2nd International Symposium: “Hypersonic Flight: from 100000 to 400000 ft”

Rome, Italy, 1st July 2016

SpaceLiner Project – Ready for Structured Development

Martin Sippel, Olga Trivailo, Alexander Kopp, Sarah Lipp, Cecilia Valluchi, Tobias Schwanekamp
Space Launcher Systems Analysis (SART), DLR, 28359 Bremen, Germany

Overview of Presentation

- **Visionary Concept SpaceLiner**

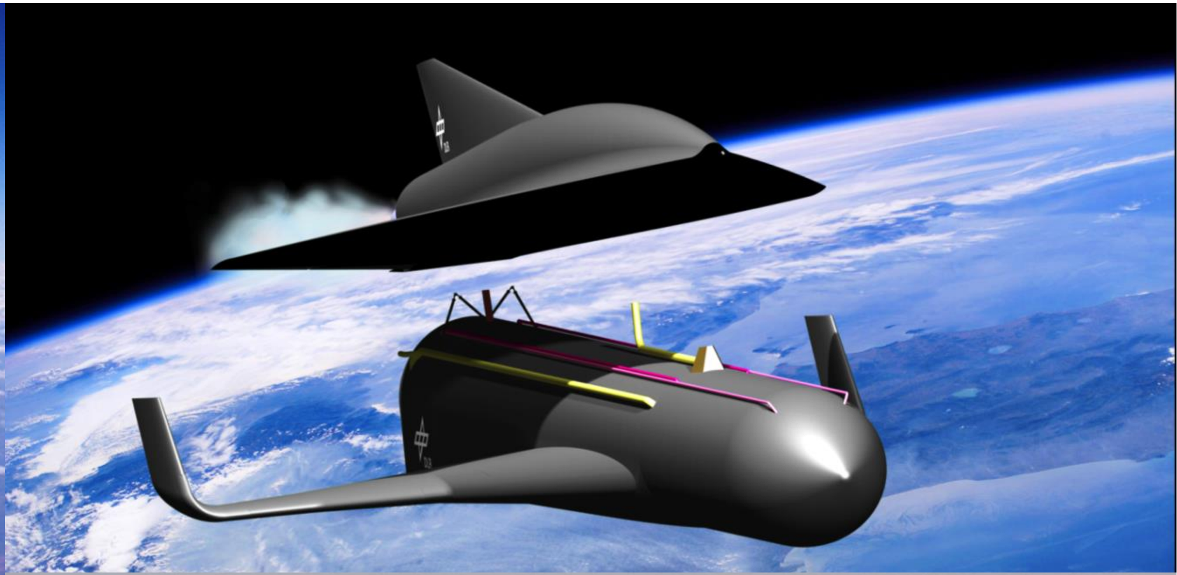
- **Maturation to SpaceLiner 7-3**
  - **Evolution of Reusable Booster Stage**
  - **Evolution of Passenger Stage**
  - **Subsystem Definition**
    - **Main Propulsion System Cabin and Rescue System**
    - **Structural Pre-Sizing**
    - **TPS & Active Leading Edge Cooling**
  - **Nominal Trajectory**

