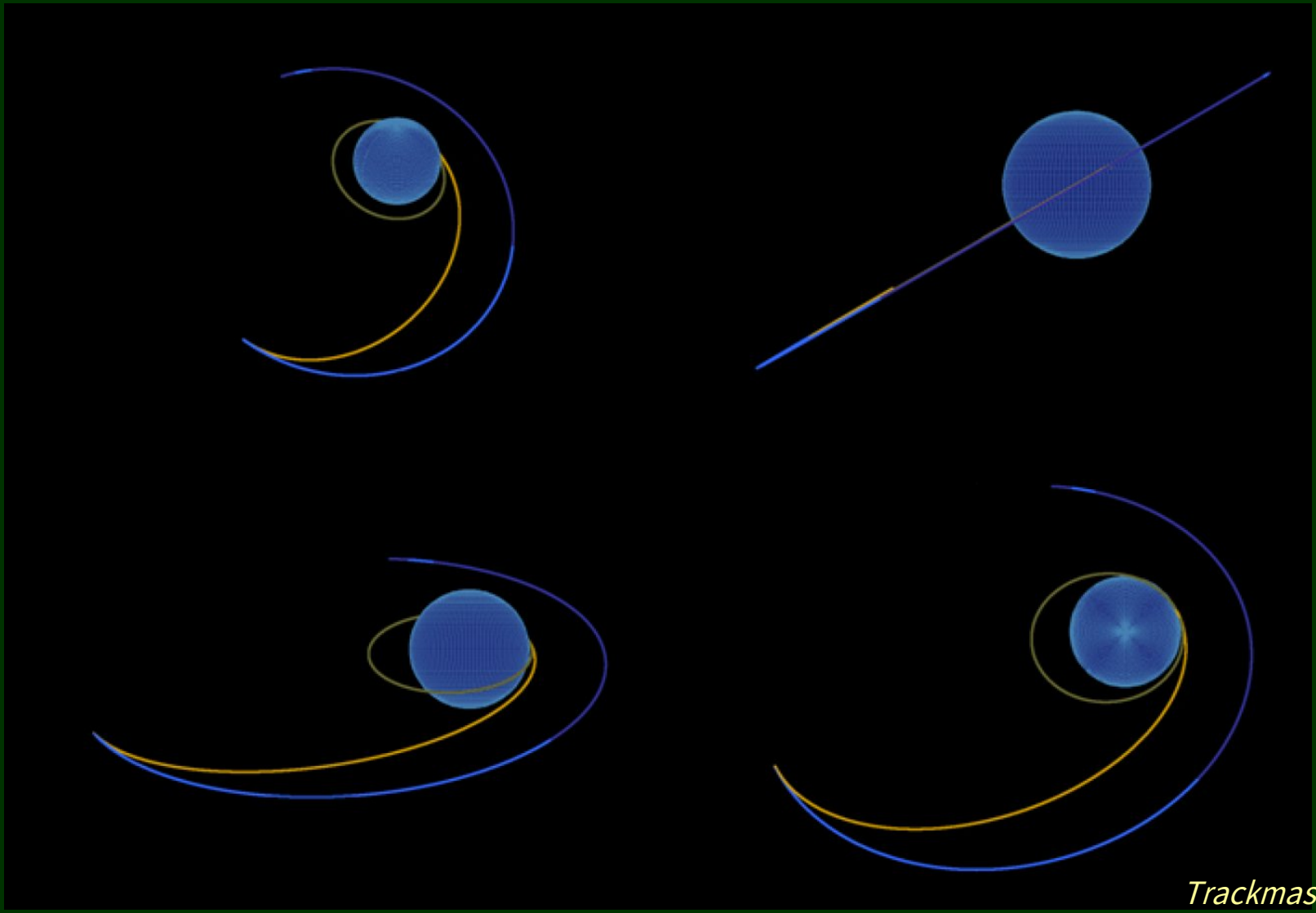
$$\beta_{max} = -\frac{H_0\,\rho_0\,e^{\frac{-h_{SBTA,design}}{H_0}}}{\left(2\ln\left[\frac{v_{sound}}{0.6065\,v_E}\right]\right)\sin\left(\gamma_{SBTA,limit}\right)}$$





