Hypersonic technologies and atmospheric entry missions at ESA

L. Marraffa, ESA/ESTEC, Aerothermodynamics Section

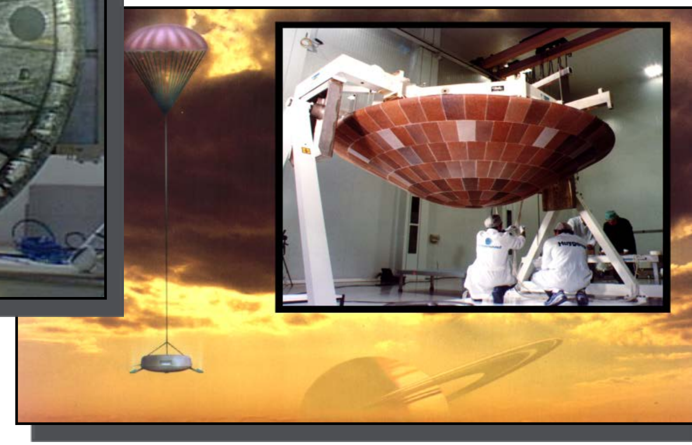
1st international symposium Hypersonic Flight
Rome,
30/6/2014

Structure of the presentation

1. Introduction
2. Technologies
    1. Facilities
        1. SCIROCCO PWT
        2. ESTHER Shock Tube
    2. Technological developments, New concepts
        1. Inflatable
        2. Deployable
        3. MHD
    3. Flight tests:
        1. EXPERT
        2. IXV
        3. Entry Observation Capsules
        4. IRDT project
        5. PHOEBUS
3. Coordination, direct technical support
4. Future developments

1. Introduction

ESA experience for (re)entry



- ARD : low Earth orbit (7.8 km/s)
- IRDT : Suborbital (7km/s)
- Huygens : Titan (6km/s)
- ATV destructive entry (7.8 km/s)

- ExoMars: Mars, <6km/s
- Expert, IXV, ARV,... < 7.8 km/s

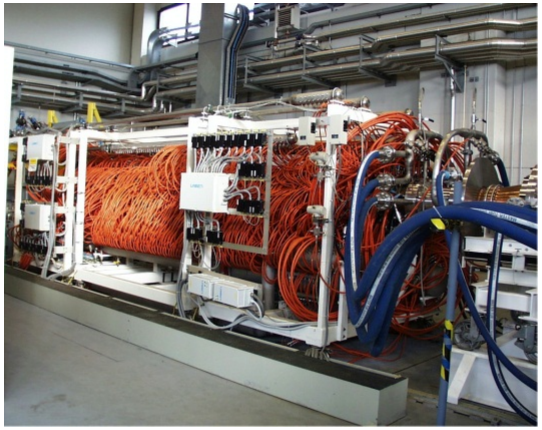
- Future sample return missions: 11-15 km/s (velocity higher than the Earth escape velocity!)
- Scaling of Earth entry fluxes for TPS design is $V^{3.5}$ for convective fluxes, and V^{9} or more for radiative fluxes.

2. Technologies

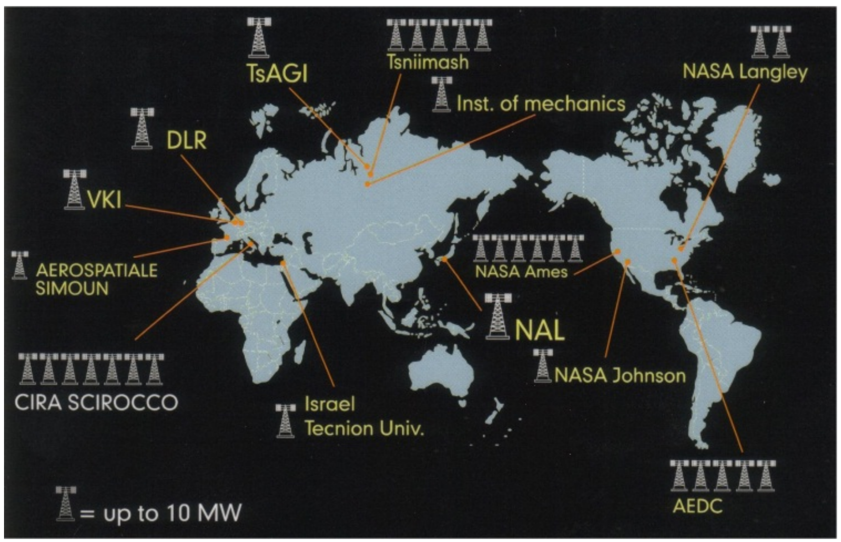
2.1. Facilities

2.1.1. SCIROCCO PWT

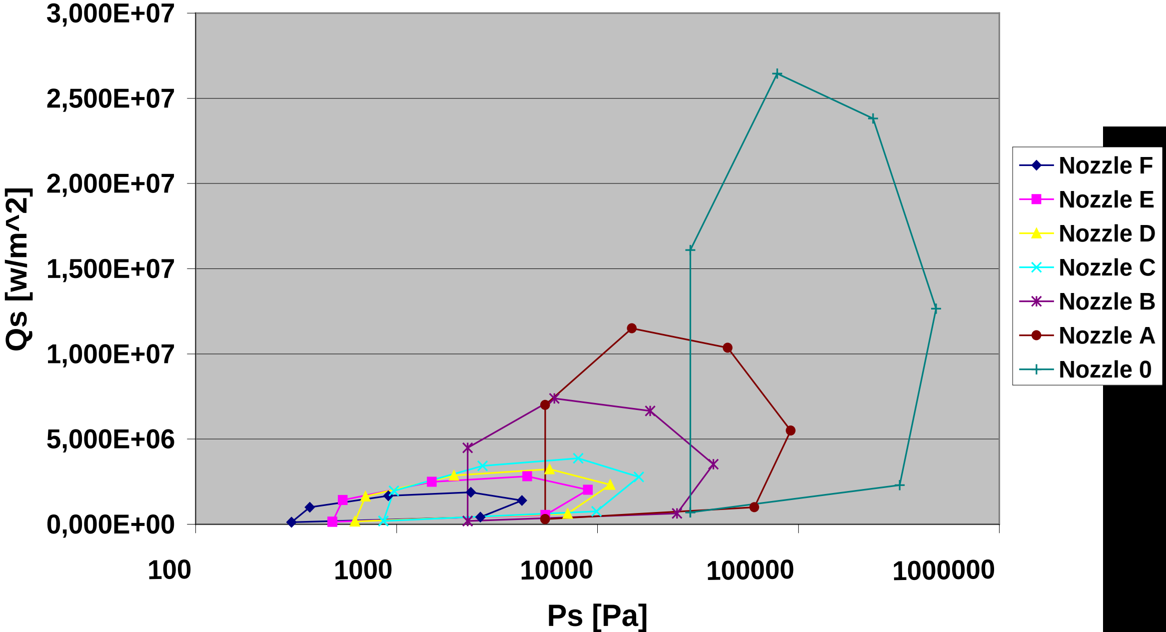
SCIROCCO PWT

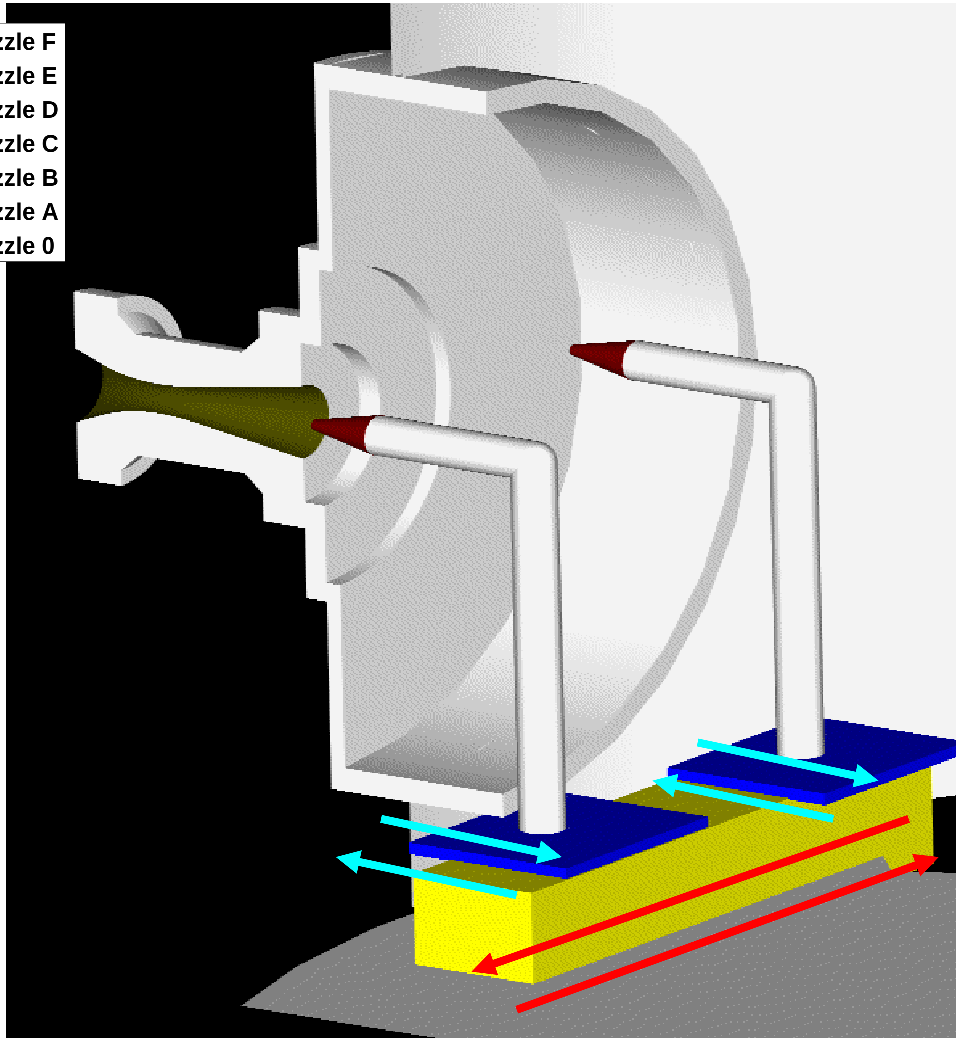


Largest facility in the world
Designed for orbital spaceplanes (HERMES)
Versatile facility



SCIROCCO upgrade





- Future high speed entry missions
- Increase SCIROCCO capabilities (20 MW/m^2, around 10^5 Pa).
- Also useful for other applications (air breathing etc…)
- Modifications:
  - Nozzle-less configuration,
  - new sample holder devt and impl.
- 14 MW/m2 achieved. 20 MW in 2nd phase

2.1.2. ESTHER shock tube

European Shock-Tube for High Enthalphy Research ESTHER

- Shock-Tube: A facility for reproducing the conditions of an atmospheric entry
- Support to planetary exploration missions and meteoroids planetary protection research
- funding from the European Space Agency and IST/IPFN
- First facility of its class to be built in the last 30 years in Europe
- World class facility capable of reaching superorbital shock-speeds in excess of 10km/s

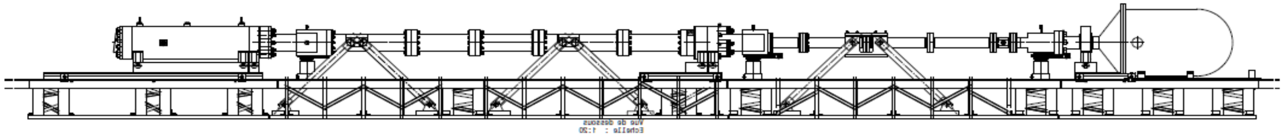
Length: 16m
Test-section diameter: 80mm

Shock Velocities: 4-12+ km/s
Pre-shock press.: 0.1--100+ mbar

Compositions: Air (Earth), CO_2-N_2 (Venus, Mars), N_2-CH_4 (Titan)