- **Operational Scenario, Cost and Development Roadmap**

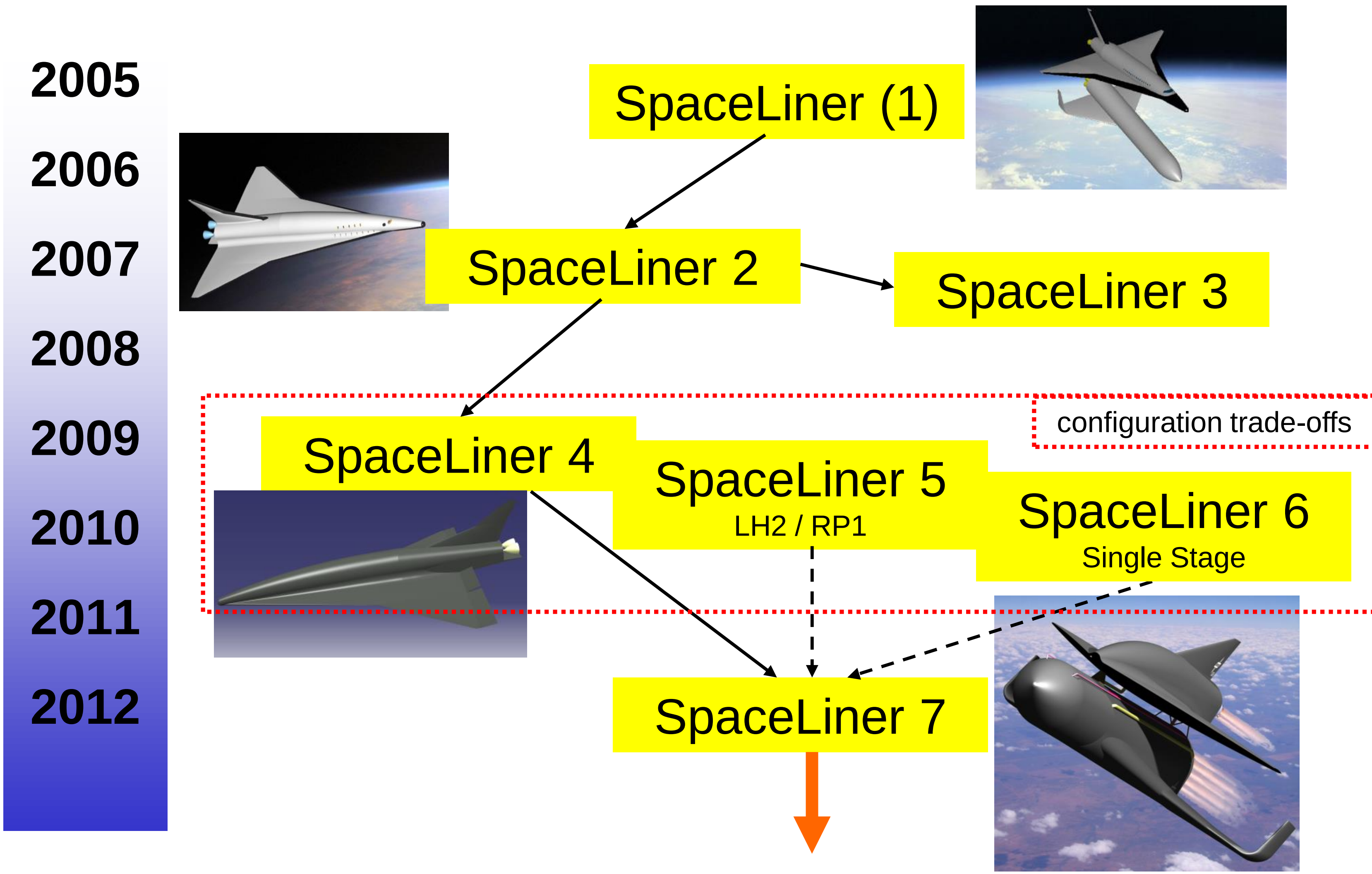
- **Conclusion and outlook**

SpaceLiner: Visionary Ultra-fast Passenger Transport

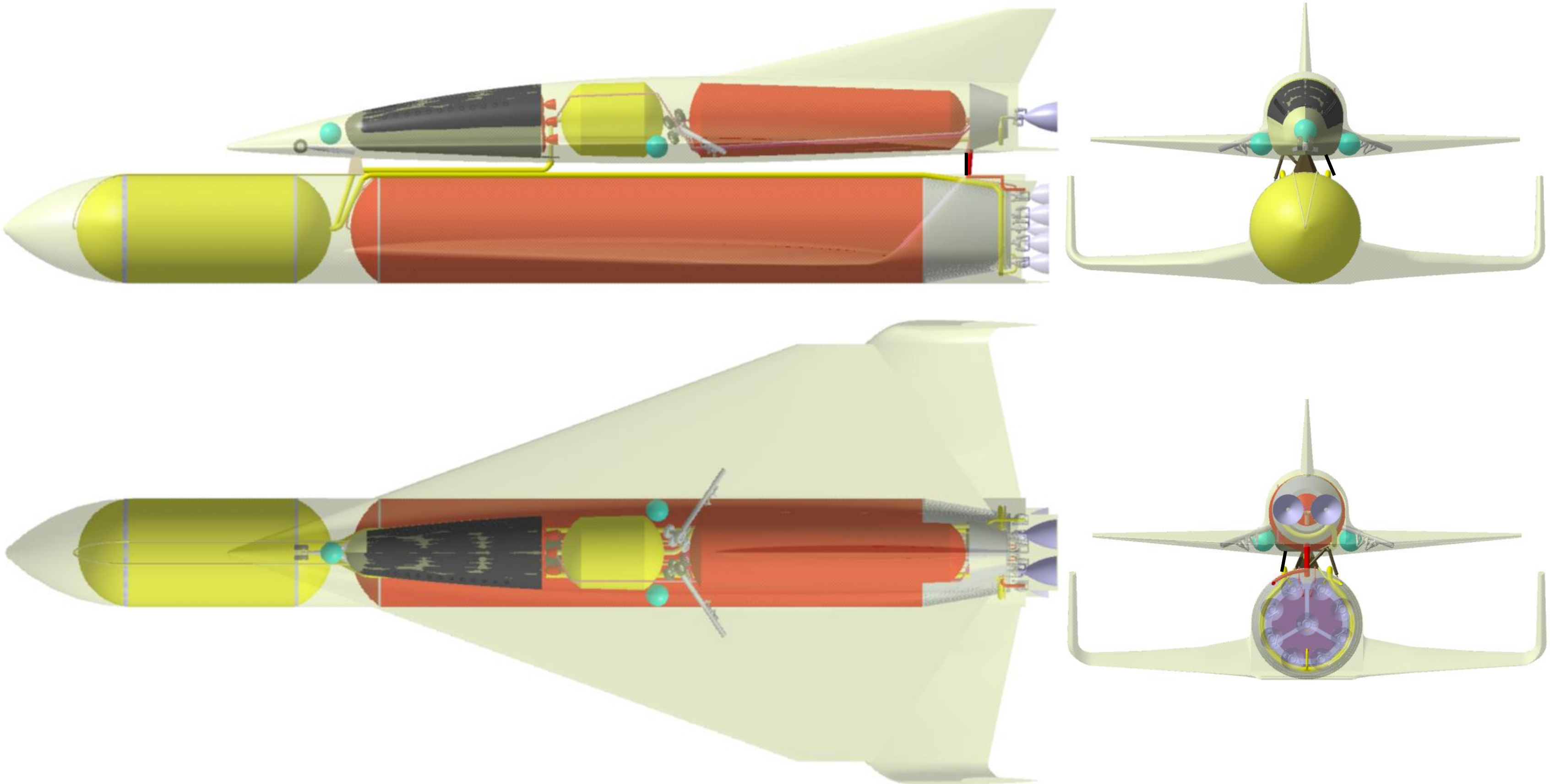
- Flying e.g. Australia – Europe in 90 minutes in a 2-stage rocket-propelled fully reusable vehicle.
- Vertical lift-off and horizontal landing on a runway like the Space Shuttle.



Technical Evolution of the SpaceLiner Concept



SpaceLiner 7 Overview Data

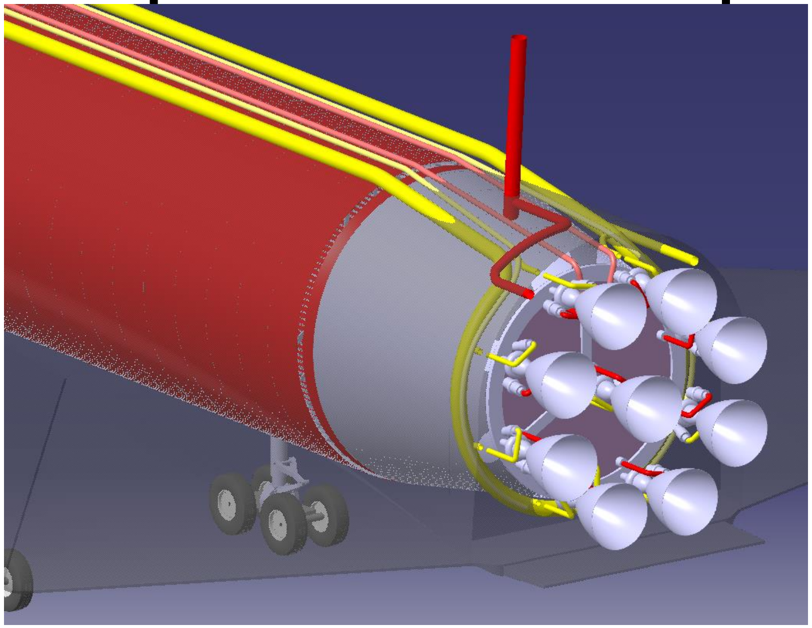


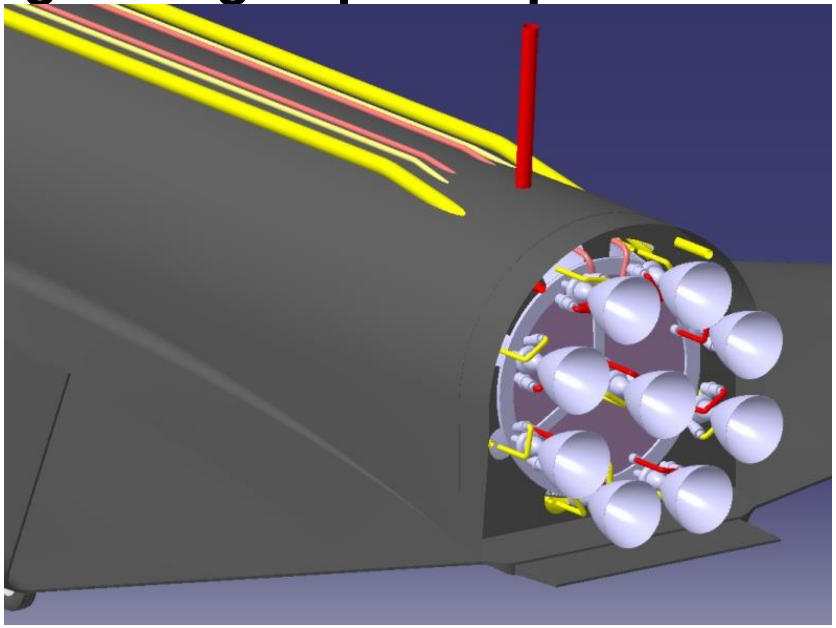
overall length [m]	82.3
overall height [m]	21.6
overall span [m]	36.0

Total dry [Mg]	Total propellant loading [Mg]	GLOW incl. passengers & payload [Mg]
314	1514	1855

Maturation to SpaceLiner 7-3: Booster Stage

- **Fully reusable stage of conventional geometry with 2 large separate LOX- and LH2-tanks + nose, wing and thrustframe structure. Some similarities to ET of Space Shuttle**
- **Preliminary structural sizing of the fuselage completed.**
- **Propellant crossfeed to passenger stage up to separation.**