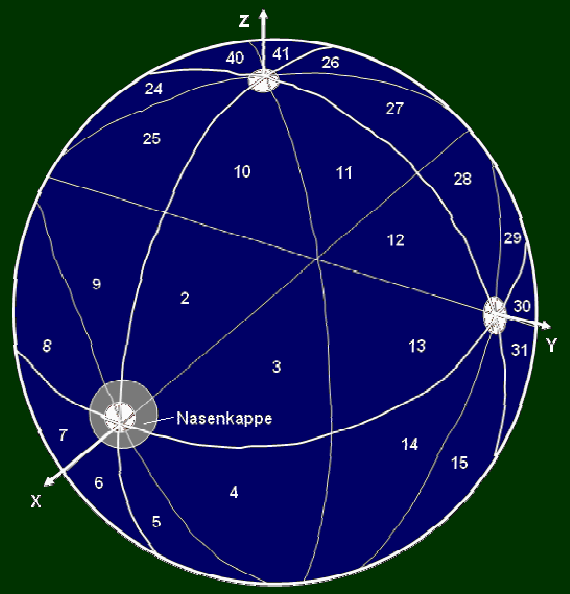
Numerical Analysis

Trajectory and Visibility Analysis

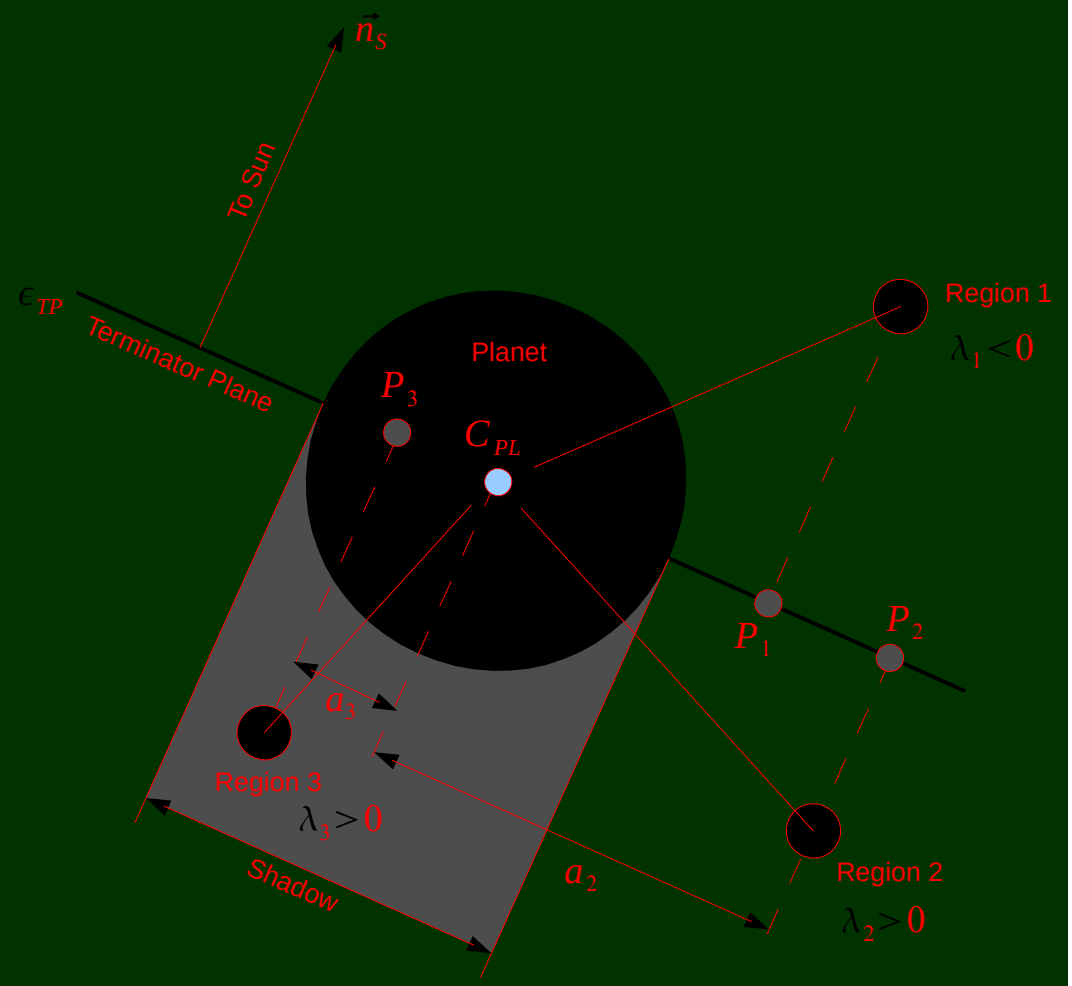


Trackmaster Plot, RSS

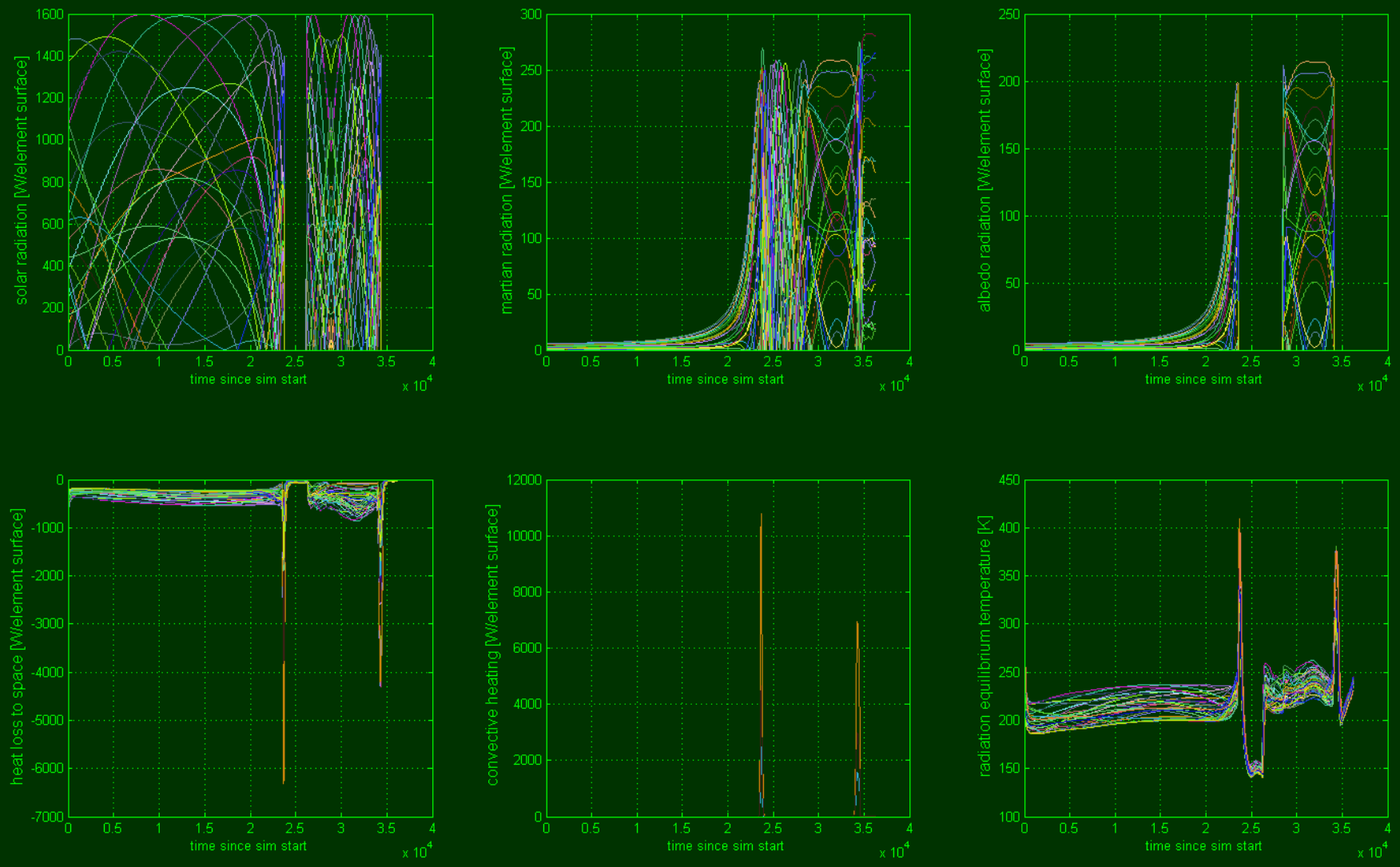
Thermal Node Model



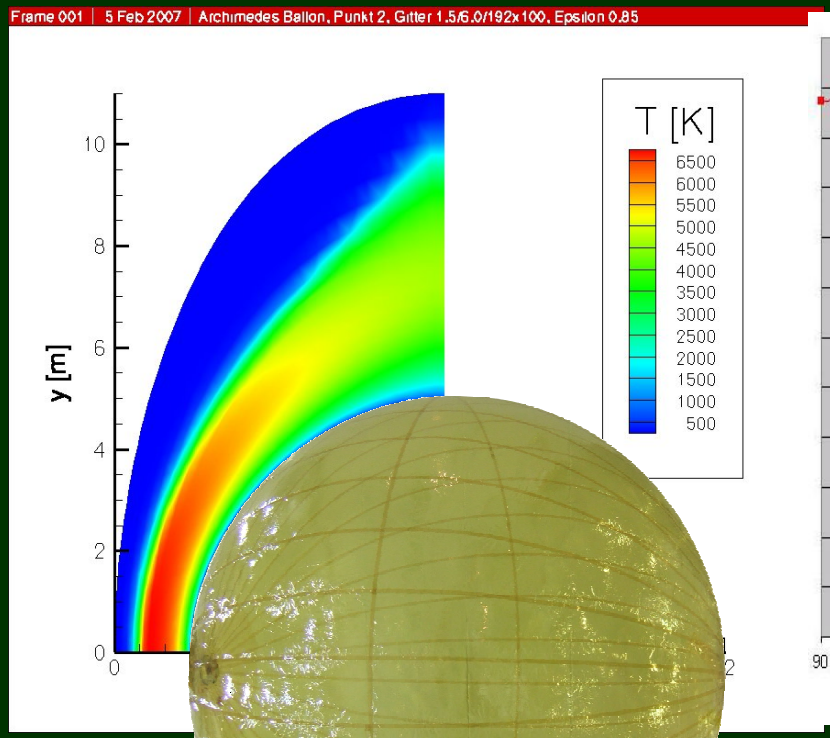
Thermal Node Modell With 51 Nodes

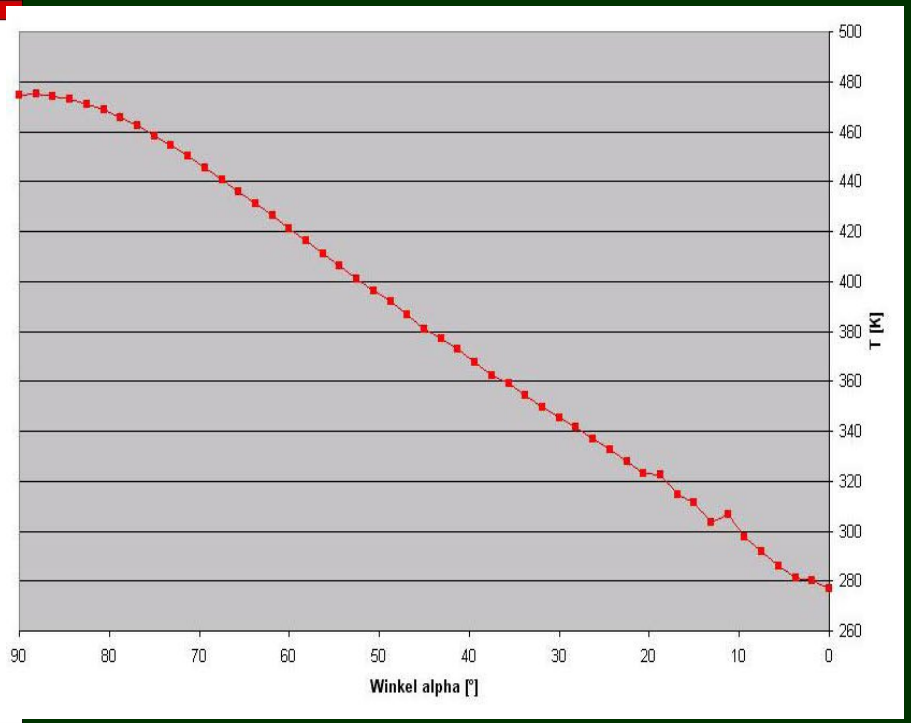


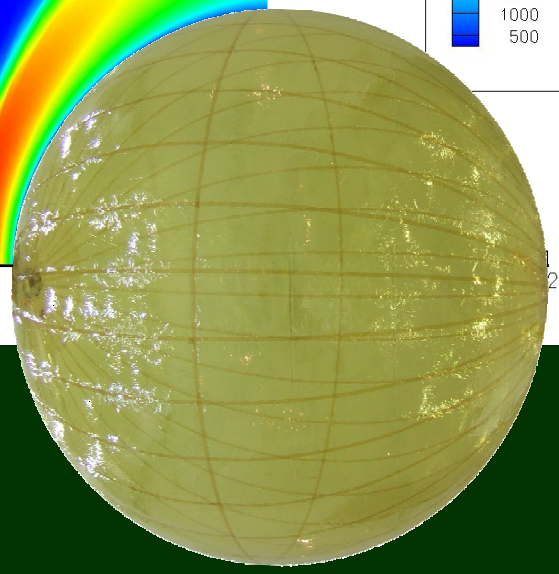
Thermal-Analysis



CFD Hypersonic Analyses







Archimedes Entry, Ma=22,3 Nonequilibrium

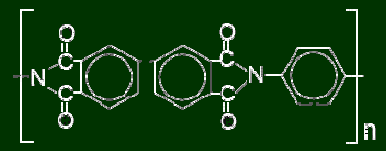
Modified CEVCATS-N CFD code (originally DLR)

Aeroelasticity & Modal Analyses

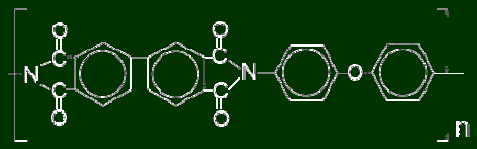
- For Mars Ballute Probe ARCHIMEDES (10m):
  - Ca. 40Hz and 50Hz 1st and 2nd Eigenfrequency
- For MIRIAM Flight Tests (4m):
  - Ca. 80Hz and 96Hz

Material Analysis and Testing

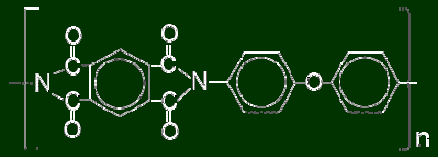
Material Analysis



UPILEX-S

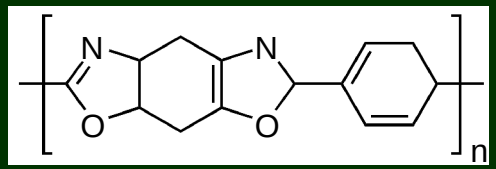


UPILEX-R

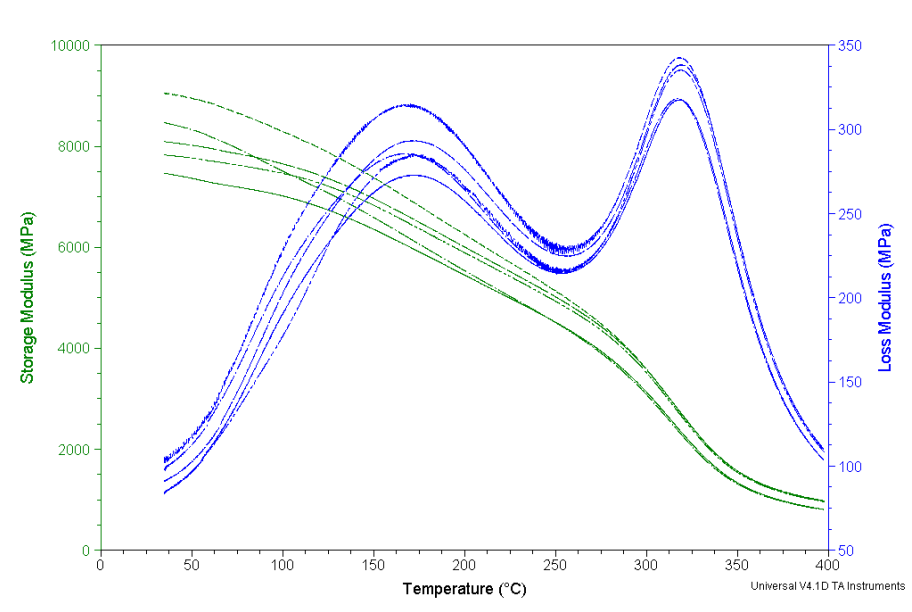


Kapton-H

- Polyimide
  - UPILEX-S and –R were tested
  - Similar to Kapton, but more durable (higher tensile strength, higher temperatures)
- Polybenzol (PBO)
  - Last word in thin film plastics.
  - Degrades under moisture but even degraded PBO better than UPILEX.
  - Available only in very small quantities

