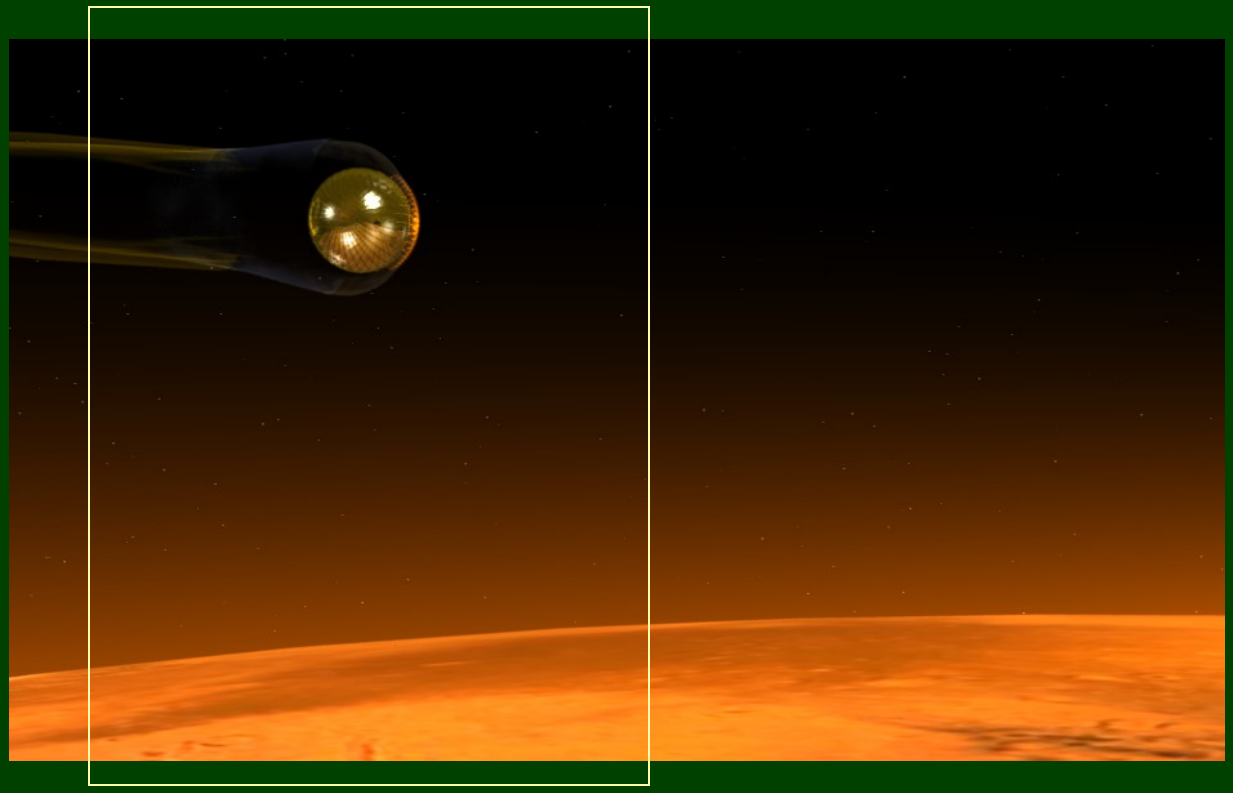
Putting a Gossammer Ballute Through Atmospheric Entry

MIRIAM-2 *Hypersonic Drag Ballute Flight Test*



Hannes Griebel

Mars Society Deutschland e.V

VEGA Space GmbH

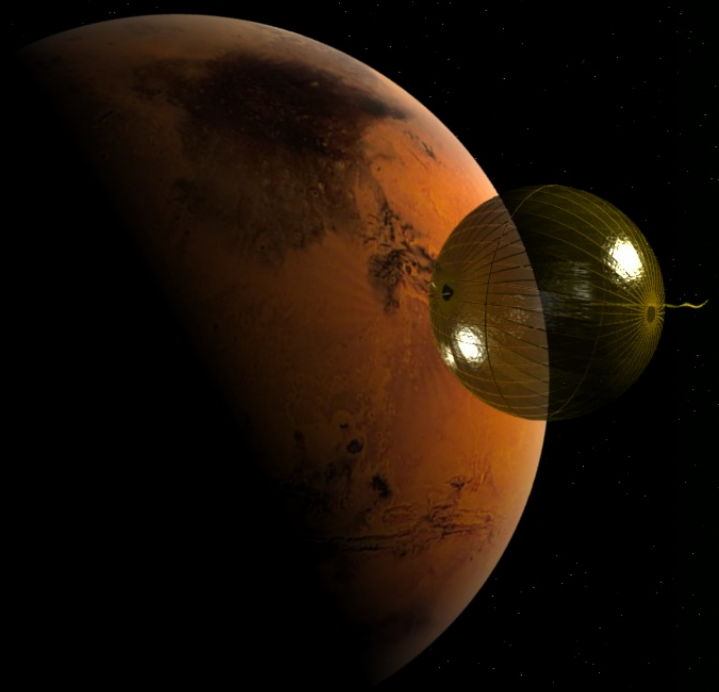
06.2011

MARS SOCIETY DEUTSCHLAND E.V.

der Bundeswehr Universität München

Overview

Miriam 2 Overview

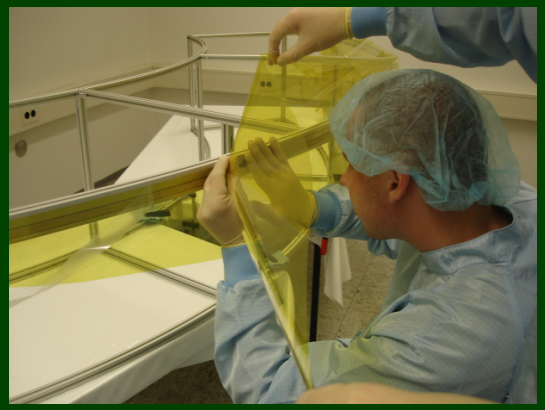


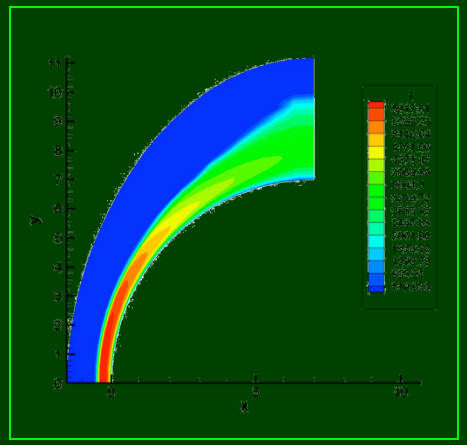
- Technology demonstrator for a hypersonic drag balloon (BALLUTE)
- Designed primarily to obtain data required for the design of the Mars mission ARCHIMEDES, but other applications also possible…
- International cooperation between Mars Society Germany, University of the Federal Armed Forces and others.

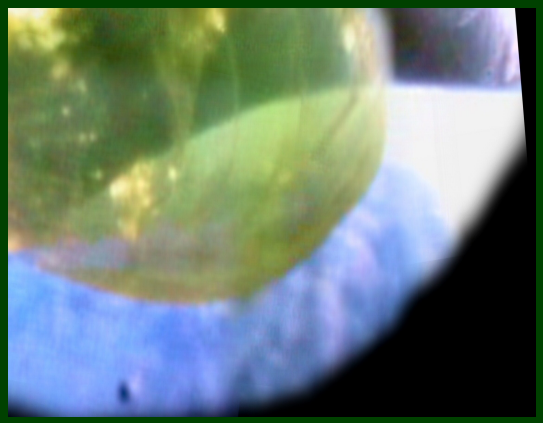
Development Programmes

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

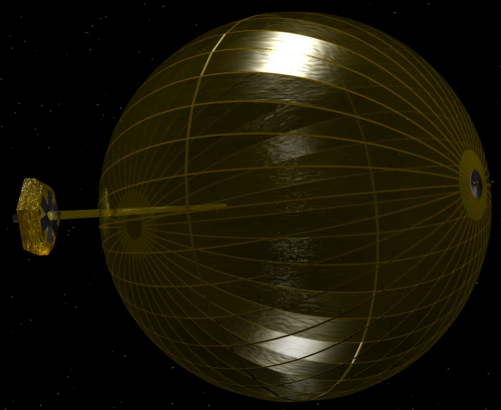
- MIRIAM-2 is the ultimate test for all!

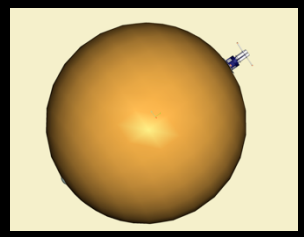






System Design
(MIRIAM & ARCHIMEDES)

