DEIMOS Space R&D projects on Reusable Launchers

DEIMOS Space

Flight Systems Business Unit,

Atmospheric Flight Competence Center

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Context & motivation

Brief overview of current launchers and DEIMOS R&D projects presented

Credits: Orbex, Prime Launcher

Credits: Avio-ESA, VEGA

Credits: SpaceX, Falcon9

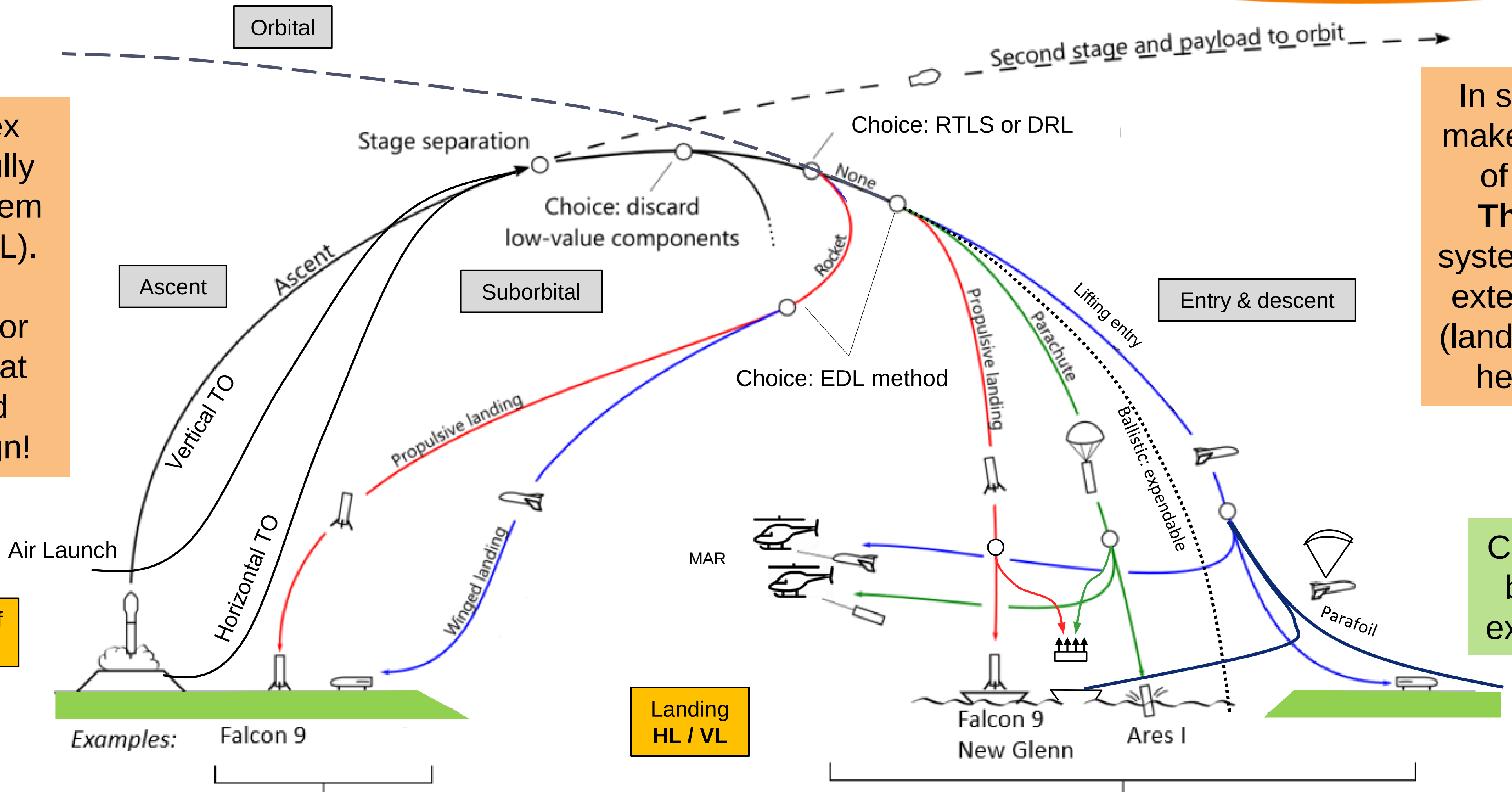
Typical values (Take-off mass, P/L mass to LEO, Size)

Launcher class	Micro	Small	Large / Very large
Take-off mass	20 t	Wide range, 50-150 t	>300 t
P/L mass to LEO	0.2 t	2 t	>10 t
Size	20 m	30 m	>40 m
Current state of art Europe	Under development, expendable & partially reusable	VEGA operative, expendable. VEGA-C coming soon, expendable	Ariane 5 and Soyuz operative, expendable. Ariane 6 coming soon, expendable. Partially reusable launchers under design
Current state of art Worldwide	Several operative (expendable) and partially reusable under development	Several operative (expendable)	Several operative (expendable); partially reusable operative (Falcon 9 & Heavy, New Shepard) and under design
DEIMOS R&D projects dealing with **REUSABILITY** (launcher stage)	**RRTB (1st)**	**EFESTO (upper)** **Space Rider (upper)**	**RETALT (1st)** **RESOLVE (1st)** **ASCENSION (any)**

Recovery strategies overview: many options and trade-offs possible. Generally applies to any launcher's **valuable** hardware.

Very complex end-to-end fully coupled problem (Ascent + EDL).