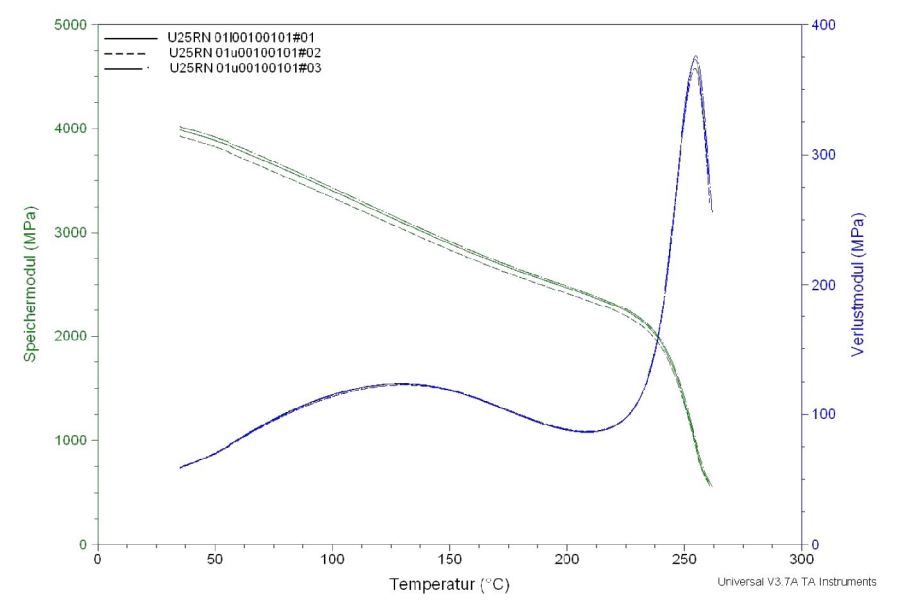


Material Testing



UPILEX-S

(Storage- and Loss Modulus)

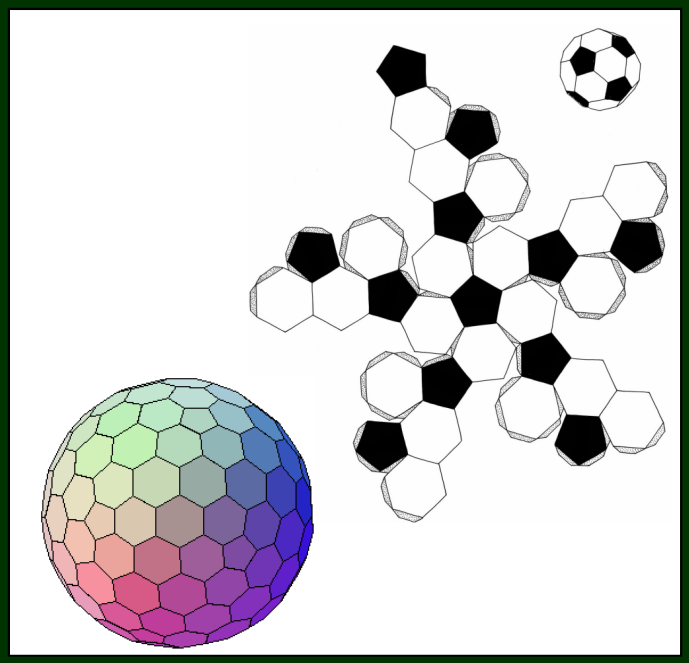


UPILEX-RN

(Storage- and Loss Modulus)

Production Patterns

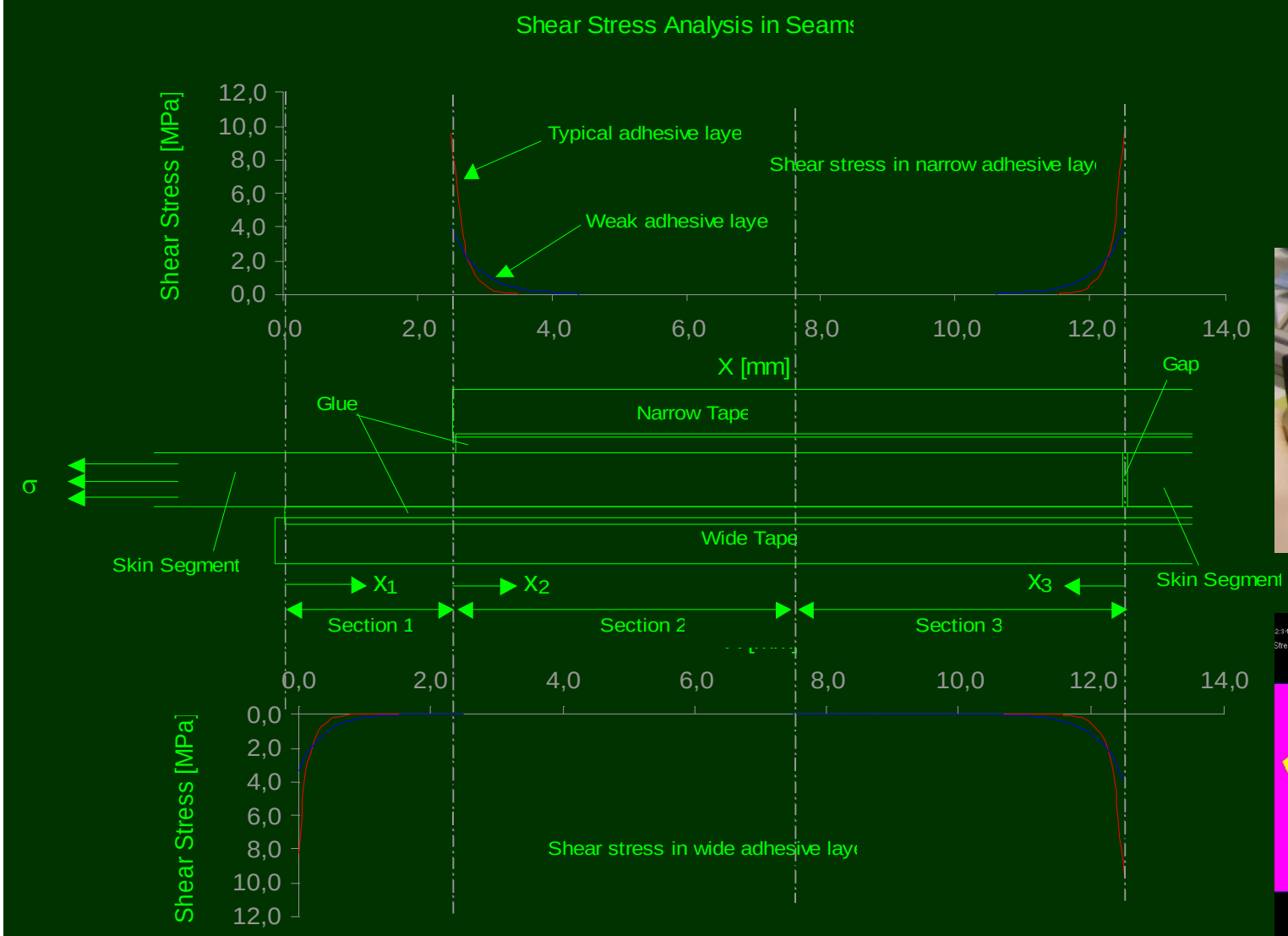
Beach Ball

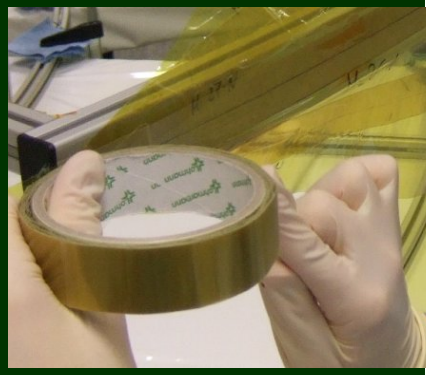


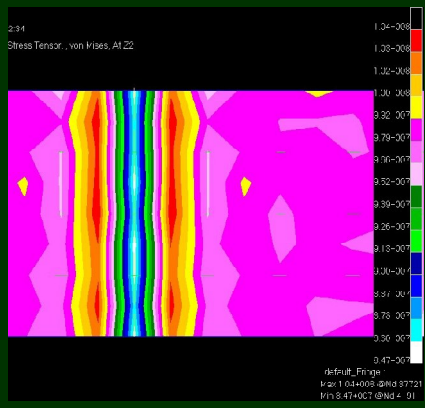
Truncated Icosahedron

(Football)

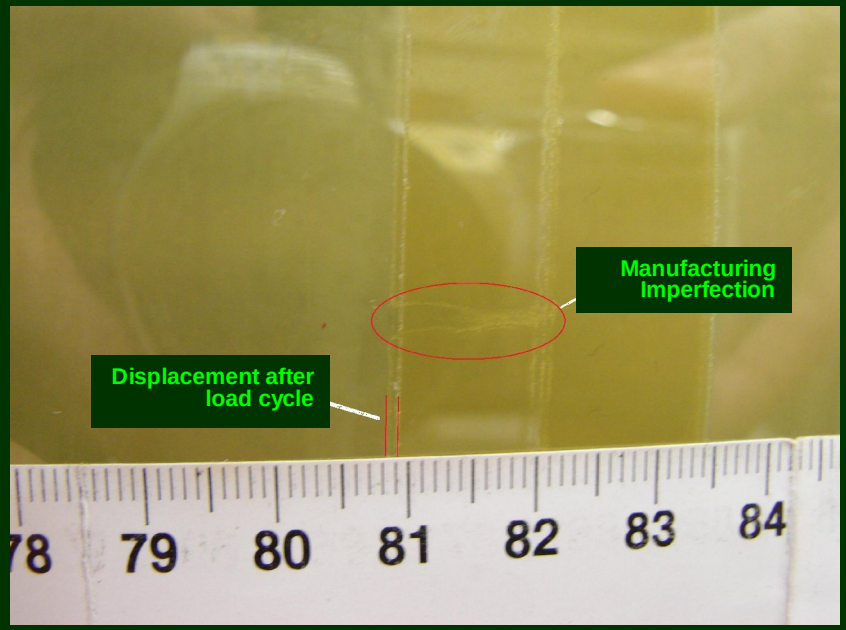
Seam Stress Analysis

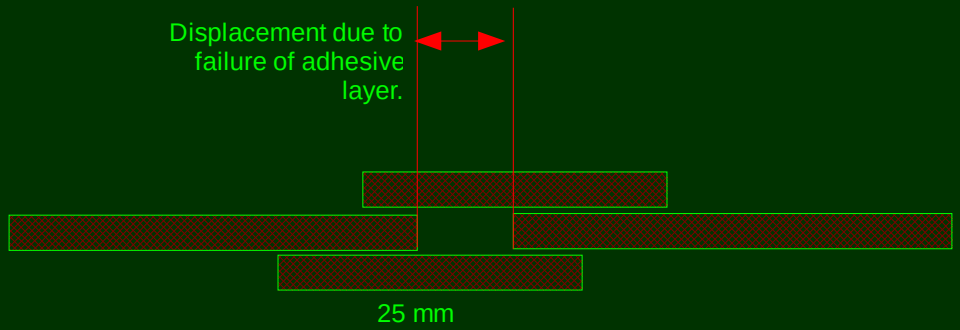




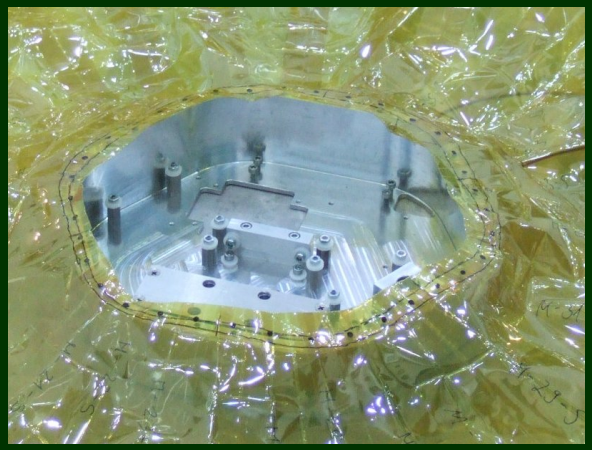


Stress Tests





Seams and Fittings



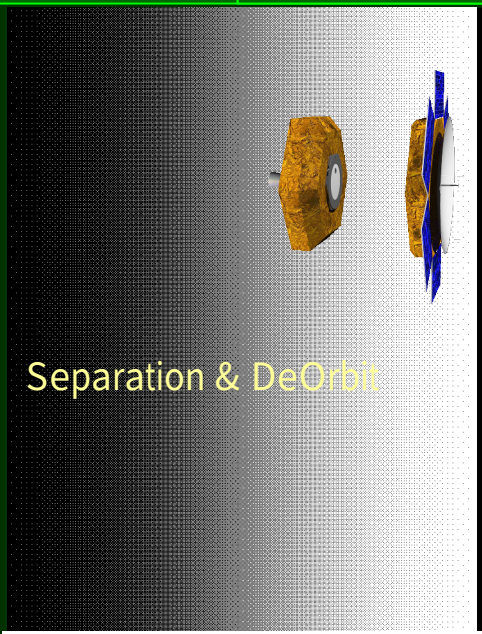
Miriam Instrument Pod (South Pole)

