Technologies for Re-entry Vehicles

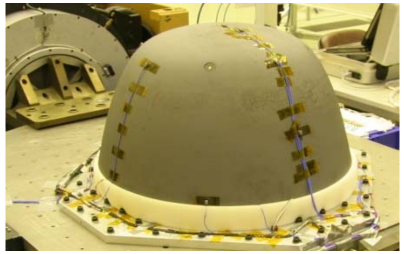
SHEFEX and REX – FreeFlyer, DLR‘s Re-Entry Program

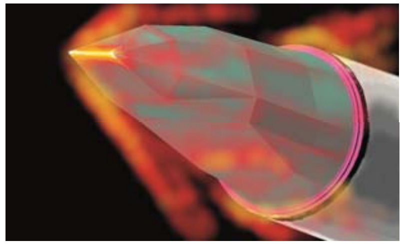
Hendrik Weihs

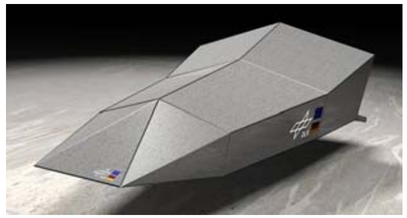
DLR

DLR`s Re-Entry Program, Why?

- Re-entry or return technology respectively, is a strategic key competence which becomes obvious after retirement of the Space Shuttle fleet.
- Currently, the national industry and DLR is well experienced and prepared within all related disciplines due to a lot of recent development programs.
- CMC based thermal protection systems are available up to a technology readiness level of 6 to 7
- Within the SHEFEX/REX Development program all related scientific disciplines like materials and structures, TPS, flight control from atmosphere up to vacuum, GNC and aerodynamic are linked together to develop and flight test new innovative space crafts with enhanced re-entry capability.



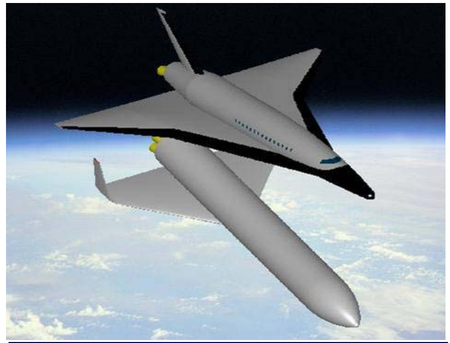


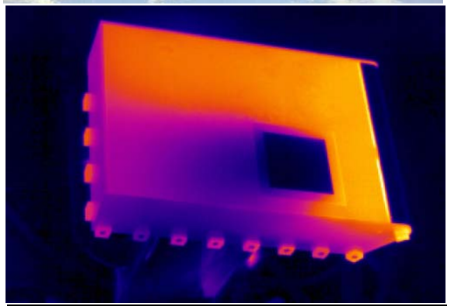


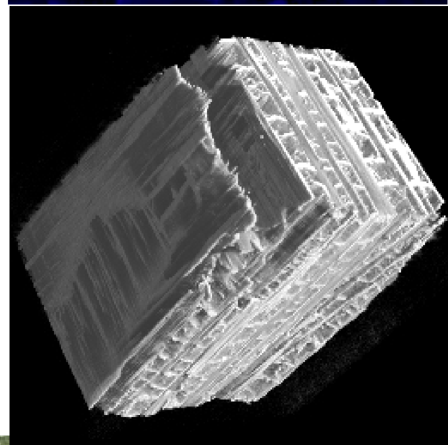
Returnable Spacecraft Technology – Enabling Research

Objectives

- New launcher concepts and Vehicle design (e.g. REX Free Flyer, Space Liner)
- Enhancement of numeric tools and integration in one interdisciplinary design environment (e.g.IMENS)
- Creation of a Concurrent Engineering Facility
- Fluid/structure interaction of spacecraft components with active and ablative cooling
- GNC Technology and Health monitoring systems
- New fiber reinforced ceramics, active cooling and ablatives, related analysis tools and design principles for TPS and hot structures
- Verification of analysis tools and design and control concepts by laboratory, ground and flight tests







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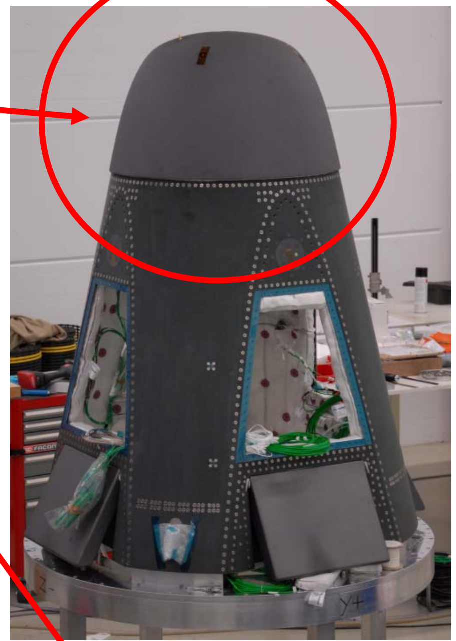
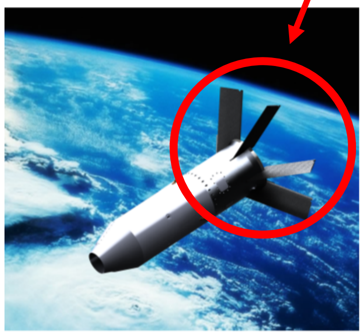
Re-entry technology – Flight tests

- Nosecapsystem for EXPERT (ESA)
- TPS Experiments on FOTON Missions
- CMC Fin Experiment on HIFIRE 5 and ablative Fin leading edges for HIFIRE 3&5 (AFRL, USA)
- CMC Stabilisers for SCRAMSPACE (UQ/DSTO Australien)
- SHEFEX Flight test program





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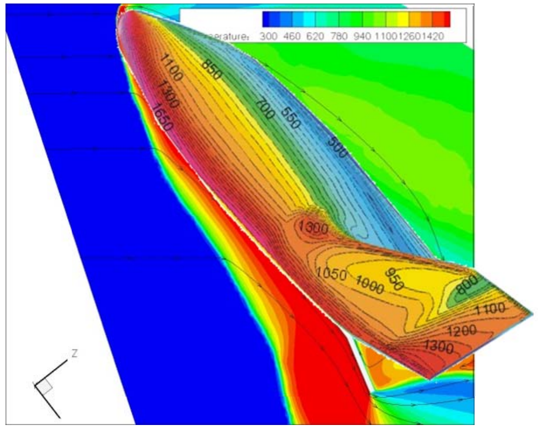
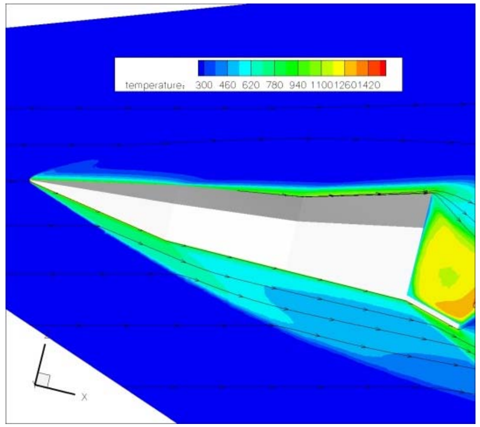
SHEFEX-Concept, Why?

- Reduction of manufacturing and maintenance costs of the thermal protection system up to 50% due to facetted shape and flat TPS elements
- Sharp edges allow optimized hypersonic aerodynamic performance with lower drag and enlarged cross range or re-entry flexibility respectively
- Scale able aerodynamic performance at hypersonic velocity.
- Low angle of attack and defined shock geometry reduces "communication black-out"
- A mission optimized return vehicle shall be possible