Lot of room for optimization at mission and system design!



In simple terms: make efficient use of **Drag, Lift, Thrust** of the system, or of other external systems (landing platforms, helicopters...)

Commercial benefit vs expendable!

RTLS (Return to Launch Site)

DRL (Downrange Landing)

Refurbishment after landing, new flight

•Modified Image from : IAC-18-D2.4.3

RRTB: Recovery and Return To Base
MESO Micro launcher, 1st stage reusability

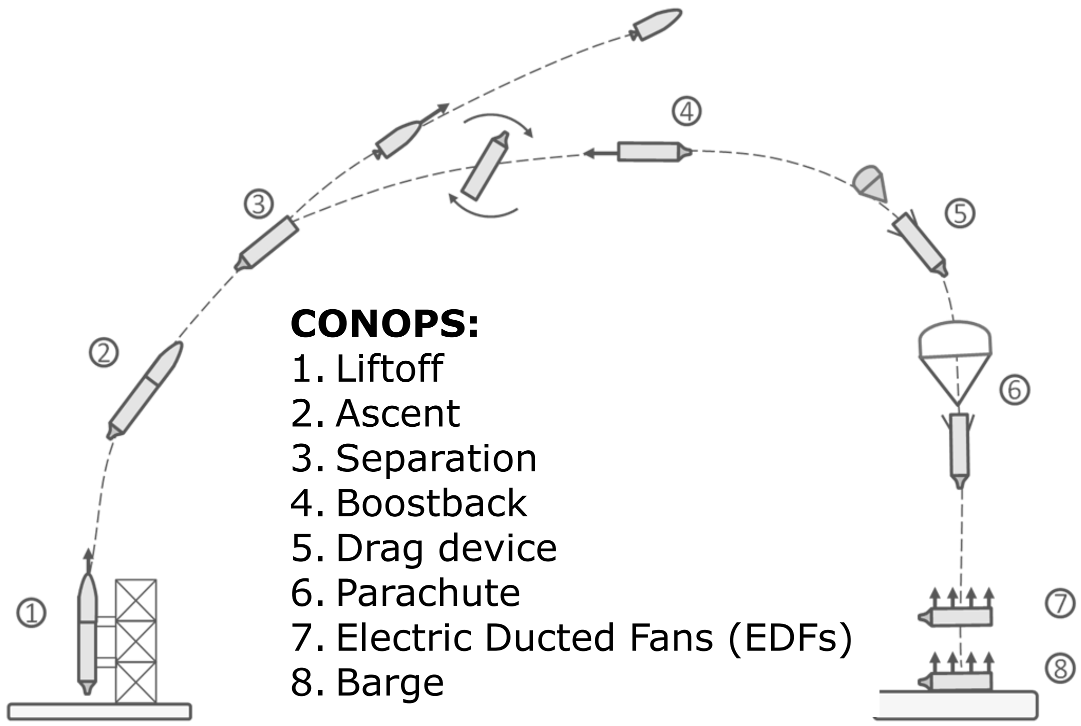
Context: EU funded project (Access to Space 2019 call). Start: Feb 2020, 3 years.

System Objectives:

- ❑ Inject a relevant payload to orbit: 150 kg to SSO
- ❑ Achieve a competitive expected cost per kg (<25K€) of payload mass launched
- ❑ Return the MESO micro launcher first stage, safely to the surface after flight
- ❑ Ensure easy and quick reuse and re-flight of the first stage by the vehicle’s design and concept of Operation

Project objectives:

- ❑ Determine feasibility of passive re-entry conditions
- ❑ Validate landing manoeuvre and develop landing control software
- ❑ Define the design & materials for a reusable cryogenic tanks



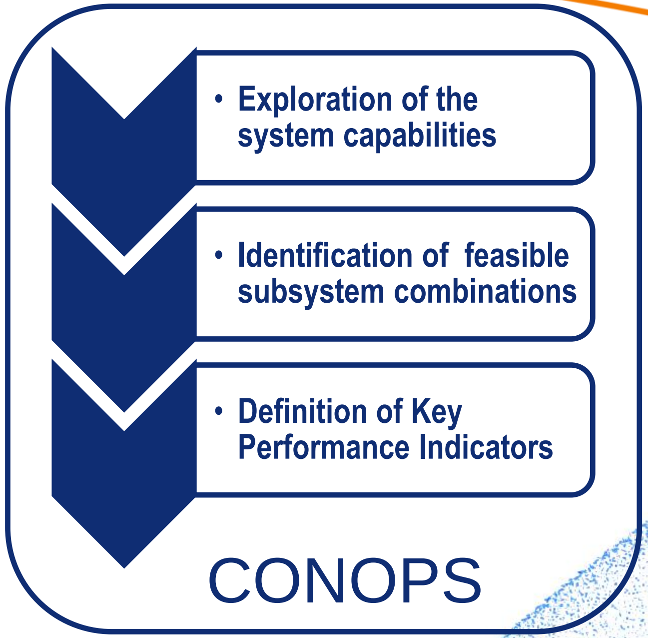
Reusable | Aerospike | 150kg LEO | LCH4/LOX | Two Stage

PANGEA AEROSPACE · heron engineering · Technische Universität München · RWTH AACHEN UNIVERSITY · ThalesAlenia Space (a Thales / Leonardo company) · von KARMAN INSTITUTE FOR FLUID DYNAMICS · toseda (technology · science · development) · deimos elecnor group