Shock tube parts machining

Outside view of the laboratory and view of the experimental hall



ESTHER shock-tube

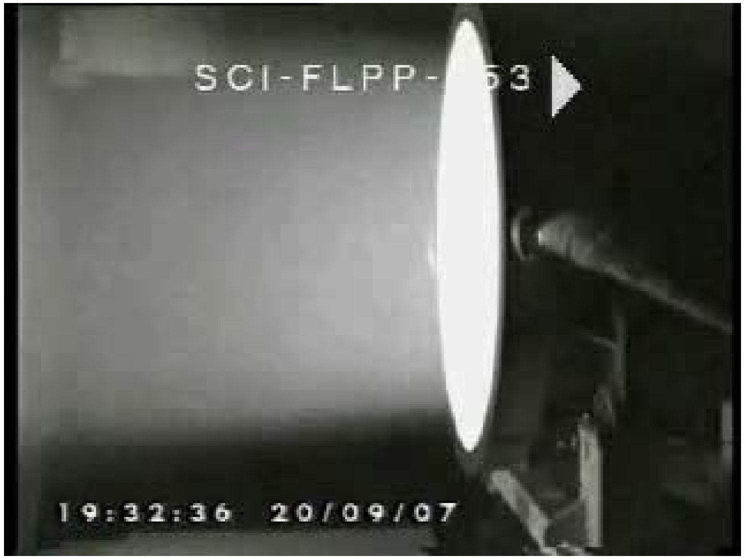
Credit IST

2.2. Technological developments, new concepts

FLPP: reusable launcher technology

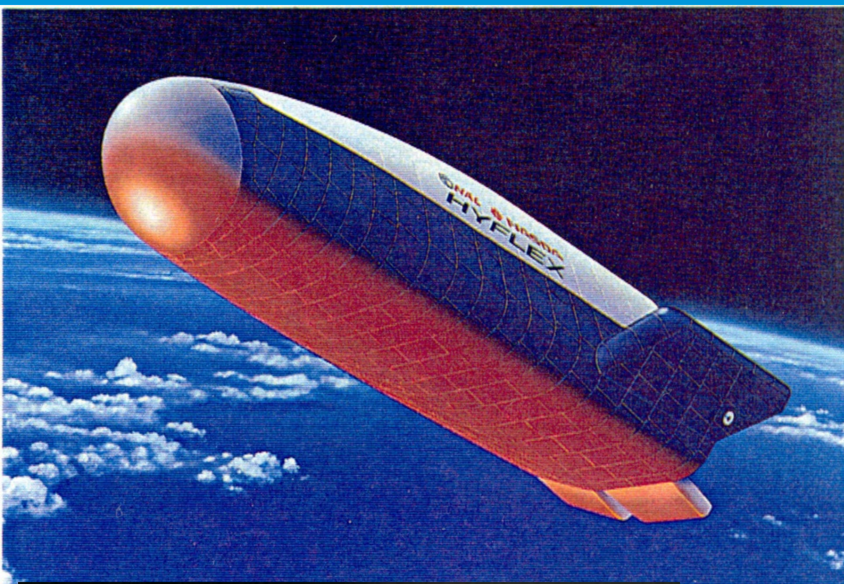
Ceramic Matrix Composites (CSiC) TPS (for fluxes ≤ 0.8 MW / m2)

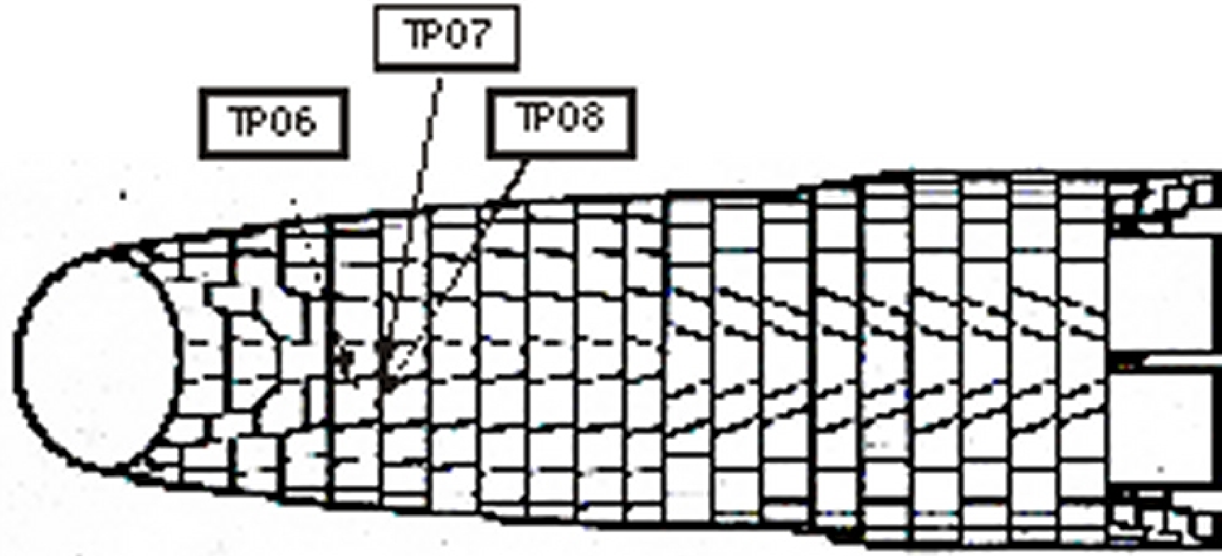
- Oxide Protection Layer performance
- Extended lifetime plasma exposure
- Stability of artificially induced damages in plasma
- Observation of the partial catalycity effects on heat flux-to temperature relationship

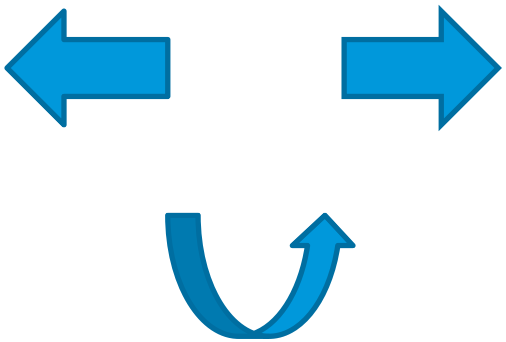


- Residual strength and mass loss inspection
- behavior of sensor instrumented shingle,
- inter panel gaps arrangement and sealing systems,
- thermal insulation fastening system to the vehicle substructure

Gap Heating: HYFLEX



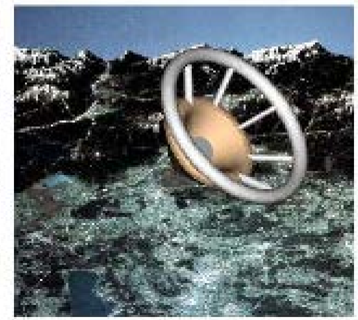




PARES Project History

1999-2000

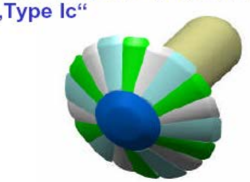
ISS Download System
Driven by technological considerations
→ Inflatable Braking Device

Nov 2003 – Jun 2004

OCRS Pre-Phase A
→ Payload requirements & download needs

#1: Deployable Heat Shield „Type Ic“

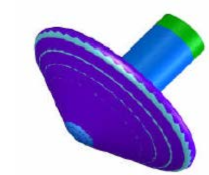


#2: Deployable Decelerator „Type IIb“

Sep 2004 – Nov 2004

PARES Concept Consolidation Phase
→ Shape selection, EADS-ST internal team

#3: Inflatable Heat Shield „Type Ia“



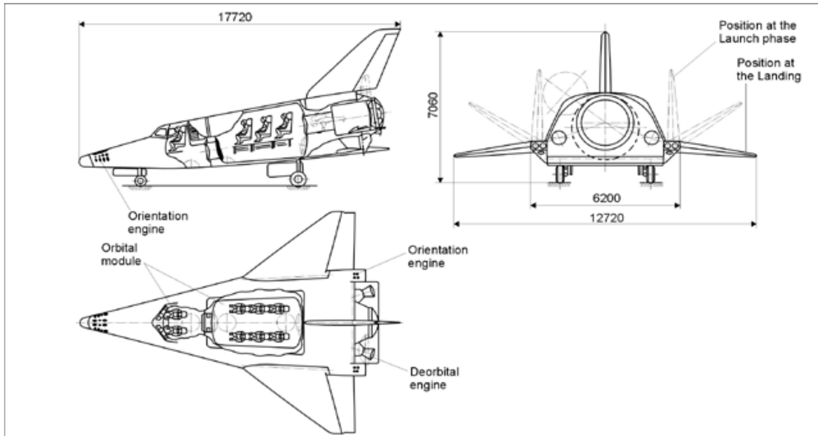
#4: Rigid Stabilizer TPS „Type III“

Dec 2004 – May 2006

PARES Phase B
& Pre-development Activities as Risk Mitigation Measure
Apr 2005: SRR
Mar 2006: PDR

EADS SPACE TRANSPORTATION
ALCATEL ALENIA SPACE
An Alcatel/Finmeccanica company
APCO TECHNOLOGIES SA

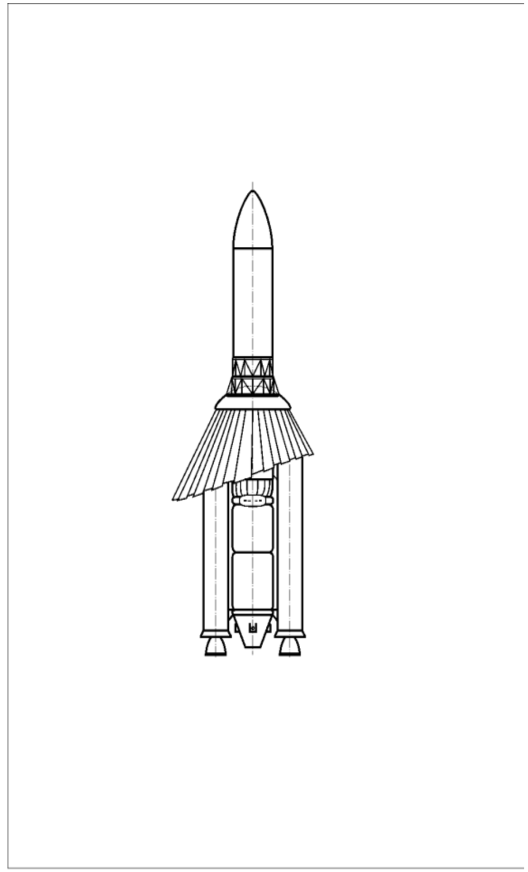
Foldable wings study

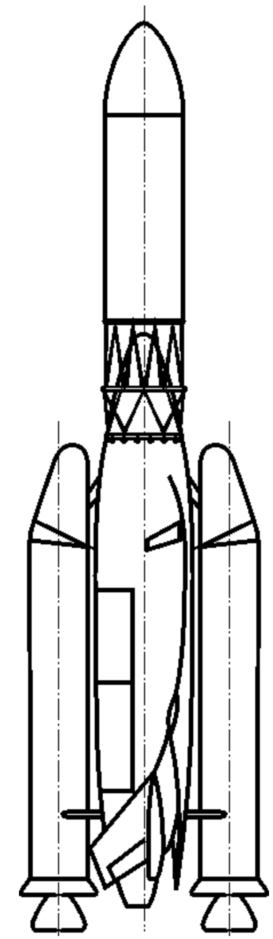


Layout diagram of the rescue vehicle

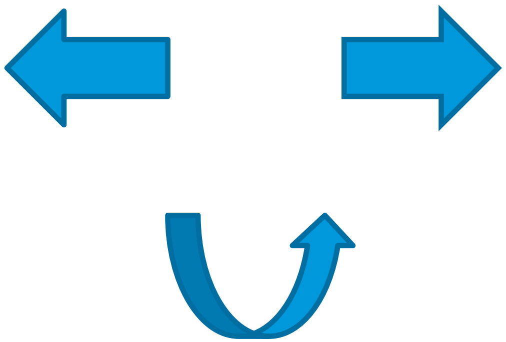
EADS SPACE TRANSPORTATION

Molniya-T





New TPS concepts



Inflatable Reentry Technology

IRT: Masses and Dimensions

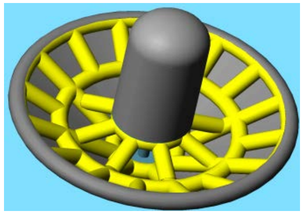
Dimensional Characteristics	Cone Semi-Angle of 60° and nose radius: 1000 mm Reference diameter: 2500mm
Mass	DLS mass: 350 kg IHS mass: 59 kg IRT (IT and TPS) mass: 52 kg Inflation system mass: max 7 kg
Folded volume	175 litres
Main functions	to slow down the speed of DLS from 8 km/sec to 0.9 km/sec in 200 second approximately.
	to withstand 405 kW/sqm and 50MJ/sqm (non catalytic wall, radiative equilibrium, initially cold wall)

IRT - Requirements

IRT Concept Selection

Tubular Beam Truss vs. Axisymmetric Structure

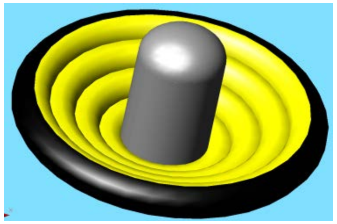
Tubular Beam



Plus
- Lower weight (4,8 kg)
- Lower inflation volume (0,5 m³)
- Reduced contact areas with TPS
- Folding capability
- Stability
- Shape requirement

Minus
- Manufacturing complexity

Axisymmetric Structure



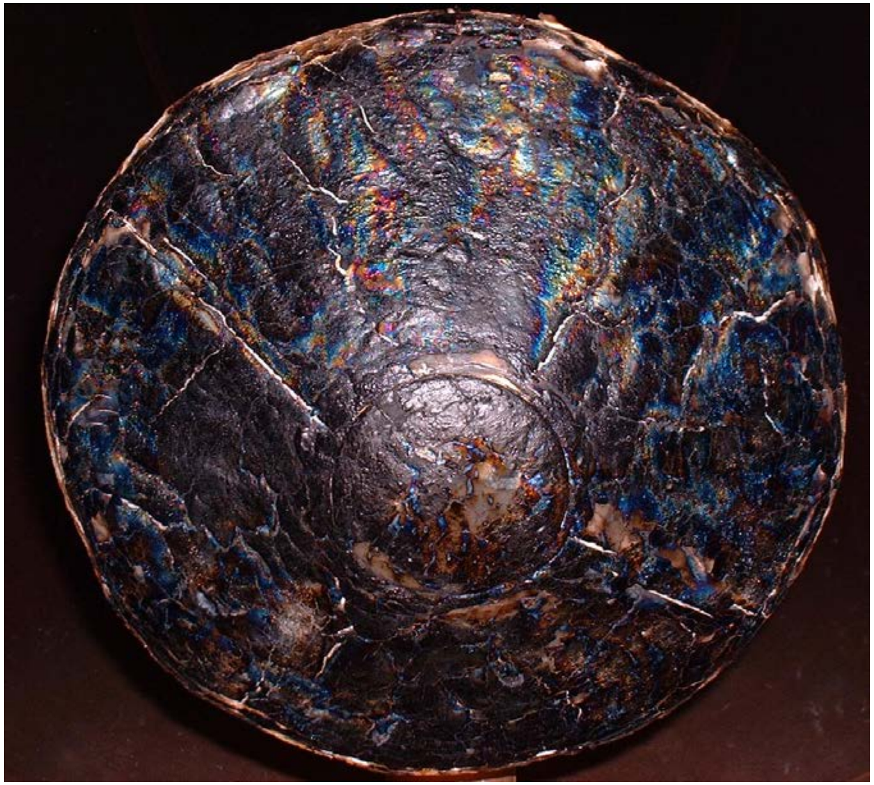
Plus
- Manufacturing simplicity

Minus
- Higher weight (6,5 kg)
- Higher inflation volume (1,4 m³)
- High contact areas with TPS
- Folding capability
- Stability
- Shape requirement