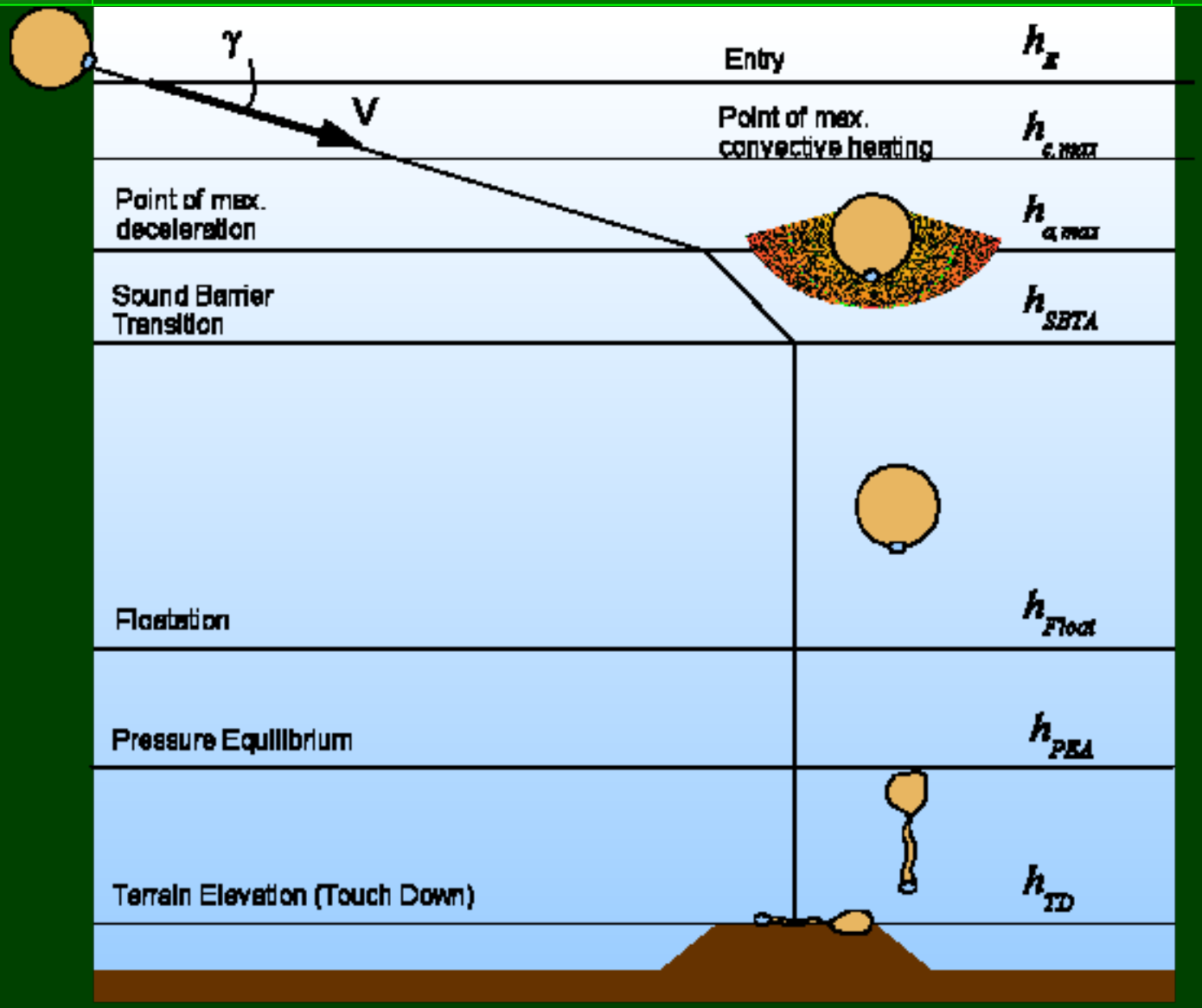




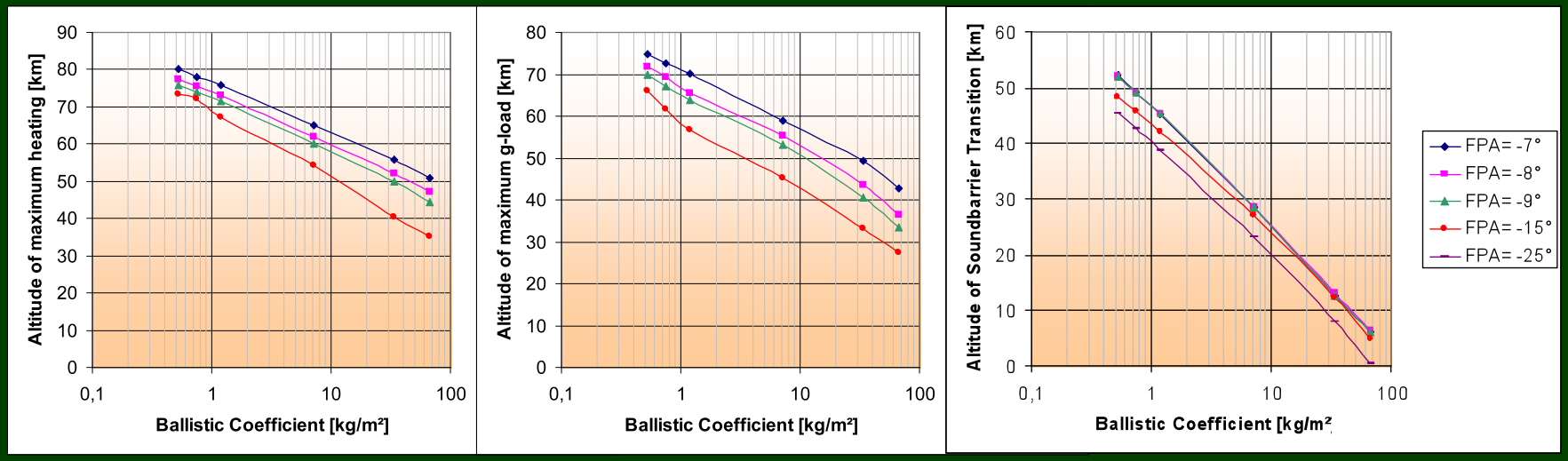
Item	*ARCHIMEDES Mars Mission*	*MIRIAM Earth Test*	*Relation*
Mass Instrument Pod [kg]	ca. 18.3	2.9	1 : 6.3
Mass Ballute [kg]	ca. 15.1	2.6	1 : 5.8
Mass EV [kg]	ca. 33.2	5.4	1 : 6.1
Pod : Ballute [-]	ca. 1.21	1.12	1 : 1.08
Ballist. Coeff. [kg / m²]	ca. 0.54	0.59	1 : 0.92
Ballute Diameter [m]	ca. 10	ca.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

Theory

Phases of a Ballute Probe



Basic Principle

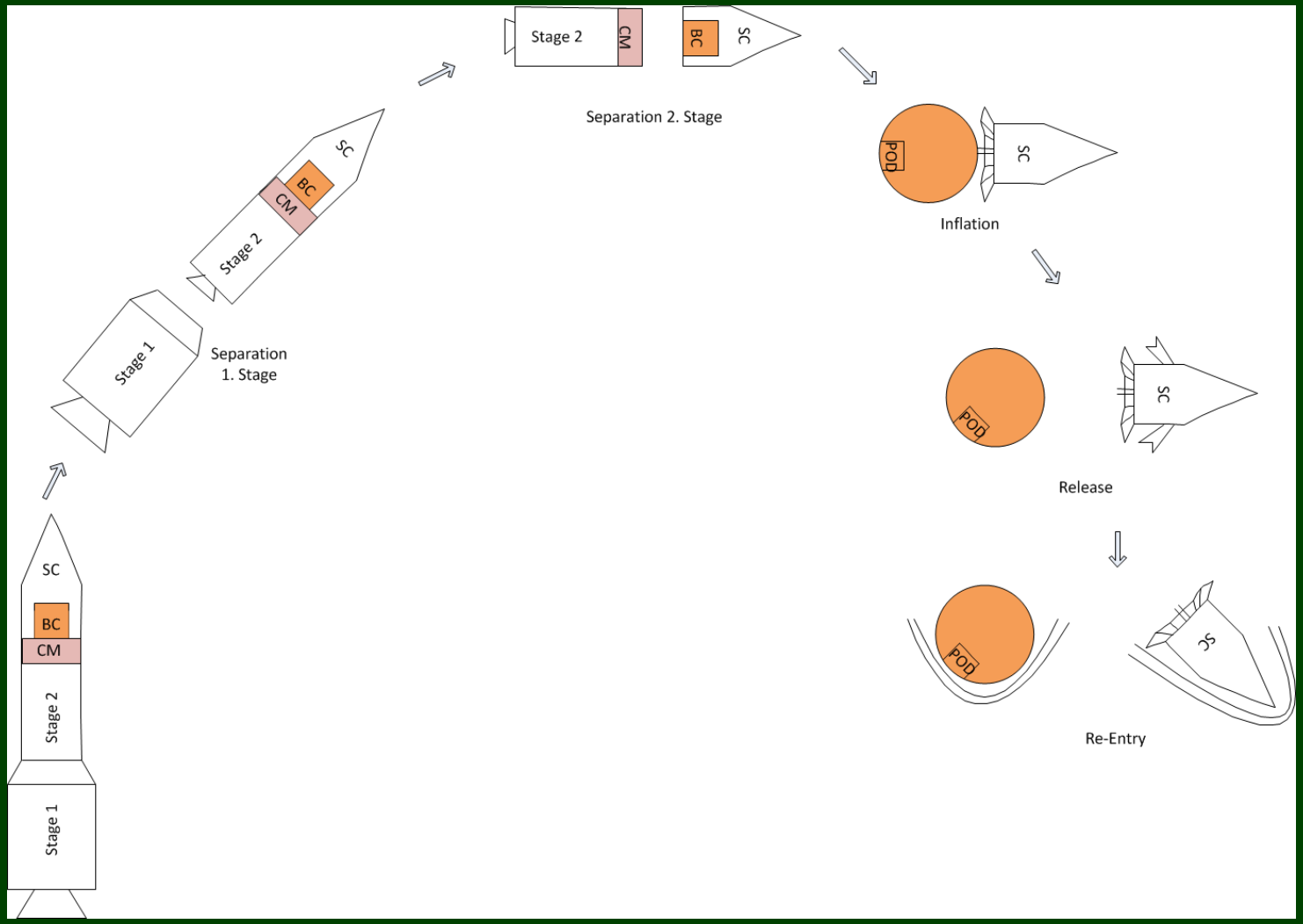


- => Spherical Balloon
  - Large, light and blunt
  - Natural pressure vesser (simple design)