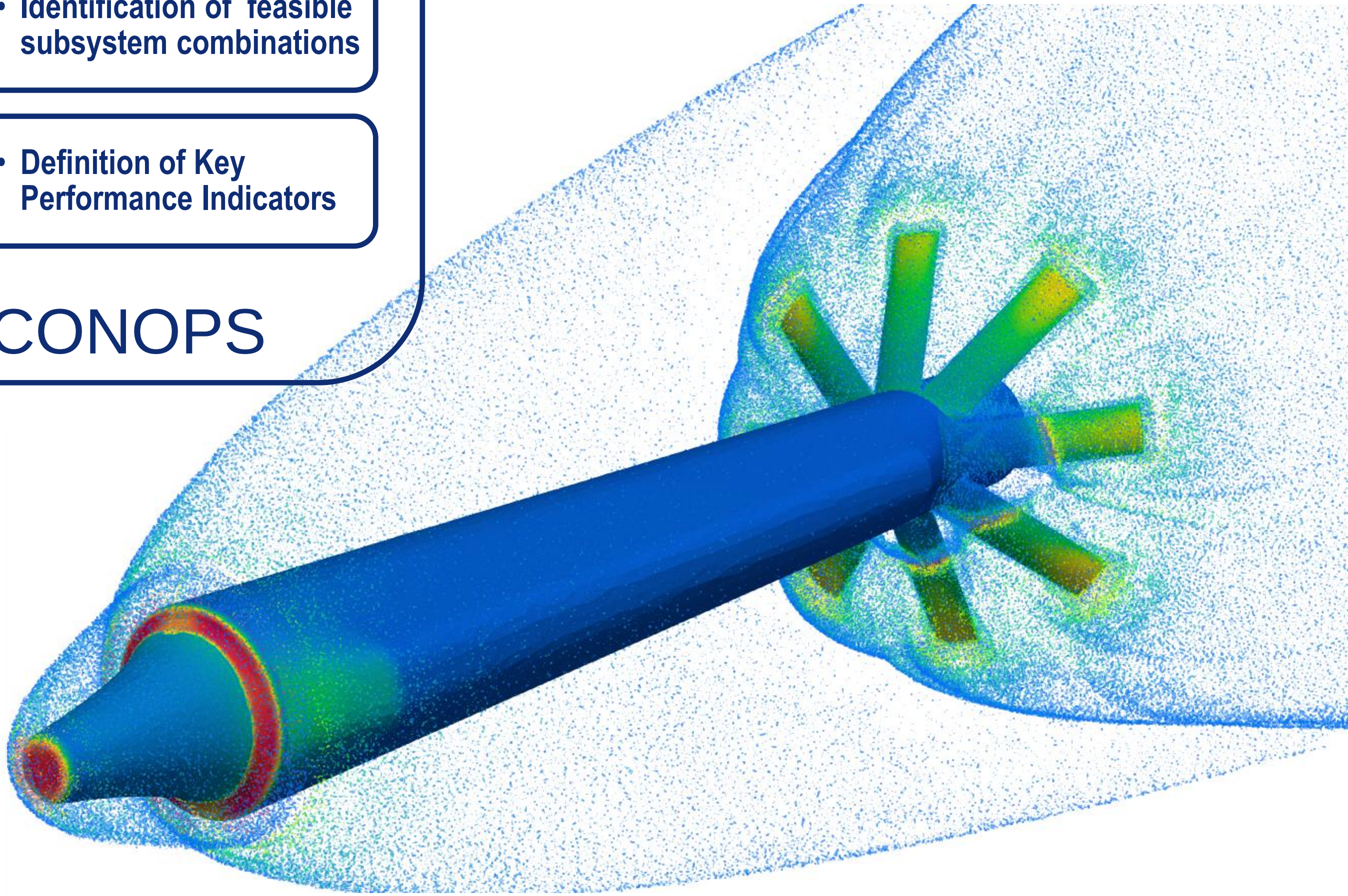
RRTB: Recovery and Return To Base
MESO Micro launcher, 1st stage reusability

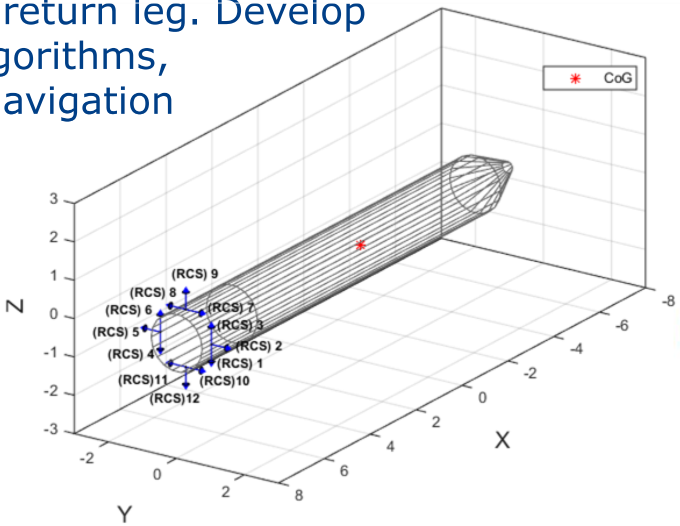
Deimos Contributions:

- ❑ **Operations**: CONOPS analysis, trade-off, definition.
- ❑ **Mission Engineering**: trajectory design, orbit and launch site selection, risk and safety assessment, feasibility assessment, requirements definition.
- ❑ **Aerodynamics**: preliminary CFD analysis of the decelerator. Concept feasibility validation.
- ❑ **Performance**: Flying qualities, controllability, flight stability of the return leg.
- ❑ **GNC**: Concept of the return leg. Develop guidance and control algorithms, implementation of the navigation solution.