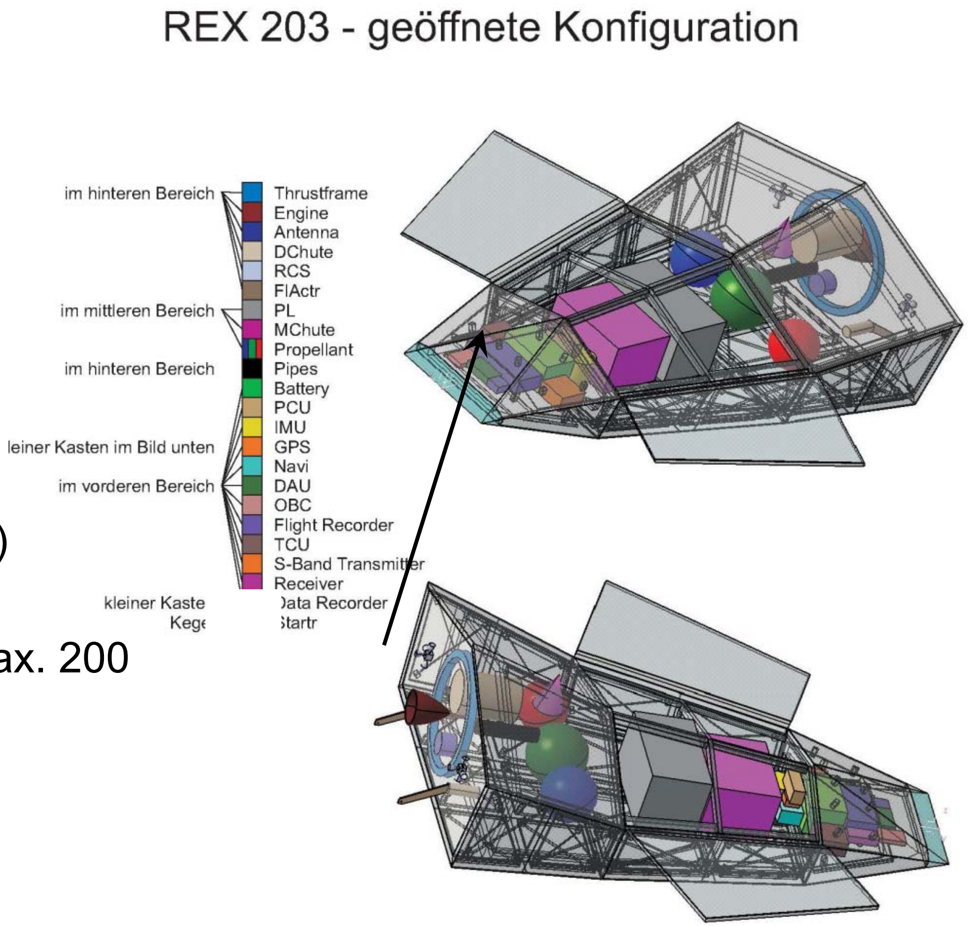


"classic", high angle of attack



"optimized" low angle of attack

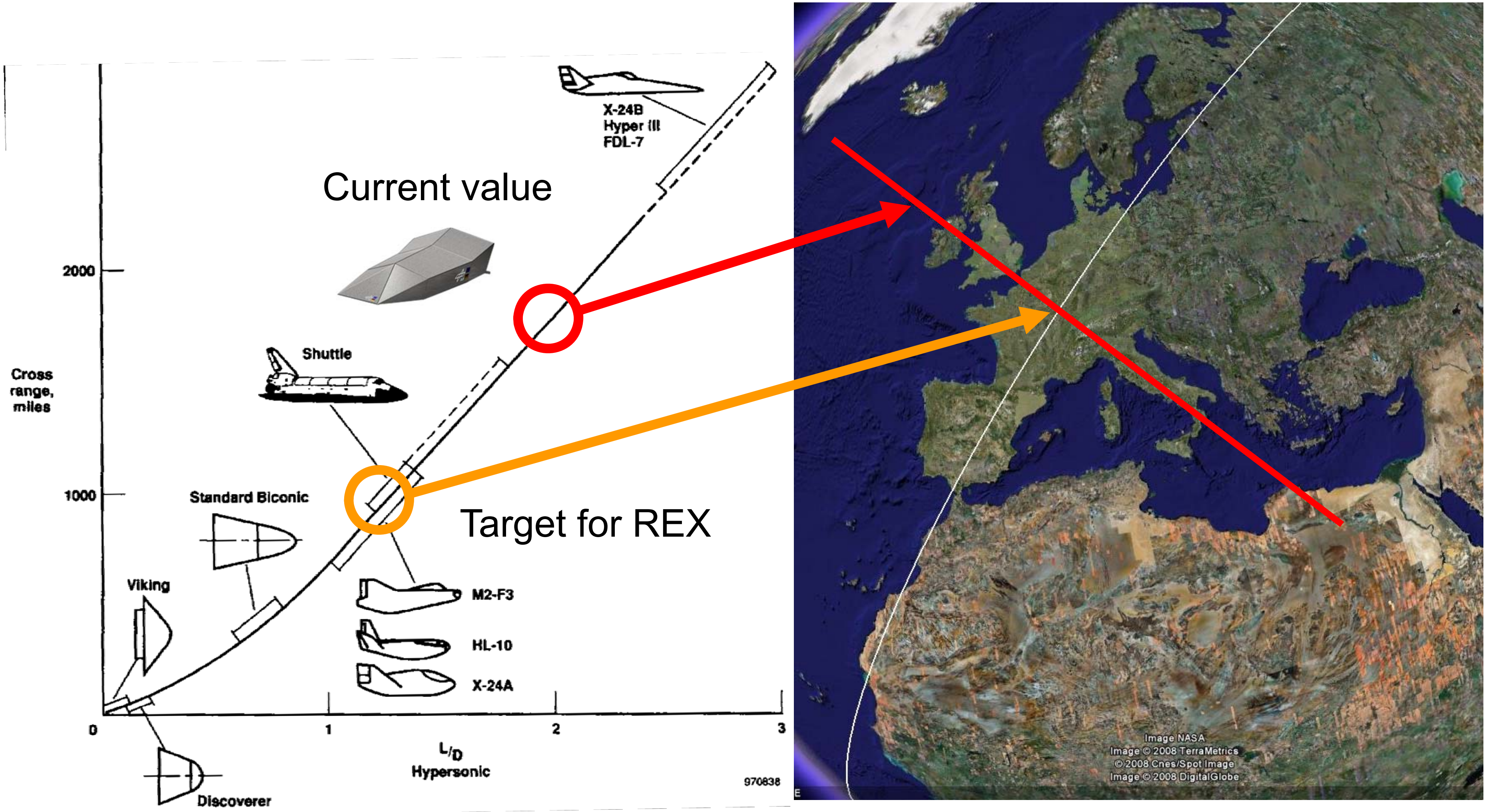
REX Free Flyer: Reference concept for a returnable Microgravity Research platform



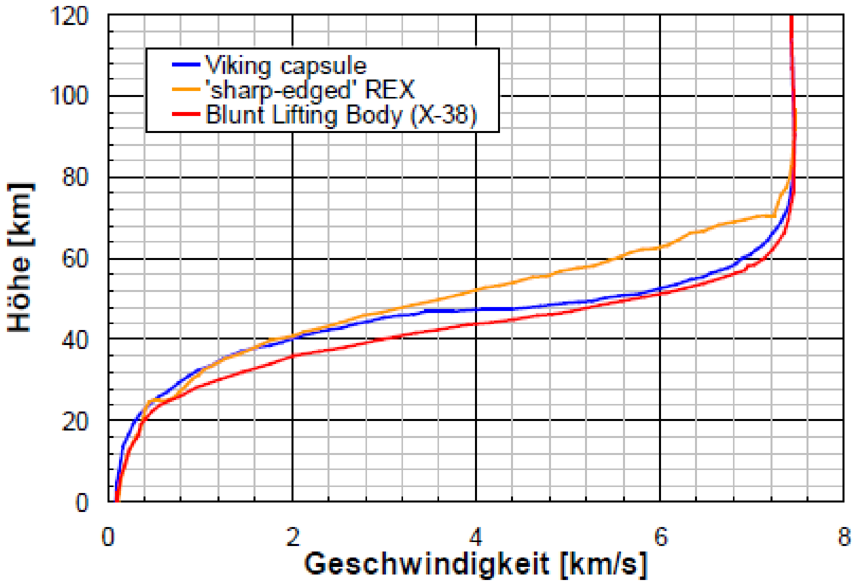
- L= 3,36 m, B_{max}= 2,10 m, H_{max}= 0,72 m
- Mass: max.1500 kg
- Center of Gravity: 63% (to vehicle length)
- Aerodynamisch stable und trimmable,
- Payload volume ca. 1,3x 0,5 x 0,6 m³, max. 200 kg
- Reference Launch system: Vega
- Current Status:

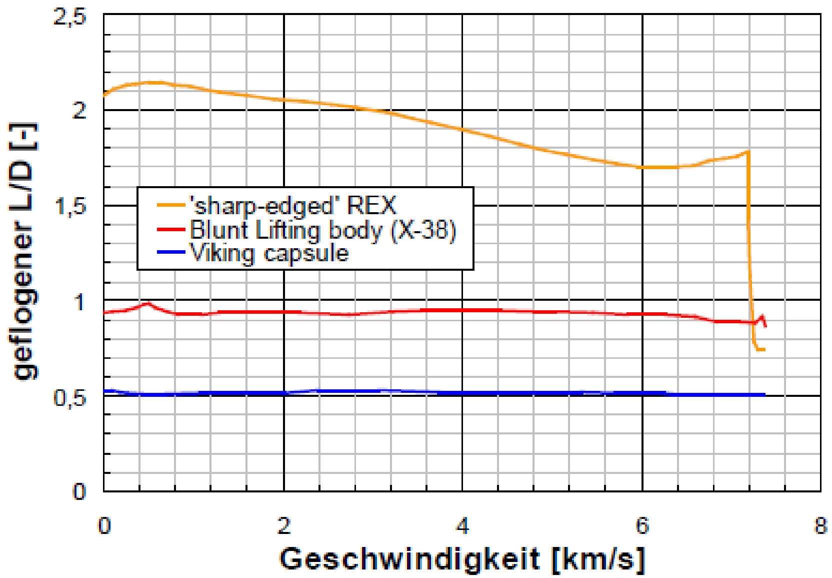
  Phase A finalized

Hypersonic lift to drag performance

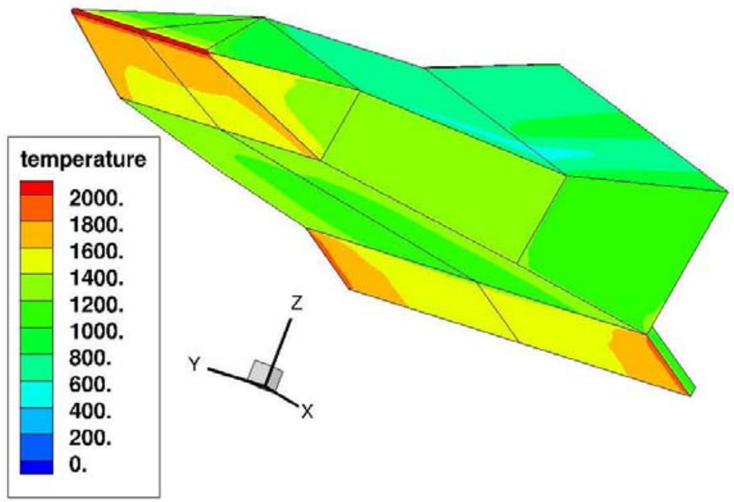


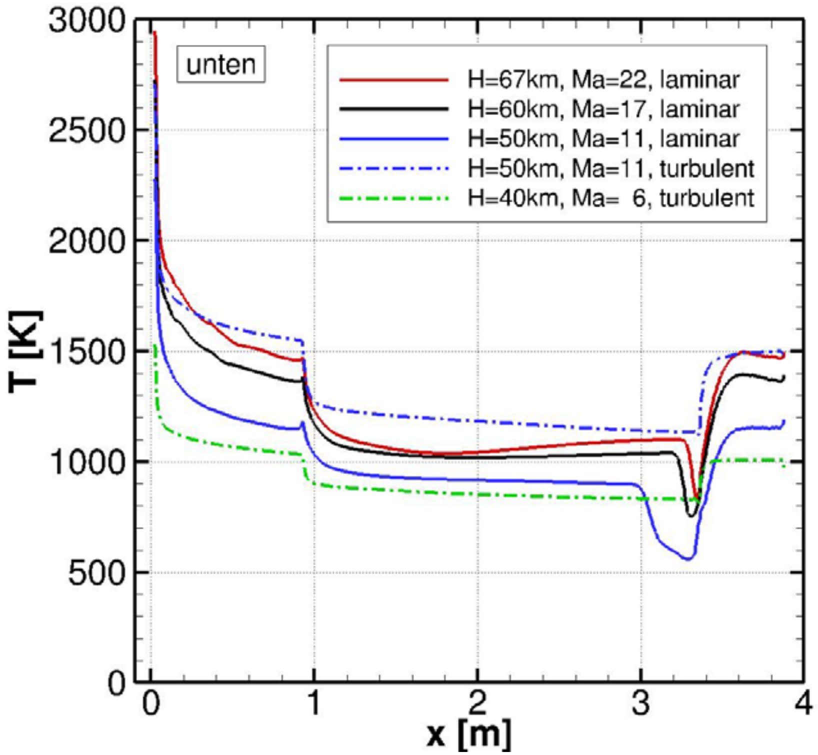
Aerodynamic Performance





SEFEX III: Aerodynamic data base (derived from REX shape)



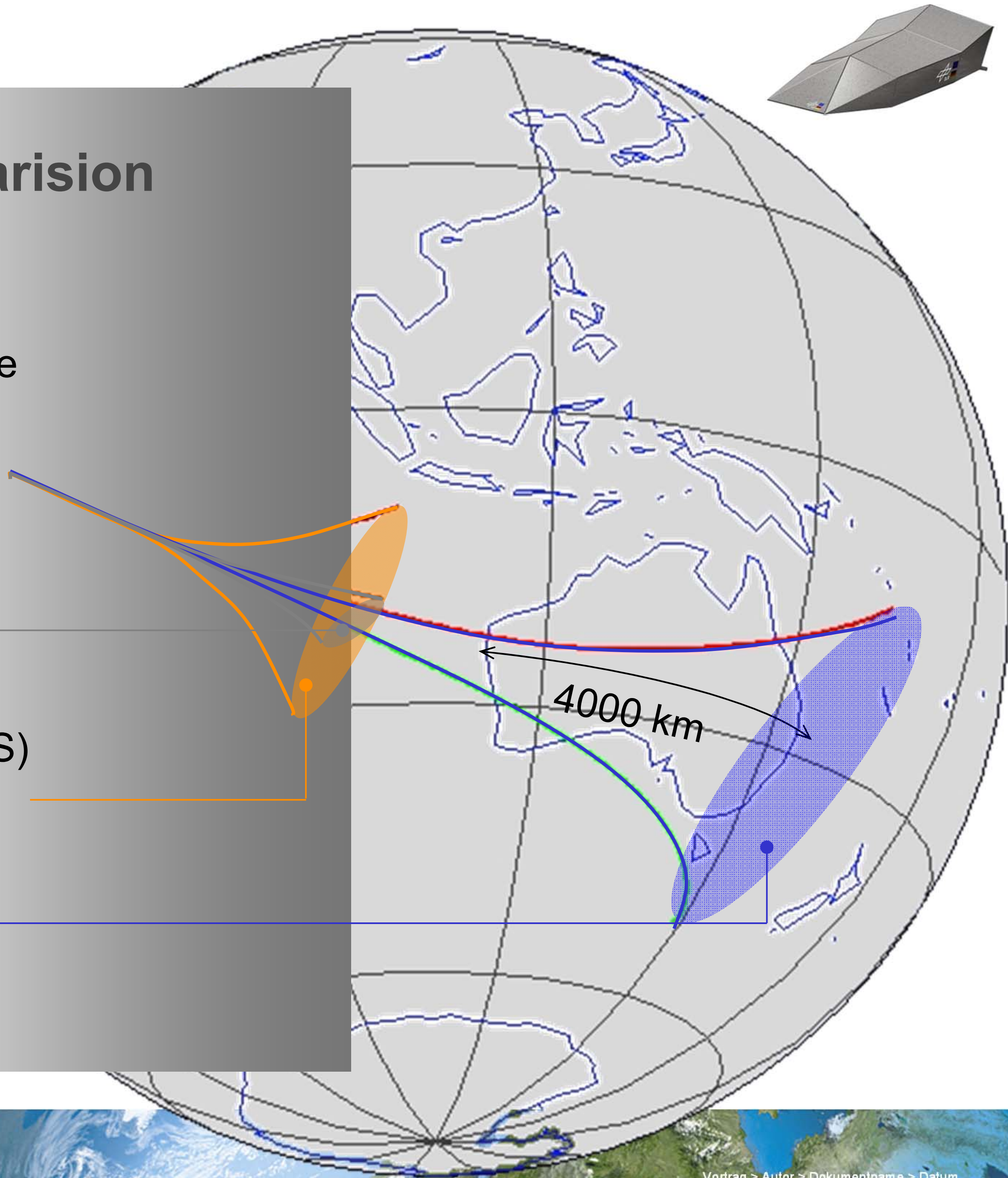


Surface temperature at radiation adiabatic boundaries (ε=0,83, real gas) Ma = 11, h = 50 km, α = 15°, I, turbulent boundary layer

Side range comparision

Max. Range/ Siderange

- Apollo
- Space Shuttle (STS)
- REX Free Flyer



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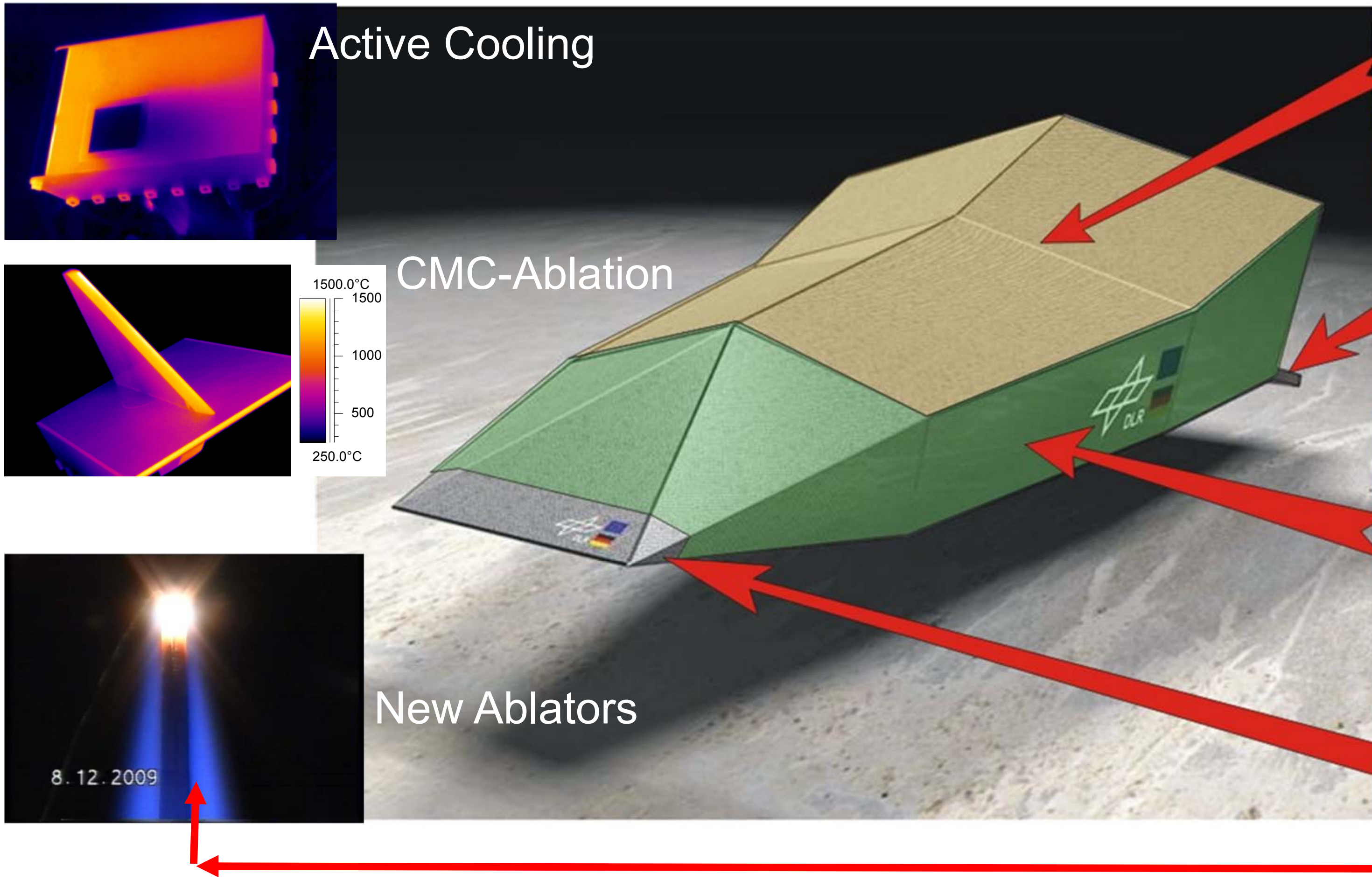
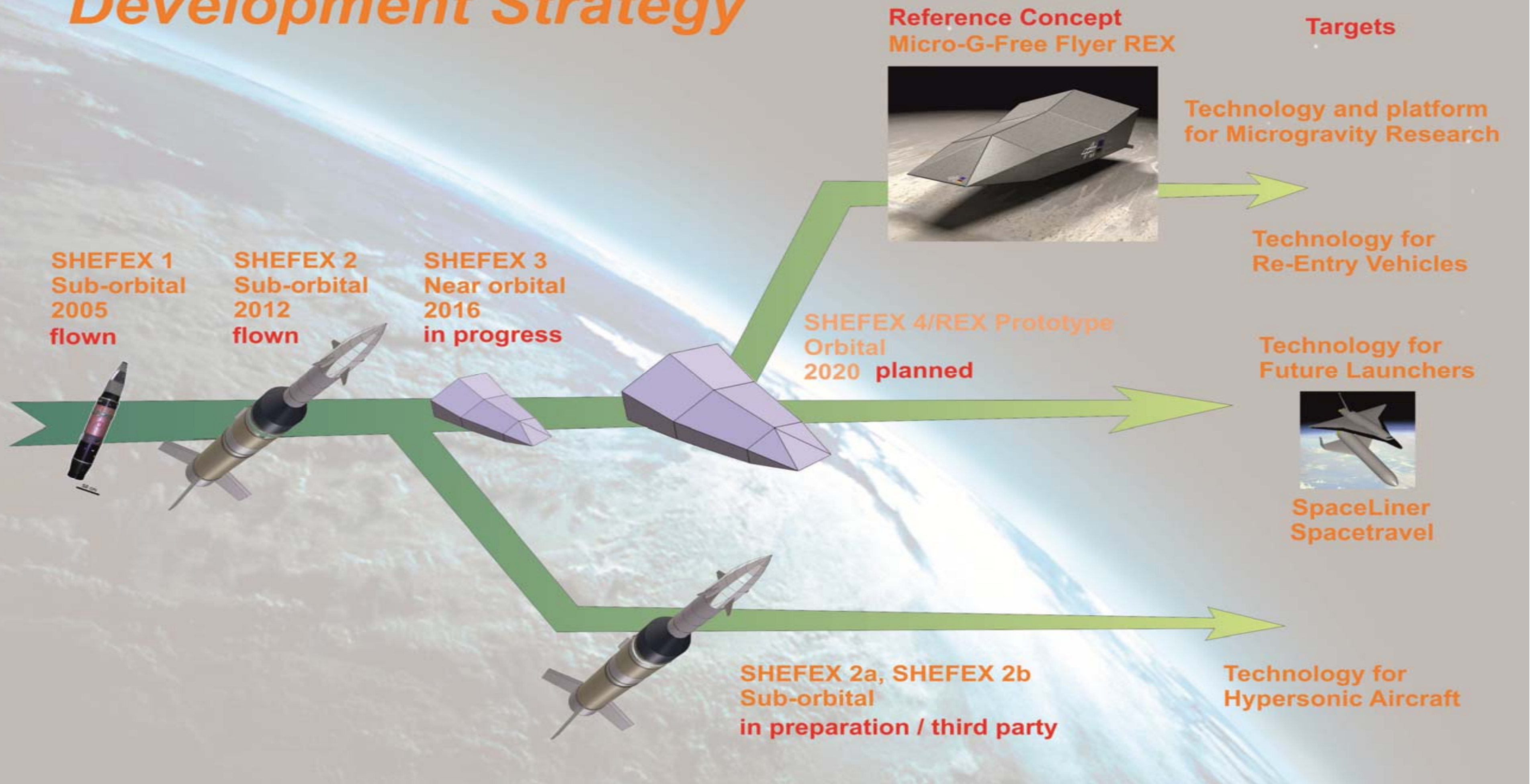
TPS-Concept for REX and SHEFEX III