- Ballistic Coefficient [kg/m²]: Ca. 0.5-0.6

Mission and Spacecraft Design

MIRIAM-2 Mission Phases



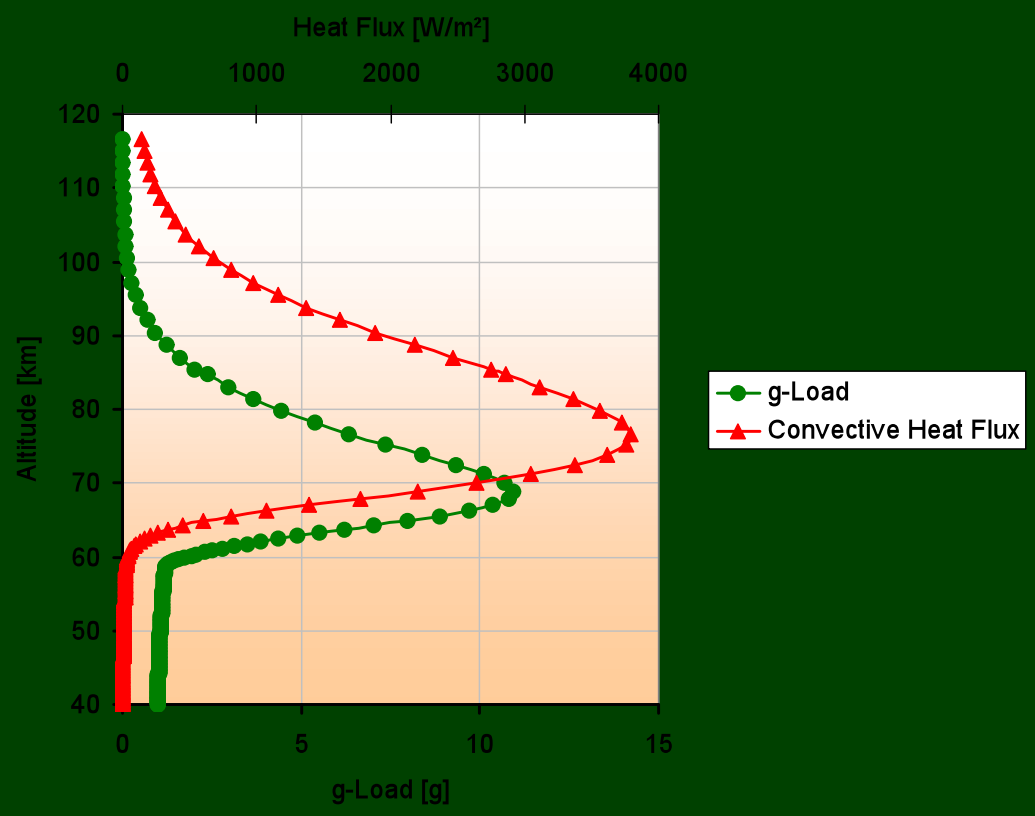
MIRIAM-2 Launch Vehicle

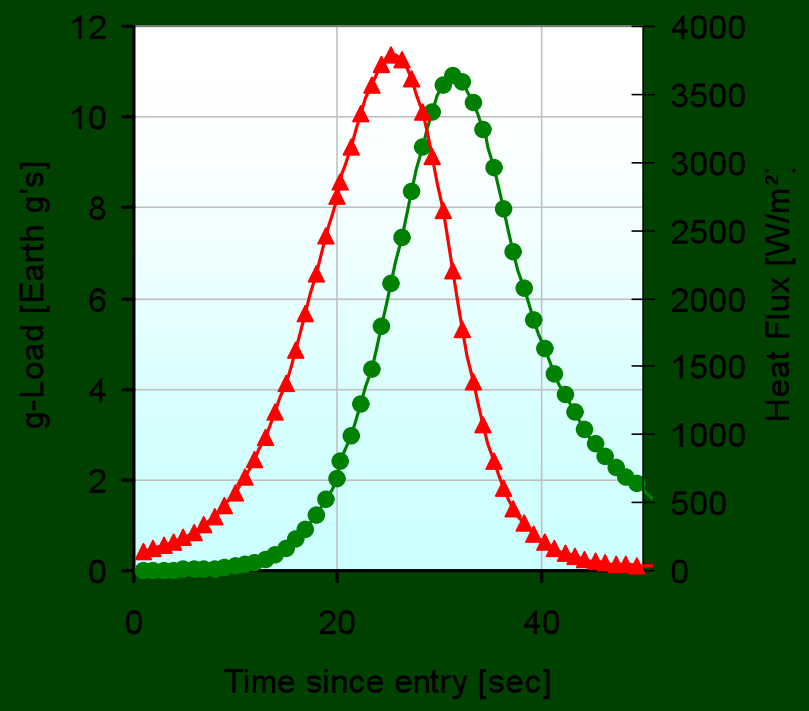
Design Reference Trajectory "Bonneville" I1R0

- "Bonneville" Trajectory: Main Features
  - Ballistic trajectory to suit MIRIAM test
  - Apogee between 200-300km
  - Downrange between 30-200km

- "Issue 1, Release 0" Main Assumptions:
  - Ballute Type: MIRIAM-1-Type Phase-II D400N32
  - Material: Upilex 25RN
  - Diameter: 4.0m
  - Pod Mass: 2.9kg
  - Peak Altitude: 250km
  - Entry Altitude: 120km
  - Entry Angle: -79.2°
  - Atmosphere Model: CIRA April Sweden
  - Cd-Ma Model: Goodyear Ballute 1967
  - Convective Heating Model: Sutton & Graves

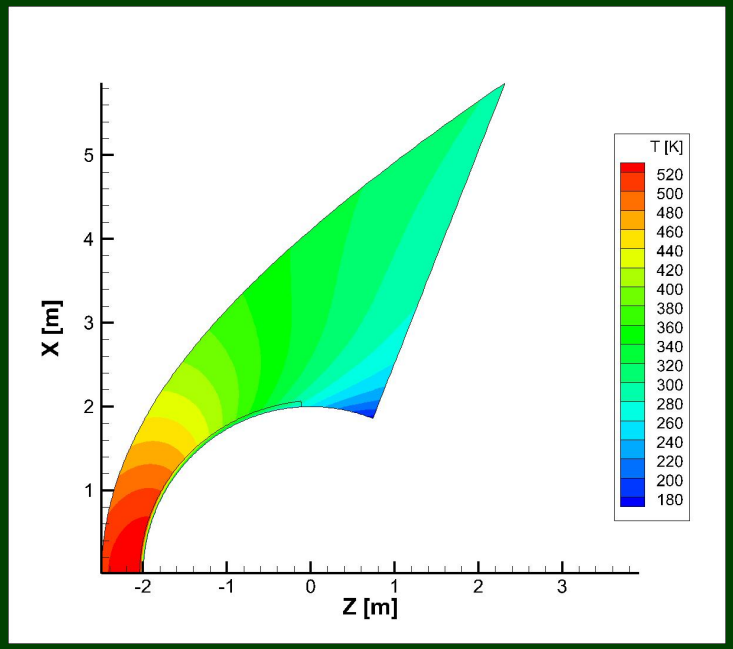
Bonneville 1.0 Characteristics

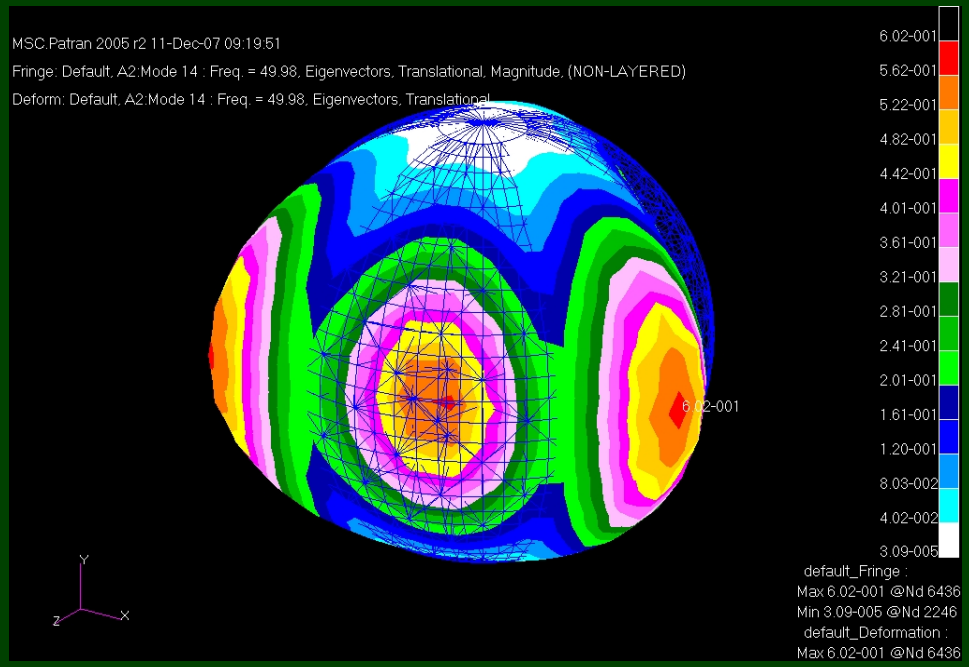




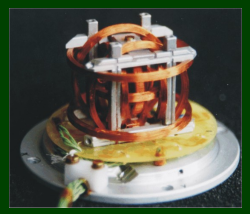
CFD and Aeroelasticity Analyses

- Max. Surface Temperature: approx. 500K
- Eigenmodes (4m Ballute): approx. 80Hz and 96Hz (1st and 2nd)



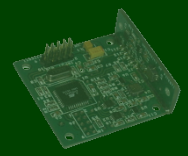


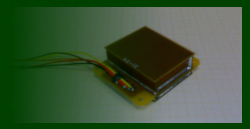
MIRIAM-2 Payload



- MIRIMAG (MiriMag)
  IGEP, TU Braunschweig
  K.H. Glassmeier

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

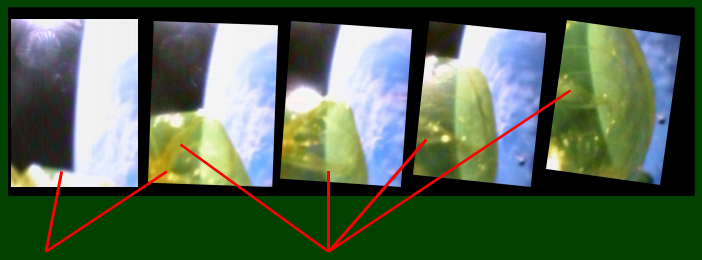




- ATMOS-B (Ballute Pressure)
  Finnish Meteorological Institute
  A.-M. Harri, J.Polkko