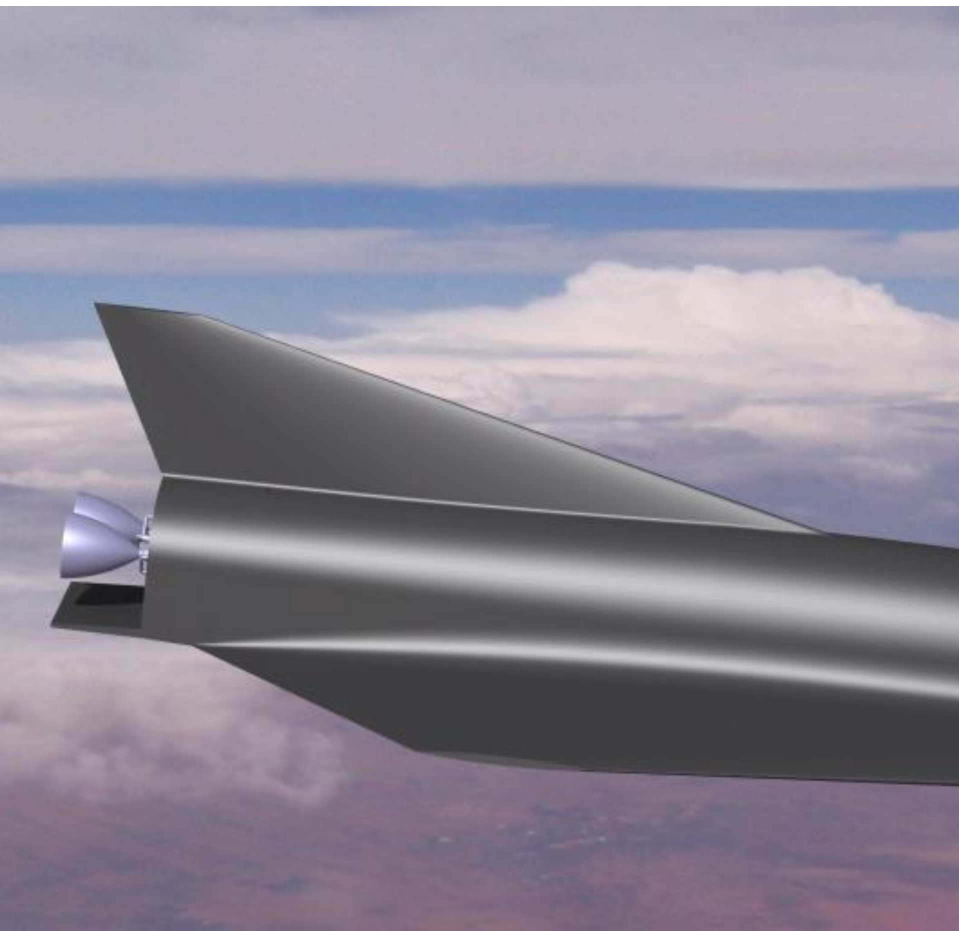


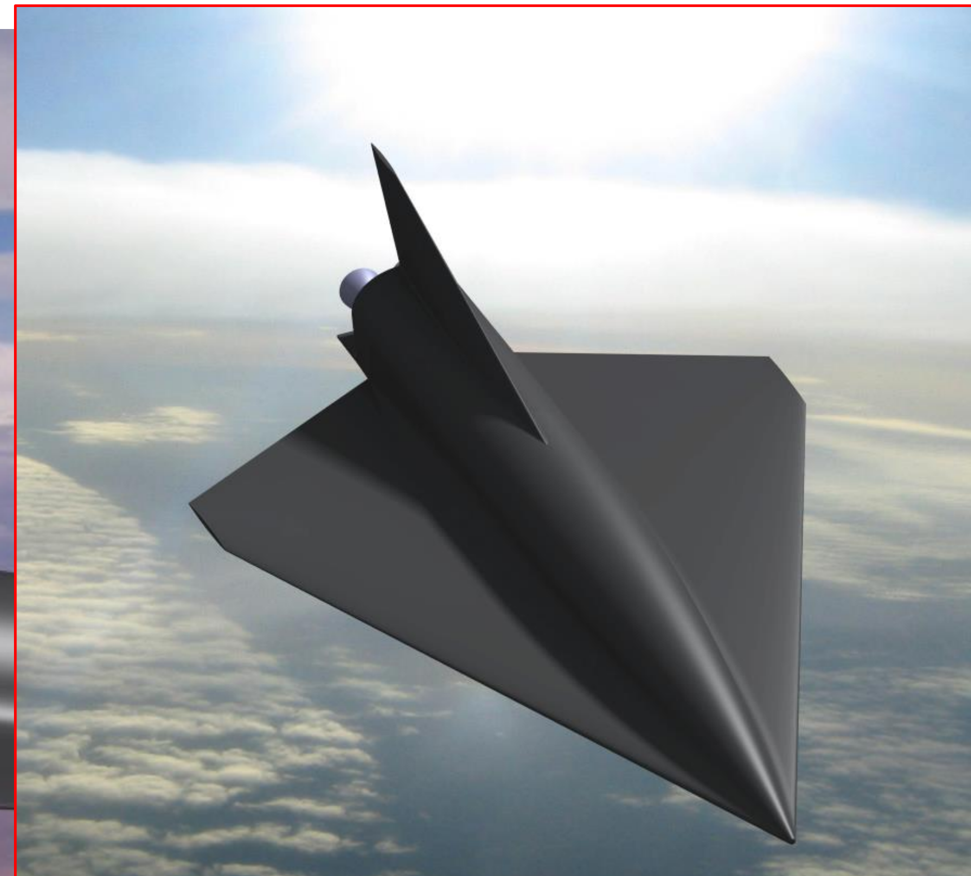


- **Total length: 82.3 m, span 36 m**
- **Total dry weight: 205 Mg, GLOW: 1485 Mg**

Maturation to SpaceLiner 7-3: Orbiter Geometry

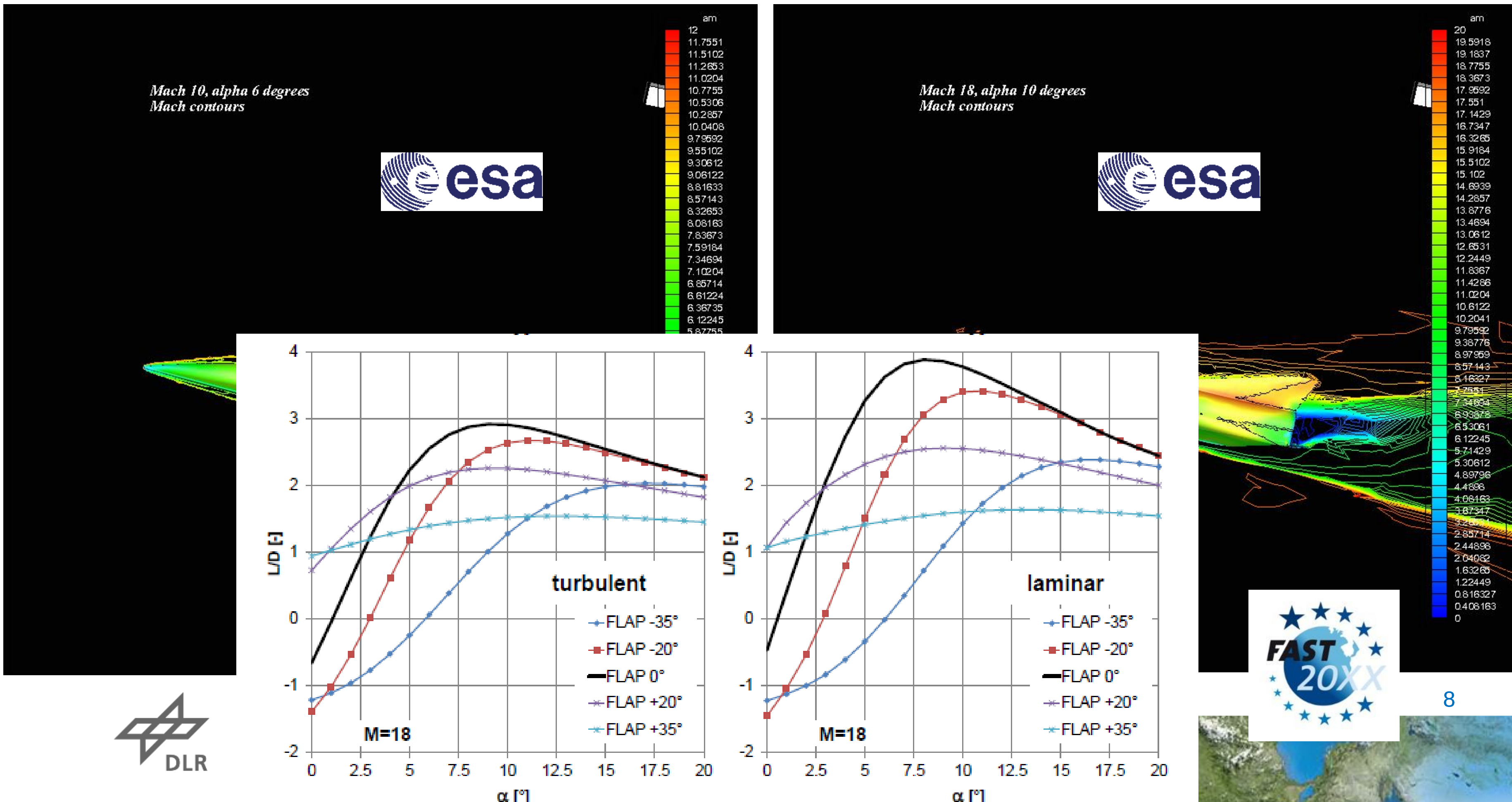
- **Objective: Very good hypersonic L/D with minimum flap deflection in nominal gliding.**
- **SpaceLiner7 was the first SL configuration characterized by an aerodynamic shape from fully automated optimization.**