AEROSEKUR

IRT Demonstrator for ground tests

Demonstrator before plasma test



Demonstrator after SCIROCCO plasma test

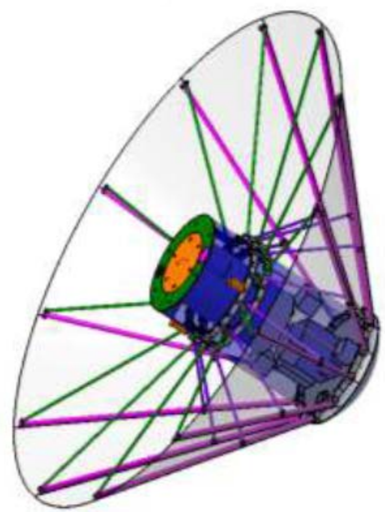
AEROSEKUR

Deployable heat shield: IRENE

Deployable heat shield: mini IRENE

ASI has supported since 2010 a research programme, called IRENE, to develop a low-cost re-entry capsule, able to return payloads from the ISS to Earth and/or to perform short duration, scientific missions in LEO.
The main features of the IRENE capsule are:

- light weight (100-200 kg), 3 m fully deployed
- payload recoverability and reusability
- low-cost, deployable, disposable heat shield composed by:
    - o a fixed nose (ceramic material)
    - o a deployable aero-brake (umbrella-like, multi-layered fabric).



agenzia spaziale italiana

Aerospace Laboratory for Innovative components

Deployable heat shield: mini IRENE (2)

Feasibility study (2011).
TPS materials, for cone and for flexible umbrella shield, tested in Italy in the SPES hypersonic WT U. of Naples, and in SCIROCCO PWT at CIRA (Capua).

Based on previous results, ASI and ESA are supporting a study to address the main issues of an IRENE demonstrator: MINI IRENE:

- to be embarked as a piggy-back payload for a future mission of a sub-orbital sounding rocket.
- launch of a **demonstrator** of IRENE from a sounding rocket requires **scaling down** the most important parameters

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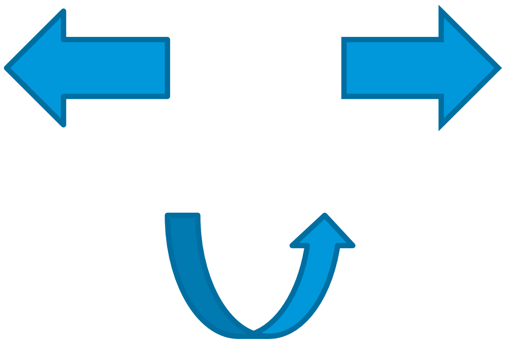
Aerospace Laboratory for Innovative components

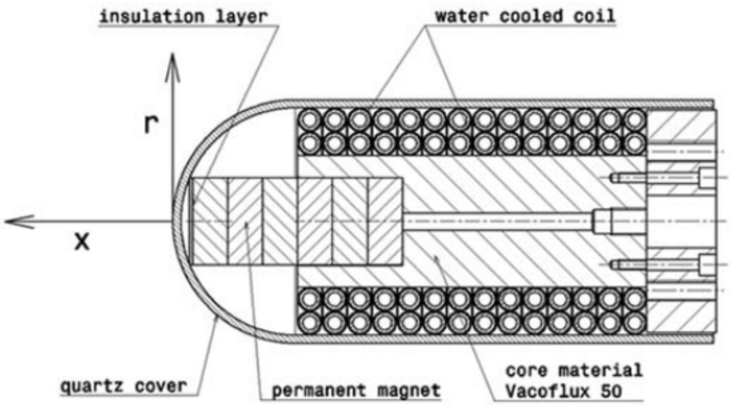
MINI IRENE REQUIREMENTS

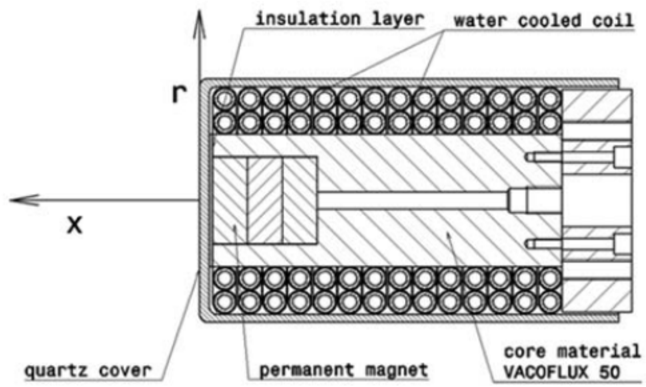
- Max diameters: 29cm (folded) 100cm (deployed)
- Max length: 25 cm (folded)
- Total mass 15 kg / Ballistic coefficient ≤ 20 kg/m^2
- Auto TPS deployt system (exo-atmospheric) => 45° blunt cone
- Loads at launch and during reentry (12 kPa stagnation pressure, 35g deceleration, impact loads for landing at 20 m/s)
- TPS heat fluxes 300-350 kW/m2
- CoG location to guarantee stability and reduce trim angle

MHD shield

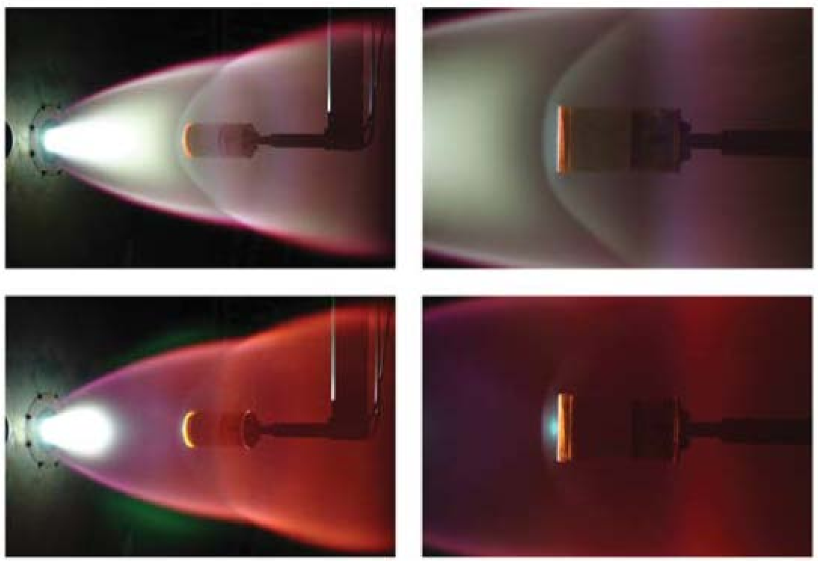


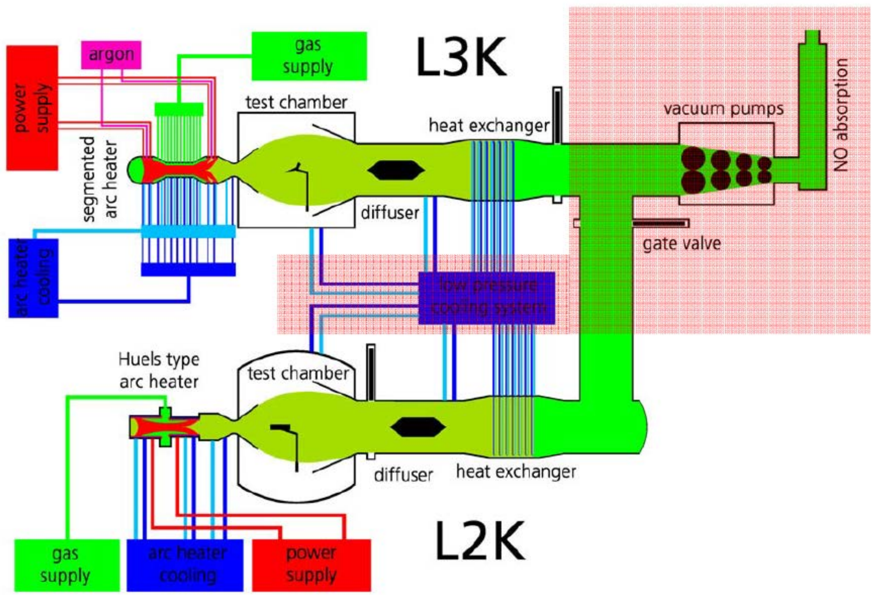
MHD shield





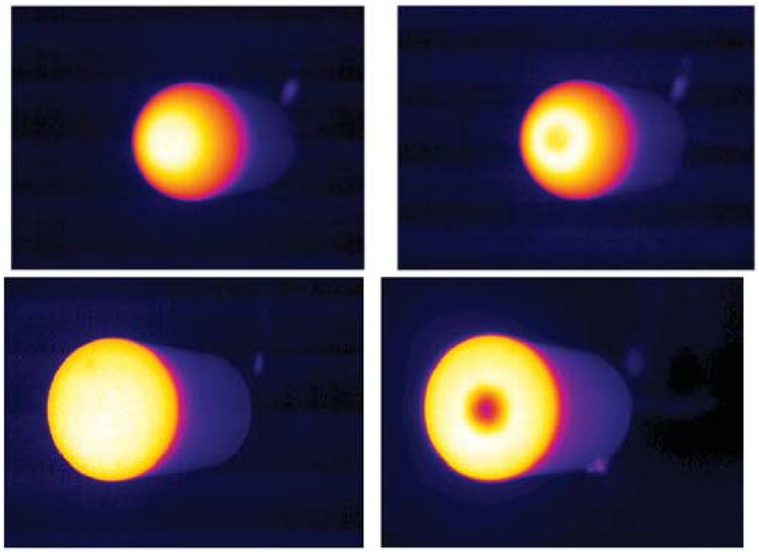
DLR Deutsches Zentrum für Luft- und Raumfahrt

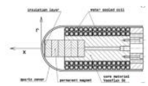


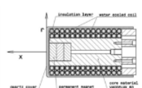


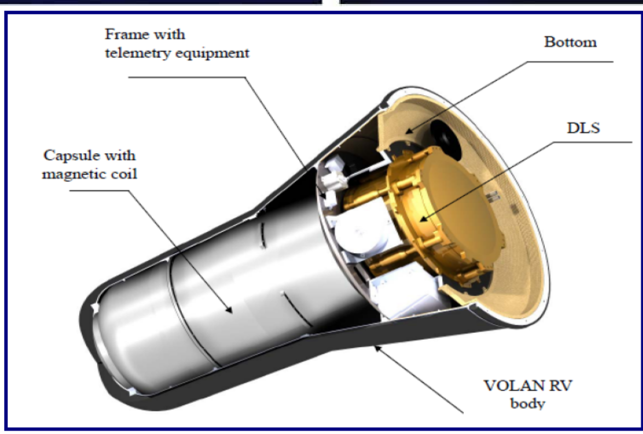
MHD shield: From ground to flight

Without MHD field | With MHD field









Lionel Marraffa, 1° int symp hyp flight, 30/6/2014

Superconductor systems :
MgB2 multifilamentary wires
YBCO-coated conductors

2.3. Flight tests

In flight Experiments classification

IN-FLIGHT EXPERIMENTATION STRATEGY – CLASSES 1-3

CLASS 1. FULL-SCALE DEMONSTRATION AND QUALIFICATION, WHEREBY PERFORMANCE ENVELOPES ARE GRADUALLY EXTENDED:

e.g.
- SHUTTLE, BURAN, APOLLO, ARD, ARIANE-5
- X38, HOPE, HERMES, OSP
- HERCULES, SOCRATES

CLASS 2. EXPERIMENTAL VEHICLES FOR IN-FLIGHT QUALIFICATION OF SYSTEM/SUBSYSTEMS:

e.g.
- BOR4 for TPS ; BOR5 for GNC;
- HYFLEX for TPS; ALFEX for GNC
- IRDT for INFLATION SYSTEM
- PHOENIX 1 and 2 for GNC
- IXV (SPHYNX – PRE-X – USV)

PROGRAMME

CLASS 3. IN-FLIGHT RESEARCH FOR DESIGN TOOL/PHYSICAL MODEL VALIDATION IMPROVEMENTS:

e.g.
- SHARP B1, B2 FLIGHTS, HYSHOT,
- MIRKA, EXPRESS
- EXPERT multiple flights for aerothermodynamic research