Example of DEIMOS CFD results





Example of RCS layout

Inflatable Heatshields

- **Inflatable heatshields enable new missions, protecting payloads during re-entry in conditions that cannot be covered by rigid heat shields**
- Morphing allows:
  - Lower the re-entry ballistic coefficient
  - Fit the heatshield in the launcher fairing, inflate before re-entry
  - Reduce the loads during re-entry

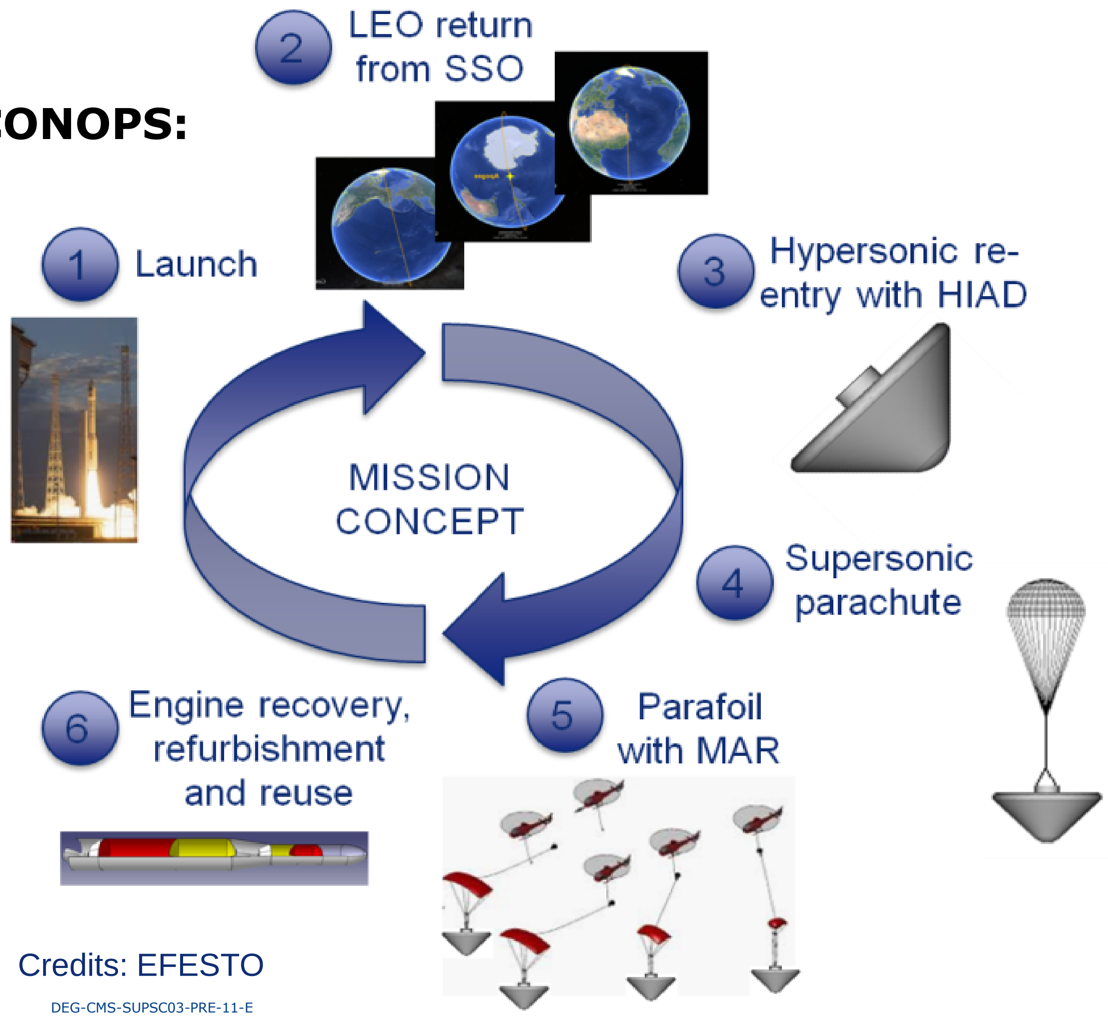
Inflatable heatshield =
Inflatable structure +
Flexible TPS

DEIMOS leads EFESTO. Key facts:

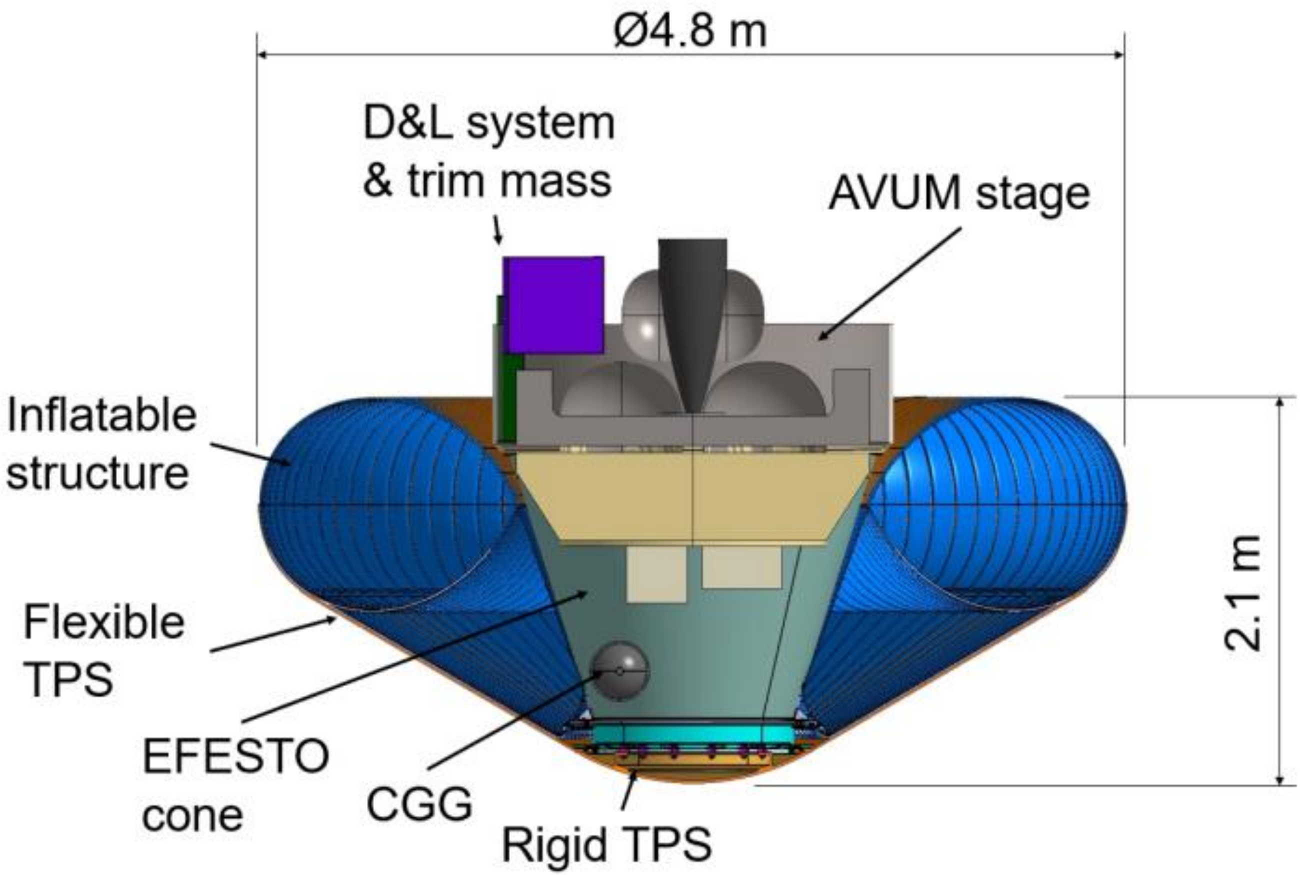
- Funded by EU commission (H2020, 3M€), started in 2019, coordinated by DEIMOS Space.
- Partners: DEIMOS Space, CIRA, DLR, ONERA, Aviospace, Polytechnic Univ. Torino.
- Current state of art in Europe in inflatable heatshields: detailed design ongoing, ground test campaigns under preparation in 2020 (Plasma wind tunnel, Inflatable structure).
- Applications:
  - Earth (reusable upper stages re-entry, in combination with parafoil for descent and landing)
  - Mars (Robotic Exploration, in combination with Supersonic Retro-Propulsion, SRP)

AVUM Reuse as possible EFESTO application: CONOPS & System overview

CONOPS:



Credits: EFESTO

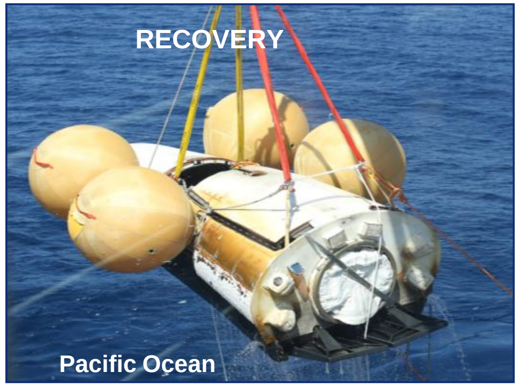


Reusable AVUM (VEGA upper stage)
Credits: EFESTO

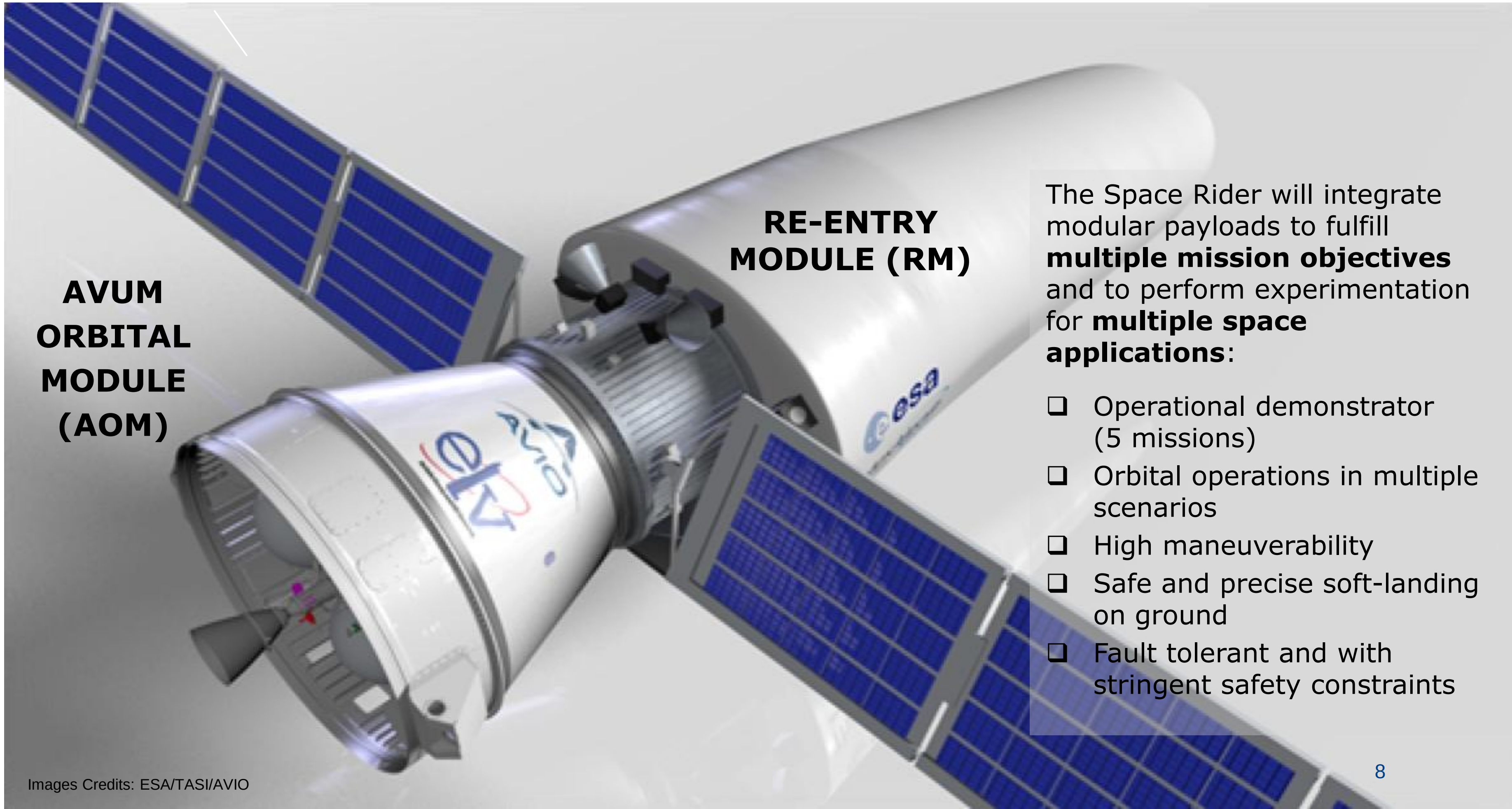
Space Rider: ESA's reusable re-entry module. Last stage of VEGA-C

Following the **successful development, qualification and flight** of the Intermediate eXperimental Vehicle (**IXV**), ESA initiated an effort to develop a **sustainable reusable European space transportation system** integrated with VEGA C launcher (ISTS) to enable **routine launch and return** space missions: the **Space Rider**.

Intermediate eXperimental Vehicle (IXV, 2015 flight)



MISSION SUCCESS!
IN-FLIGHT QUALIFICATION OF GNC SW, DESIGN RESULTS AND METHODOLOGY



The Space Rider will integrate modular payloads to fulfill **multiple mission objectives** and to perform experimentation for **multiple space applications**:

- Operational demonstrator (5 missions)
- Orbital operations in multiple scenarios
- High maneuverability
- Safe and precise soft-landing on ground
- Fault tolerant and with stringent safety constraints