Miriam Ballute Instrumentation

UHF Antenna

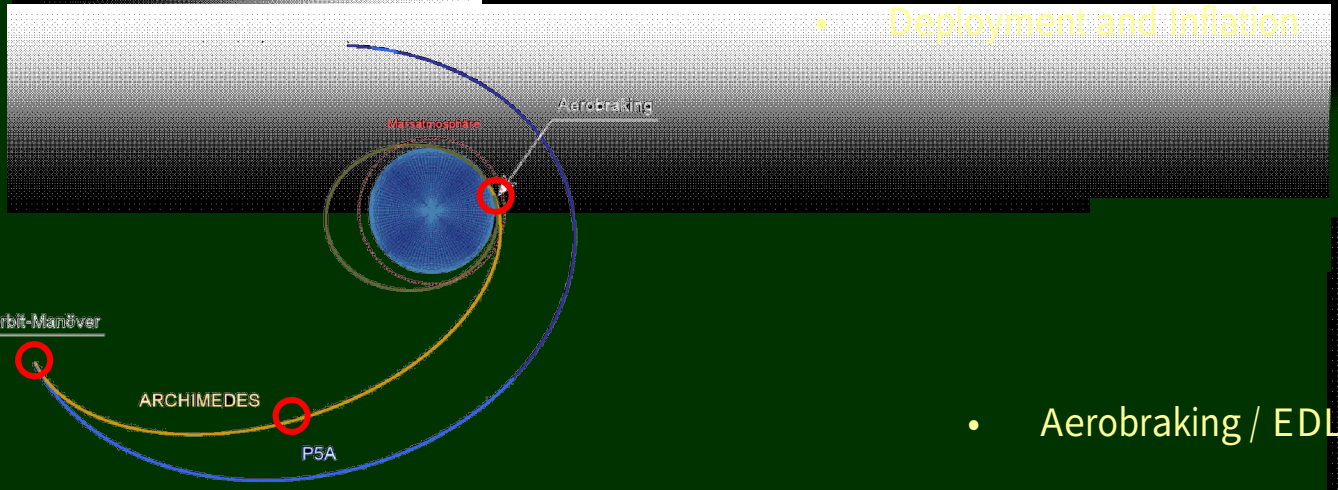
Deployment Concept

Ballute Mission Scenario

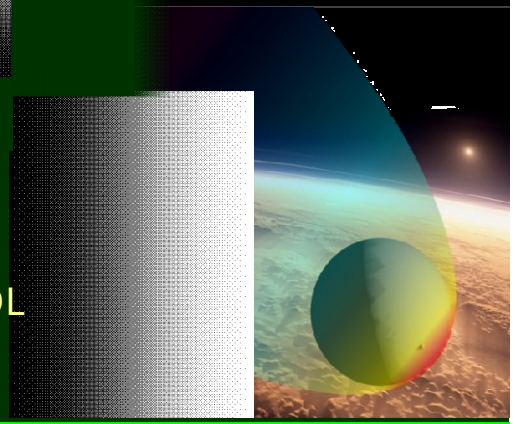


- Separation & DeOrbit

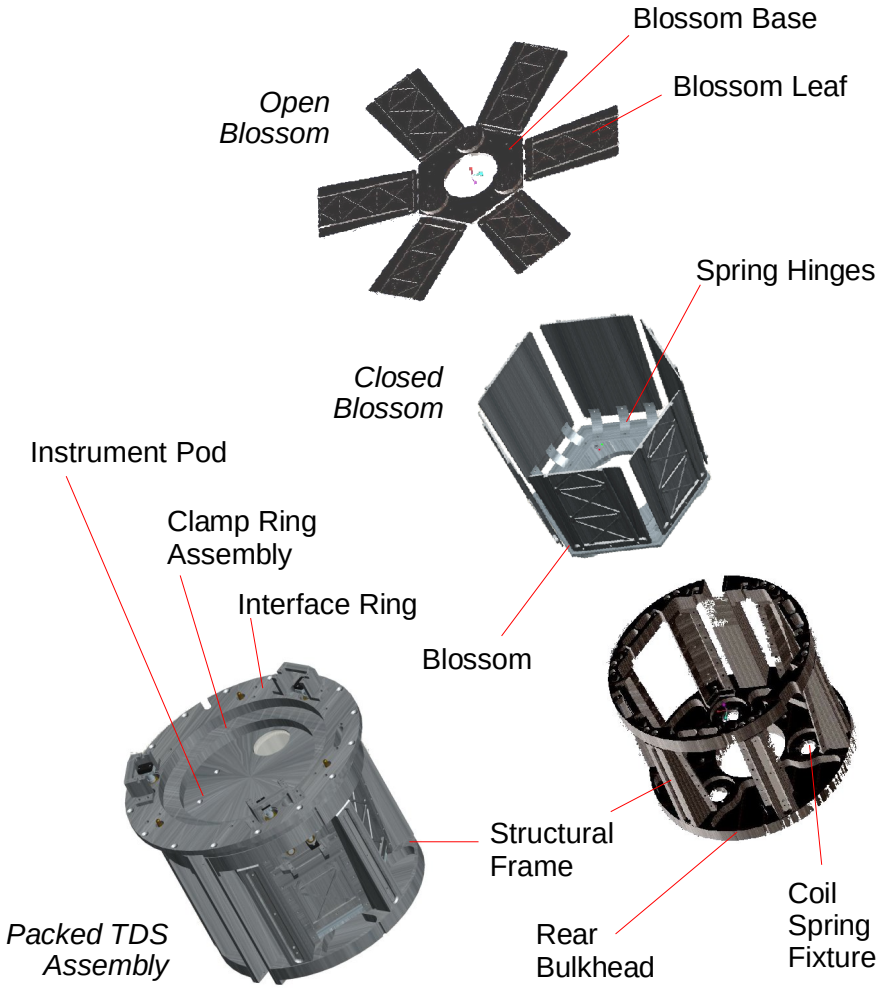
- Deployment and Inflation

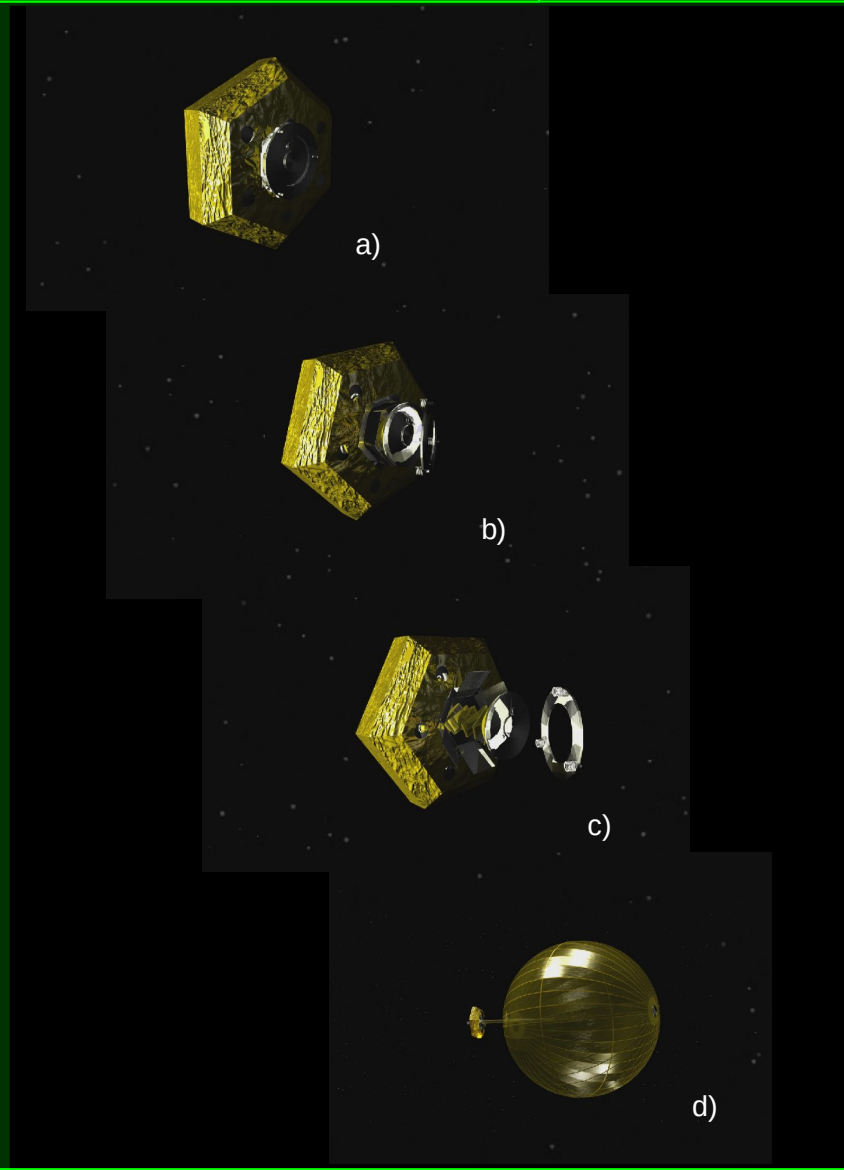


- Aerobraking / EDL

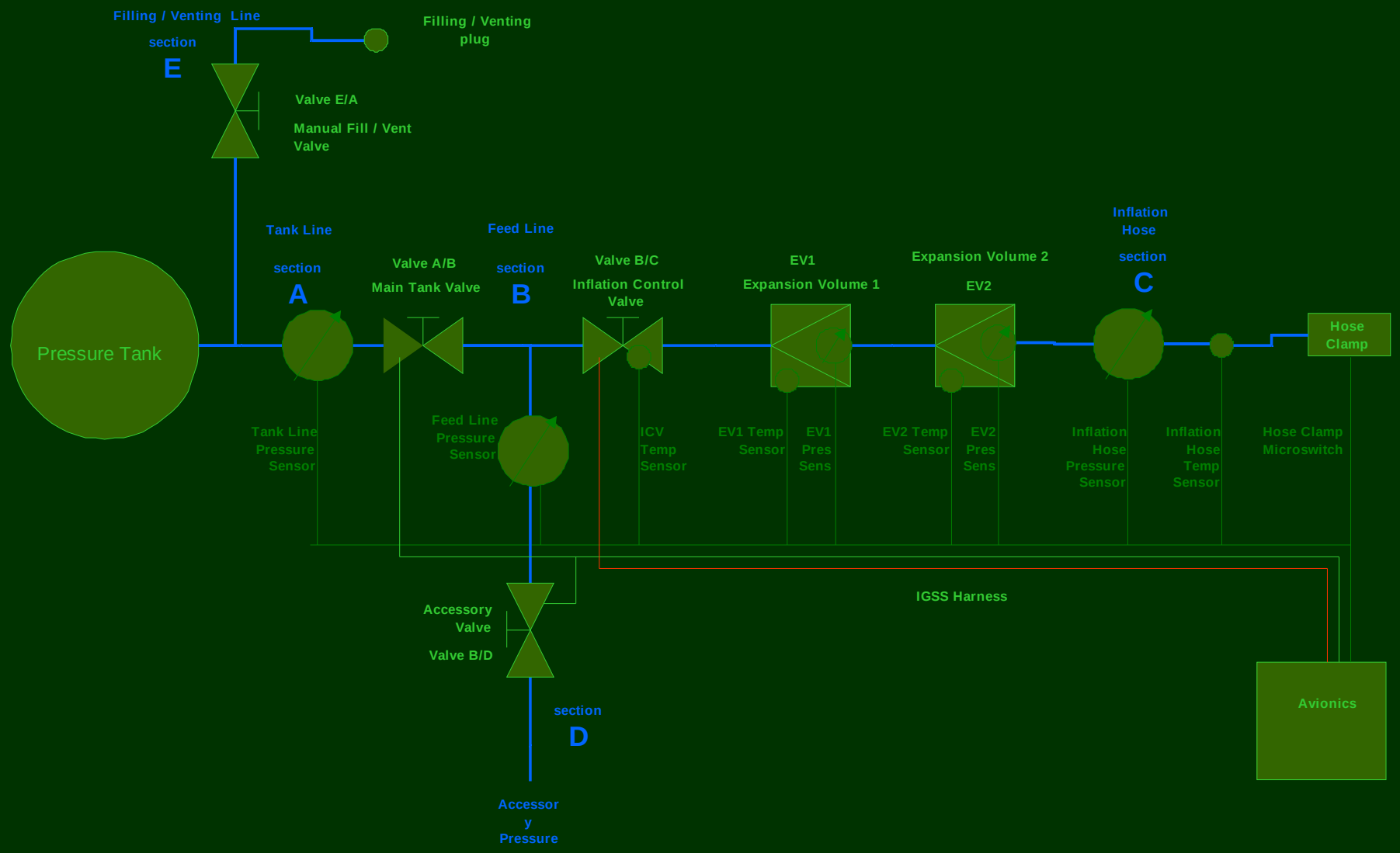


Deployment Mechanism



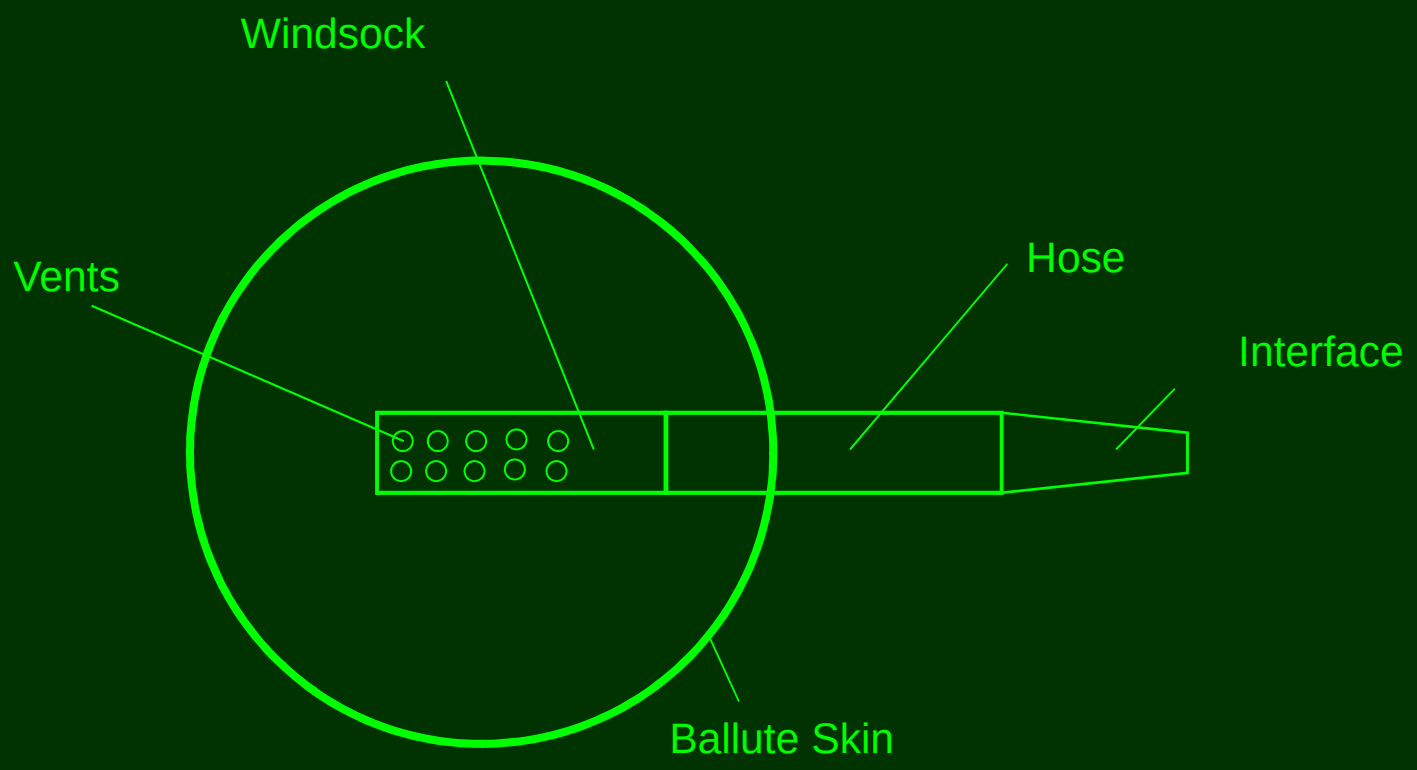


Inflation Control and Gas Storage



IGSS Deck for MIRIAM

Windsock & Hose

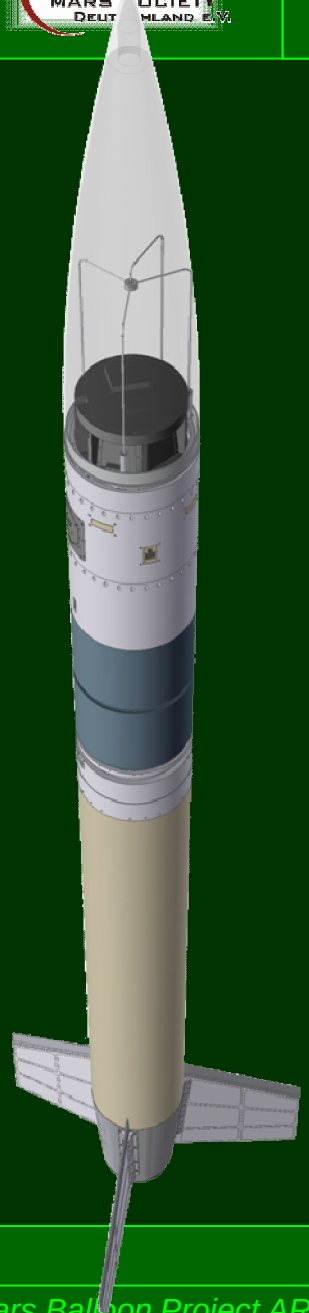


MIRIAM Ballute Type D400N32

- Diameter: 4m
- Mass: 2639g (without Pod)
- Material: Upilex-25RN (25µm)
- 32 Meridian-Segments x 2 Hemispheres
- Polar reinforcements through skin doublers, 600mm
- Inflation through 1.5m Windsock