R&D

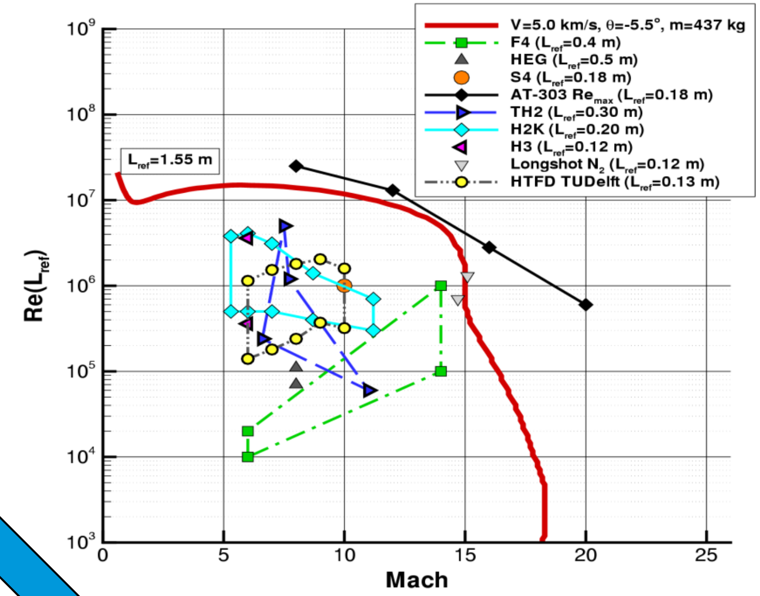
Source: ESA bull. 114, chap 4

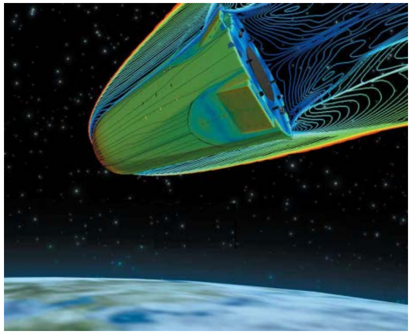
2.3.1. EXPERT

EXPERT: Objectives of the Project

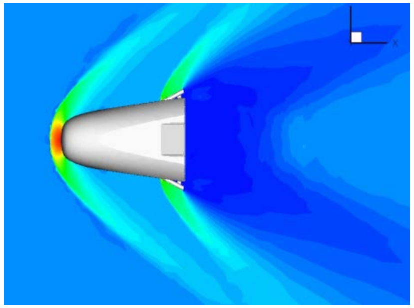
EXPERT aims at

- validation of aerothermodynamic models
- maturation of reentry technologies

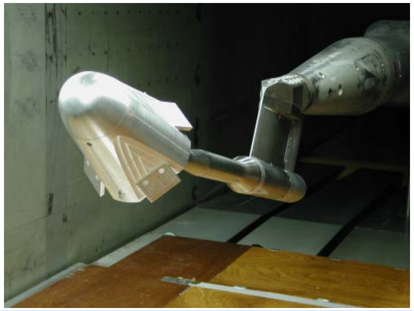




Flight



Prediction



Test

EXPERT Aerothermodynamic: 5 Scientific Disciplines

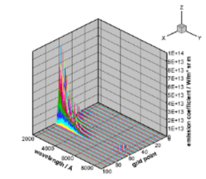
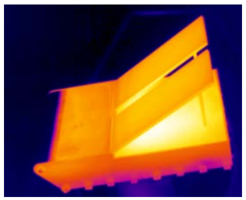


Figure 3.2-22 spatially resolved spectra, SH1, 70km

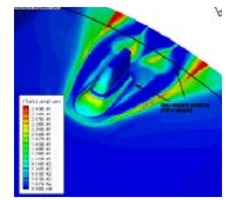
Gas Phase Physics

PL03/PL10



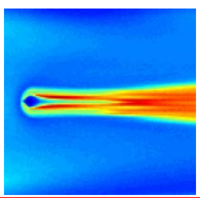
Control Surfaces

PL06/PL07/PL08



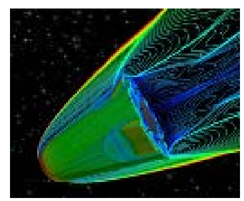
Materials & Material Performance

NAP/PL02/PL11/PL15/PL18



Laminar, Transitional, Turbulent Flow

PL04/PL05/PL13



Aerothermo-dynamics

PL01/PL12

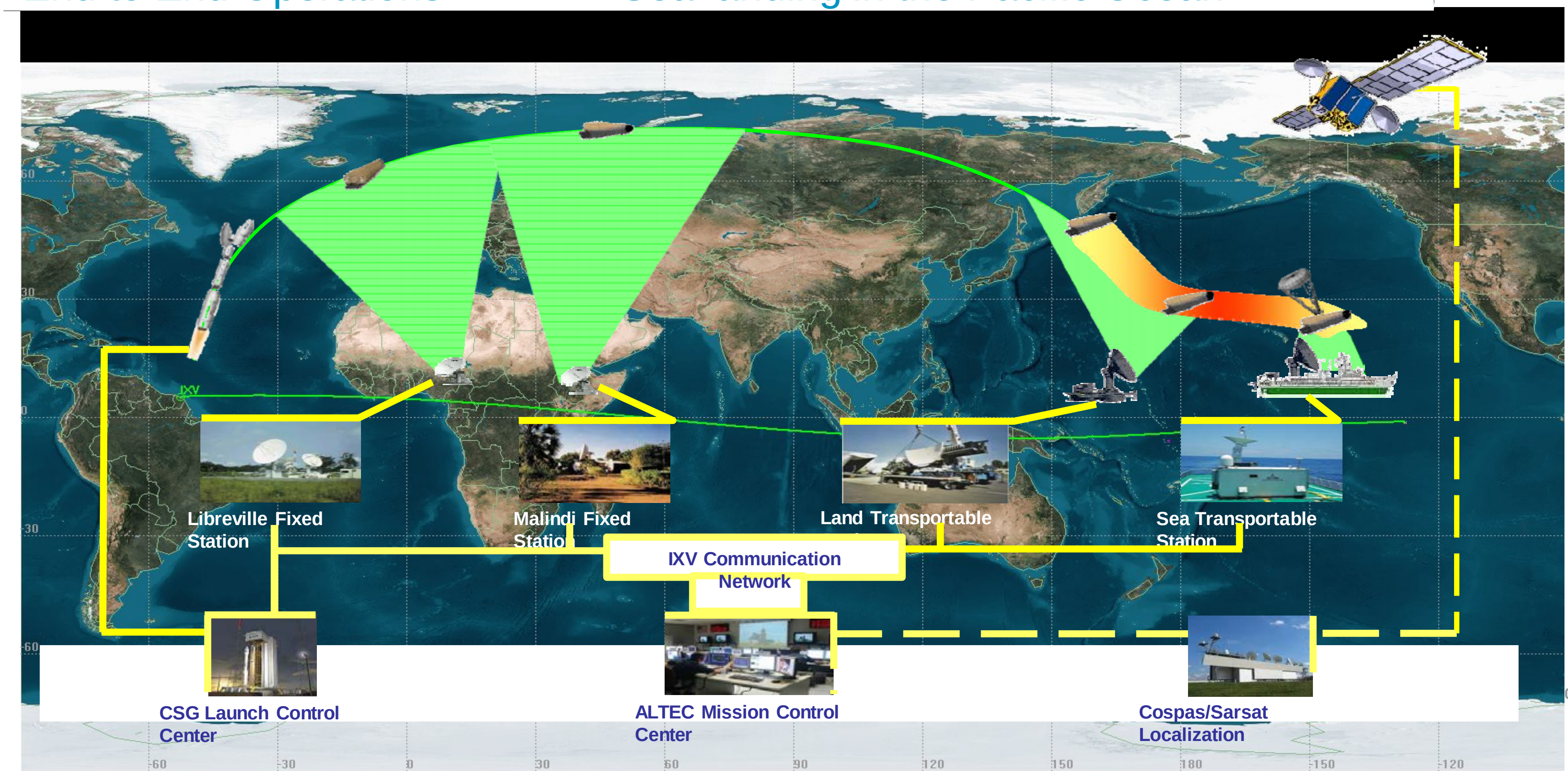
2.3.2. IXV

IXV MISSION

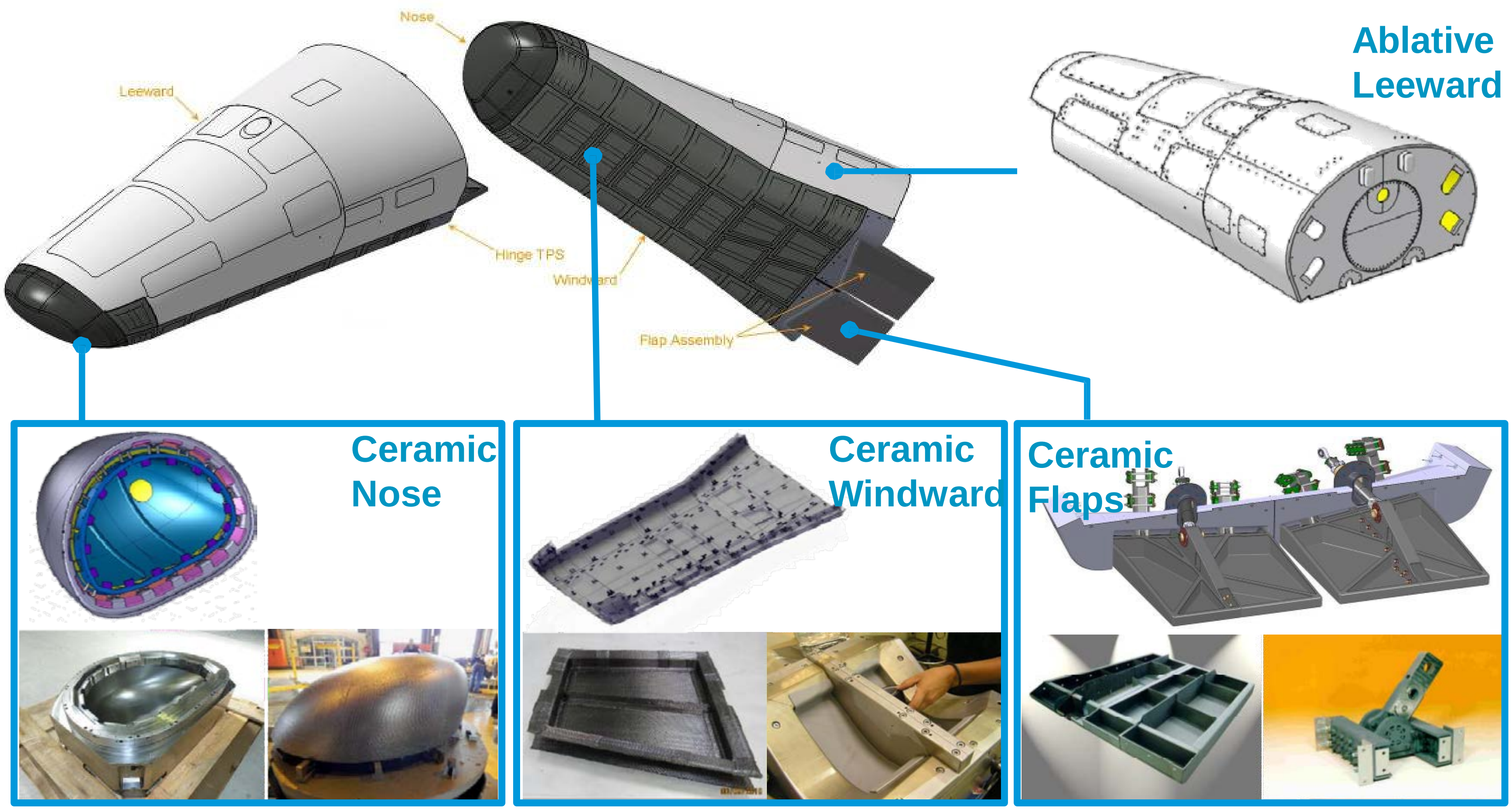
Objectives and Scenario

Mission Objectives:
- Integrated System Demo
- Technology Verification
- End to End Operations

Mission Scenario:
- VEGA launched from Kourou (5º inclinat.)
- 470 km altitude with 7.5 km/s entry speed
- Sea landing in the Pacific Ocean