Images Credits: ESA/TASI/AVIO

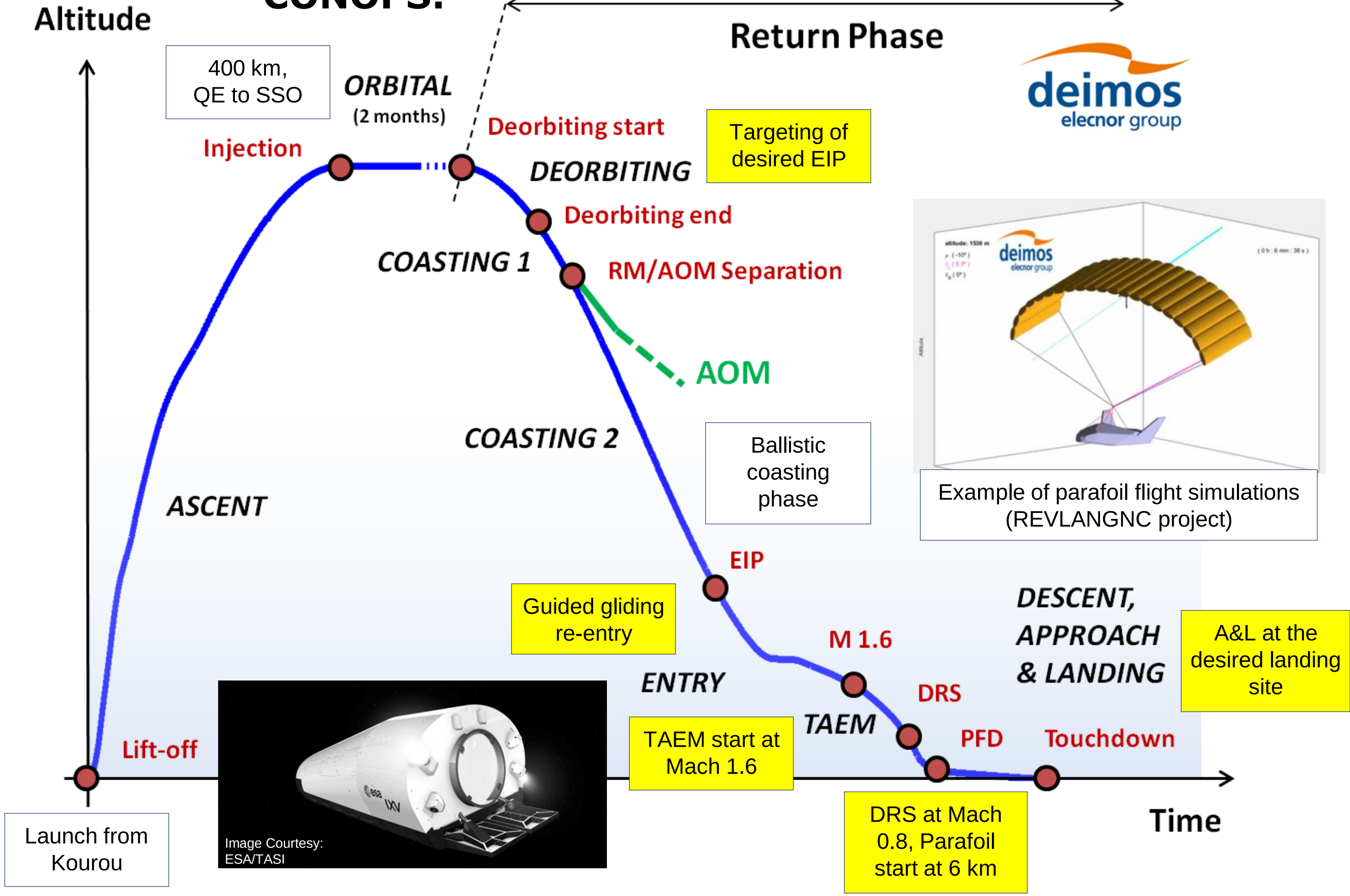
Space Rider: ESA’s reusable re-entry module.
Last stage of VEGA-C

DEIMOS Space contribution to the SR program for the preliminary design in phases AB1/B2/C:

❑ **Responsible** of the complete **Mission and Flying mechanics design of the RM**:
- **Mission design** and E2E trajectory definition and analysis
- Trimline design and **flying qualities**, support to system design and CoG definition
- **Visibility** and **safety** analyses

❑ **Responsible** for the **Entry and TAEM GNC:**
- Responsible for the **Re-entry G&C** algorithms
- Responsible for the **TAEM GNC and DRS triggering** algorithms
- Support to the GNC engineering for the Entry and TAEM phases

CONOPS:



Example of parafoil flight simulations (REVLANGNC project)

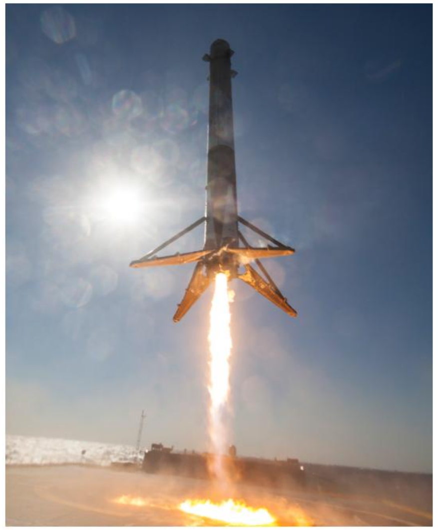
RETALT: RETropulsion Assisted Landing Technologies. First stage, large launchers.

RETALT main objective is to investigate and develop key RETropulsion Assisted Landing Technologies to enable launch system reusability:

- Understanding of complex **aerodynamics and aeothermodynamics**
- Develop a **GNC concept**
- Develop a **structural concept and mechanisms** for landing legs and aerodynamic control surfaces
- Develop and test **TPS** for critical structural parts

RETALT technologies will be applied to an example of an operational launch vehicle (TSTO) and to an example of a future launch vehicle (SSTO).

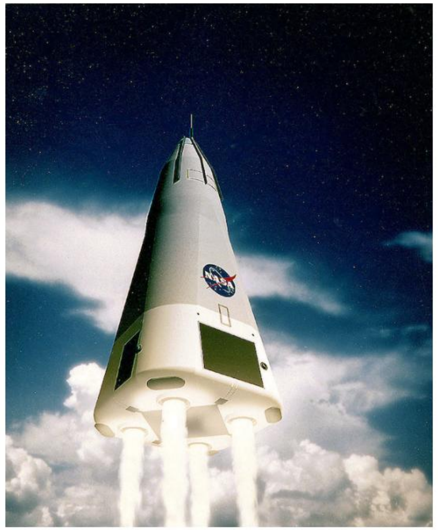
OPERATIONAL LAUNCH VEHICLE



Vertical Take-off Vertical Landing (VTVL) Two Stage To Orbit (TSTO)

Similar to the Falcon 9

FUTURE LAUNCH VEHICLE



Vertical Take-off Vertical Landing (VTVL) Single Stage To Orbit (SSTO)

Similar to the DC-XA

www.retalt.eu

Deutsches Zentrum für Luft- und Raumfahrt DLR · deimos elecnor group · almatech · CFS Engineering · MT Aerospace An OHB Company · AMORIM CORK COMPOSITES