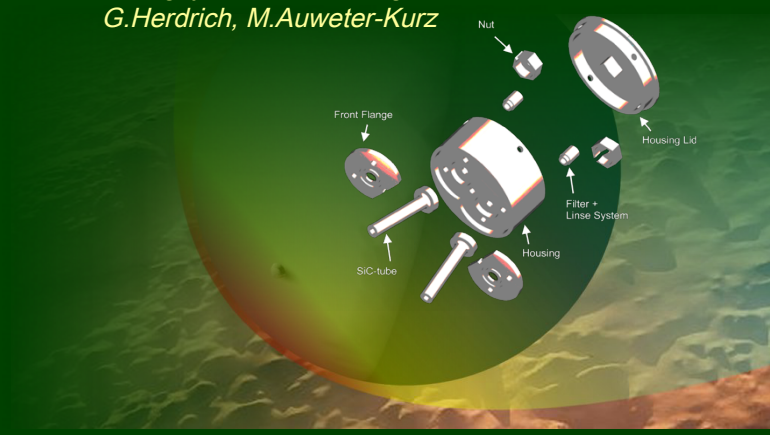
- GPS Tracking (Trajectory)
  DLR Oberpfaffenhofen
  M.Markgraf

- HDTV Camera (Ballute Dynamics
  Mars Society Deutschland
  H.Griebel

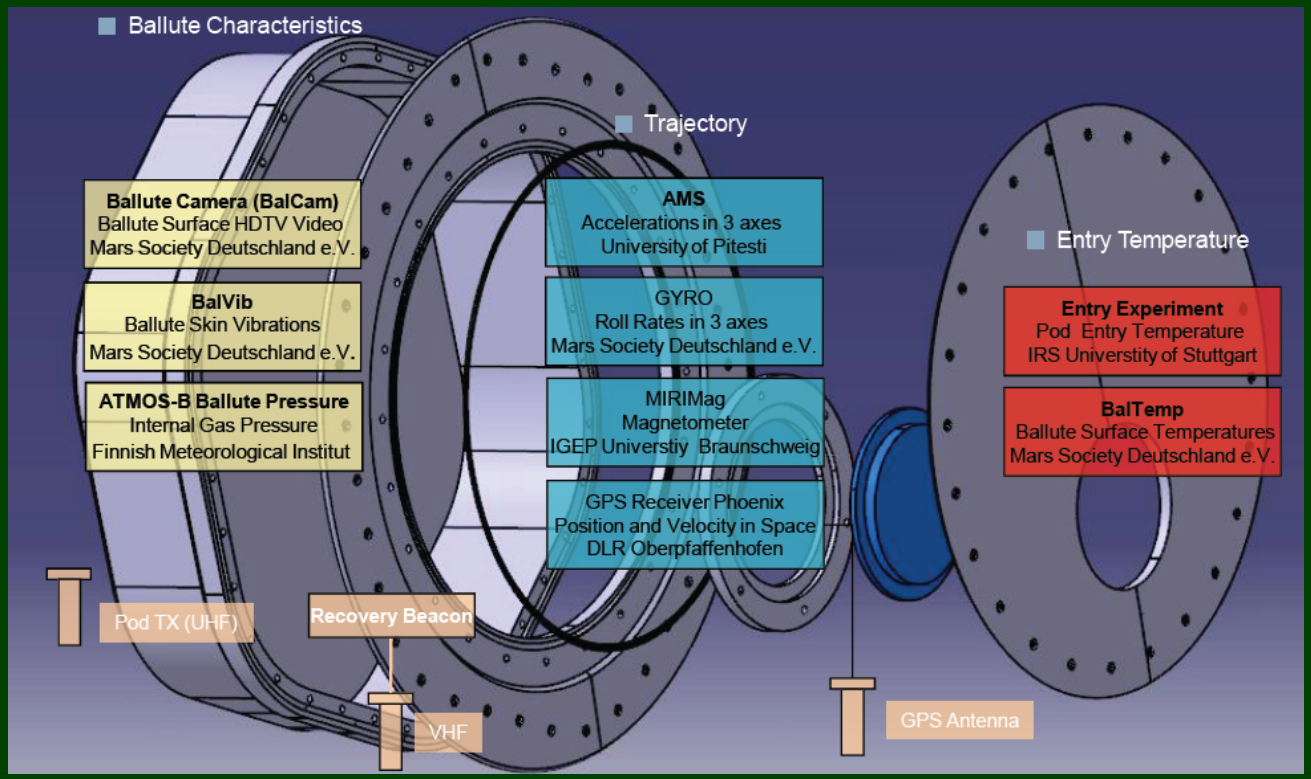


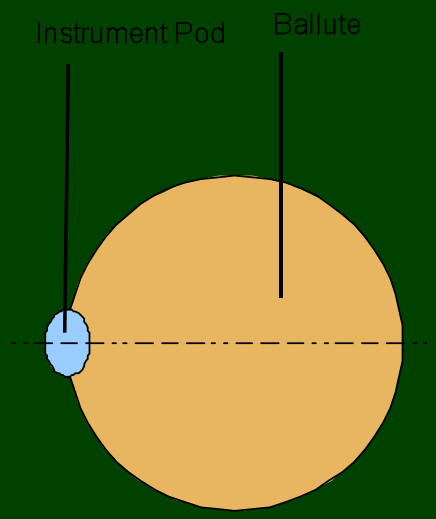
- Skin Vibrations (Ballute) Dynamics)
  Mars Society Deutschland / h.Griebel