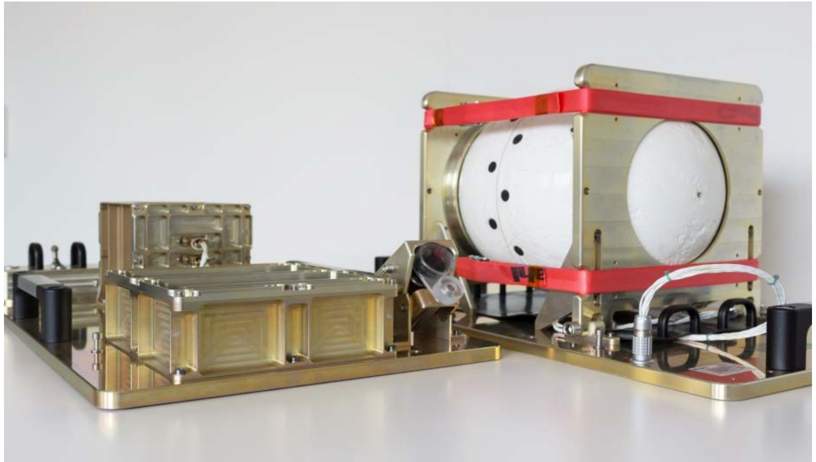
IXV FLIGHT SEGMENT
Thermal Protections

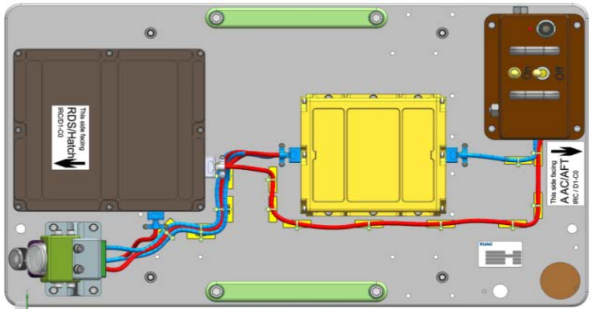


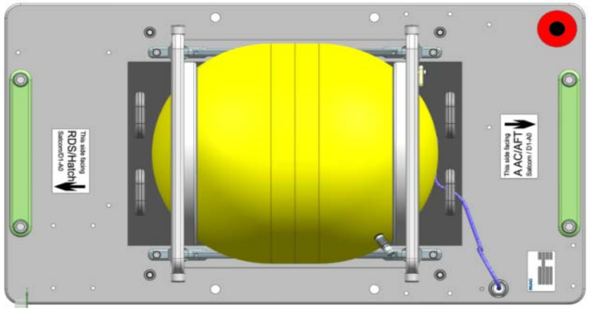
2.3.3. Entry Observation Capsules

ATV-Break-up Camera (BUC): Main Concept

- **Infra-Red Camera (IRC)**
  - Acquires IR images from ATV Hatch and Forward Cone during reentry phase
  - Manages mission timeline & autonomously switches on equipt when reentry phase detected.
  - Transfers the images to the SATCOM
- **SATCOM**
  - Buffers and compresses the raw IR images until a downlink connection is available
  - designed to survive ATV5 destructive reentry and harsh thermal environment during subsequent reentry phase
  - Establishes and maintains a downlink connection via the Iridium network. Satcom will attempt to transmit immediately after the breakup of ATV5.
- **Targets**
  - Are of known emissivity and will be used to calibrate the IR camera images.







Future observation vehicles

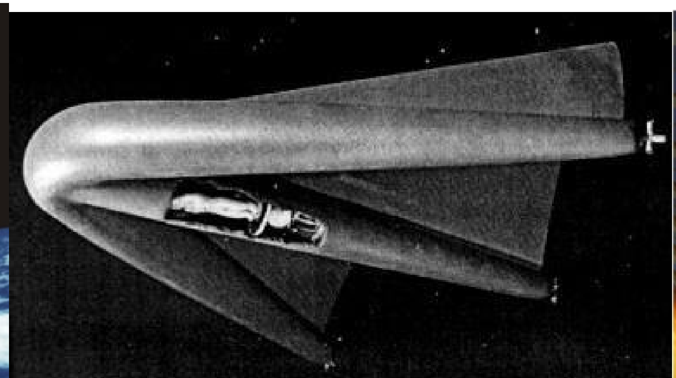
- Interest also for Launcher stages observation
- Enhancement of the concept: optical observation of fragmentation events
- Entry from LEO and GTO?

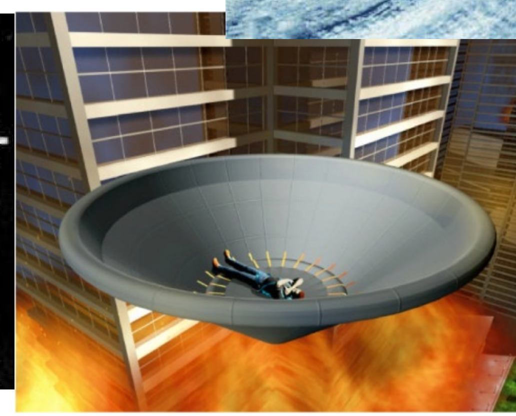
2.3.4. IRDT project

L. Marraffa, TEC-MPA

IRDT(1)

- Inflatable technology developed in Russia for Mars96 penetrators and moon lander airbags.
- IRDT = Evaluation of Russian inflatable technology performance and functionality.
- Main application: ISS payload return.
- ESA, ISTC contracts to EADS, Babakin.
- Low cost program, 1999-2005, 4 launches, 2 test-flights: IRDT-1 (Soyuz-Fregat) and IRDT-2R (Volna).
- Various applications studied





EADS SPACE TRANSPORTATION

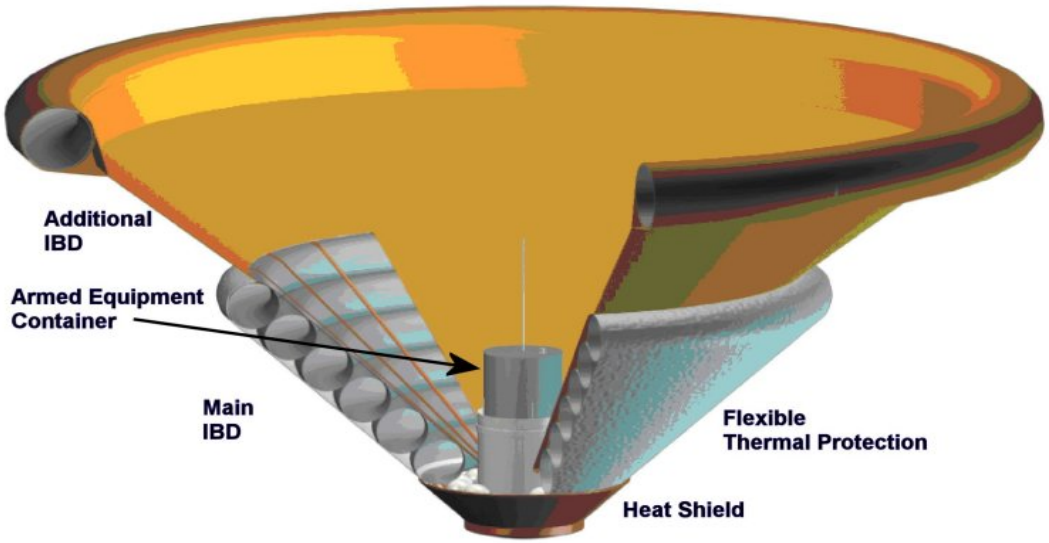
BABAKIN SPACE CENTER

IRDT (2)

- IRDT-2R: 140 kg at entry, 80 cm in launch configuration, 2.3m during entry, 3.8m before landing.
- Mission:

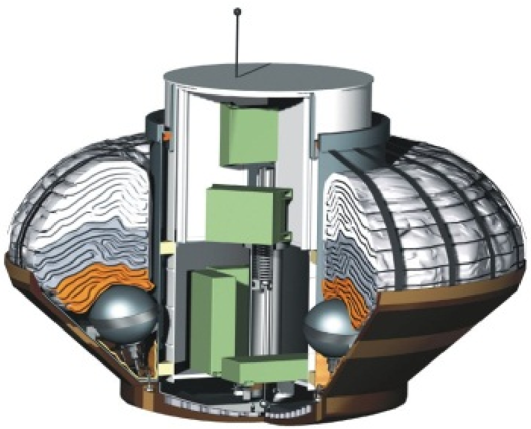
EADS SPACE TRANSPORTATION   BABAKIN SPACE CENTER

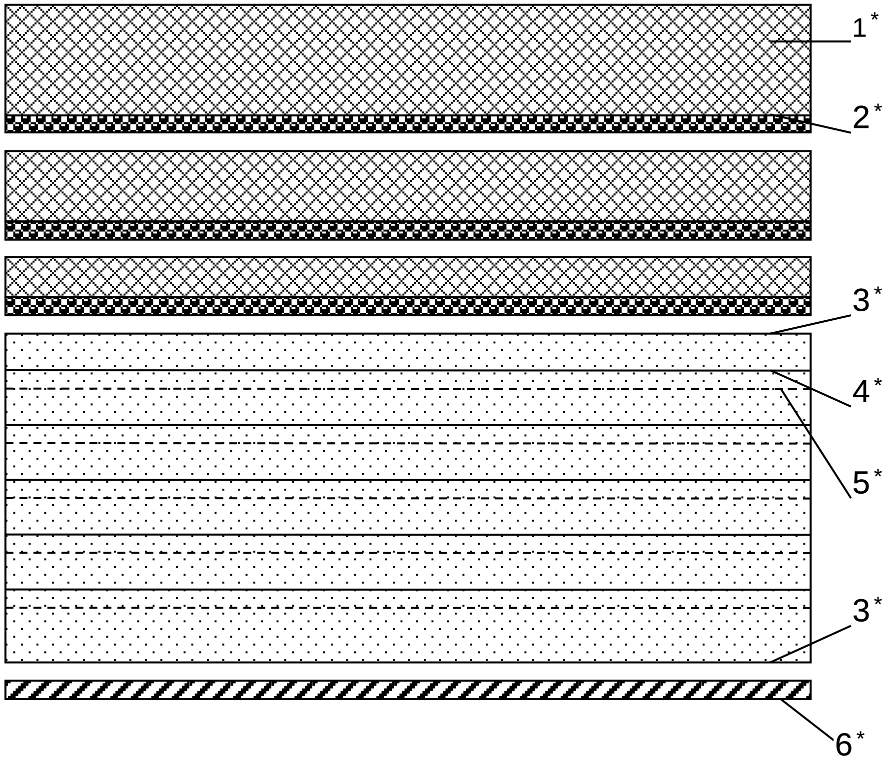
IRDT System Design



$Q_S = 680\ kW/m^2$

$Q_3 = 400\ kW/m^2$





1'– sublimating substance, 2'– heat-resistant fiber, 3'– MLI mat facing material, 4'– polyimide foil , 5'– fine glass fiber, 6'– IBD envelope material.

EADS SPACE TRANSPORTATION

BABAKIN SPACE CENTER

2.3.5. PHOEBUS

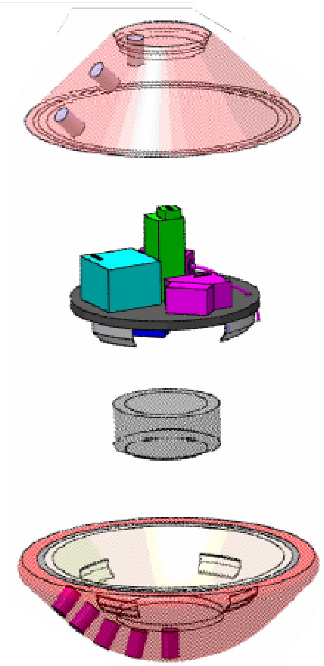
PHOEBUS: Summary of motivations

- Future Sample Return missions require capsule for high speed Earth entry
- ESA has no experience of entries at more than 8 km/s
- High speed entry:
  - New TPS materials needed,
  - radiative flux in VUV becomes important,
  - ablation and radiation interact strongly
- No ground duplication possible, good quality data are not available
- However, techno base and expertise available in Europe

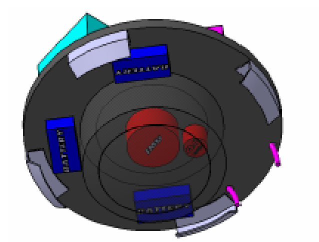
=> RADFLIGHT/PHOEBUS

PHOEBUS main features

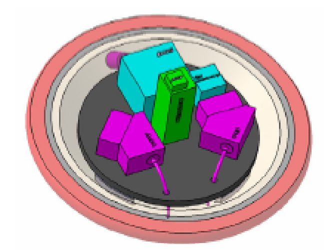
Payload	2 Spectrometers (VIS and (V)UV) 7 TPS plugs (4 on front, 3 on back cover), each containing 4 Thermocouples (heat flux, recession) 1 Pressure transducer 1 Radiometer Total mass: 4.18 kg
Capsule Mass	25 kg (inc. margin)
Capsule shape and , dimensions	Scaled Hayabusa shape 45° half cone angle 255 mm nose radius 510 mm base diameter Ballistic coefficient = 107 kg/m²
Re-entry conditions (@ 100 km entry i/f)	Speed = 11 km/s FPA = -16.4°
Design Heat Flux	14 MW/m² (Max)
TPS	Front shield: European PICA-like development, 40 mm Back shield: Norcoat Liège, 10 mm Internal insulation material, 10 mm
Propulsion (When applicable)	1 x ATK STAR 37XFP Solid Rocket Motor for acceleration 2 x ATK STAR 3A Solid Rocket Motors to provide spin stabilization
DLS	No parachute Crash landing on Land Recovery : Beacon tracking
Telecommunication / Data Retrieval	No TMTC Recovery of data via crash resistant beacon(to be developed/upgraded) Mission data stored in crash resistant memory unit, which holds the mission data.
Structure	CFRP honeycomb composite Crash resistant container for memory Use of crushable foam
GNC	Trajectory measurement only by use of MEMS based IMU and additional axial accelerometer for high accelerations.
Data Handling	Inspired by CubeSat equipment and merged with power conditioning / distribution to provide miniaturization. 2 Processor boards (OBC, Payload) 2 Analog acquisition boards 2 Power boards
Data concept	Recoverable on board recording, no Telemetry
Power	Primary batteries only