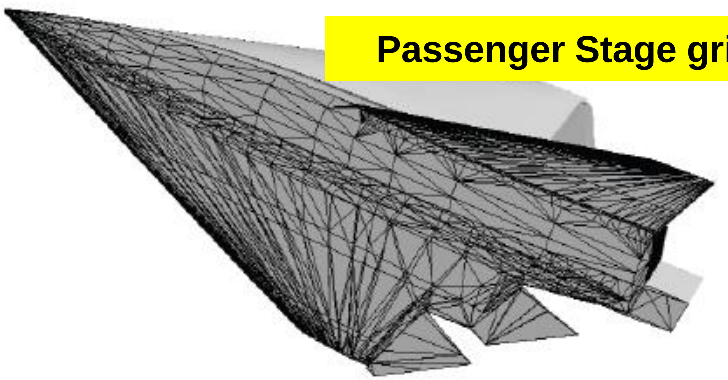
SpaceLiner 7-2 AEDB: Example Orbiter

- **Maximum hypersonic L/D assuming turbulent boundary layer is up to 3.5**
- **Euler calculations of ESA-ESTEC support reference data.**



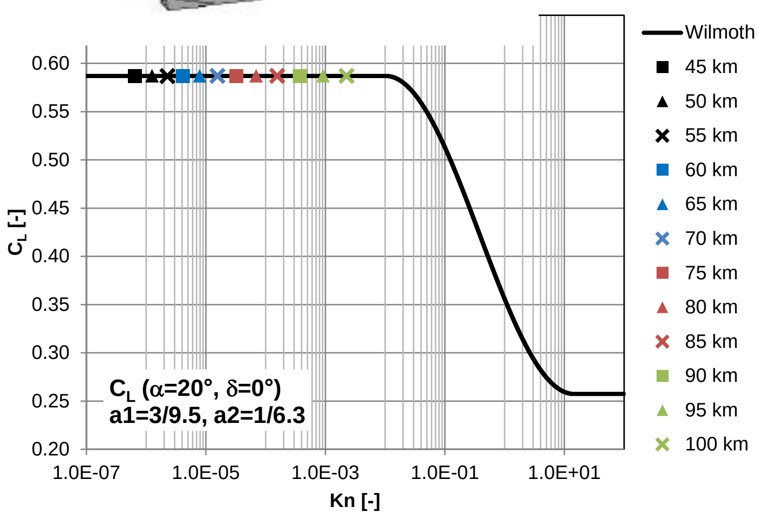
SpaceLiner 7-2 AEDB: Rarefied Aerodynamics

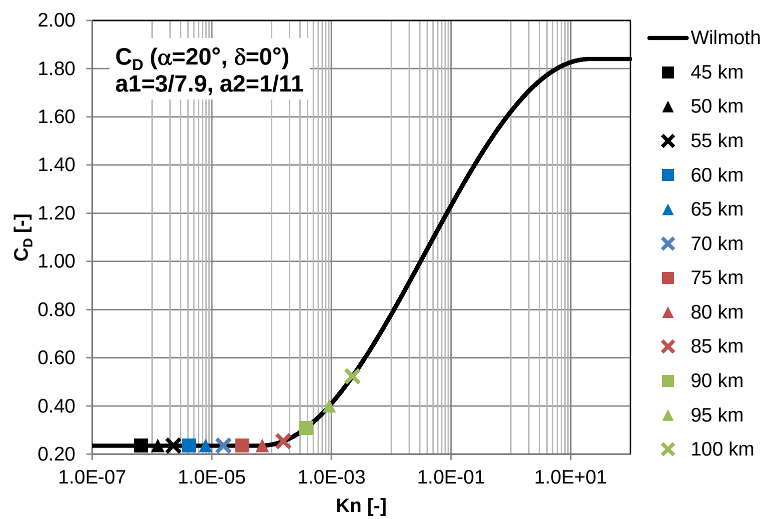
- **FAST20XX initiated investigations of aerodynamic characteristics in transition regime, from continuum low density to free molecular flows**
- **Work by CIRA (DSMC) and DLR (windtunnel) with later support of University of Naples**



Passenger Stage grid for DS3V

- **Bridging functions generated with Wilmoth formula as function of Knudsen number:**