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



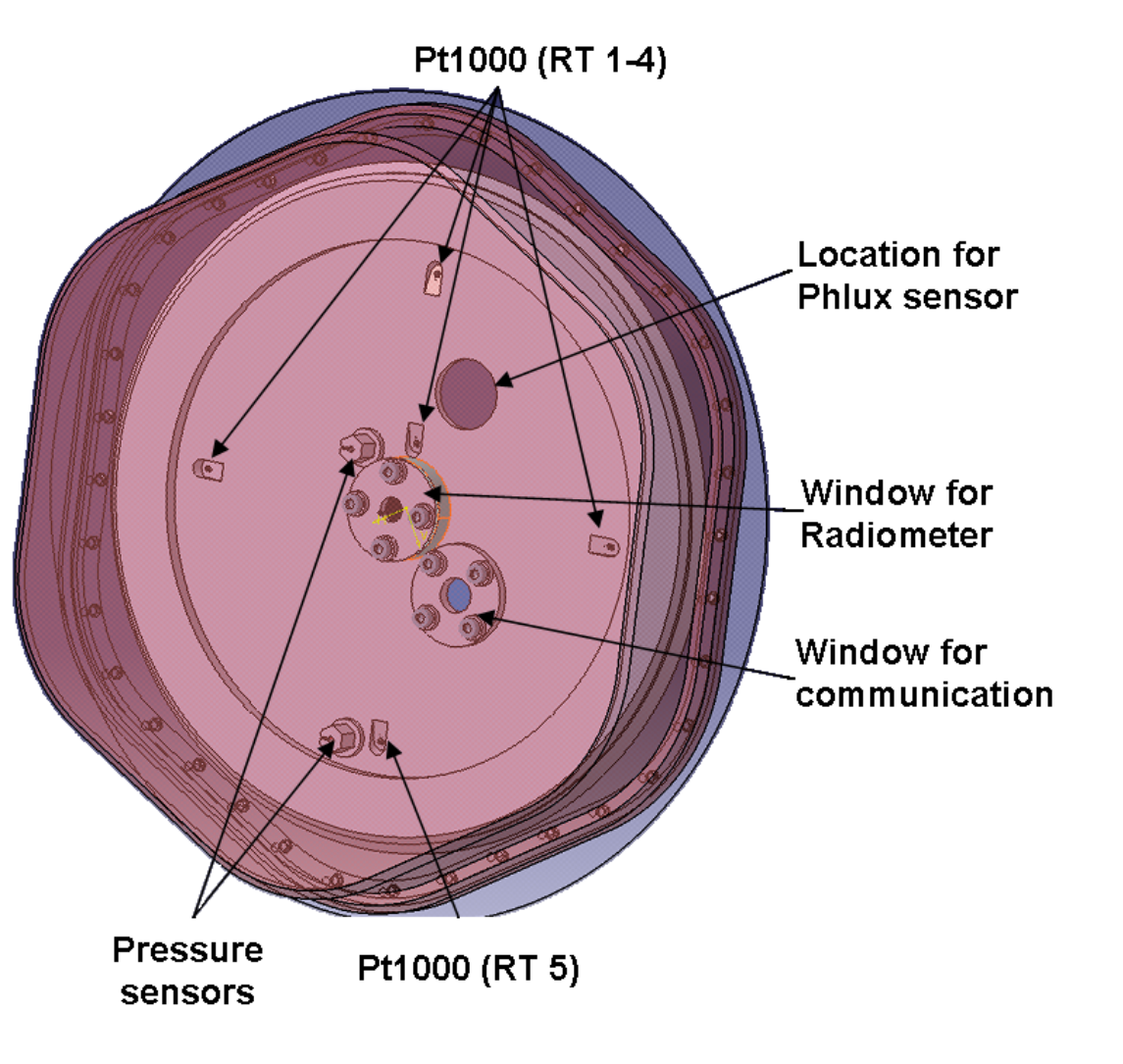
Ballute Spacecraft

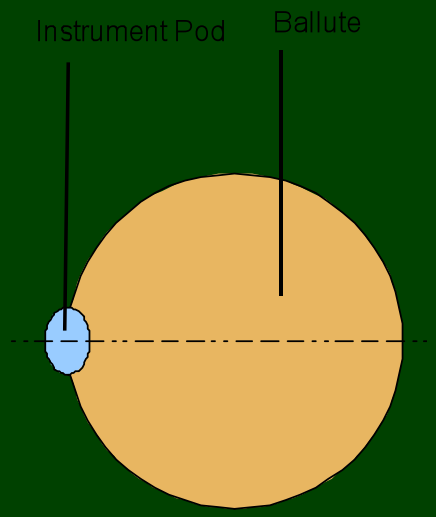




a) Spherical Ballute

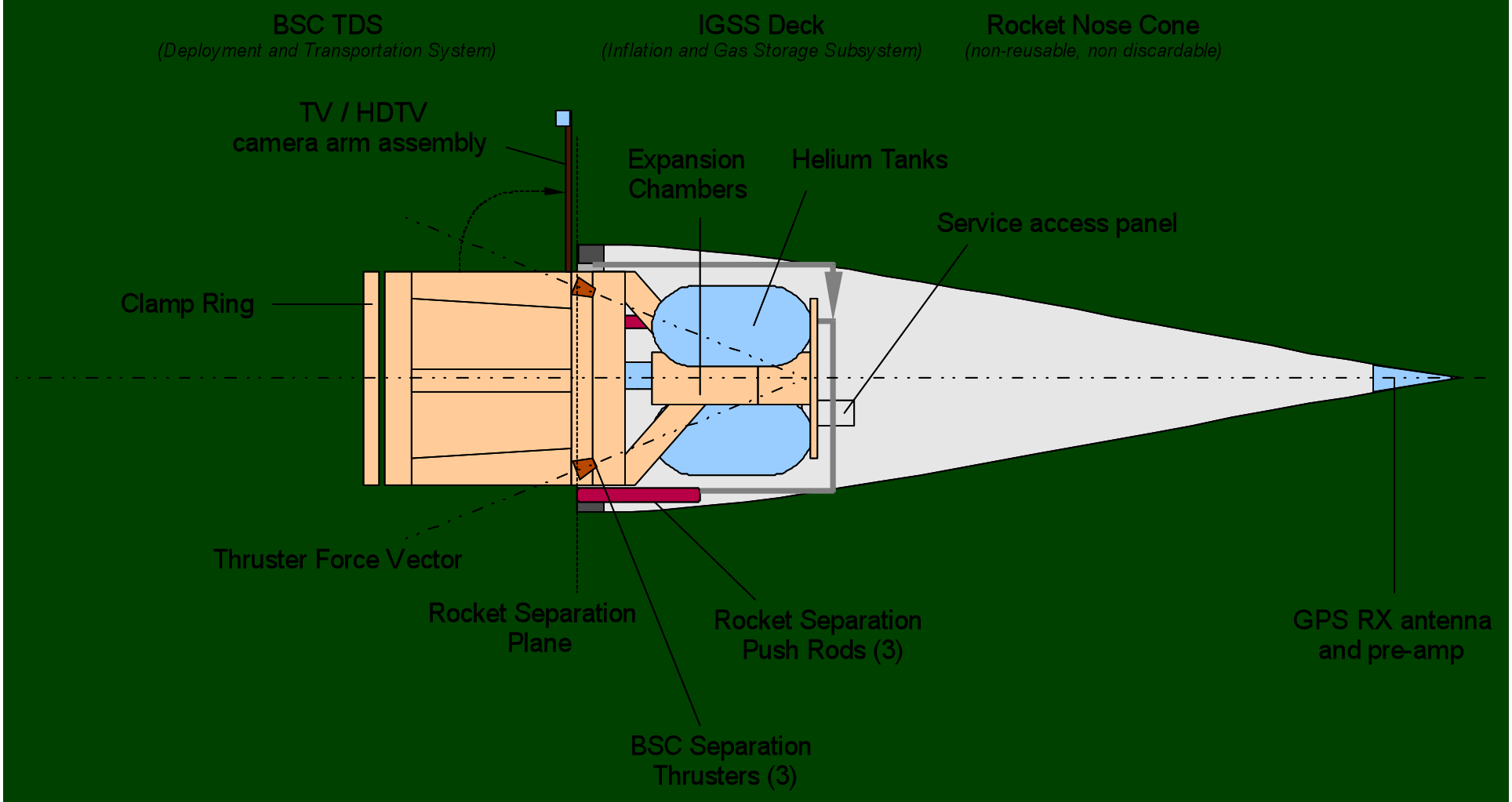
Ballute Spacecraft





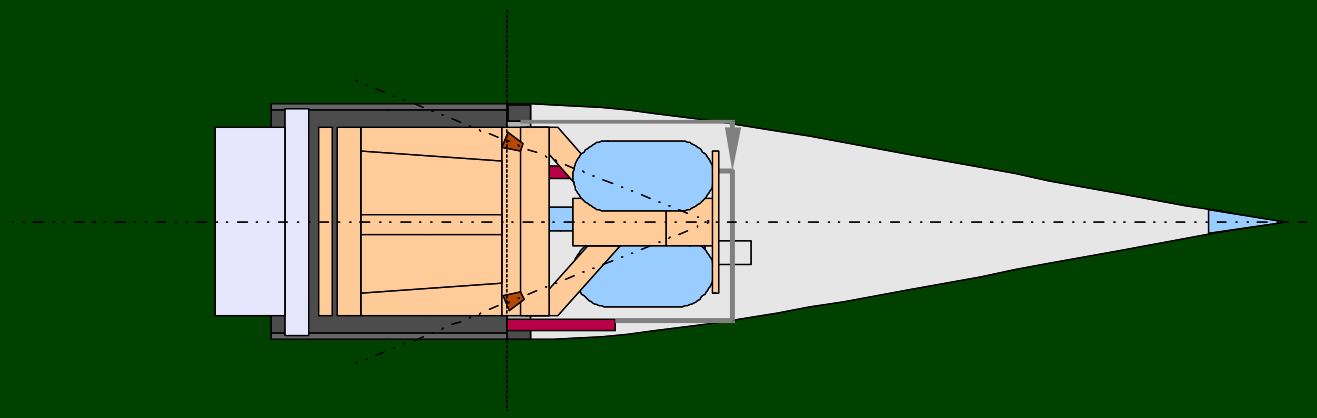
a) Spherical Ballute

MIRIAM – 2 Service Spacecraft



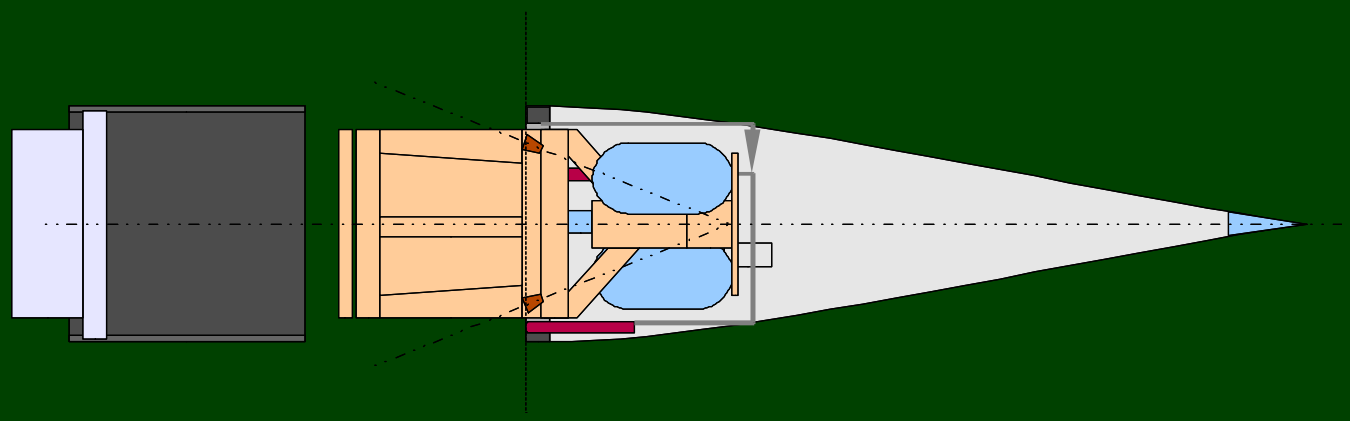
MIRIAM-2 “Paguros” Configuration Overview

Launch Configuration

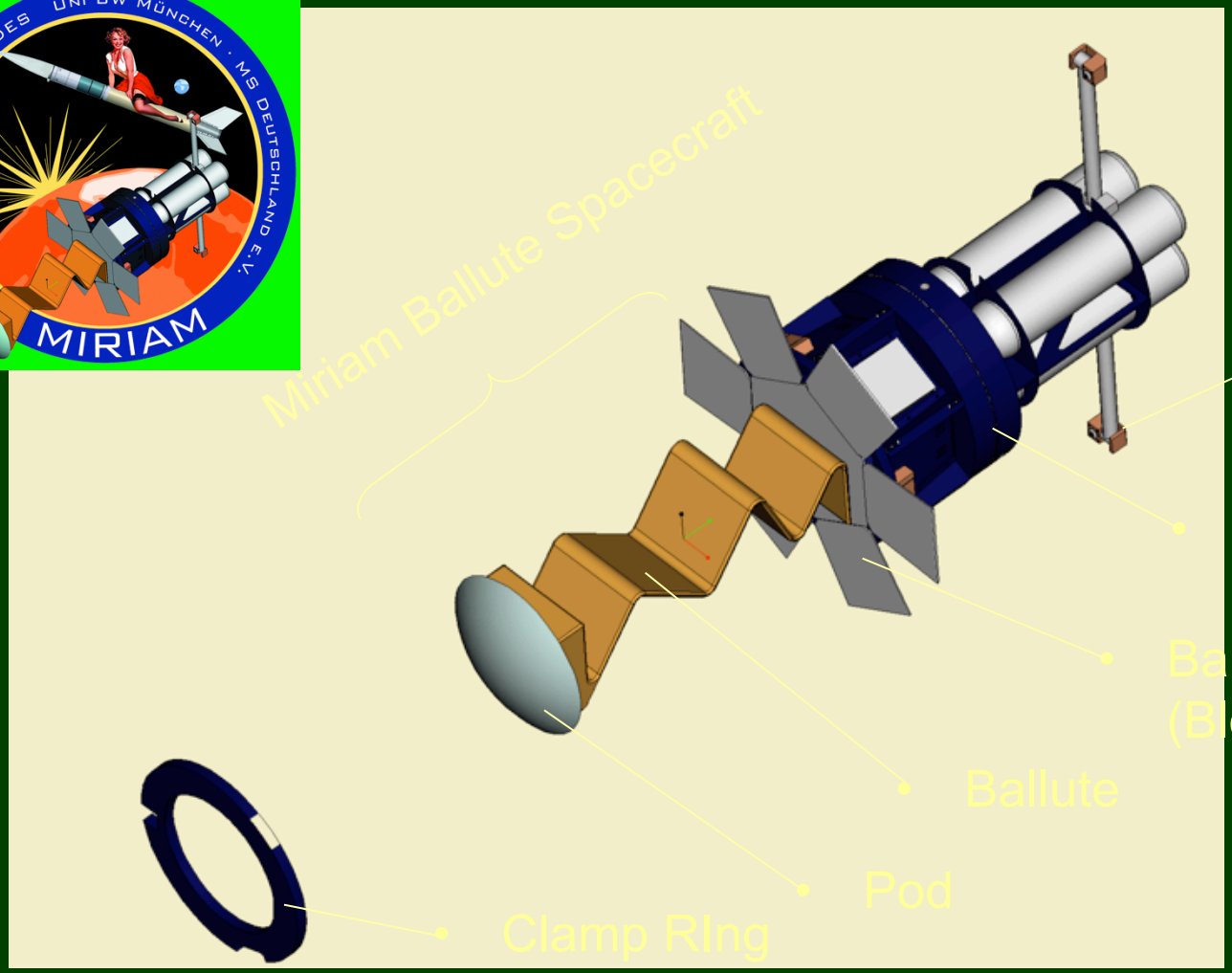


Camera Module and
Launch Vehicle Interface

Service Spacecraft



Miriam Flight Test



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
  - Parabolic flight deployment tests
  - Automated inflation and deployment system (ground based and space inflation tests (REGINA, MIRIAM-1))
  - Material tests
- Flight test of MIRIAM-2 essential next step.
  - Planned for October 2014