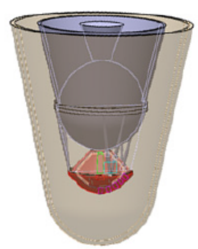
PHOEBUS Capsule exploded ISO view



Bottom view of the central shelf



Top view of the central shelf



3. Coordination, Direct technical support

Workshops, working groups

esa

EUROPE IN THE POST-CONCORDE ERA

KEY TECHNOLOGIES TO FLY FAR BEYOND TRANSONIC

Overview of the EU-Programs LAPCAT & ATLLAS

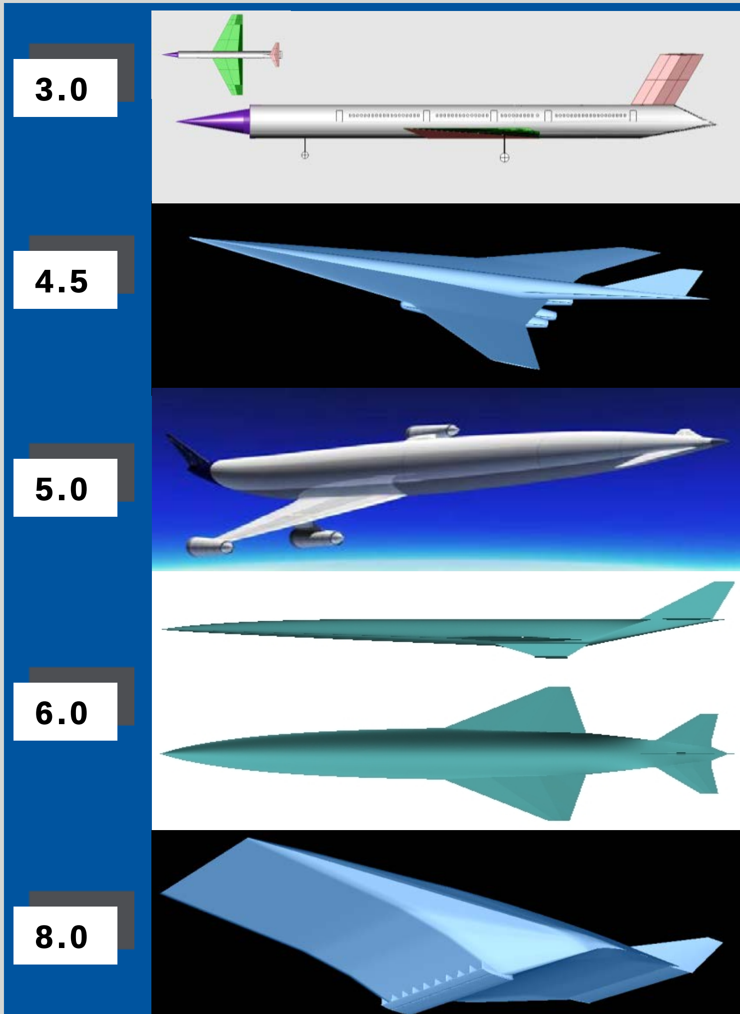
J.M.A. Longo[(1)] & J. Steelant[(2)]

[(1)]LAPCAT/ATLLAS Principal Investigator
Institute of Aerodynamics and Flow Technology
German Aerospace Center, DLR, Braunschweig

[(2)]LAPCAT/ATLLAS Coordinator
Division of Propulsion and Aerothermodynamics
ESTEC-ESA, The Netherlands

Research in Fluid-dynamics and Aircraft Design within the EU Framework Mini-Symposium
West-East High Speed Flow Field Conference, WEHSFF 2007
Moscow,19-22 Nov. 2007

ATLLAS / LAPCAT Strategy



requirements derived from to improve

Propulsion efficiency
(combine cycles concepts and modeling; combustion experiments, modeling and process characterization)

Structure efficiency
(ultra-light high-temperature materials manufacturing; porous-materials characterization & cooling systems management)

Aerodynamic efficiency
(airframe-propulsion integration characterization; turbulence, sonic boom propagation & flow control modeling; MDA / MDO processes)

UNIVERSITÀ DI BARI

UNIVERSITY COLLEGE OF LONDON

CENTRO ITALIANO RICERCHE AEROSPAZIALI

INGÉNIERIE ET SYSTÈMES AVANCÉS

UNIVERSITÀ DI PERUGIA

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

UNIVERSITAT DE BARCELONA

PHYS4ENTRY

PLANETARY ENTRY INTEGRATED MODELS

SEVENTH FRAMEWORK PROGRAMME

INSTITUTE FOR PROBLEMSIN MECHANICSRUSSIAN ACADEMY OF SCIENCE

VONKARMAN INSTITUTE FOR FLUID DYNAMICS

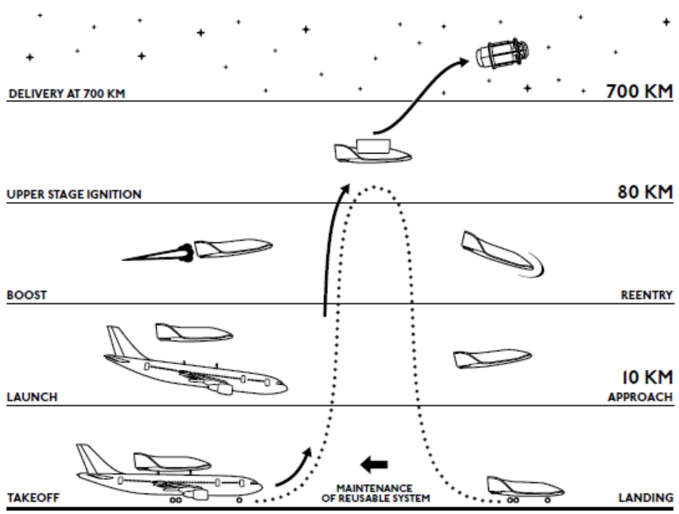
CONSIGLIO NAZIONALE DELLE RICERCHE

POLITECNICO DI TORINO

SOFTWARE ENGINEERING RESEARCH & PRACTICES

POZNAN UNIVERSITY OF TECHNOLOGY

ESA support to suborbital flight



- S3
- Space Expedition Corp. SXC
- Skylon

Future developments

Potential Future Developments

- Clean Space
  - Rarefied regime characterisation
  - Demisable concepts for launchers stages
  - Demisable concepts for S/C
  - EoL S/C re-entry
- Space Exploration
  - Propellant tanks
  - Decelerator technologies
  - Hypervelocity regime characterisation
- Commercial space
  - Re-usable airframes
  - Re-usable propulsion systems (air-breathing, rocket engines)

Many thanks to:
CESMA, and in particular General Cornacchia for inviting ESA to this symposium
D/TEC for giving the opportunity to present our work in the domain of hypersonic flight
My Colleagues at ESA that provided support and information for this presentation:
J. Gavira (EXPERT), G. Tumino (IXV), J. Steelant (EC), R. Molina (S3)
G. Ramusat, A. Sirbi (FLPP)
D. Giordano, A. Passaro and D. Estublier (MHD)
N. Murray (RBB)
Jose Longo
TEC-MPA

THANK YOU

Lionel Marraffa

Lionel.Marraffa@esa.int

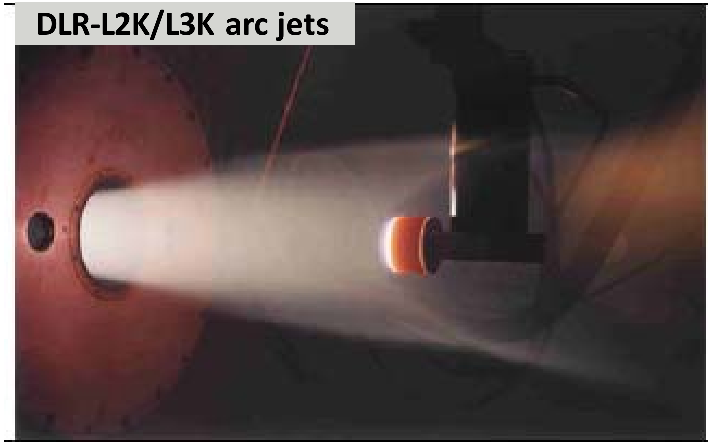
Backup slides

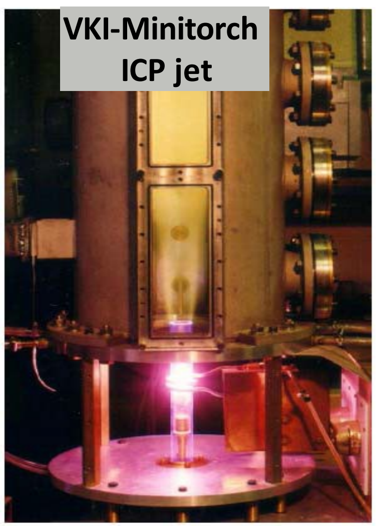
Radiation data provision

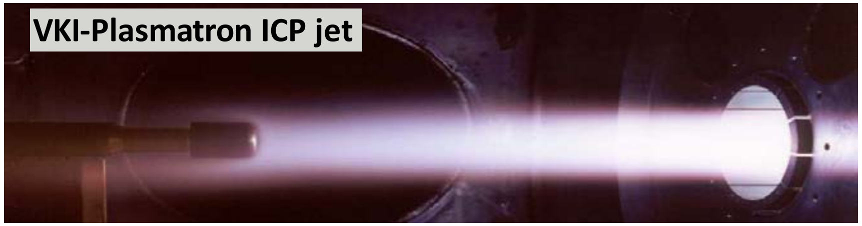
Objective: produce emission spectra to validate the radiative code

Total enthalpy (MJ/kg)	10.27	33.7	62
Temperature (K)	4970	6900	11220
Pressure (hPa)	28.7	241.8	272.3

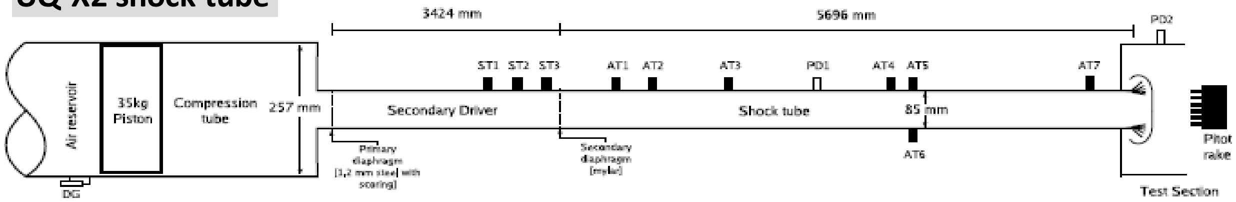
Credit: VKI







UQ-X2 shock tube



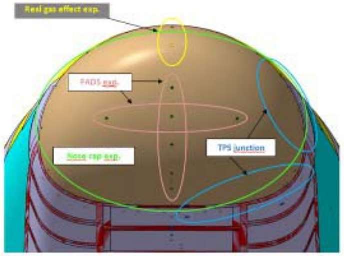
Spectro at ESA, Lionel Marraffa, VKI LS Spectro,

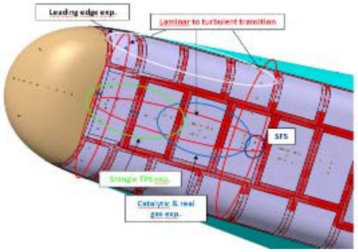
IXV FLIGHT SEGMENT
In-Flight Experimentation (IFE)

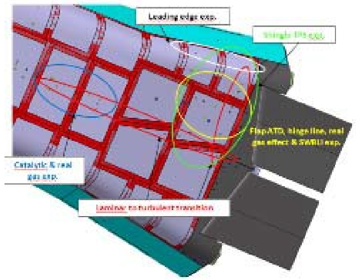
The technological objectives of the IXV mission are met by flying a set of experiments chosen among a wide range of proposals, addressing **system** issues, **aerothermodynamics**, **thermal protections materials**, **guidance**, **navigation**, **control** issues.