Flight Tests

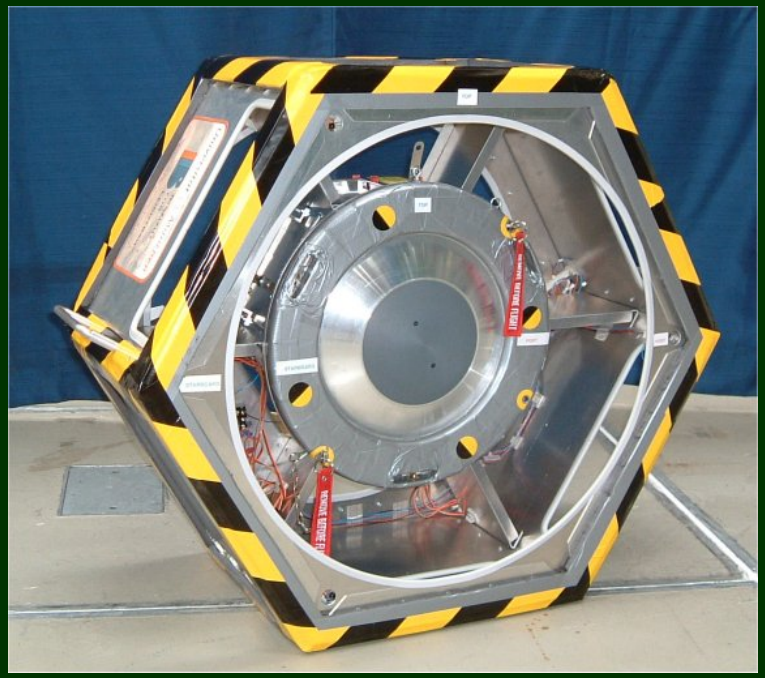
Completed Flight Tests



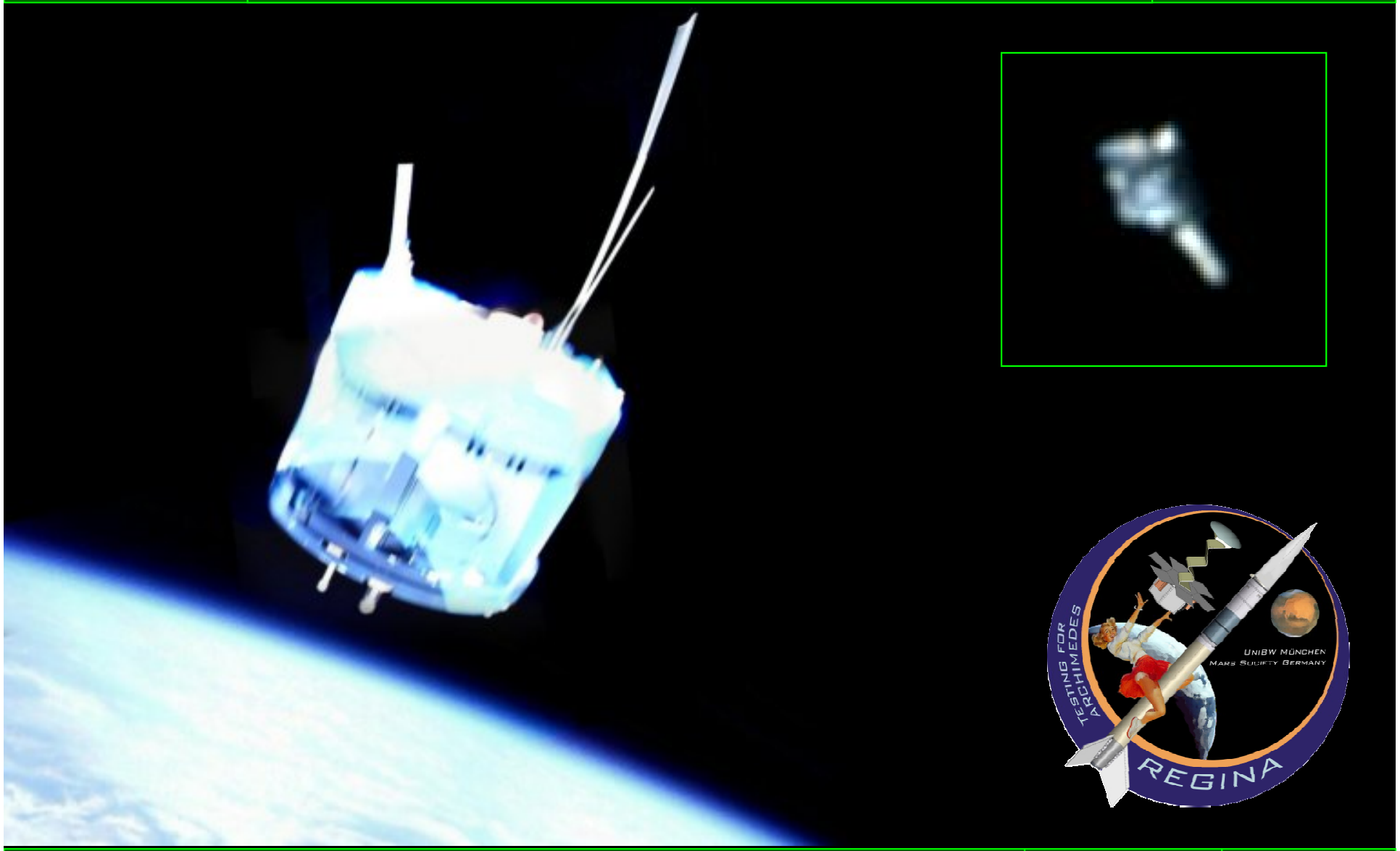
- **Parabolic Flight 1 (Airbus 300 zero-g)**
  - Balloon package behavior and release mechanism in 0-g
  - June, 2005
  - Status: Highly successful.
- **REGINA (Hawk)**
  - Balloon package behavior and release mechanism in space
  - SSC / DLR MORABA, April 5th, 2006
  - Status: Successful
- **MIRIAM (Nike Orion)**
  - Complete mission test at Earth on ballistic trajectory.
  - Eurolaunch / SSC & DLR MORABA, October 22nd 2008
  - Status: Partly successful
  - TEST MUST BE REPEATED!