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)

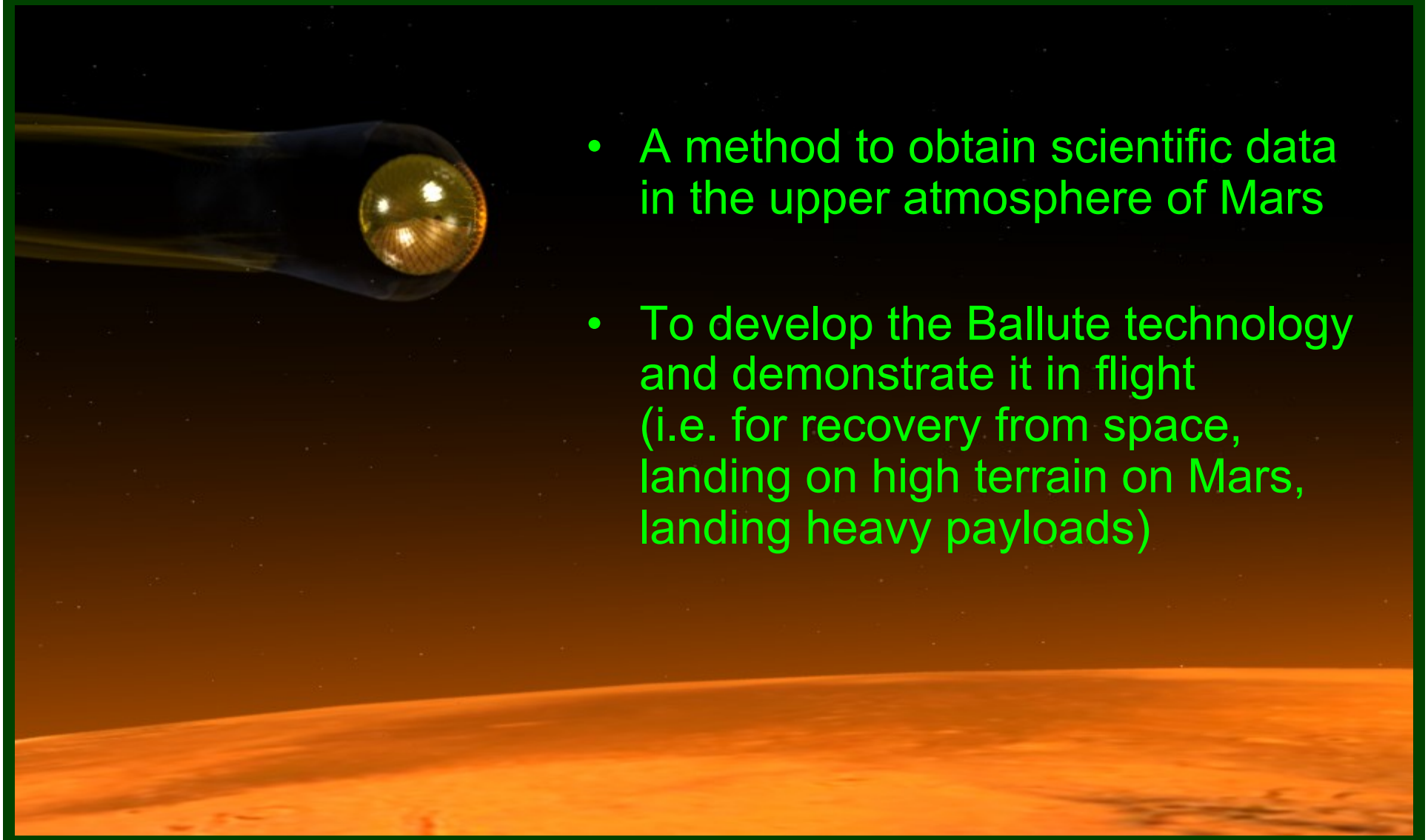
  - DLR Mobile Raketen Basis (MORABA)
  - ESA Directorate of Human Spaceflight @ ESTEC

  - Mitarbeiter des DLR Instituts für Robotik, Oberpfaffenhofen (Prof. Hirzinger)
  - Die Firma GmbH, Nürnberg
  - ELOXAL München
  - Arcotech

- *...and to you for your attention!*

Backup Slides

ARCHIMEDES 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)

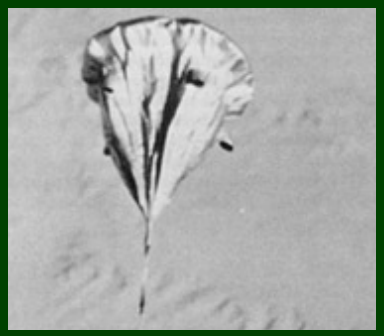
Technology Roots

ECHO
Inflatable passive communication satellite

+

IRDT
Inflatable Heatshield

+



Inflatable Hypersonic Decelerator

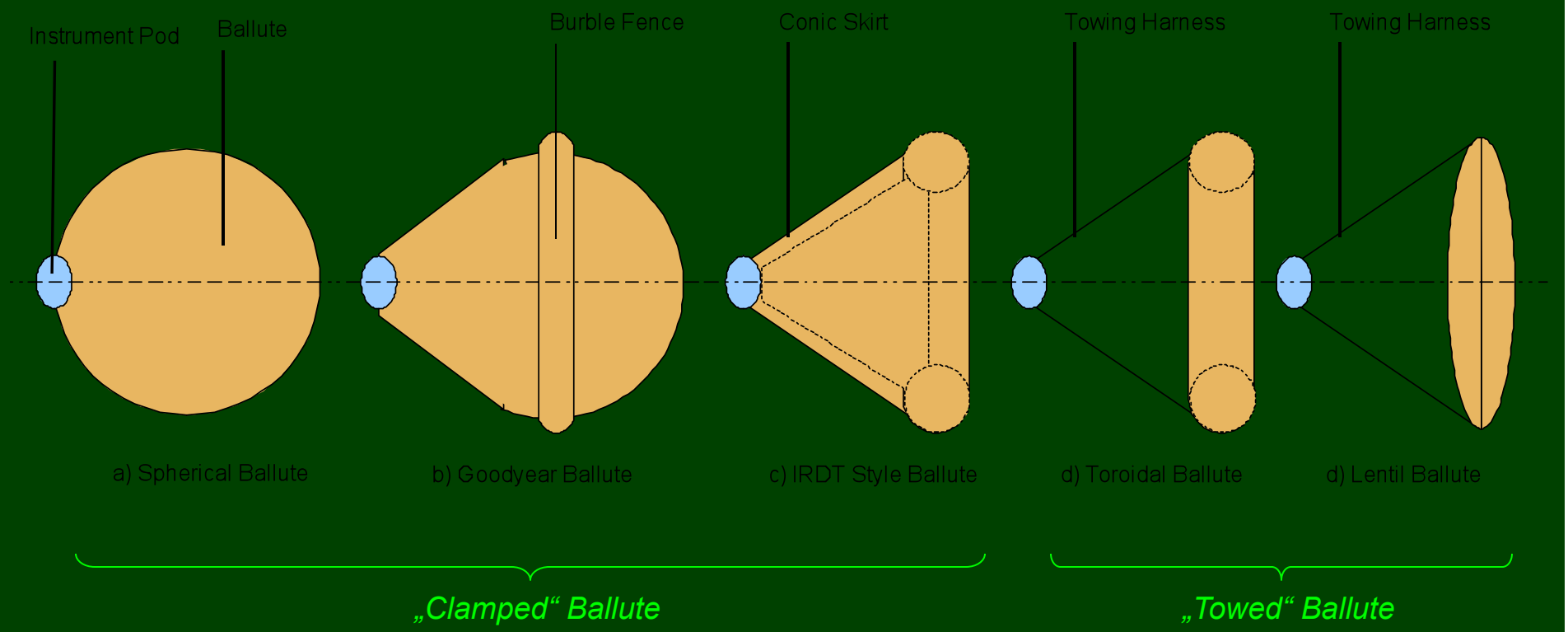
+

Stratospheric Balloon

=

Ballute Probe for high Altitude Atmospheric Sounding

Studied Configuration Options

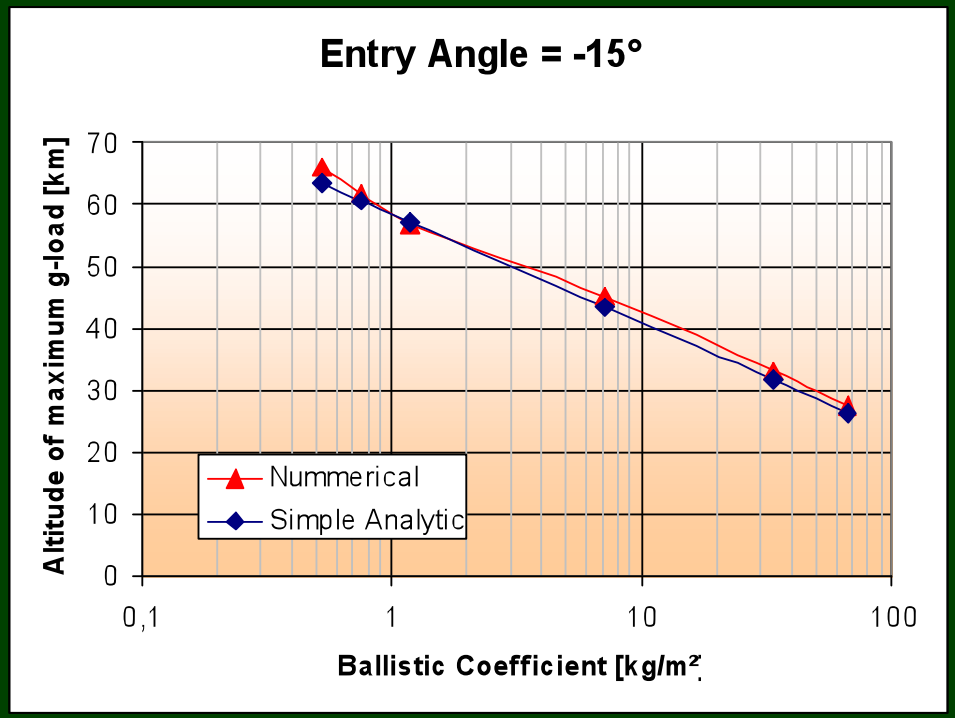


Determination Of the Desired BC: Min. Alt of Max-g

- May be a requirement
- Unrelated to actual feasibility!