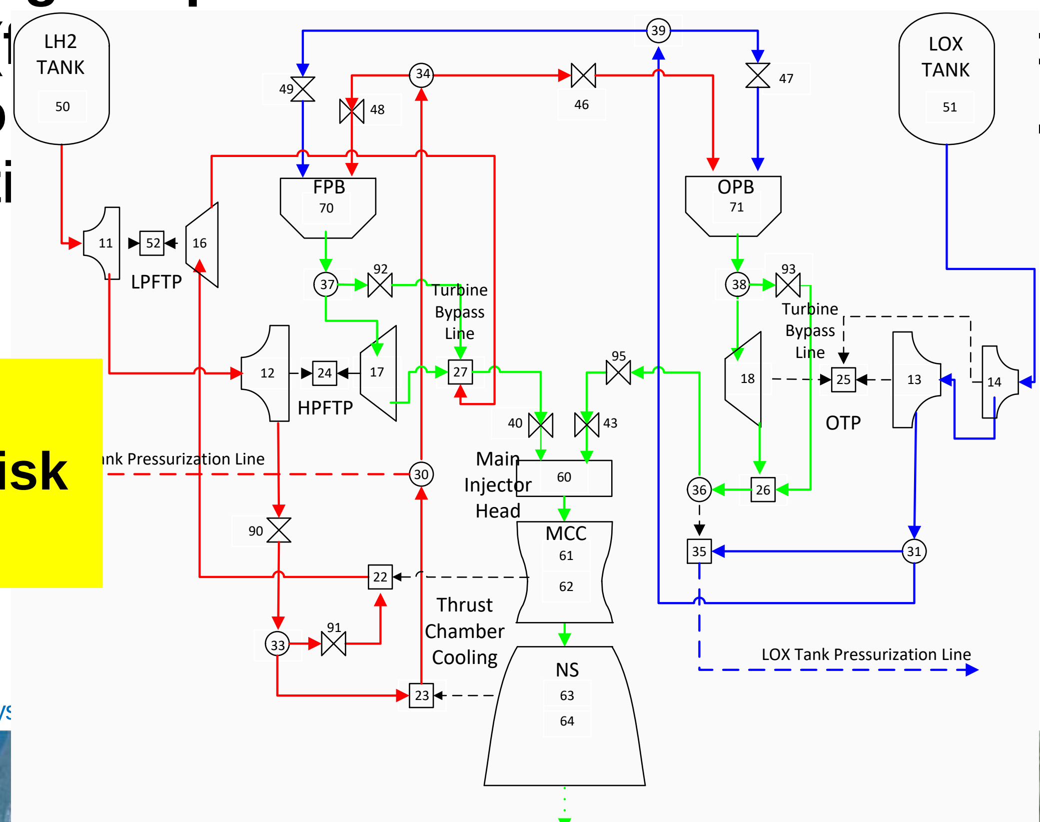




SpaceLiner Main Engine (SLME): Requirements and Functional Architecture

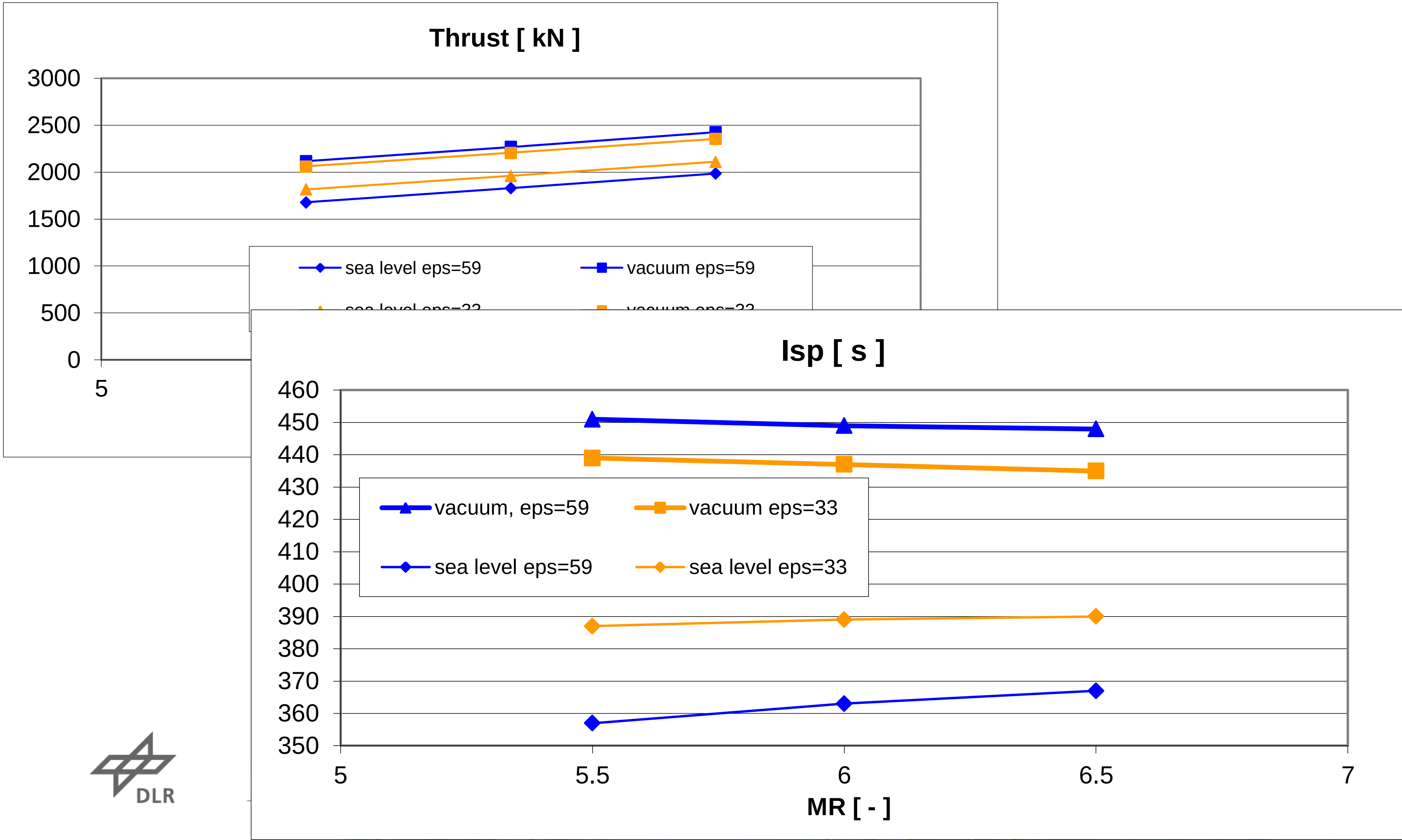
- Baseline of SpaceLiner main propulsion system are similar LOX-LH2 rocket engines in booster and passenger stage; however with adapted nozzle expansion ratios.
- Engine cycle is Staged Combustion type in order to achieve compact engines and good performance.
- Full-flow SC cycle (f … the preferred option for o … .
- Nominal MR-operati
- 25 reuses

Single type rocket propulsion system is risk reduction measure!



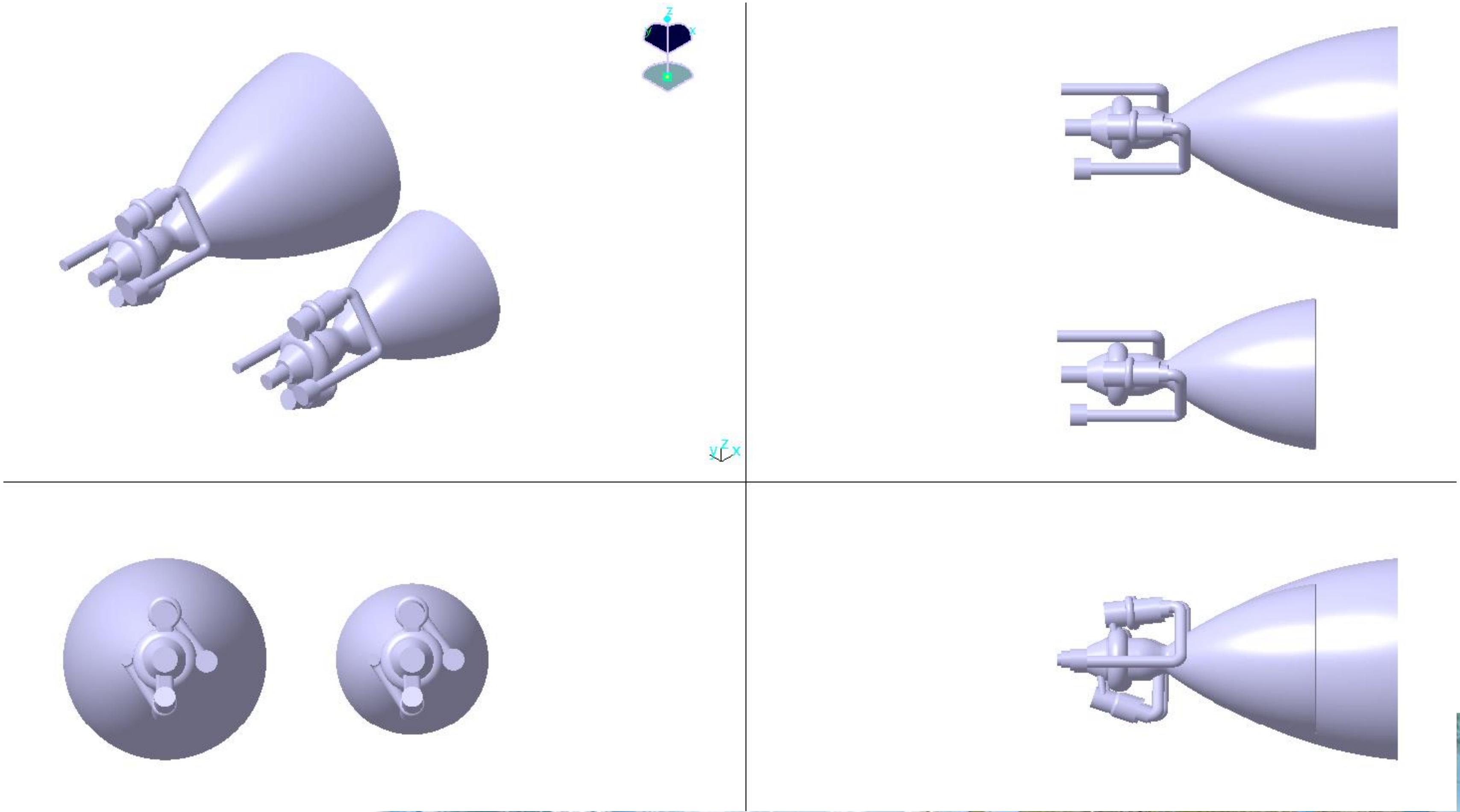
SLME calculated performance

- **Based on cycle analyses of nominal MR range:**



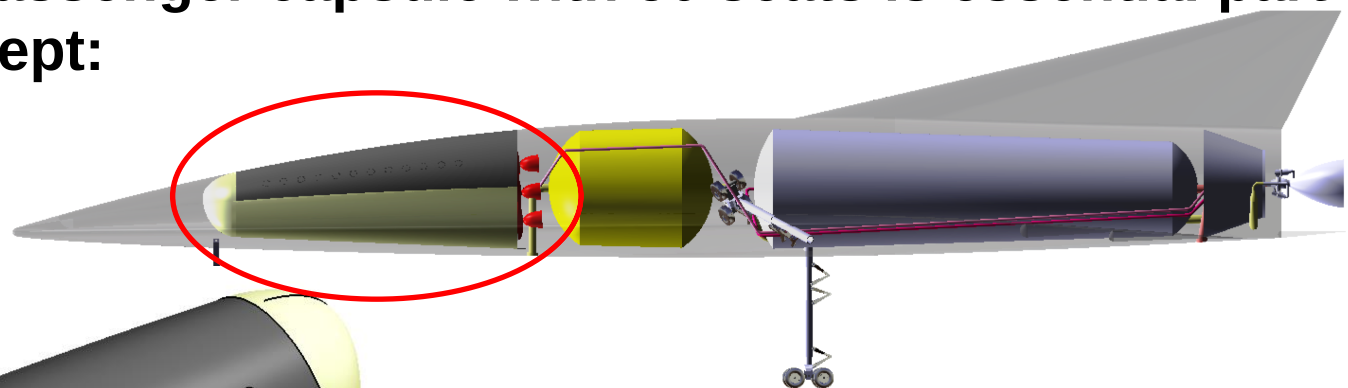
SLME: Size and Estimated Mass

- **Booster: $\varnothing_{max}$ 1800 mm, overall length 2981 mm**
- **Passenger stage: $\varnothing_{max}$ 2370 mm, overall length 3893 mm**
- **Booster: 3096 kg, T_{vac} /W = 72.6**
- **Passenger stage: 3375 kg , T_{vac} /W = 68.5**