Development in SHEFEX

Available State of the art



SHEFEX
Development Strategy



Location of DLR Competences for SHEFEX

Bremen:

Mission analysis, Navigation technology, Avionics

Braunschweig:

Aerodynamic vehicle layout, Interstage structures (VLM), aerodynamic control system,

Göttingen:

Hypersonic Wind Tunnel Tests

Köln:

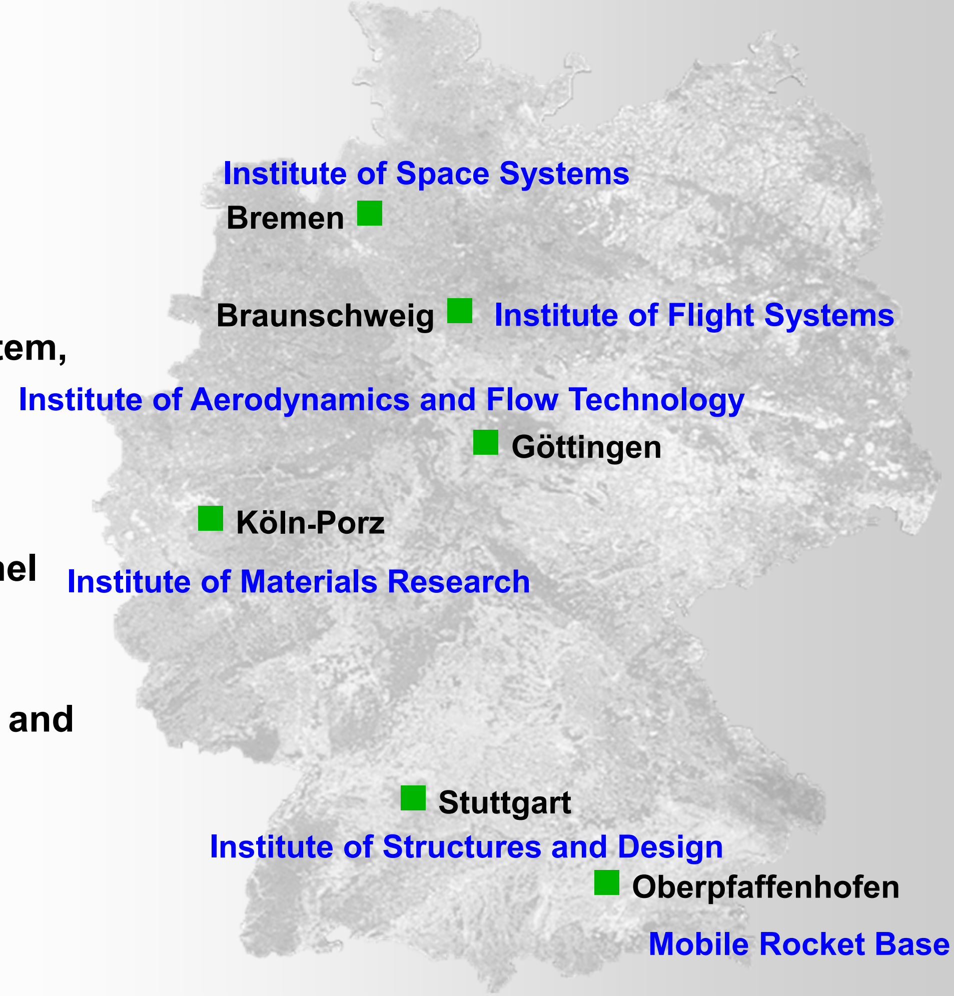
Instrumentation and Hypersonic Wind Tunnel Tests, oxide based TPS

Stuttgart:

Program coordination, Vehicle design, TPS and Hot Structures, fairing structures

Oberpfaffenhofen:

Rocket Design, Subsystems, RCS-Control, Launch Operation



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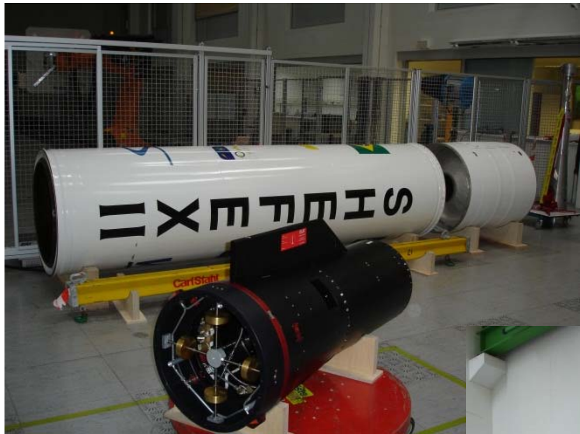
SHEFEX-Program

- Shefex I

- Pathfinder-Mission
- Suborbital
- Launchsystem VSB 30 /Imp. Orion
- Mass ca. 250 kg
- Velocity Ma 6, für 20 s
- Successful Flight in 2005
- A lot of “lessons learnt”
- External Passenger experiments

SHEFEX-Program

- SHEFEX I
- SHEFEX II



- Suborbital
- Launchsystem VS 40 (brasilian)
- Controlled hypersonic Flight
- Mass ca. 500 kg
- Velocity Ma 11(2.8 km/s)
- Entry duration 50 s
- Successful flight in 2012
- External passenger experiments

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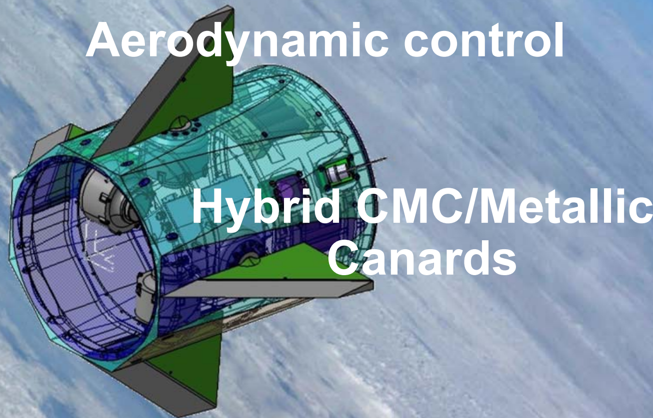
Experiments on SHEFEX II