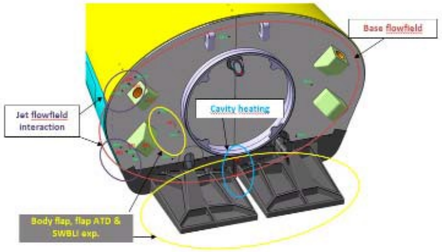
Synergies and commonalities were exploited to identify a global set of sensors covering all experimentation requirements

The sensors are split into conventional ones (pressure taps, thermocouples, displacement sensors, strain gauges) and advanced ones (i.e. infra-red camera, 3 axis accelerometers)







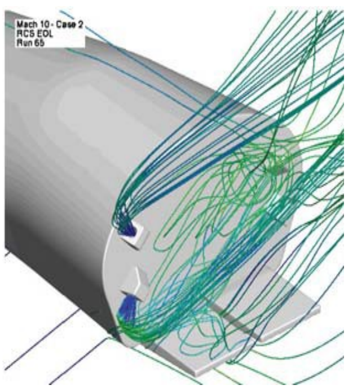


ency

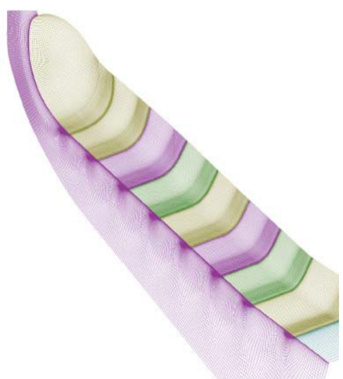
FOCUS ON ATD
Industrial Activities

About **850 CFD computations** have been performed up to CDR, including the whole range of flight parameters and flow phenomenology, i.e.:

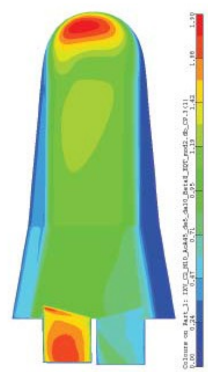
- Euler plus Boundary Layer
- Navier-Stokes (Perfect Gas, Thermo-Chemical Non-equilibrium, Laminar / Turbulent flows)
- Finite Rate Catalysis
- DSMC
- RCS Jet Flow interaction both in Rarefied and Continuum regime
- Micro ATD simulations with/without radiation coupling



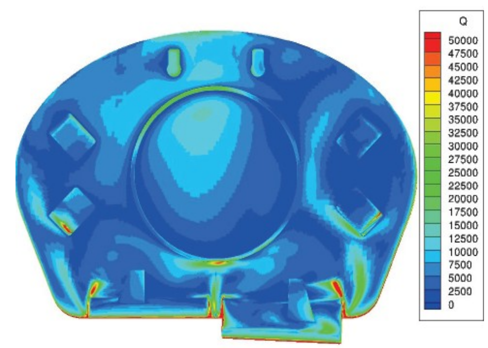
RCS Interaction



Micro ATD Shingle Steps



Aileron & Sideslip Coupling

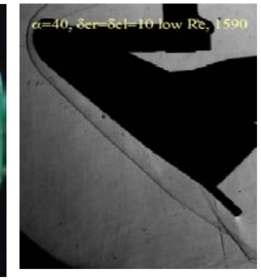


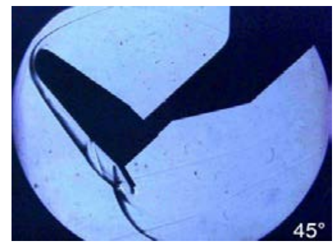
Micro ATD & Radiation Coupling

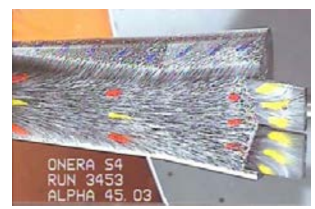
FOCUS ON ATD
Industrial Activities

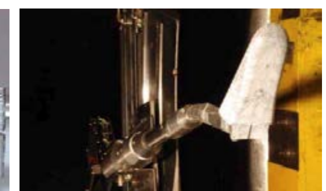
About **350 Wind Tunnel Test** for Aerodynamics and Aerothermodynamics, i.e.:

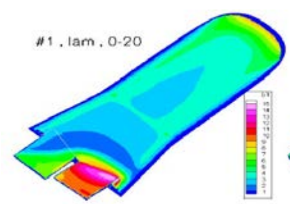
- *FOI T1500*: 60 RUNS @ M=0.8÷1.4 – MODEL A Scale 1:21 **(AED)**
- *SST DNW*: 45 RUNS @ M=1.45÷3.94 – MODEL A Scale 1:21 **(AED)**
- *S4ma ONERA*: 30 RUNS @ M=10 – MODEL B Scale 1:13.75 **(AED)**
- *H2K DLR*: 34 RUNS @ M=6, 8.7 – MODEL F Scale 1:17.6 **(AED)**
- *HEG DLR*: 11 RUNS @ M=8.17, 8.59 – MODEL D scale 1:13.75 **(ATD)**
- *H2K DLR*: 23 RUNS @ M=8.7 - MODEL E Scale 1:17.6 **(ATD)**
- *LONGSHOT VKI*: 30 RUNS @ M=14 - MODEL E Scale 1:17.6 **(ATD)**
- *STARCS T1500*: 65 RUNS @ M=0.8÷1.4 – MODEL A Scale 1:21 **(AED)**
- *LONGSHOT VKI*: 17 RUNS @ M=14 - MODEL E Scale 1:17.6 **(ATD)**
- *S3ma ONERA:* 40 RUNS @ M=5.5 - MODEL G Scale 1:12.57 **(ATD)**
- *PLASMATRON VKI*: TPS Catalysis and Emissivity characterization

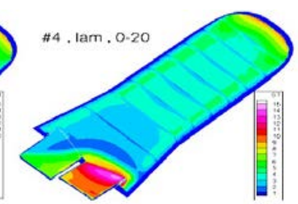












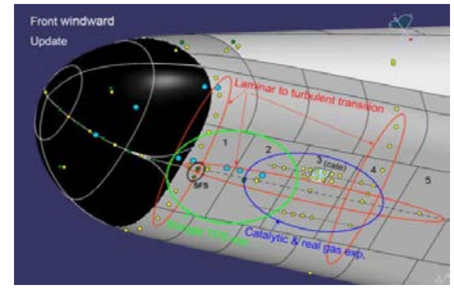
FOCUS ON ATD
IFE Experiments

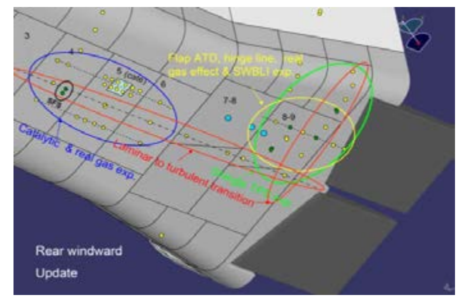
The fullfillment of Aerothermodynamics objectives is achieved with the implementation of several **Experiments**:

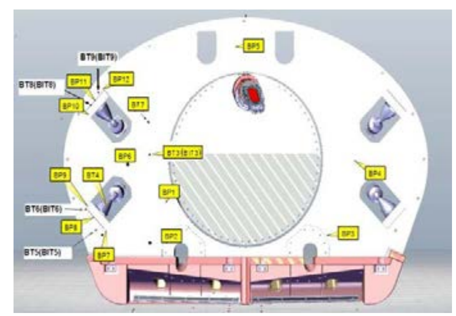
- *Continuum Flow*
- *Gap and Cavity Heating*
- *High Altitude AED 3axis accelerometer*
- *Base Flowfield*
- *General Heating*
- *Wall Catalysis*
- *Flap ATD and SWBLI*
- *Jet Flow Interaction*
- *Laminar to Turbulent Transition*
- *Skin Friction Sensor*
- *IR Camera Temp Mapping*
- *FADS*

Overall instrumentation:

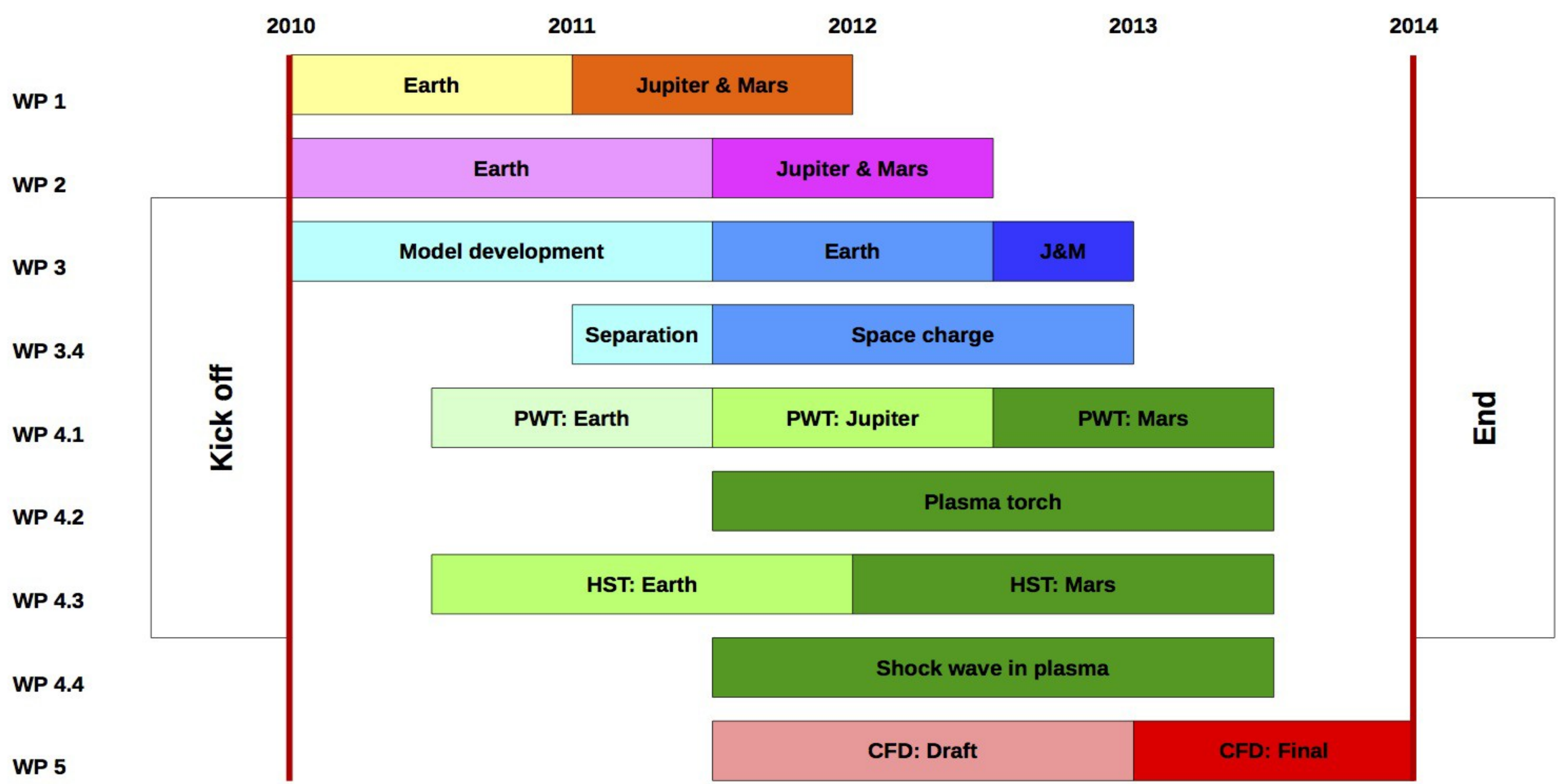
- *194 Thermocouples*
- *39 Pressure Sensors*
- *Displacement Sensors*
- *IR Camera*
- *3AX Accelerometer*







PHYS4ENTRY Work Plan



Dust Erosion study

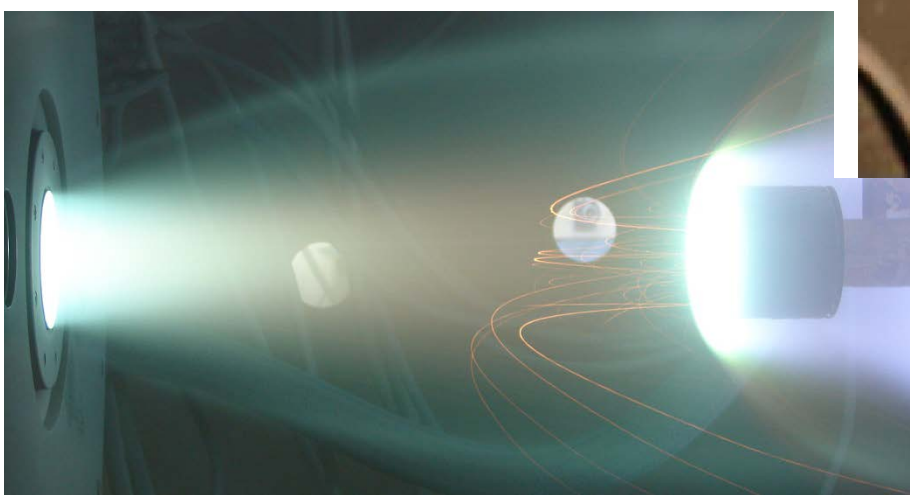
Appearance of Test Samples after Exposure to Supersonic Hot Flow

Working gas CO_2/N_2 ; heat flux 296 kW/m²

With 3 µm BN particles: Rough surface pattern, samples clearly reduced in thickness

Without particles: Fissured surface pattern, samples slightly increased in thickness