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

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

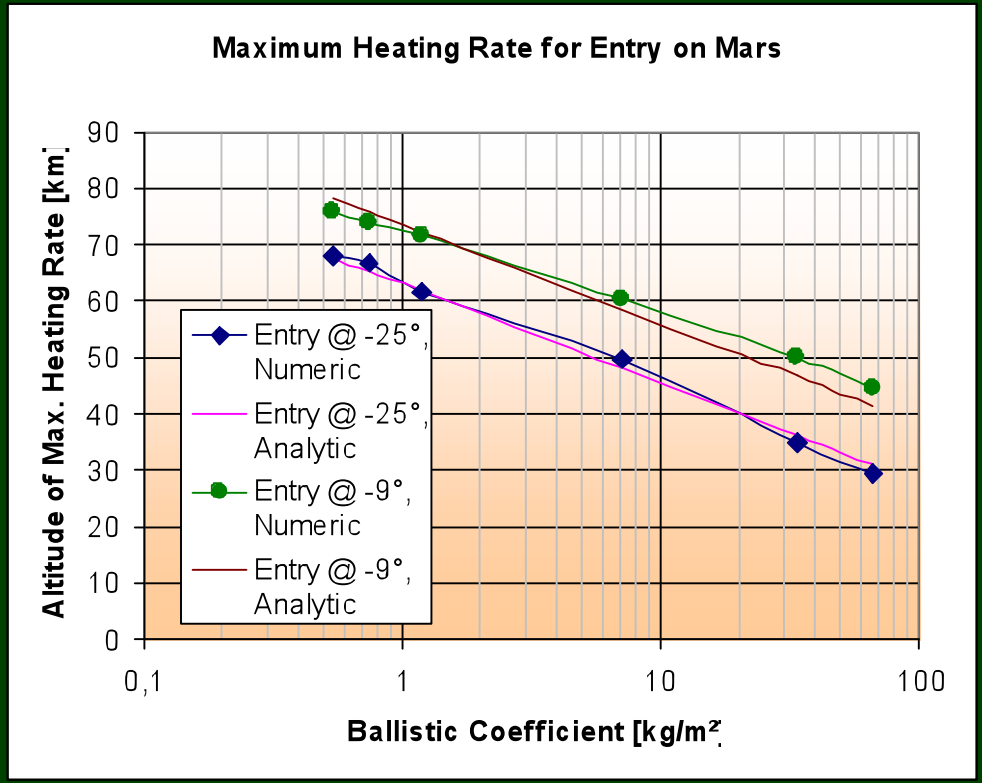


Determination Of the Desired BC: Max. Heat Influx

- May be a requirement
- Based on Sutton & Graves

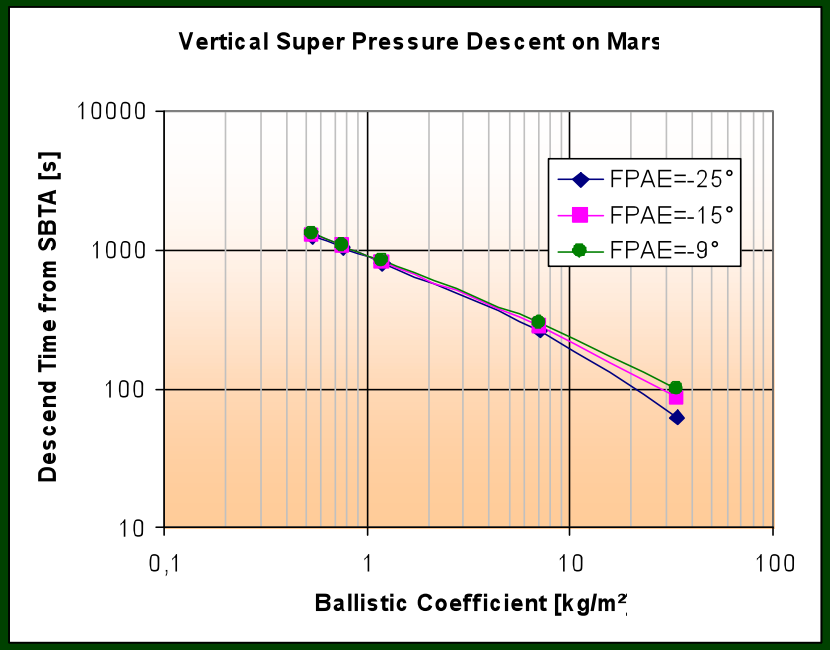
$$h_{c,max} = H_0 \cdot \ln\left(\frac{3 H_0 \rho_0}{\beta \sin\gamma}\right)$$

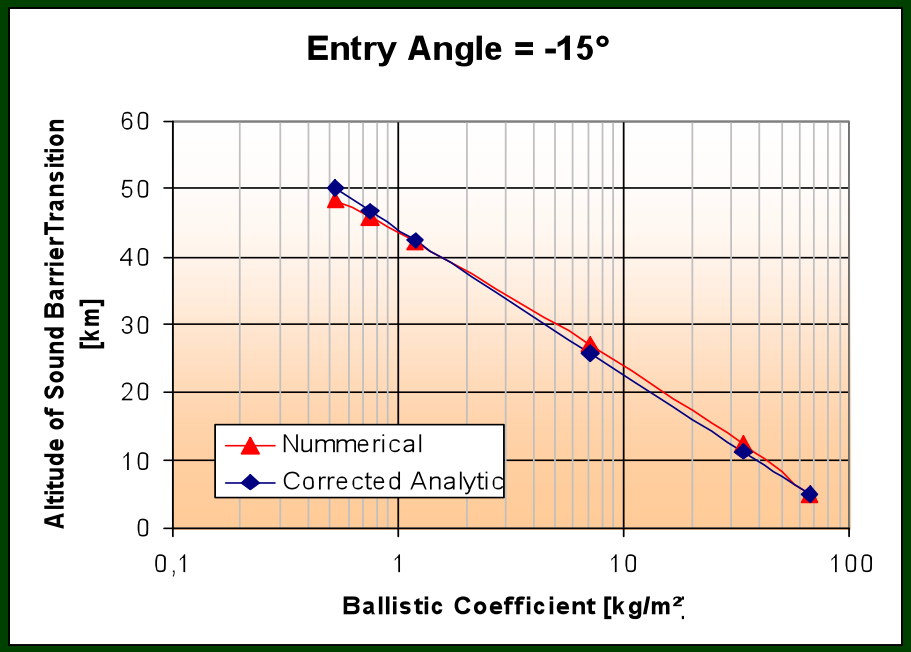
$$\beta_{design,max} = \dot{q}^2_{c,max} \cdot \frac{3 e\, 10^{10} H_0 R_N}{v_E^6\, \tilde{k}^2 \sin(\gamma)}$$



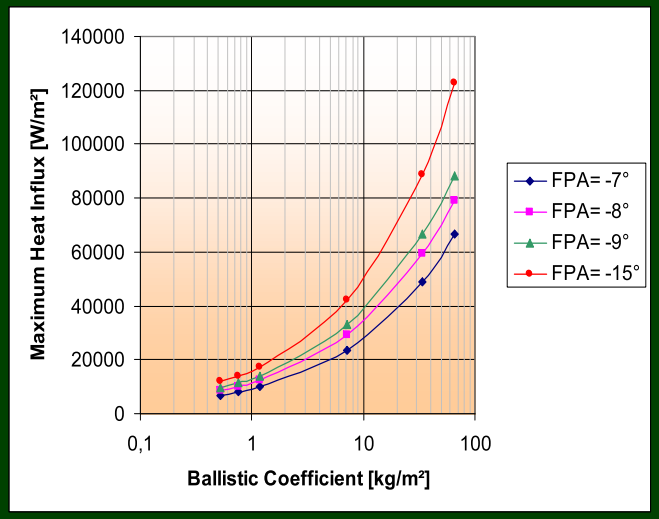
Determination Of the Desired BC: Mach-1 Transition

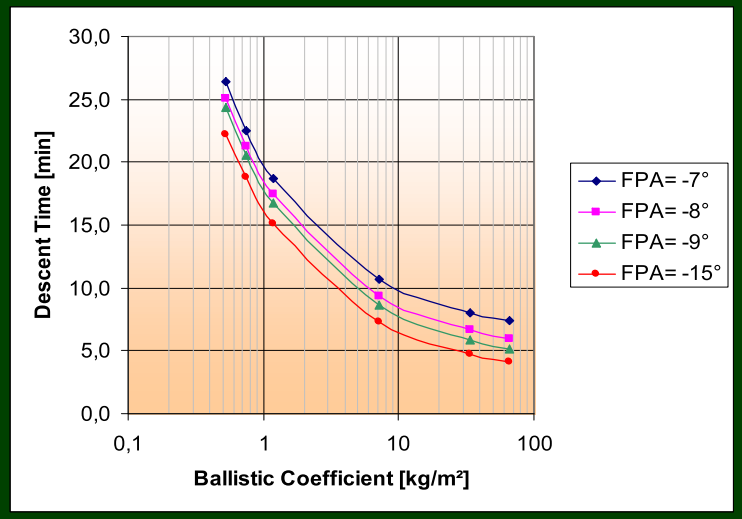
$$\beta_{max} = -\frac{H_0\,\rho_0\,e^{\frac{-h_{SBTA,design}}{H_0}}}{\left(2\ln\left[\frac{v_{sound}}{0.6065\,v_E}\right]\right)\sin\left(\gamma_{SBTA,limit}\right)}$$