Parabolic Flight Test

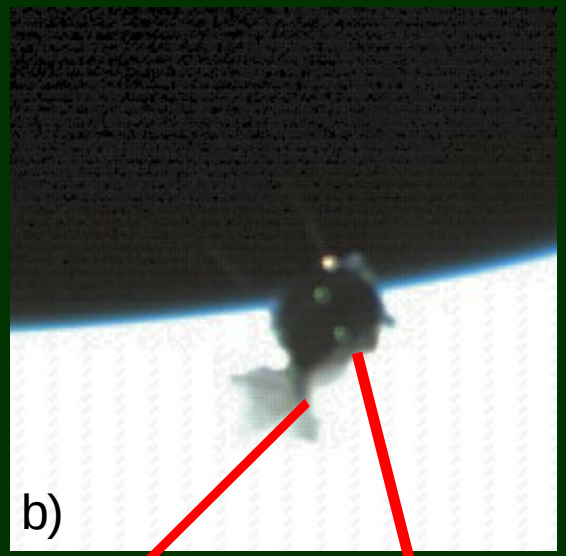
Deployment Mechanism, Scale 1:2

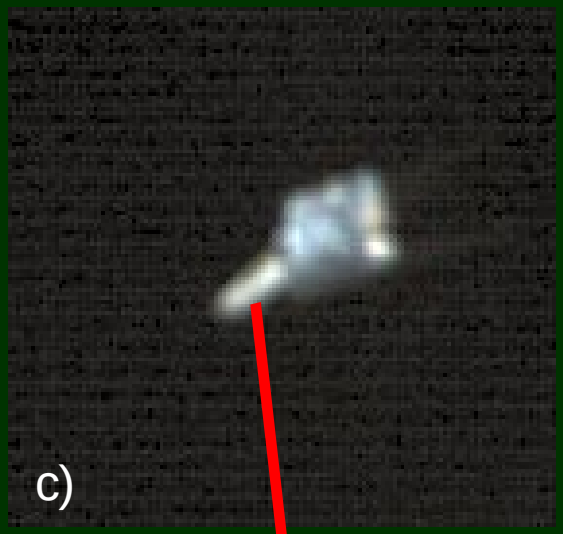


Spaceflight Test REGINA



REGINA Deployment Sequence



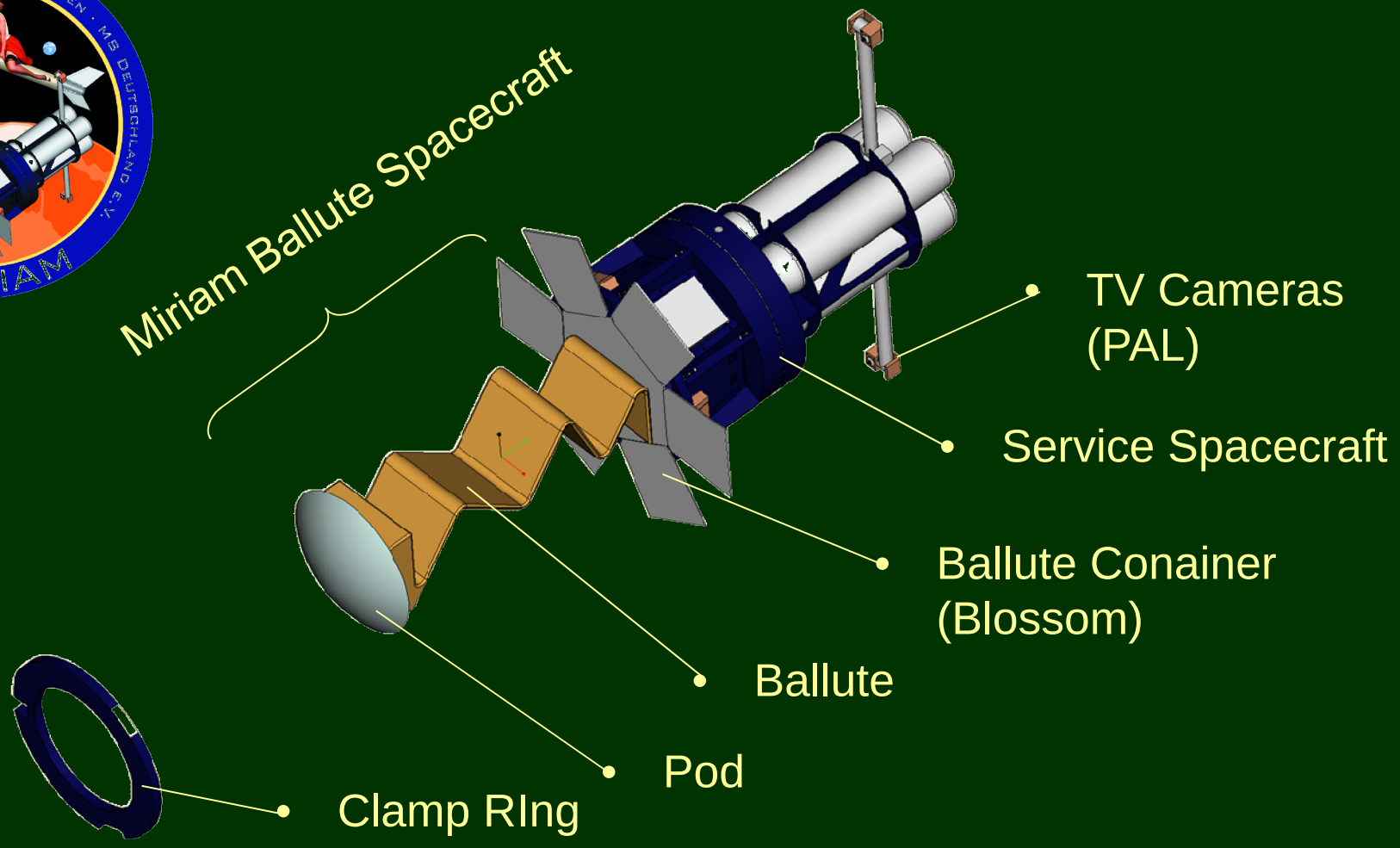


Clamp-Ring

Pod

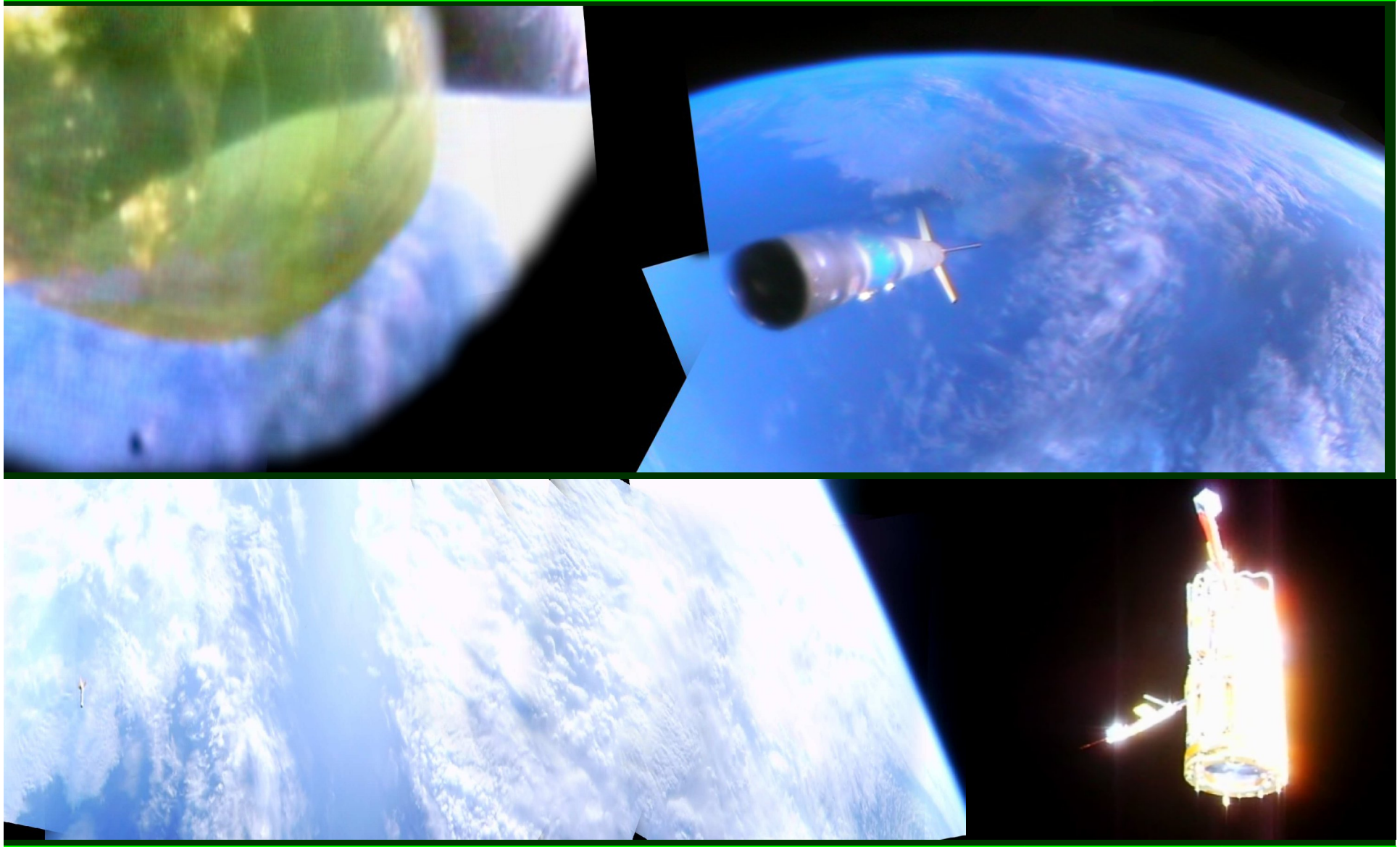
Ballute Dummy

Miriam Flight Test

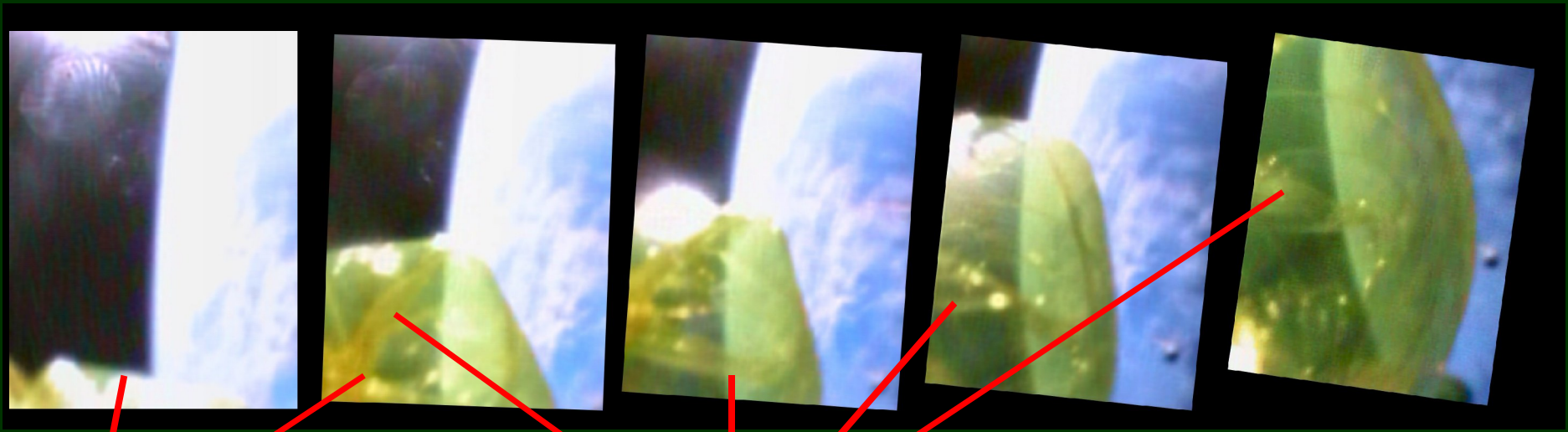


MIRIAM Flight Preparation

MIRIAM in Space



MIRIAM Deployment Sequence



Main Package

E-Pleats

Last Week in Lappland…

Conclusion & Acknowledgements

Conclusion

- Analyses show that ballutes can provide a unique platform for new applications.
  - Venus Ballute
  - SkyRaft (emergency recovery / extreme sport)
- Technology development highly successful
  - progress could be made.
- Further flight testing is essential.
  - MIRIAM-2 planned for 2013

Special Thanks To…