New ablative fin structure

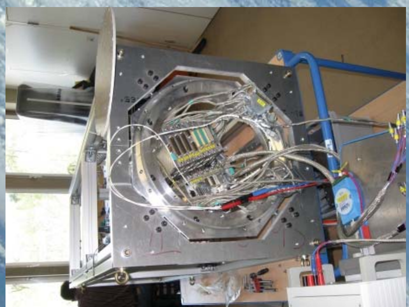
Hybrid navigation system

Aerodynamic control



Hybrid CMC/Metallic Canards

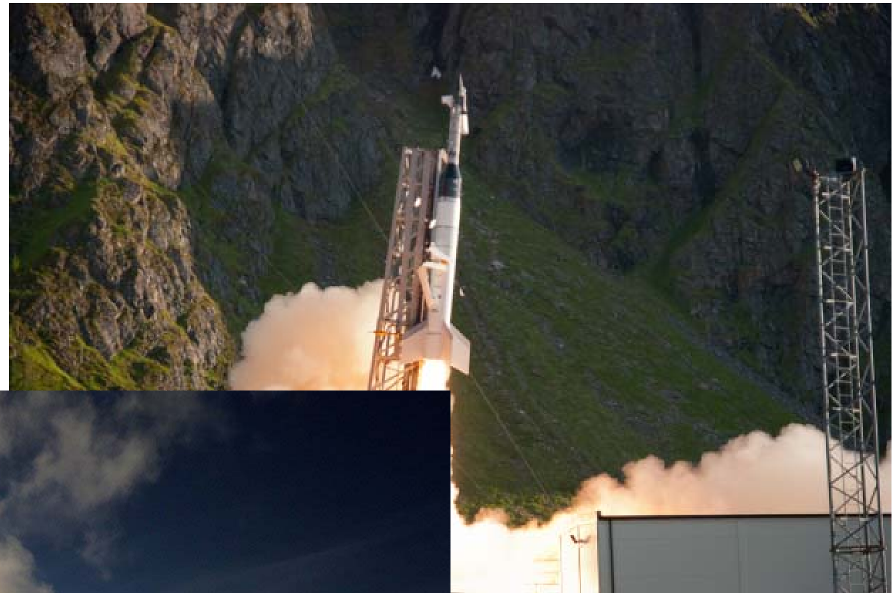
Instrumentation, TC, Heatflux, pressure, Pyrometer, Compare (IRS)