Basic Principle

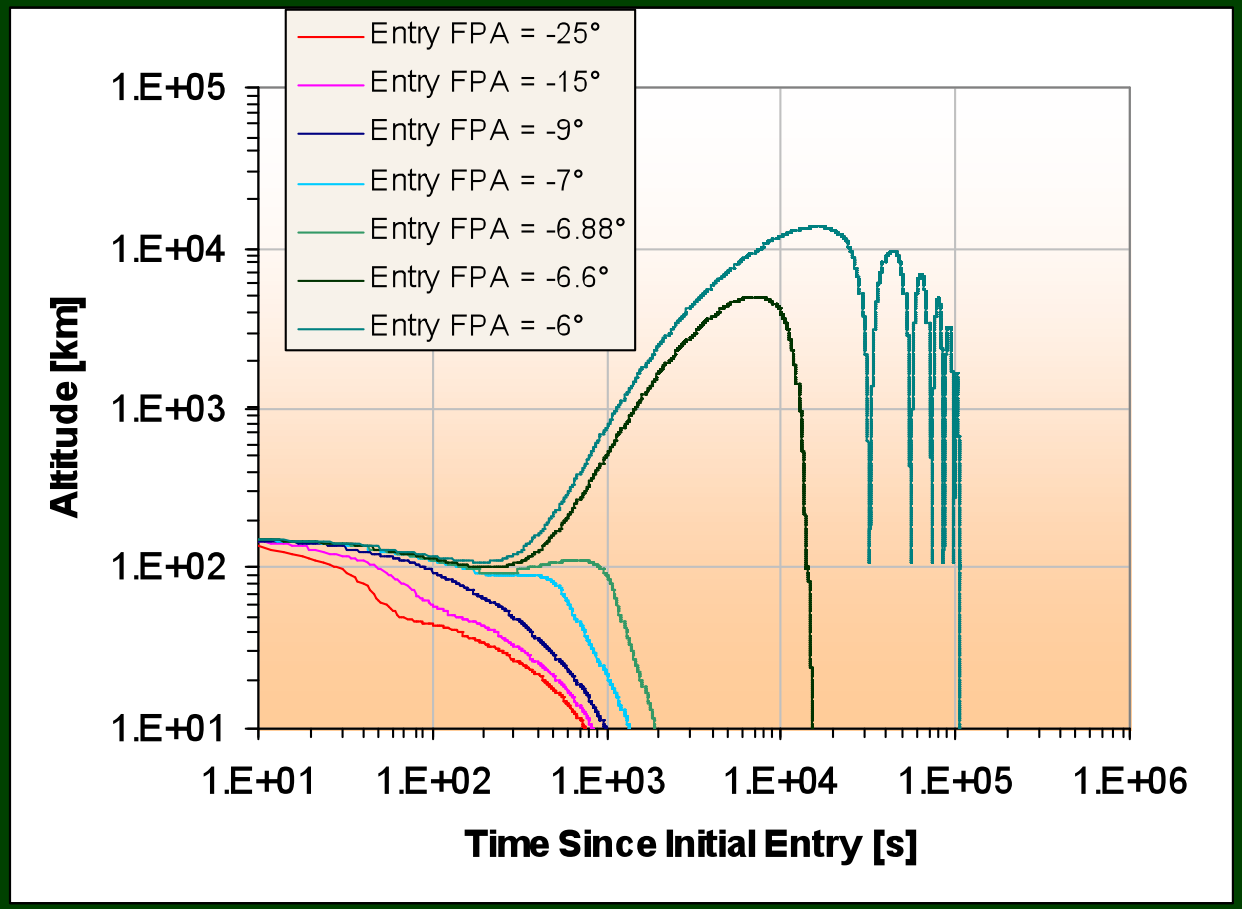




- => Spherical Balloon
  - Large, light and blunt
  - Natural pressure vesser (simple design)

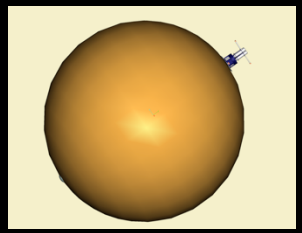
- Ballistic Coefficient [kg/m²]: Ca. 0.5-0.6
  - IRDT: Ca. $10^0 – 10^1$
  - Classic EV: Ca. $10^1 – 10^2$
  - Cannon Projectile: Ca. $10^2 – 10^4$

Ballute Probe on Mars



Ballute S/C Payload (s.KB)

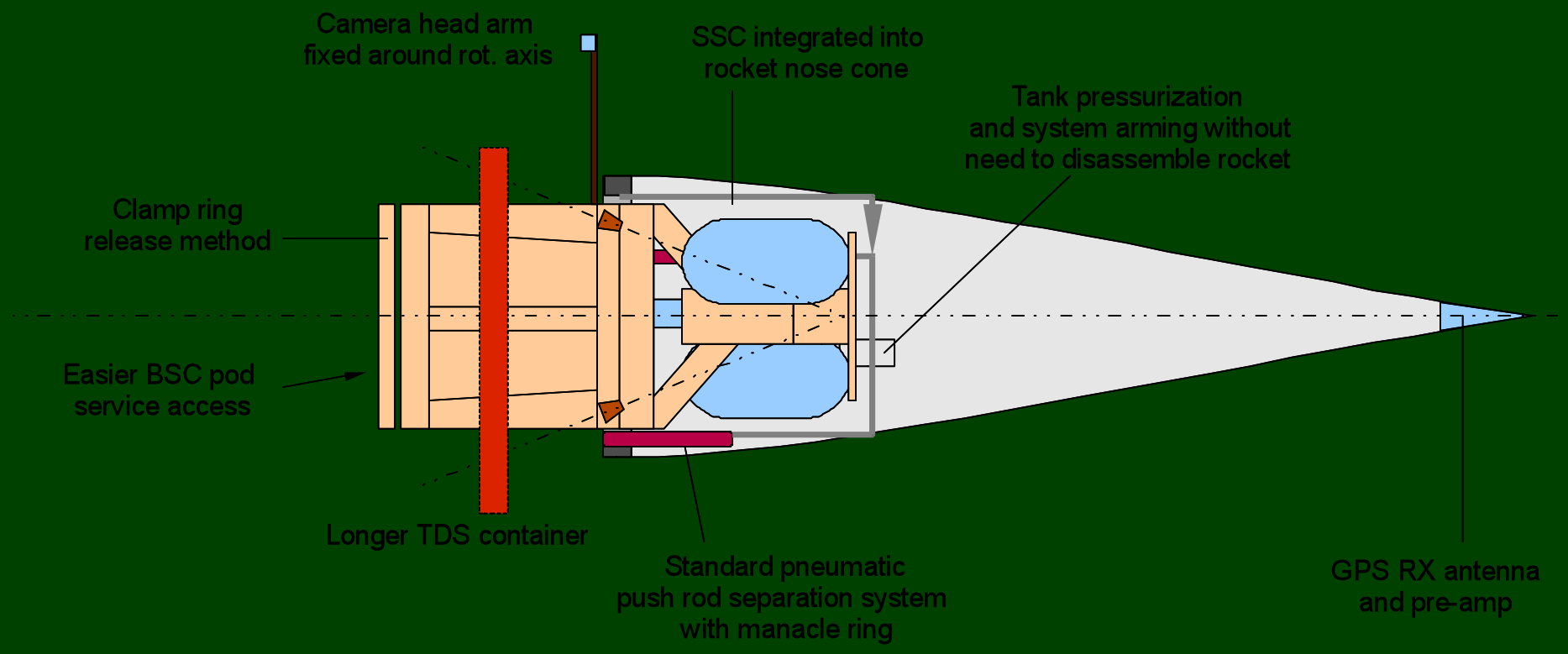
MIRIAM2



Instrument	*Ballute Propert.*	*Ballute Shp.*	*Ballute Vibs*	*Ballute Orient.*	*SC Charact.*	*Traj Temp.*	*Traj Prop.*	*Pod*
MiriMag				x				
Ballute Pres	0-20hPa							
Ballute Temp.	100-700K							
Accel & Gyro			0.5-5g	x			1.1-20g	
Down Look. Cam.				x	640x480			
Pod Temp.						100-700K		
Pod Power Bus								100-700k
GPS Rx							x	
Ballute Cam	HDTV@30fps			x				
Stereo Recorder			Skin Vibs 20kHz					

MIRIAM – 2 Service Spacecraft

Configuration Differences as compared to MIRIAM-1



MIRIAM-2 SSC

- Main Tasks (Top Level only!)
  - Has to interface with CMLV
  - Has to interface with BSC
  - Has to transport and deploy BSC
  - Has to inflate and release BSC
  - Has to remove itself from the BSC
  - Has to provide observation platforms
  - Has to provide telemetry, TV and data storage
  - Has to be recoverable

- "Unfair" asymmetry between SSC and BSC
  - SSC:
    ca. 90% of complexity (moving parts incl. S/W functions),
    ca. 10% of the "show".
  - BSC:
    ca. 10% of the complexity,
    ca. 90% of the "show".
  - (in between them 100%, without counting CMLV)

Camera Module and Launch Vehicle Interface (CMLV)

- Main Tasks
  - Has to interface with launcher
  - Has to transport and release SSC/BSC composite
  - Has to provide observation platform
  - Has to transmit telemetry and accept (limited) commanding
- “Unfair” asymmetry between CMLV and BSC/SSC:
  - For all its complexity, there is practically no “show”.

MIRIAM-2 SSC

- Main Differences to MIRIAM-1 SM:
  - Longer TDS container
  - Integrated in nose cone (if possible) to avoid collision risk and risk from NC separation
  - Standard push-rod separation system to avoid electromechanic actuators
  - Clamp Ring release method (pyros?)
  - Camera head assy. Deploys around one fixed axis (as compared to the additional unfixed DOF on MIRIAM-1 SM)
  - Integrated GPS receiver and GPS signal forwarding to Pod
  - Arming through hatch rather than NC removal

- Recovery Strategy
  - Provision of last GPS fix
  - Beacon with 24h minimum battery life
  - Beacon with proprietary tx frequency!