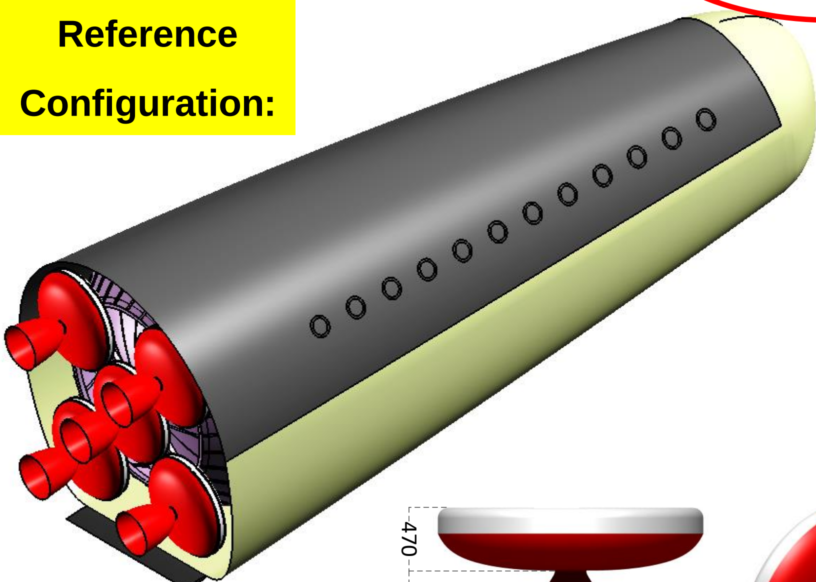


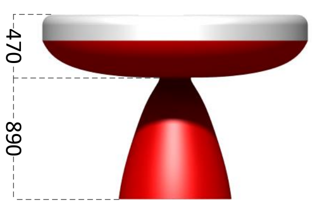
Subsystem: Passenger Cabin/Capsule

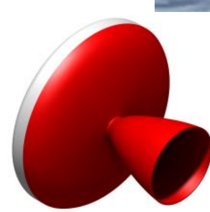
- **Separable passenger capsule with 50 seats is essential part of safety concept:**



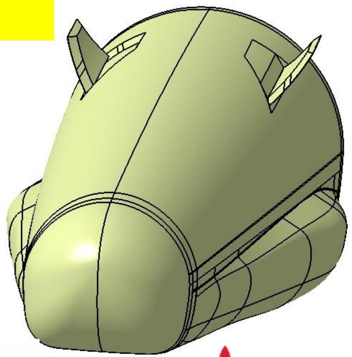
Reference Configuration:

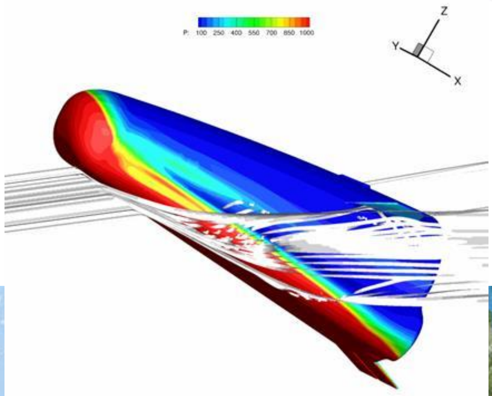






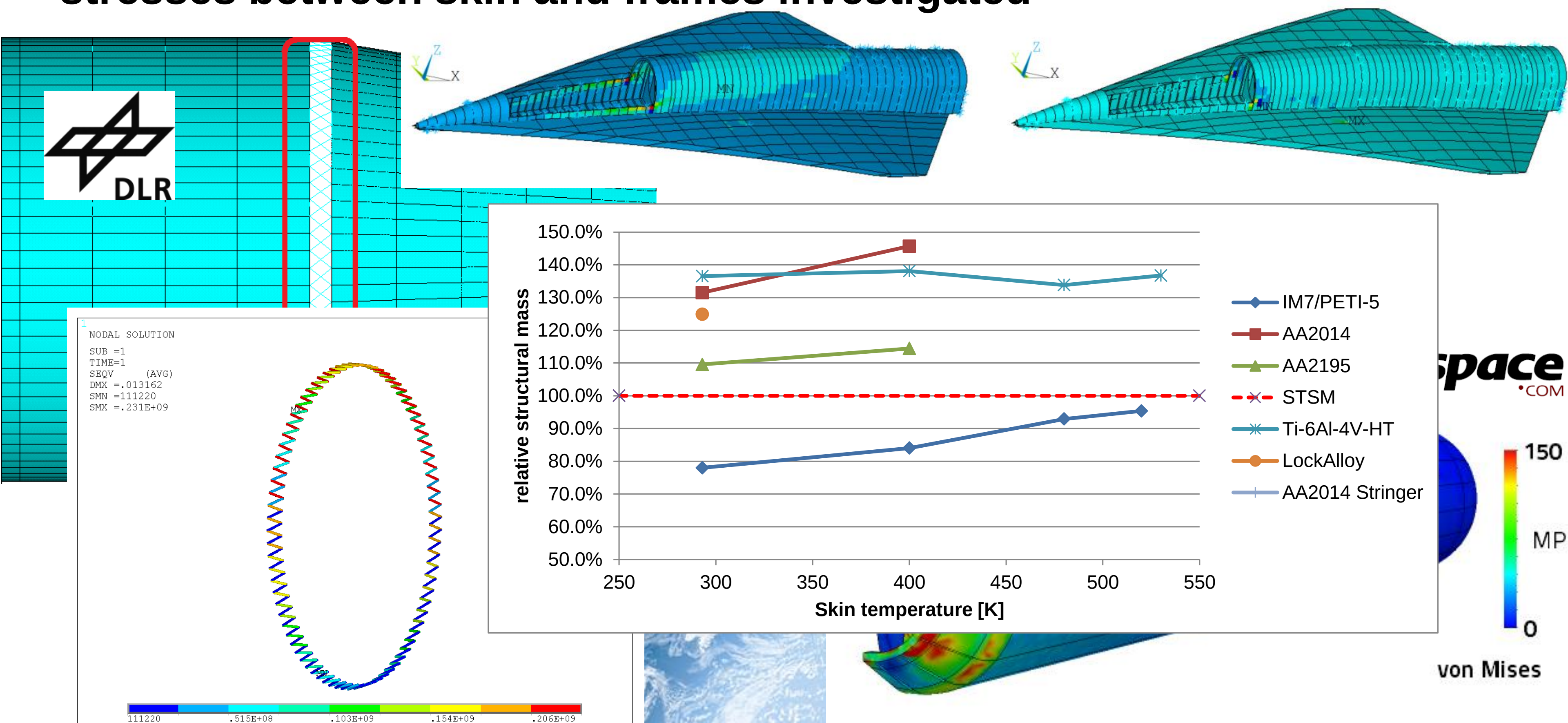
Innovative Morphing Option:





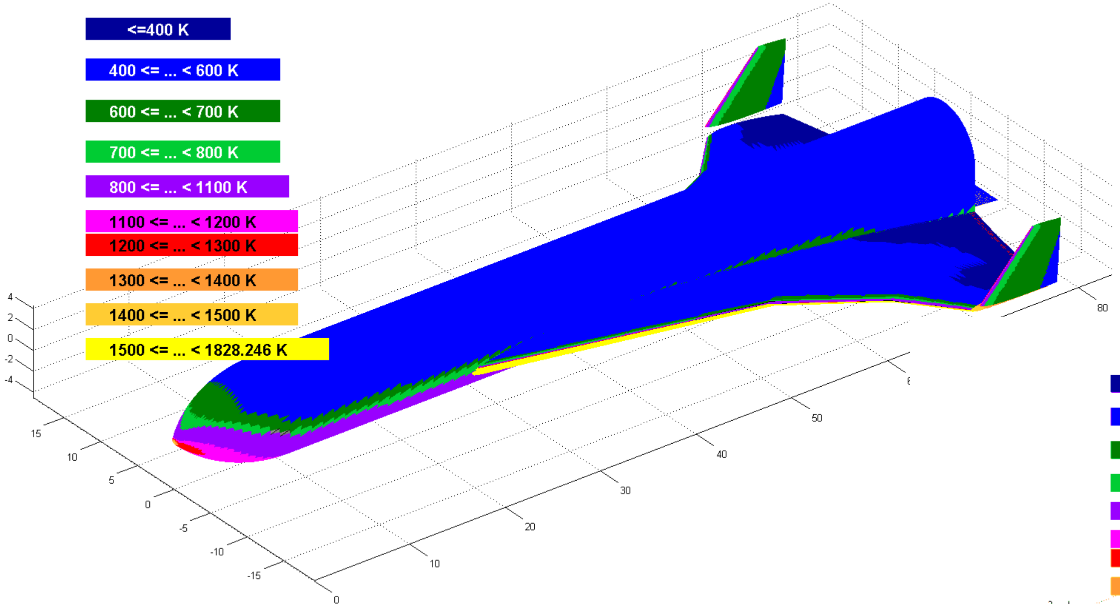
Subsystem: Structures

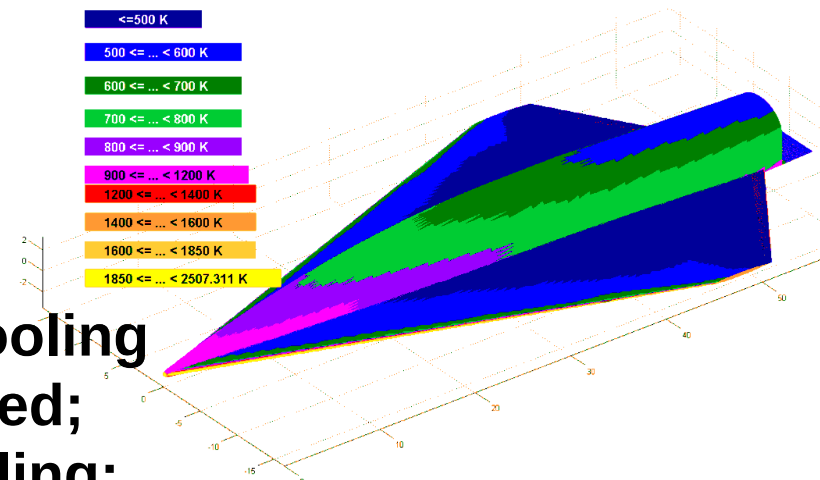
- Structural pre-designs of the Booster, Passenger stage and capsule are run at DLR, FOI, Orbspace
- Interesting option: strut element connection between pressurized and unpressurized structures on the booster
- Passenger stage is all honeycomb-sandwich design, thermal stresses between skin and frames investigated



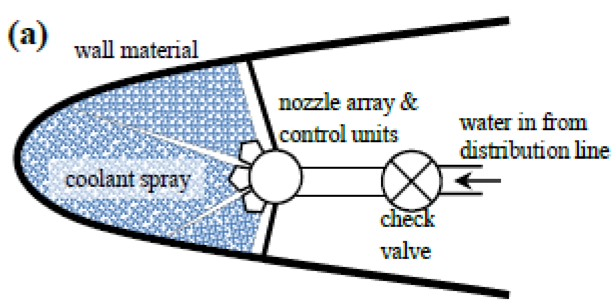
Subsystem: Thermal Protection (TPS)

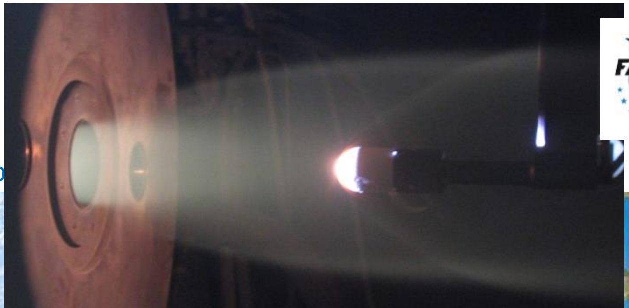
- **Preliminary sizing of booster and passenger stage:**





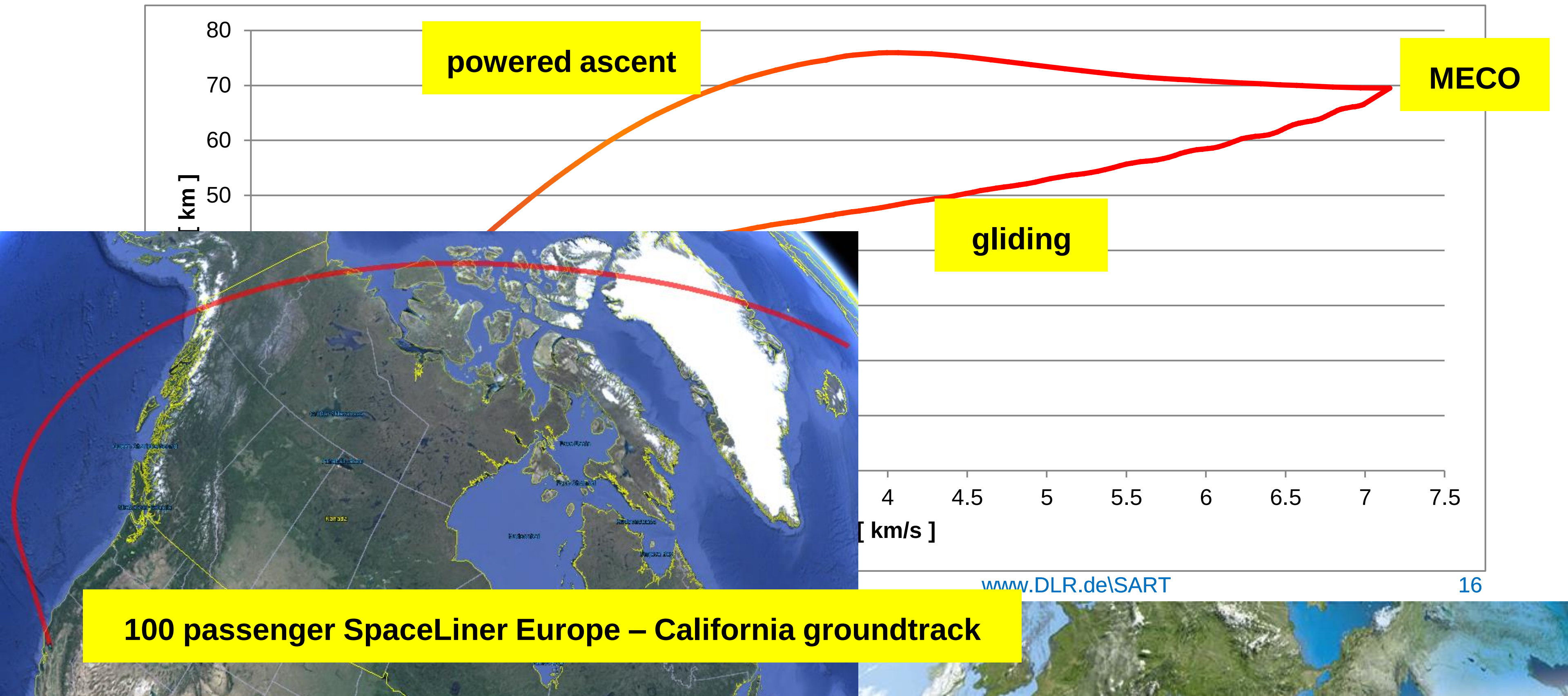
- **Active leading-edge and nose cooling with advanced methods investigated; internal spray or transpiration cooling:**