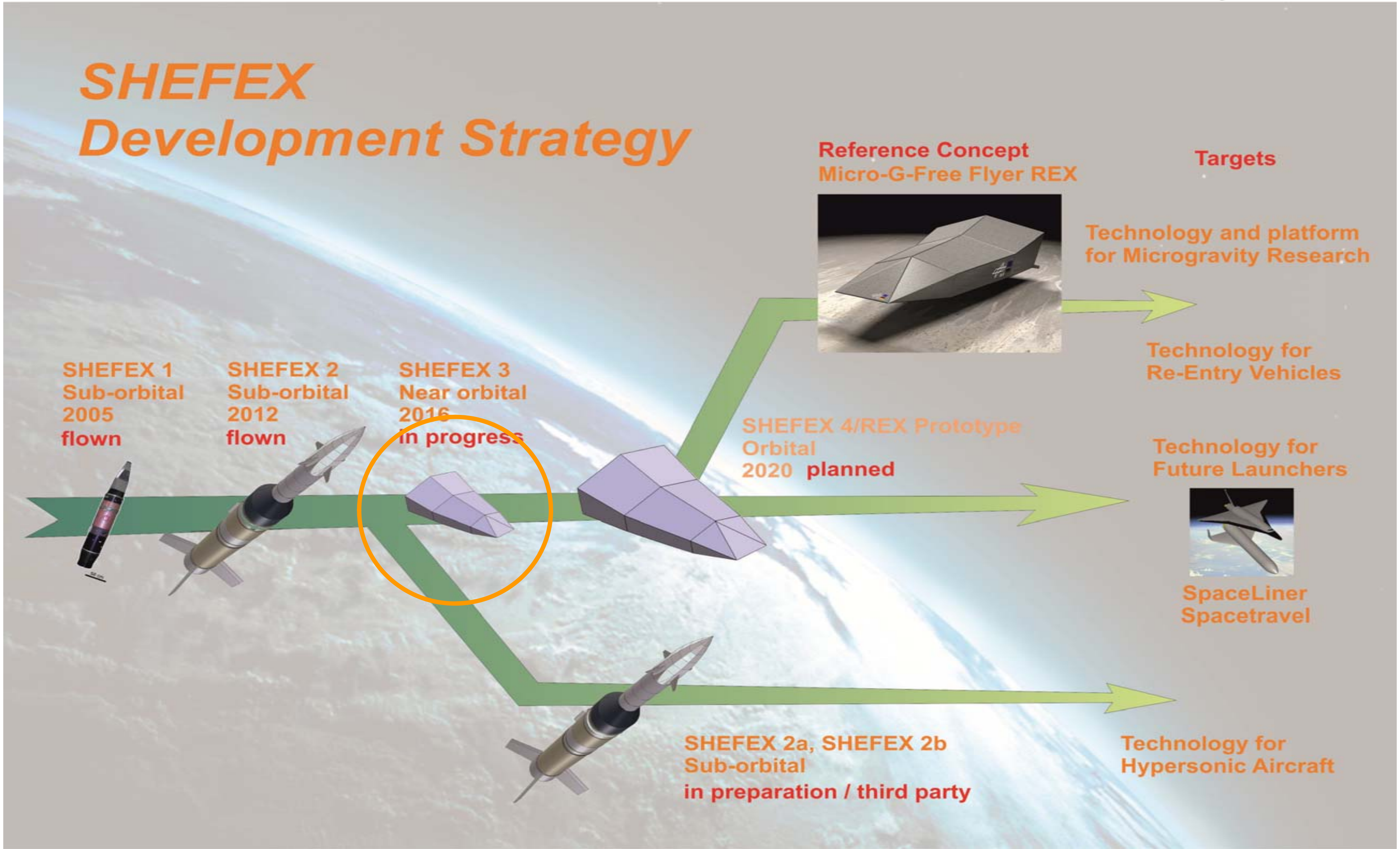


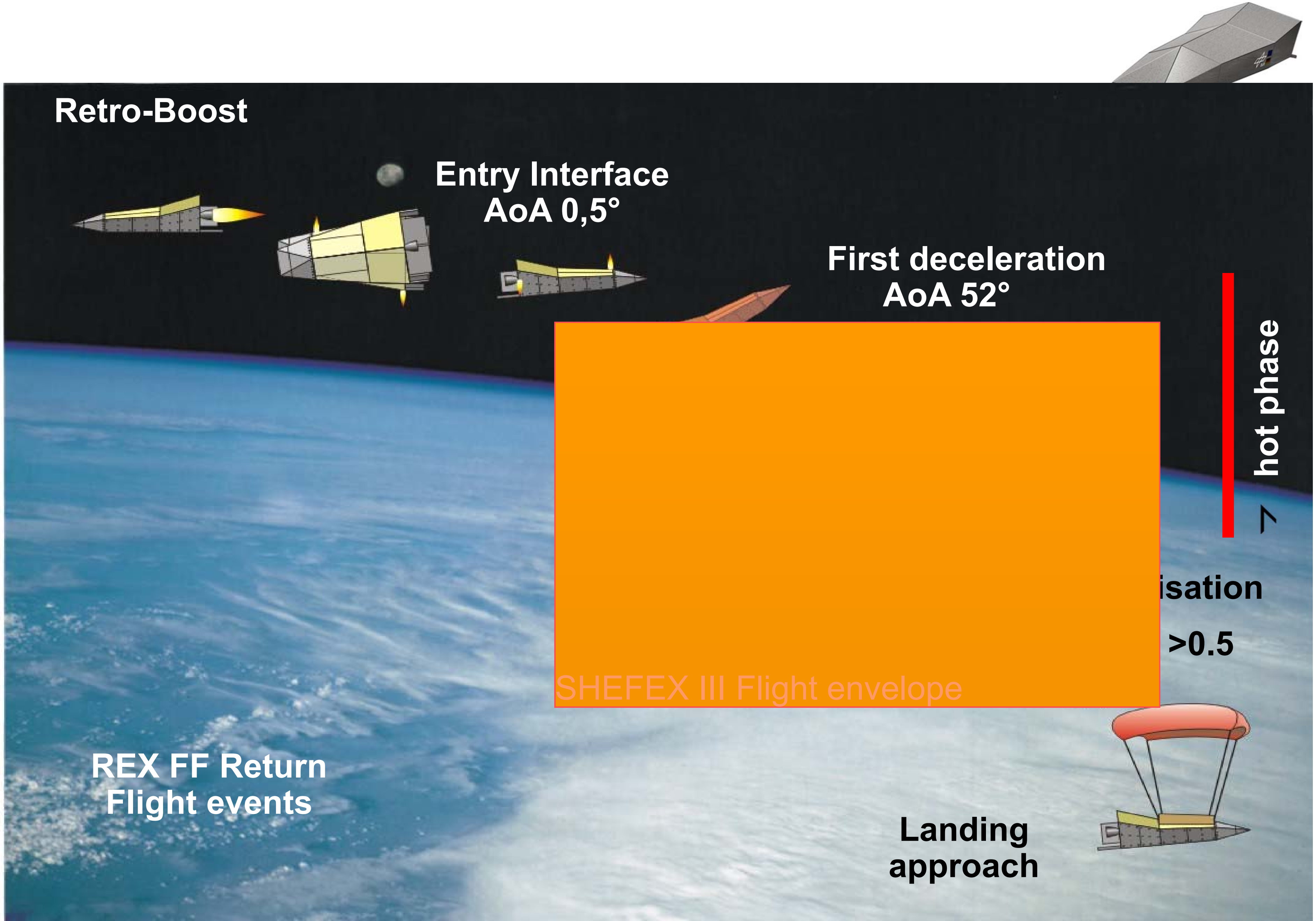
Windtunnel testing

9 TPS Systems (ASTRIUM, MT-A, AFRL, CTA, DLR)
1 actively cooled segment
4 „Hot“ Antennas

SHEFEX II-lift off, June 22nd, 2012

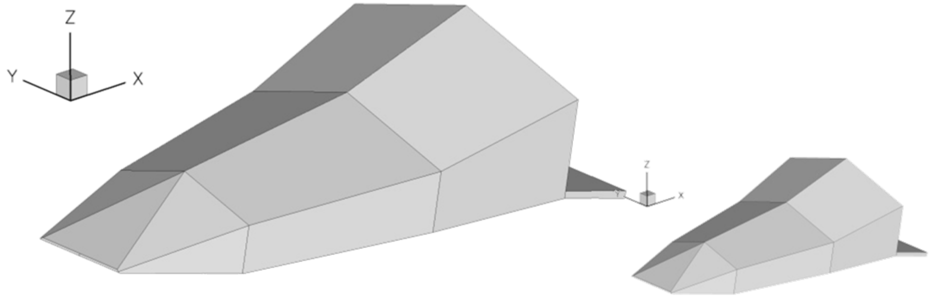



SHEFEX
Development Strategy
Reference Concept
Micro-G-Free Flyer REX
Targets
Technology and platform
for Microgravity Research
Technology for
Re-Entry Vehicles
SHEFEX 1
Sub-orbital
2005
flown
SHEFEX 2
Sub-orbital
2012
flown
SHEFEX 3
Near orbital
2016
in progress
SHEFEX 4/REX Prototype
Orbital
2020 planned
Technology for
Future Launchers
SpaceLiner
Spacetravel
SHEFEX 2a, SHEFEX 2b
Sub-orbital
in preparation / third party
Technology for
Hypersonic Aircraft

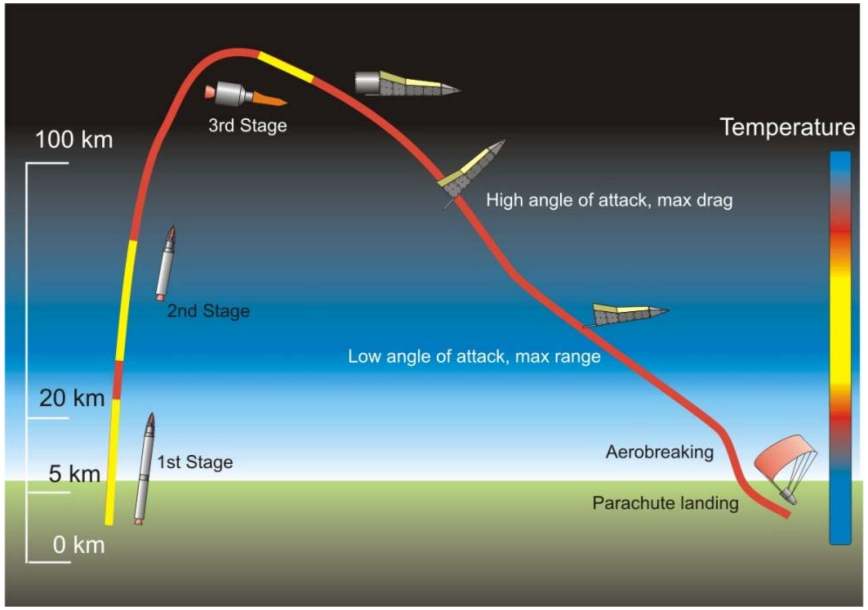

Retro-Boost
Entry Interface
AoA 0,5°
First deceleration
AoA 52°
hot phase
isation
>0.5
SHEFEX III Flight envelope
REX FF Return
Flight events
Landing
approach

SHEFEX-Program

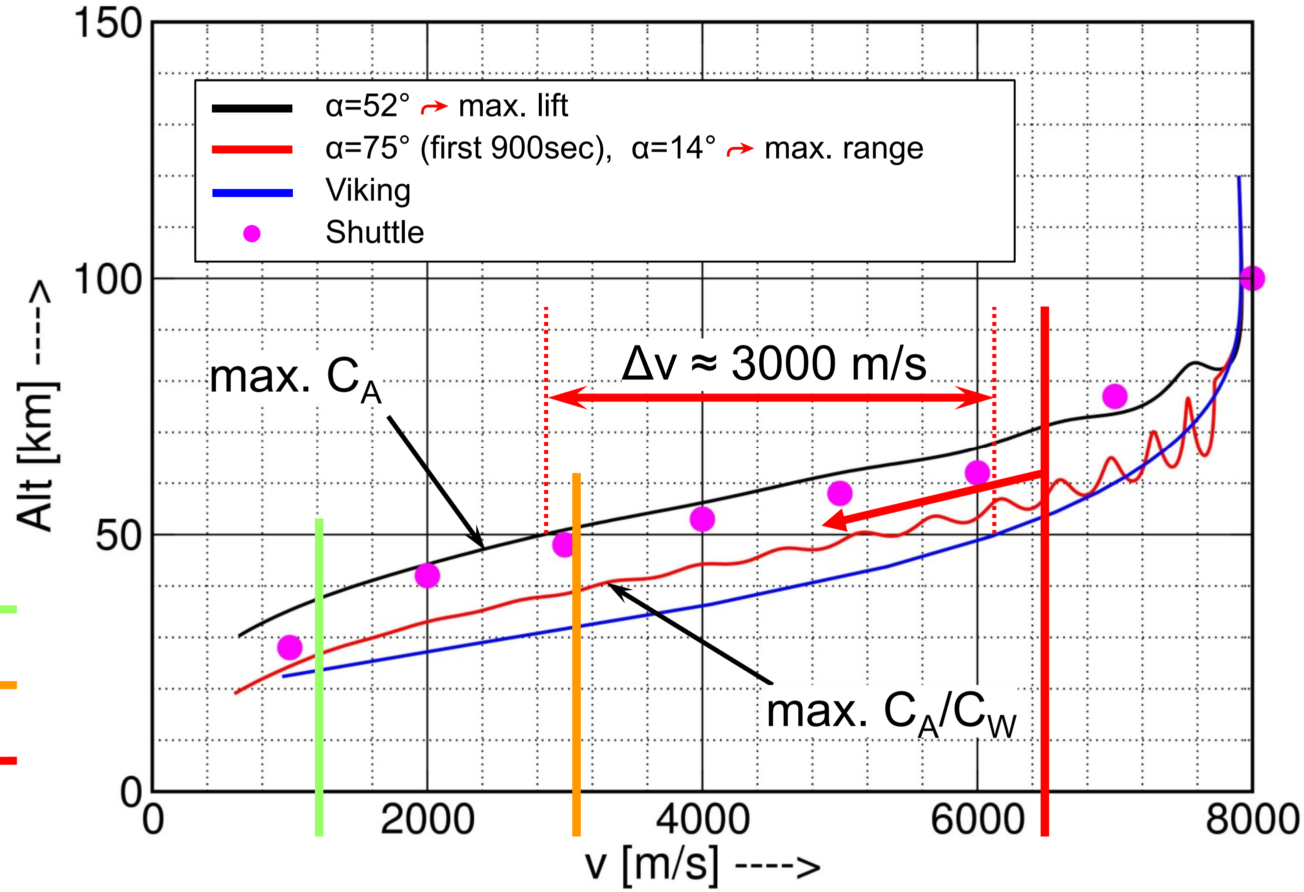
- SHEFEX I
- SHEFEX II
- SHEFEX III



- Suborbital Mission
- Demonstrating an optimized trajectory
- Rocket system VLM/S-50 (brasil.)
- Mass approx. 500kg
- Velocity approx. Ma 20
- Re-Entry duration approx. 15 Min
- Kick off in 2012
- DLR lead, external partners



Flight conditions of SHEFEX flights



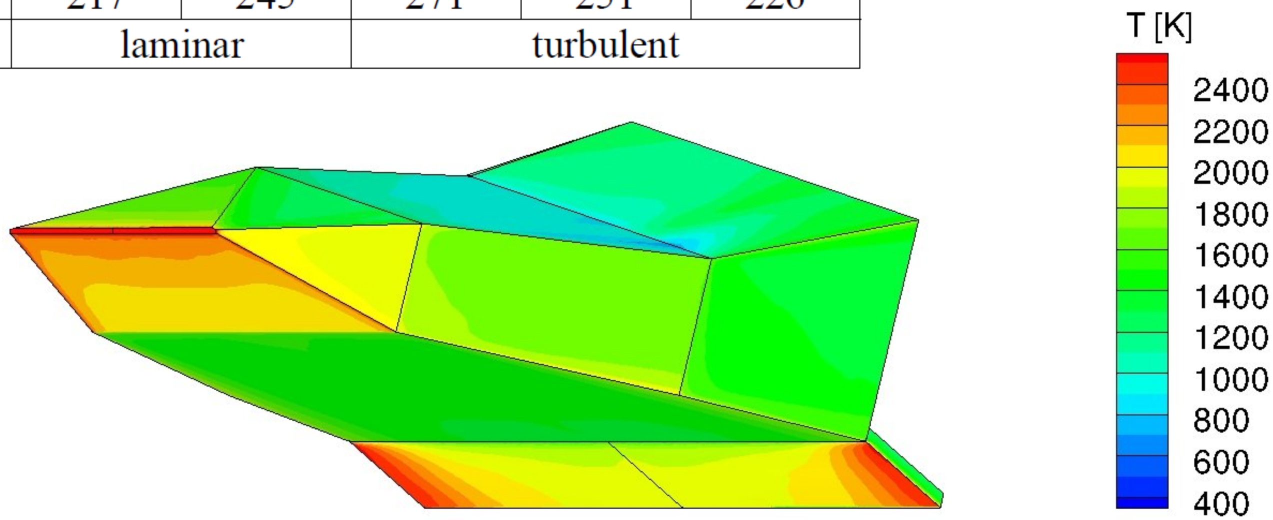
- SHEFEX 1
- SHEFEX 2
- SHEFEX 3

SHEFEX III, Technological Goals

- Flight test of advanced subsystems as partially already developed during SH II (e.g. Hybrid Navigation System)
- Demonstration of a defined and controlled re-entry at similar aerothermodynamic conditions as predicted for REX
- Demonstration of optimised re-entry trajectory using benefits from sharp edge design (lifting body L/D approx 1.8 in hypersonic velocity down to Ma 2)
- Demonstration of GNC, RCS and control components (Flaps and modified actuators)
- Demonstration of highly thermally loaded sharp leading edges and related cooling technology
- Only limited passenger experiments (Due to very hard mass restrictions)