- …all supporting institutions, companies and individuals
  - UniBw München und alle beteiligten Institute.
  - Mars Society Deutschland e.V.
  - AMSAT-DL e.V.
  - Lohmann Tapes, Neuwied
  - IABG Space Test Center, Ottobrunn

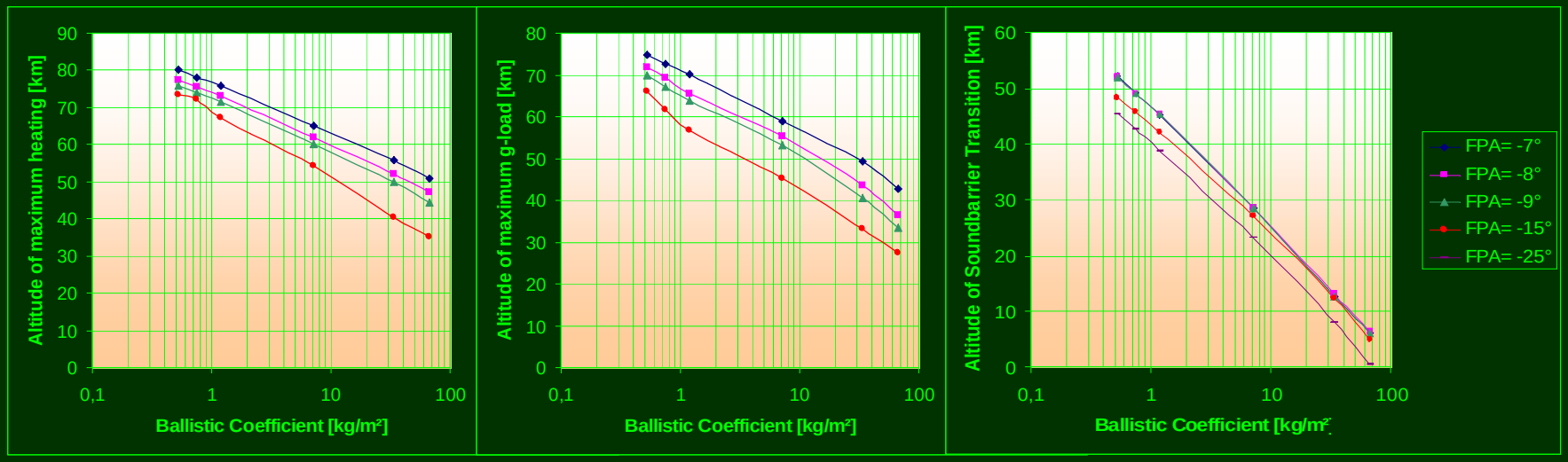
  - TU Stuttgart, Institute of Statics and Dynamics (Prof. Kröplin)
  - Hochschule Bremen, Institut für Raumfahrttechnik (Prof. Apel)

  - DLR Mobile Raketen Basis (MORABA)
  - ESA Directorate of Human Spaceflight @ ESTEC

  - Mitarbeiter des DLR Instituts für Robotik, Oberpfaffenhofen (Prof. Hirzinger)
  - Die Firma GmbH, Nürnberg
  - ELOXAL München
  - Arcotech
- *...and to you for your attention!*

Backup Slides

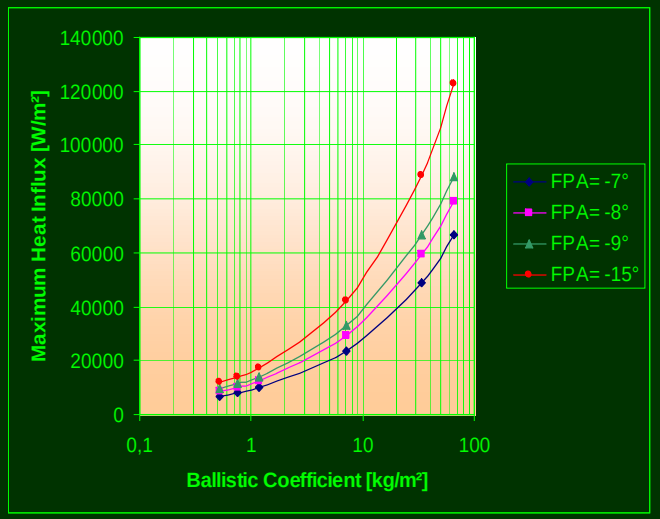
Basic Principle

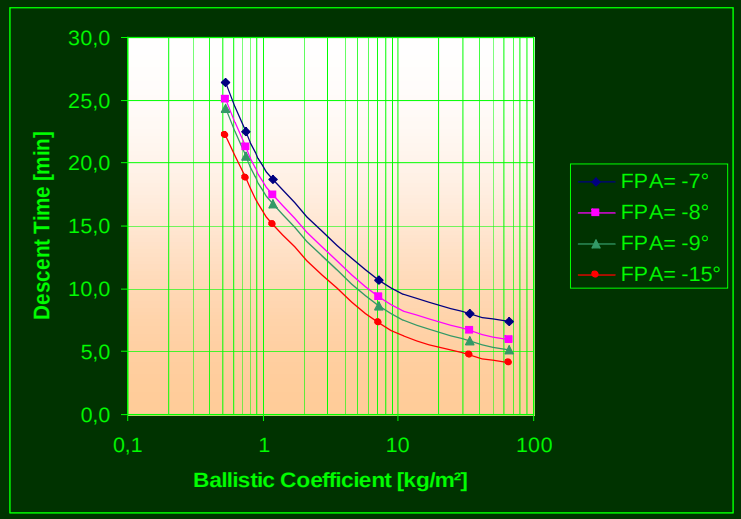


- => Spherical Balloon
  - Large, light and blunt
  - Natural pressure vesser (simple design)