SpaceLiner 7: Trajectories

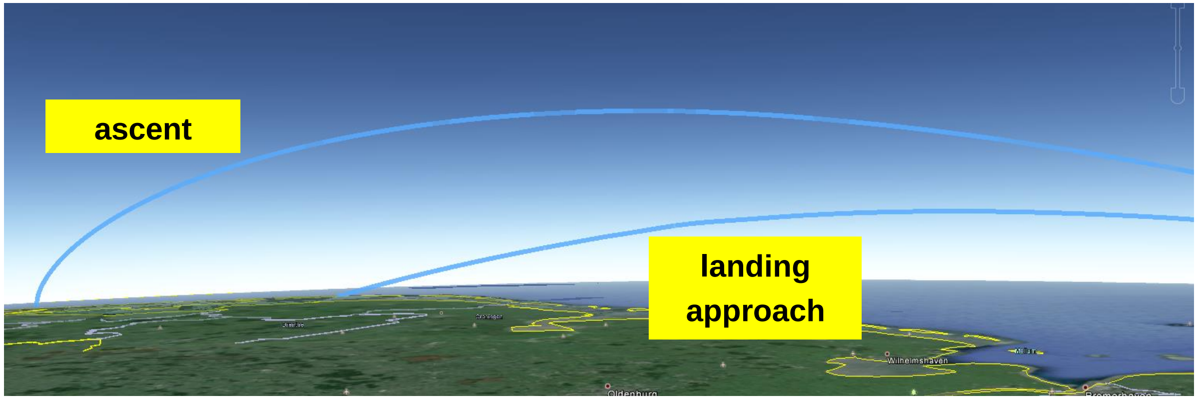
- **Several trajectory options have been traded for the Australia – Europe reference mission all following a standard launch vehicle vertical ascent.**
- **Other intercontinental trajectories established with realistic groundtrack considering sonic boom constraints.**



100 passenger SpaceLiner Europe – California groundtrack

Operational and environmental aspects

- Exhaust of SpaceLiner rocket engines is water; thus completely CO_2-free if LH2 and LOX are produced environmentally friendly.
- No NOx generated because no air is burned.
- Launch-sites need to be located close to the sea and trajectories are to be selected that ascent noise is not interfering with inhabited areas.
- Most of the SpaceLiner trajectory is at high altitudes, thus sonic boom noise is much less than for Concorde. However, final approach requires suitable routes with impact on landing site selection.
- Typical ascent and landing approach:



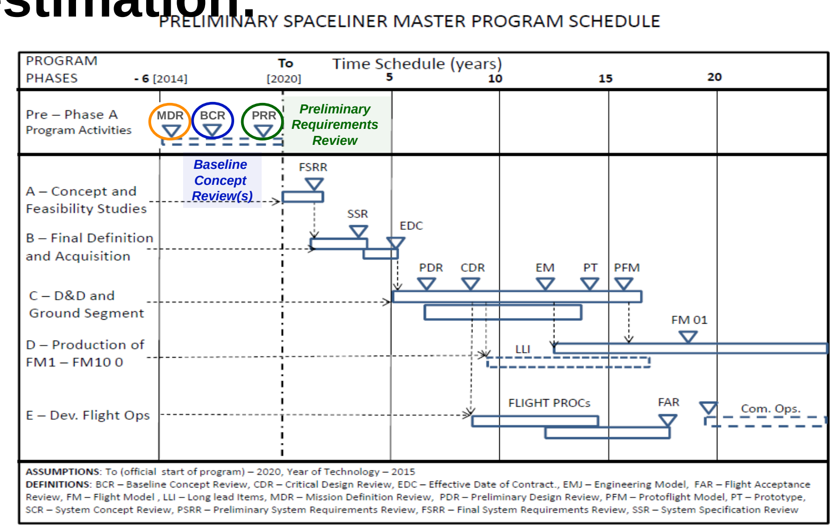
Operational aspects: Cost Assessment

- **Cost:**
  - The idea of SpaceLiner is completely new, therefore no precedence from the past. However, some similarities to:
    - Supersonic passenger transport,
    - „Space Tourism“,
    - (Reusable) space transportation
  - In early development phase parametric cost estimation is most promising.
  - Estimates for production cost parametrically performed for different production numbers.

- **Business Case**
  - SpaceLiner aims at securing small portion of the 350+ million PAX/a on intercontinental routes.
  - Simplified operational scenario has been established.
  - Balance between time and saving increased ticket price.

SpaceLiner Development Roadmap

- Structured pre-development:
  - MRR (external reviewers) successfully performed in May 2016
  - MRD soon to be released
  - Phase A development from 2016 onwards
  - PRR in approximately 2019+
- Afterwards – depending on available funding – technical development of SpaceLiner in rough estimation:
  - SRR in 2020
  - PDR in 2025
  - CDR in 2030



With contribution of B. Madauss, ISU, 2014

- First Flight SpaceLiner ca. 2035 and subsequently extensive flight testing and certification
- Operational system 2040+

International Public Interest in the SpaceLiner

TECHNOLOGY

Space Enabler

Developers plot path for Mach 20 suborbital intercontinenta

Guy Norris Los Ange

Launched vertically while attached to the booster stage, the SpaceLiner would accelerate to a maximum speed of just over 7 km/sec (4.3 mi./sec.) following simultaneous cutoff of both the

До Австралии за полтора часа

Немцы разрабатывают гиперзвуковой ракетоплан для суборбитальных полетов

Павел Котляр 19.08.2015, 17:15

) minutos

超音速客机或于15年后成真：伦敦飞悉尼仅90分

2015-08-21 09:55

علوم و تكنولوجيا

SpaceLiner تفوق سرعة الصوت وتسافر بين

ا وأستراليا فى 90دقيقة

20 أغسطس 2015 - 03:10 م

الطائرة الصاروخية الجديدة

Home > Scienza e Tecnologia

Europa Australia in 90 minuti: preso sarà possibile

Mi piace Consiglia Tweet 7 0

19 agosto 2015 - 20:55

1 di 2

Il progetto potrebbe essere realizzato entro quindici anni

Europa Australia in 90 minuti: preso sarà possibile - Il Centro Aerospaziale Tedesco (DLR, per il suo acronimo in tedesco) ha deciso di riprendere il suo ambizioso progetto di un aereo passeggeri ipersonico in grado di coprire il percorso tra l'**Europa e l'Australia** in soli **90 minuti**. Il progetto, denominato 'Spaceliner', include la

Conclusion and Outlook

- **DLR proposed reusable winged 2-stage rocket SpaceLiner concept is constantly maturing in its conceptual design.**
- **Research on the vehicle performed with support from EU projects FAST20XX, CHATT, HIKARI and HYPMOCES in cooperation with European partners.**
- **Several key-technologies are to be demonstrated in preparation of successful development to achieve affordable re-usable system including rocket engines.**
- **Challenging research areas identified are:**
    - **propulsion,**
    - **structural design,**
    - **aerothermodynamics,**
    - **environmental & medical issues,**
    - **operations and economics**
- **The SpaceLiner configuration serves as a catalyst for applied research on advanced reusable launchers.**

Conclusion and Outlook

- Assuming advanced but not exotic technologies, a vertically launched rocket-powered two-stage space vehicle transports about 50 passengers over 17000 km in 1.5 hours.
- In its second role as classical RLV, the SpaceLiner configuration is able to launch more than 35000 kg payload to LEO or (by using an upper stage) more than 10000 kg to GTO.
- Technology development roadmap has been established and will be refined in Phase A.
- MRR held in May 2016 and MRD available to partners.
- Business case simulations promising and operational scenarios investigated including pre-selection of potential launch bases.
- SpaceLiner is an open project across multiple applied research disciplines within international cooperation.

Invitation to 7th SpaceLiner Design Workshop

21./22. July 2016

- Located at the Concurrent Engineering Facility (CEF) of DLR's

Institute of Space Systems

28359 Bremen, Germany

close to the University and ZARM drop tower

Map and address: http://www.dlr.de/irs/desktopdefault.aspx/tabid-3248/7061_read-10471/

- **Starting at** **Thursday, 21st July 2016, 14h**
- **until approximately** **Friday, 22nd July 2016, 15h30**