SHEFEX III: Expected Temperatures

Höhe [km]	70	60	50	40	30
Gesch. [km/s]	7.5	6.8	5.2	3.2	1.6
Ma [-]	25	22.7	17.3	10.7	5.3
Druck [Pa]	5	20	76	278	1172
Temperatur [K]	217	245	271	251	226
Grenzschicht	laminar		turbulent		



Surface temperature (adiabatic walls) (ε=0.83),
Ma=17.3, H=50km, α=10°, turbulent boundary layer

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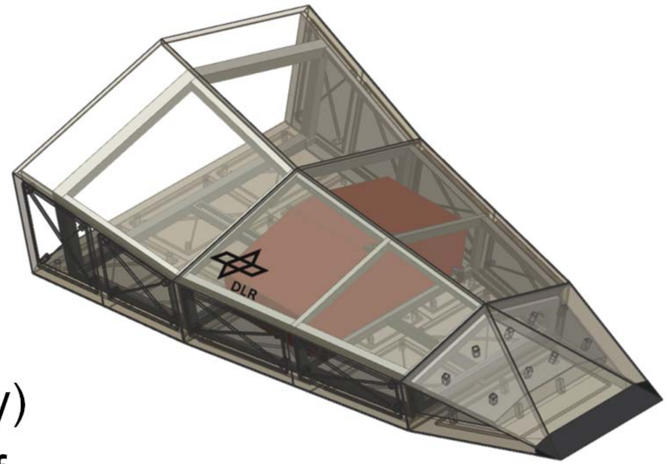
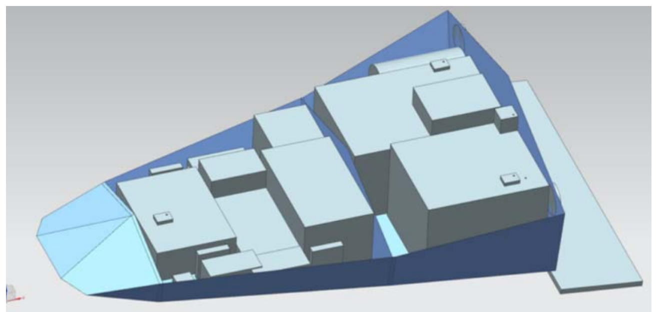
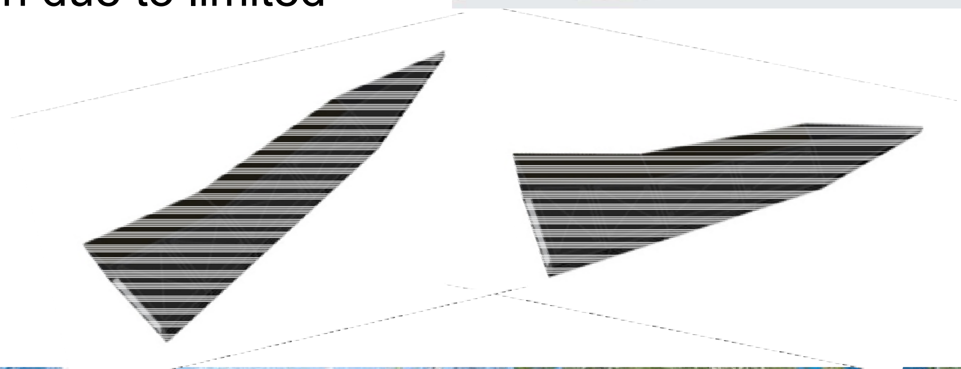
SHEFEX III Current Status

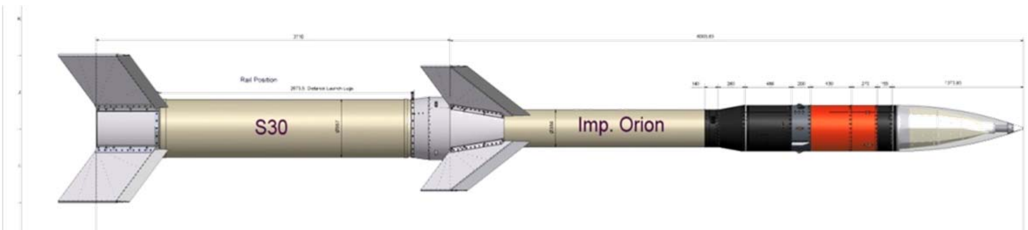


- Cooperation agreements signed
- Project kick off
- Determination of aerodynamic data base of version 0 vehicle shape (scaled REX Geometry)
- Lay out of the control system done(Tayloring of trajectory, control elements and actuators due to budget)
- First iteration of vehicle shape to Version 1 (enhancement of inner volume) in progress
- Recovery currently withdrawn due to limited budget

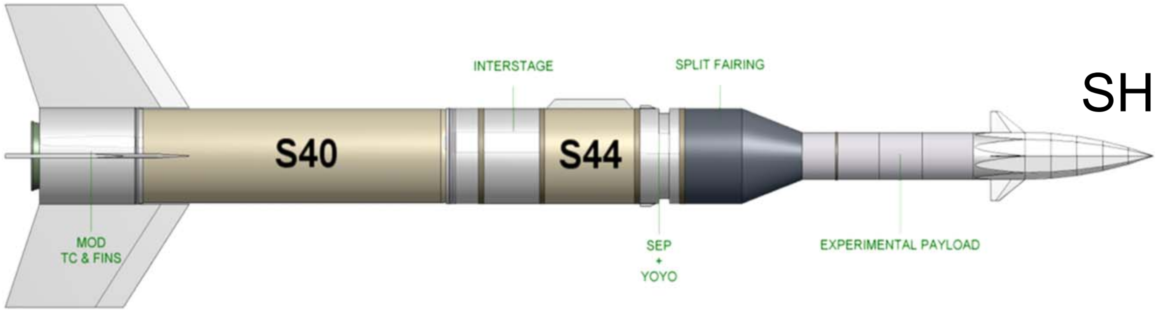




Launch system for SHEFEX III



SH I



SH II

VLM-1

SHEFEX III Project Structure

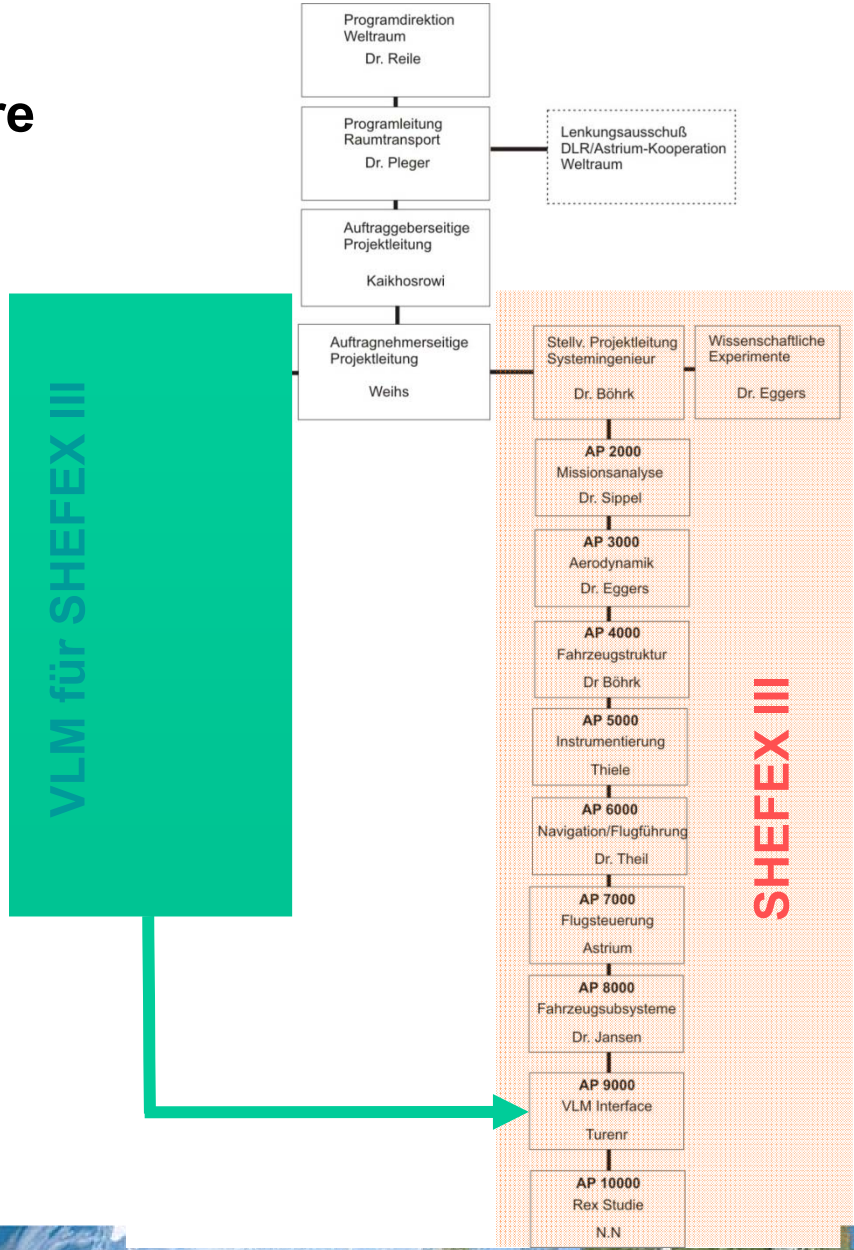
- 2 different Projectlinies
- Duration 5 Years
- Kick Off in 2012
- End 2016
- Cooperation:

    SHEFEX III: ASTRIUM

    VLM-1: DCTA/IAE Brazil

Call for Passenger experiments End 2013

- Selection by DLR review board



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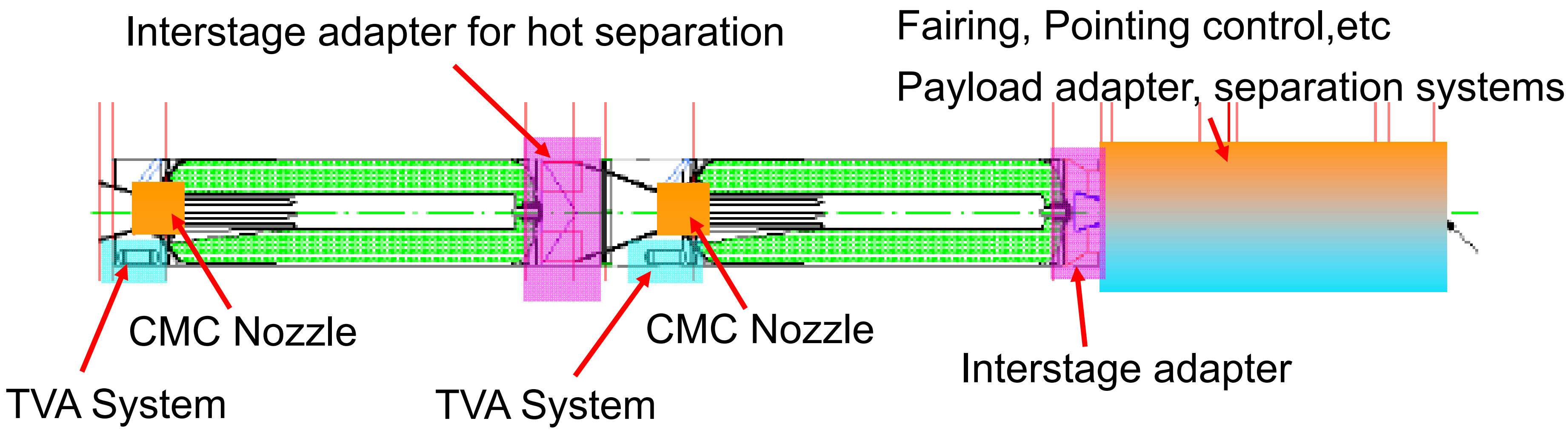
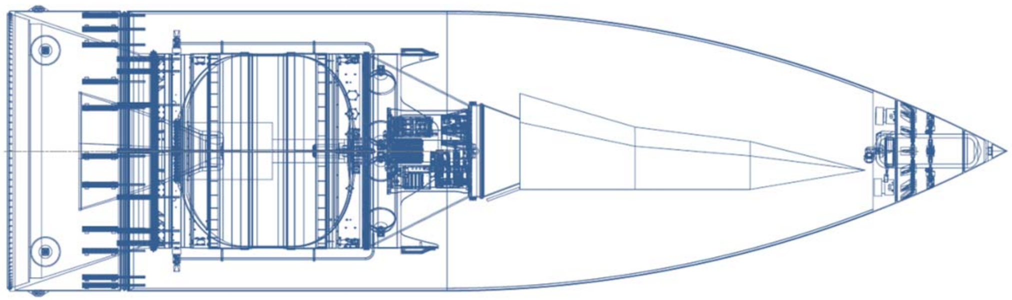
DLR Development within VLM-1 in SH III configuration



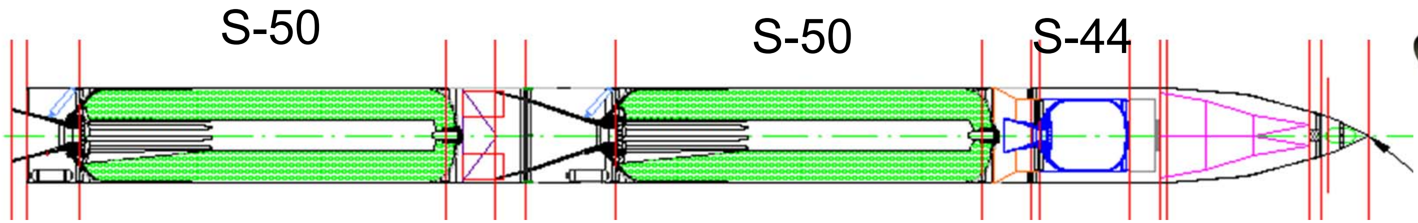
Institute of Structures and Design BK

Institute of Composite Structures

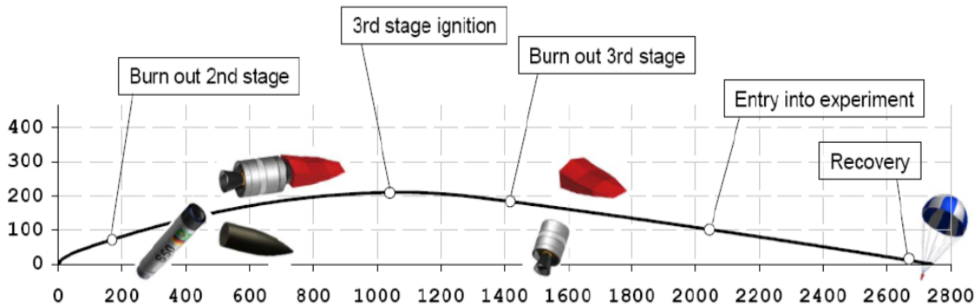
Mobile Rocket Base



VLM: Launch system for SHEFEX III



- Length: ~18 m, Diameter: 1.45 m, Mass: ~27 tons
- **Launch site:** Alcantara(Brazil)
- **Impact:** South of Canarias
- **Launcher capacity:**
- ~ 570 kg @ 100km Altitude @ 6.5 km/sec



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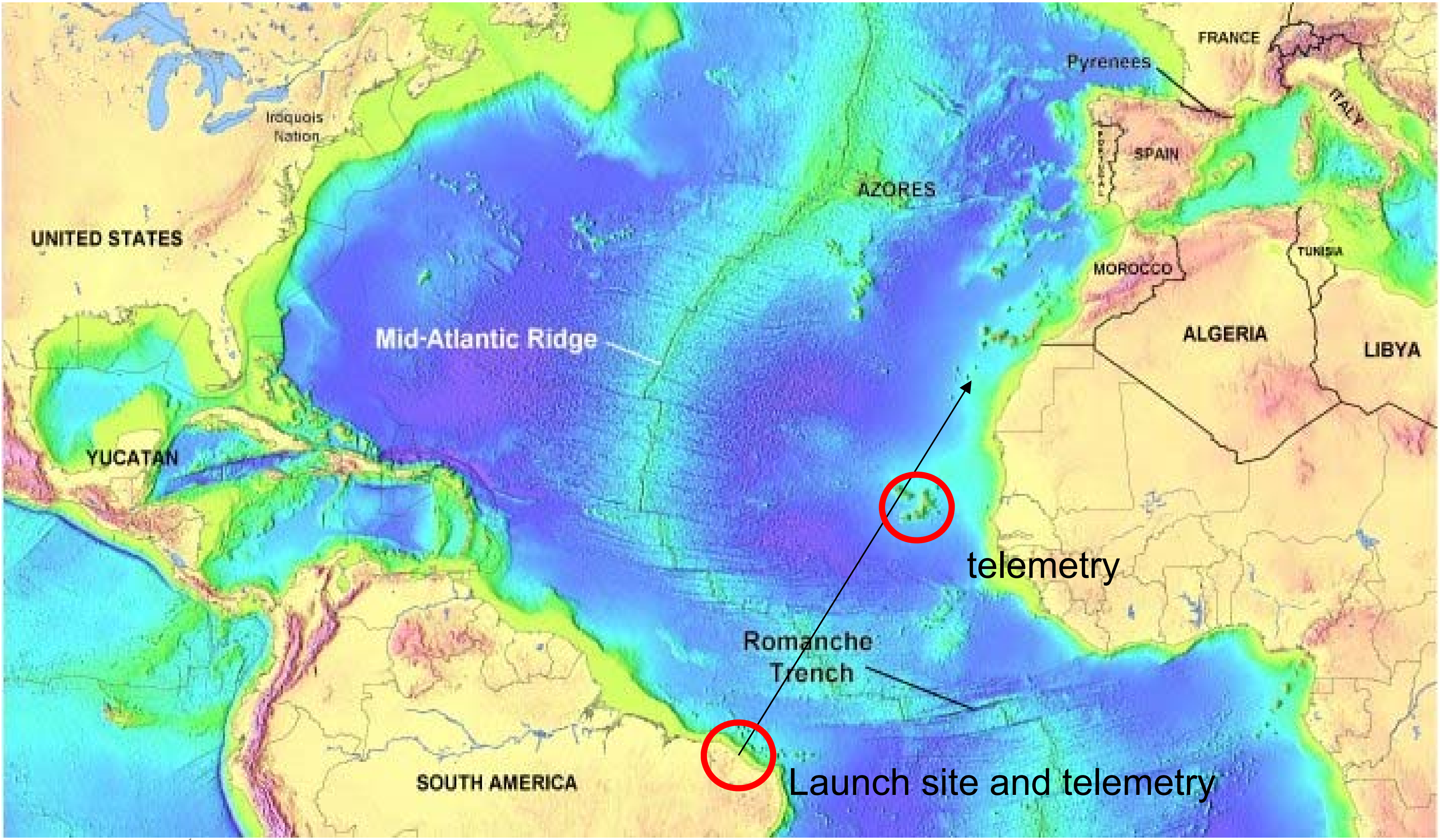
Preliminary SH III flight path



Thank You !