- Ballistic Coefficient [kg/m²]: Ca. 0.5-0.6
  - IRDT: Ca. $10^0 – 10^1$
  - Classic EV: Ca. $10^1 – 10^2$
  - Cannon Projectile: Ca. $10^2 – 10^4$

Basic Principle





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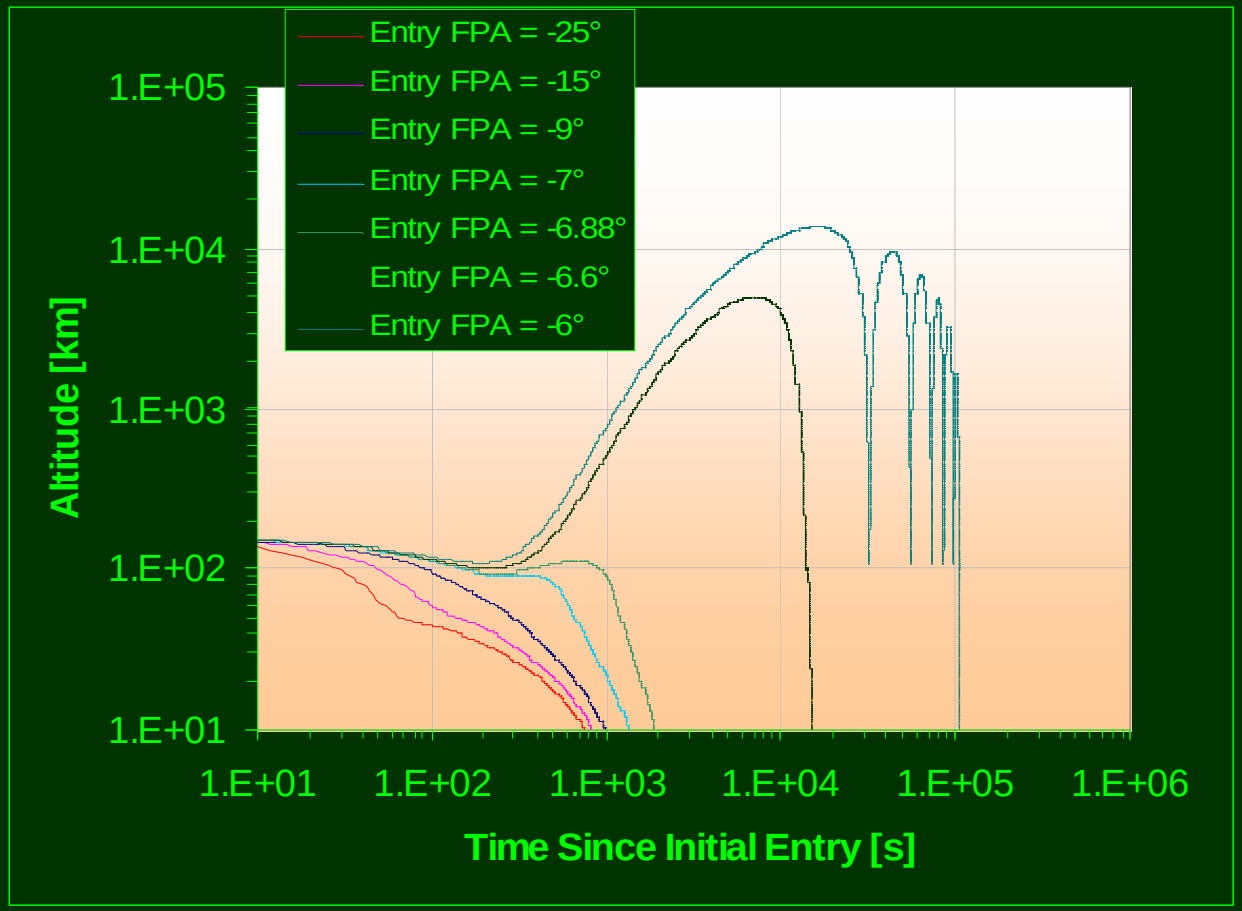
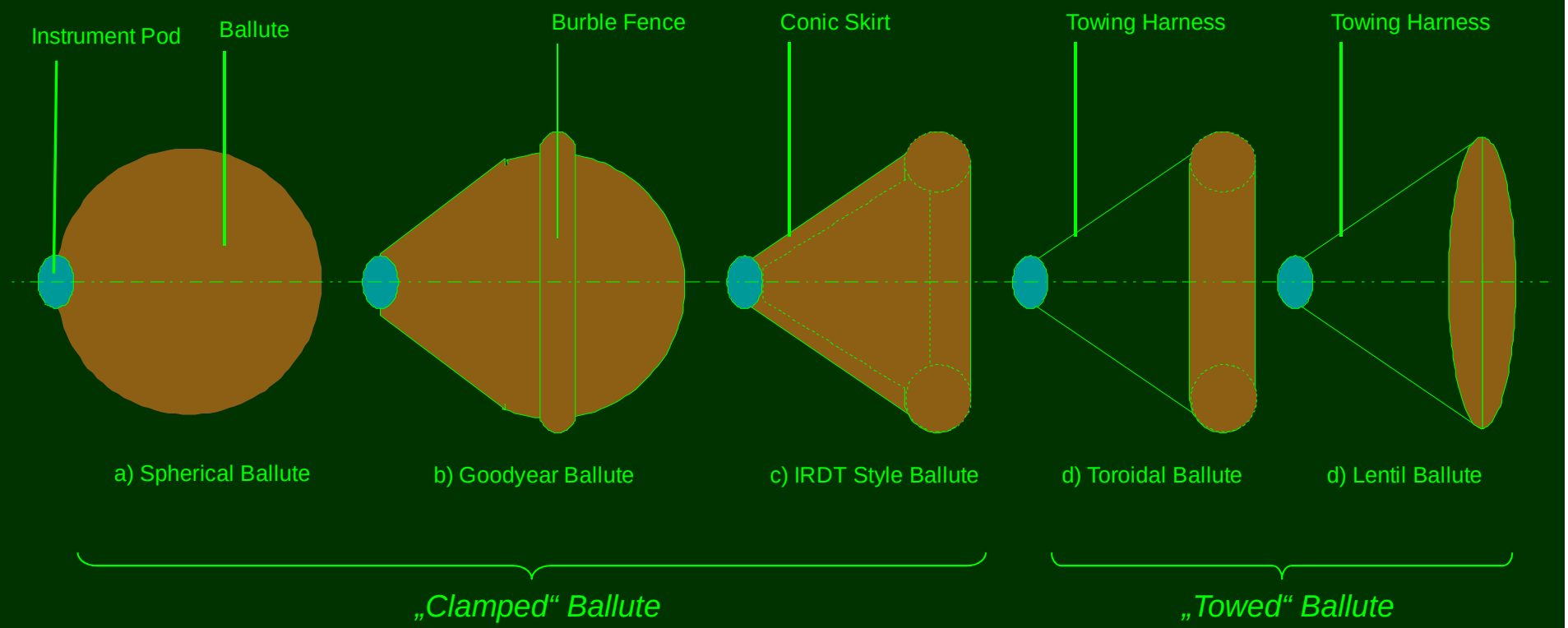
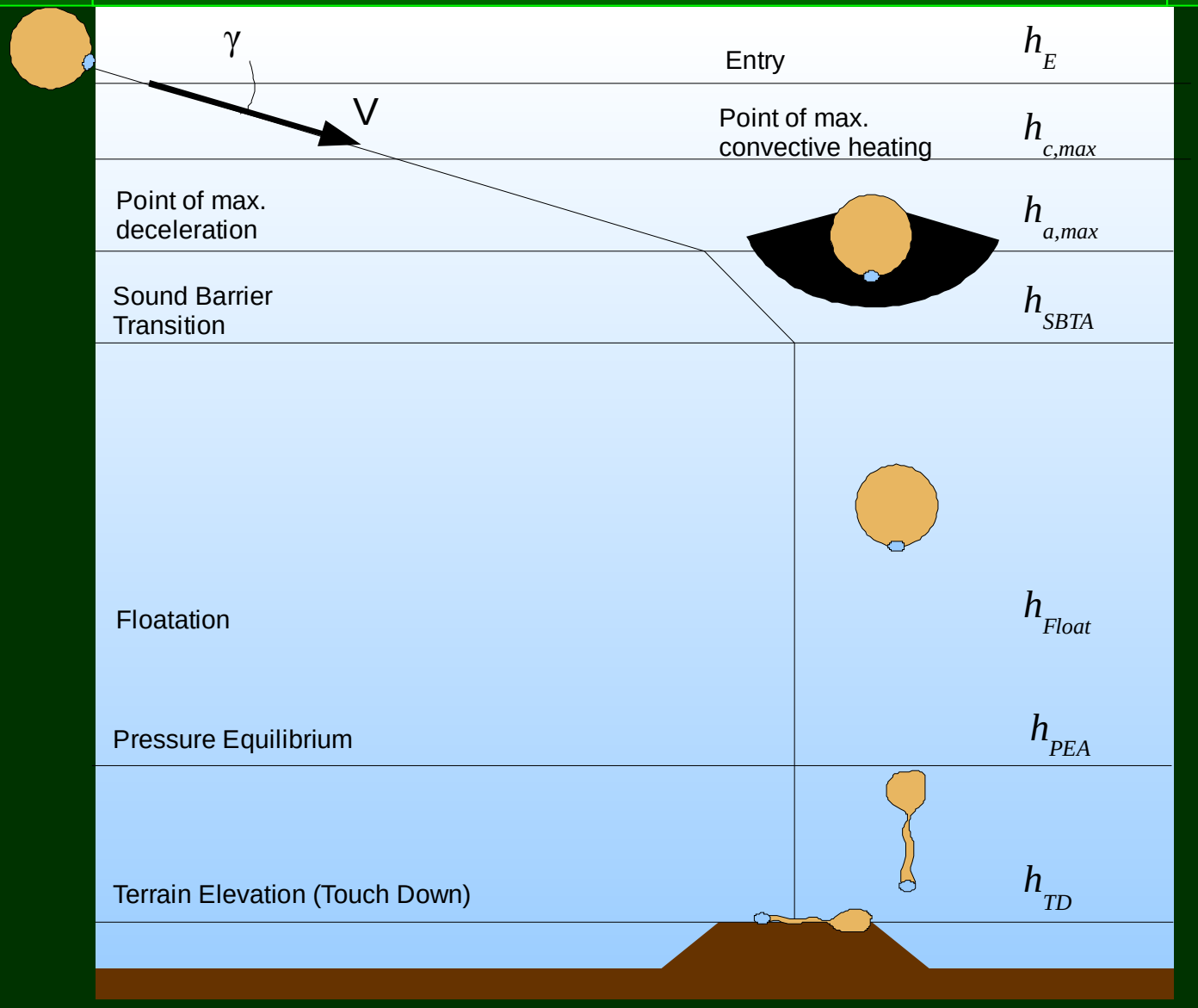
Ballute Probe on Mars



Studied Configuration Options



Phases of a Ballute Probe