Working gas air ; heat flux 292 kW/m²



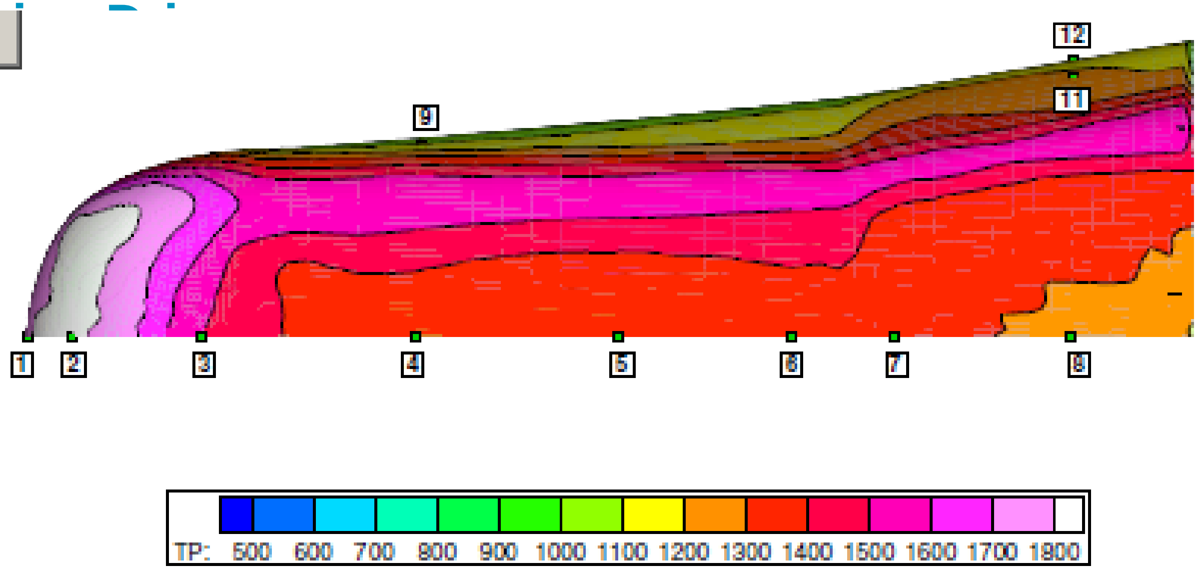
HPS

ESTHER: A support for radiation, chemical kinetics and advanced metrology

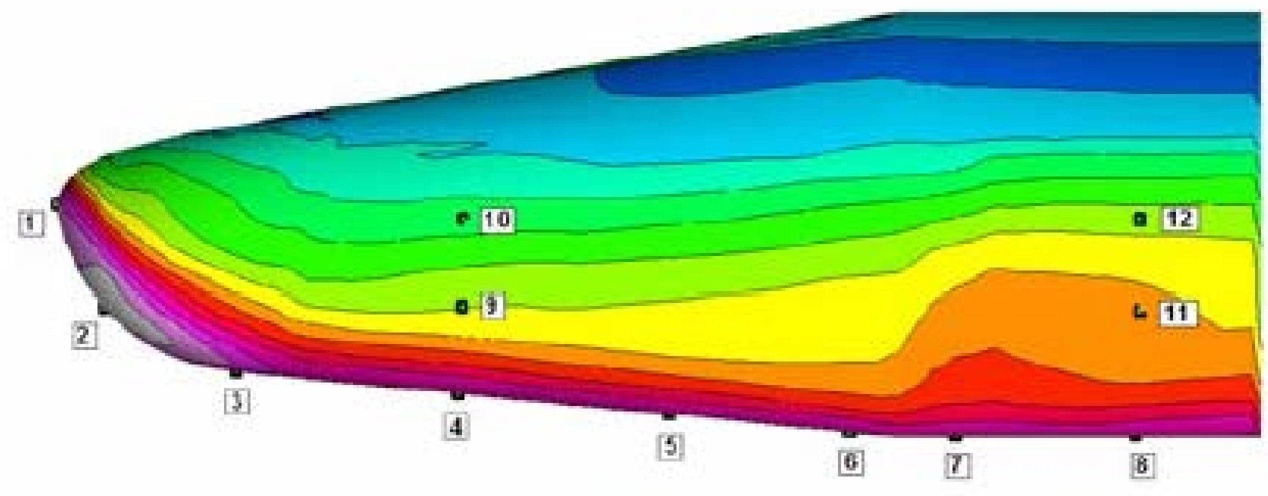
– For the first step, only emission spectroscopy is foreseen: first in visible, then UV/VUV, and then with IR investigations.
– In a second phase, absorption techniques will be implemented, soon after first campaign
– Facility designed for networking and cooperation

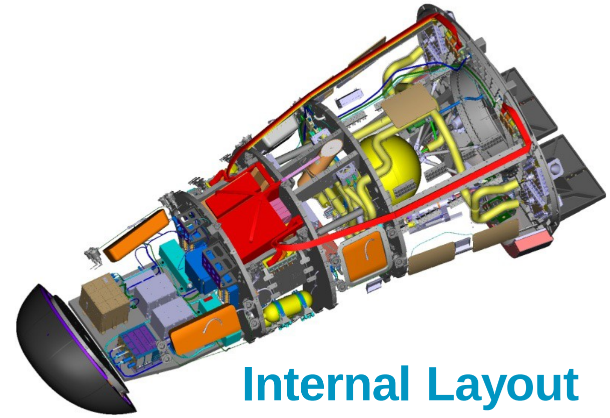
IXV FLIGHT SEGMENT
Vehicle

De…
• V…

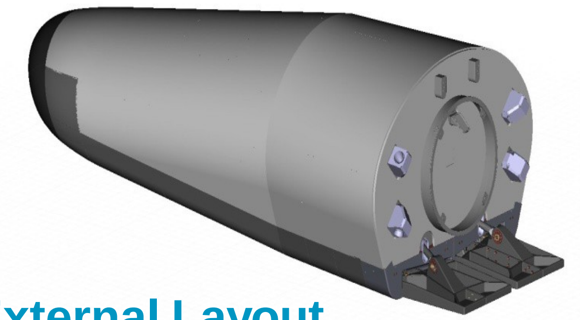


• E…
• Fl…
• S…
M…
•
•





Internal Layout



External Layout

guidance : to maintain the required drag-velocity profile.

navigation : inertial measurements and GPS updates before 120 km, and a Drag Derived Altitude (DDA) update at 60 km.

Control:

- Yaw: by thrusters.
- Longitudinal and lateral axes: aerodynamic flaps.

Good perfo. & accuracy down to parachute deployment.

esa

IRT - Requirements

CFD ANALYSIS CONDITIONS

Inputs

Non catalytic wall
Initially cold wall
Radiative equilibrium
Max heat flux: 405 KW/m2
Max energy: 50 MJ/m2

Revised

Catalytic wall
Initially cold wall
Radiative equilibrium
Non equilibrium gas flow

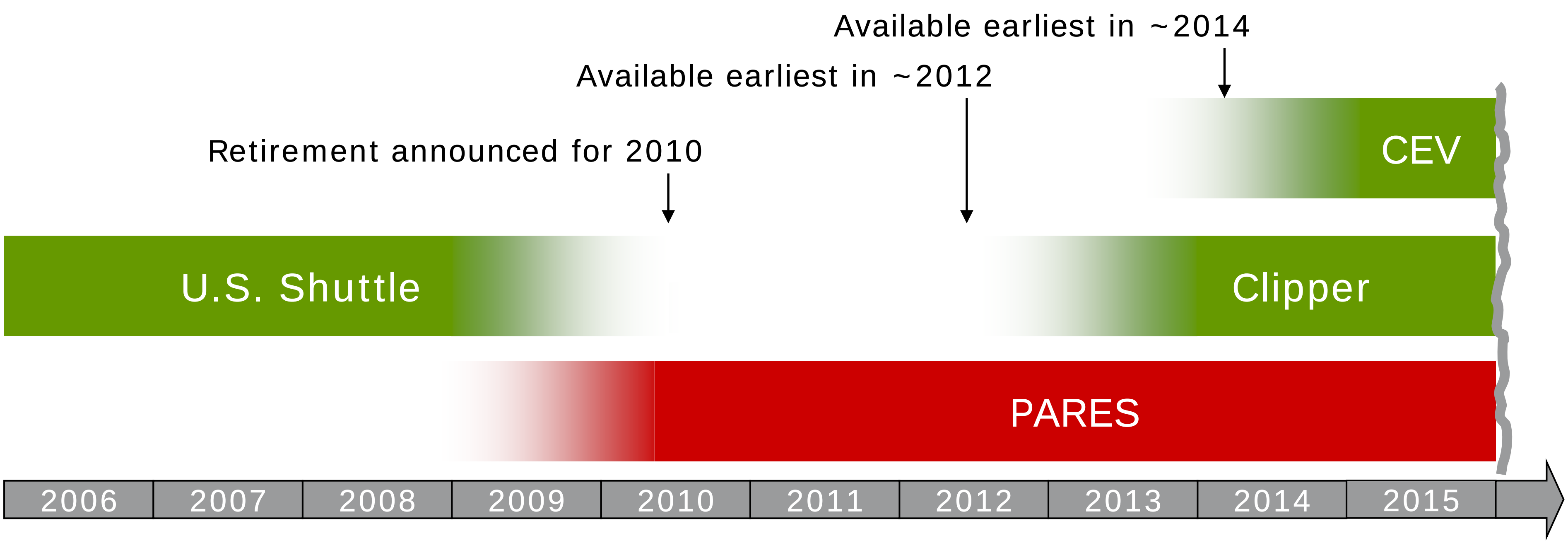
Design

Max heat flux: 680 KW/m^2
Max energy: 60 MJ/m2

AERO SEKUR

Motivation
The Future of ISS P/L Retrieval

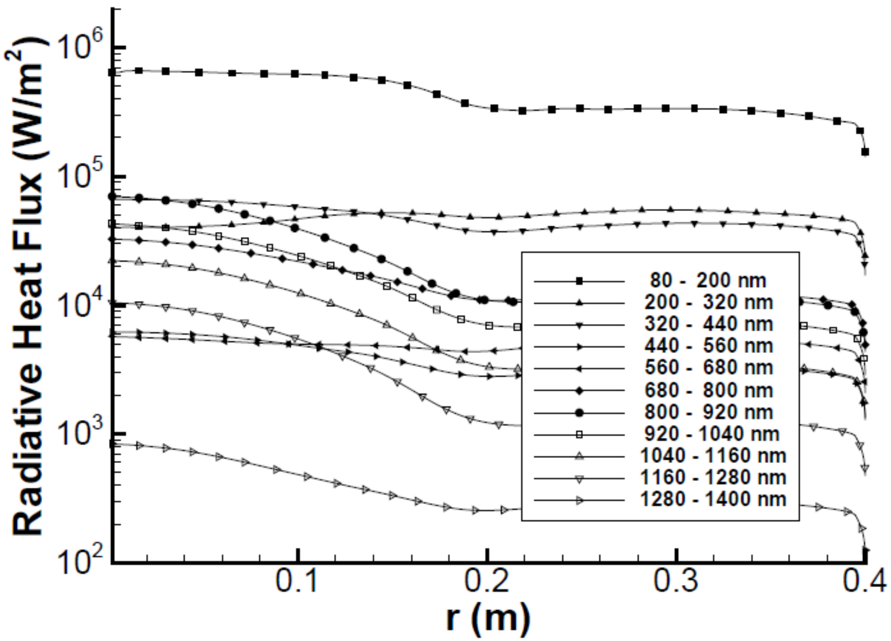
esa



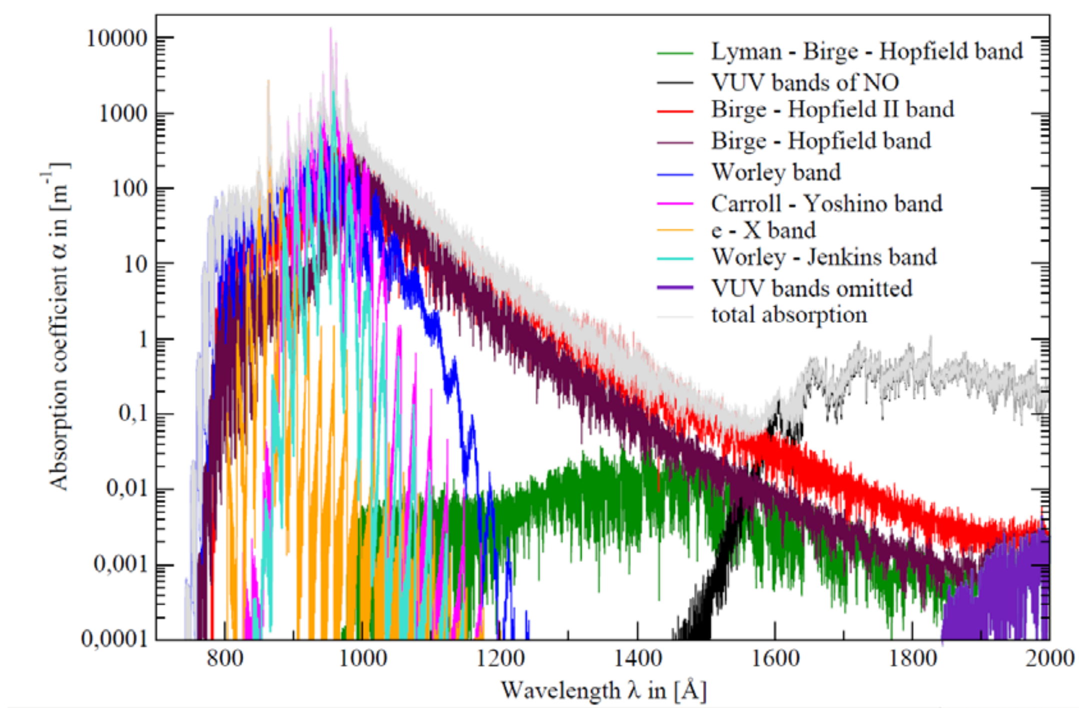
In case, both Shuttle retirement as well as development of new systems will be as scheduled, PARES would mainly complement existing systems by providing download also via cargo vehicles -> additional flexibility !

In case of premature Shuttle retirement and/or delayed availability of new systems, PARES partially closes the gap for ISS download !

VUV Radiation



Source: AIAA 2010-4774 (IRS)



Contrib. of electronic states to VUV radiation of N_2

T = 7000 K, equil compos. of LAUX test case