3 YEARS · 6 PARTNERS · 4 COUNTRIES · 3 MILLIONS (BUDGET)

The project has received funding from the European Union's Horizon 2020 research and innovation framework programme under grant agreement No 821890

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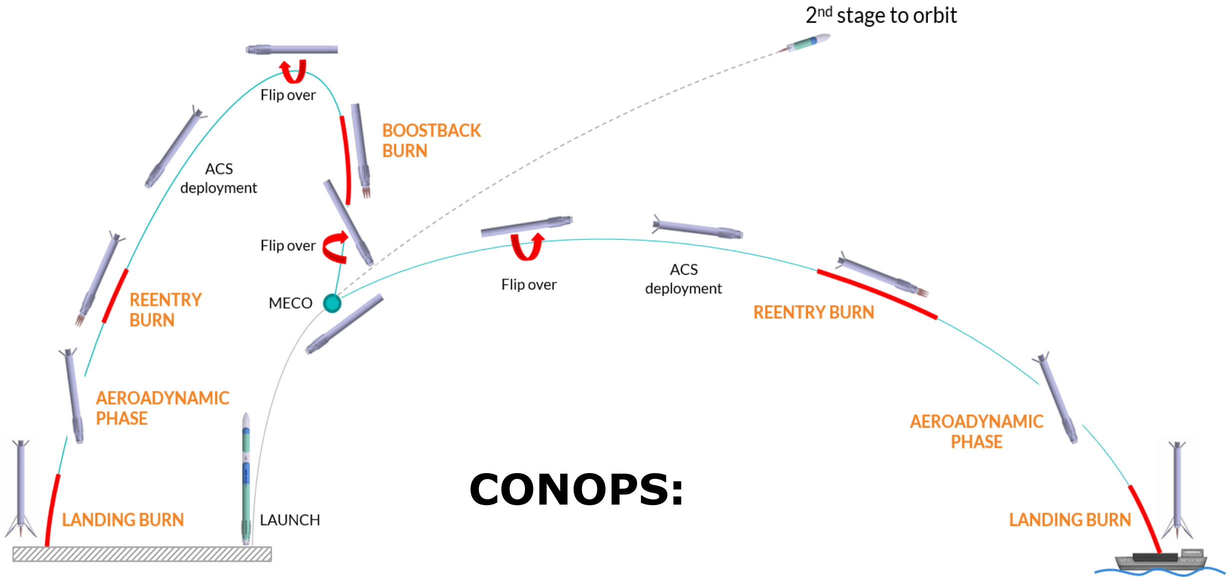
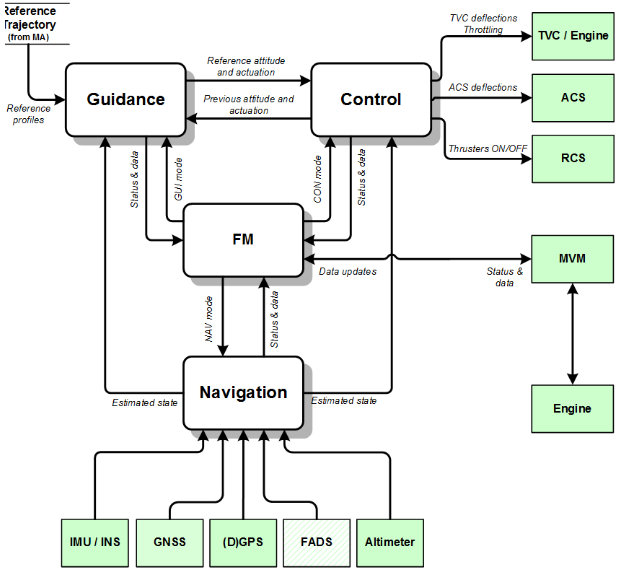
RETALT: RETropulsion Assisted Landing Technologies. First stage, large launchers.

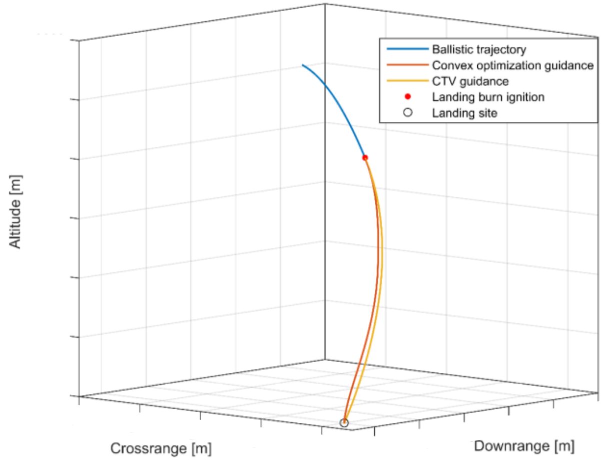
DEIMOS Contribution: responsible of Flight Dynamics and GNC, derived from RETALT scientific and technological objectives:

- To perform the **Mission Analysis** of the return mission for the reusable launch vehicles (RLV)
- To perform **Flying Qualities Analysis** of RLVs during the return flight with retro-propulsion
- To develop a **Guidance, Navigation** and **Control** concept to steer the RLVs to the planned landing site
- To develop a **Functional Engineering Simulator** for the end-2-end return flight
- To perform **GNC testing** and reach **TRL 3** for the GNC concept developed

CONOPS:







Target reached

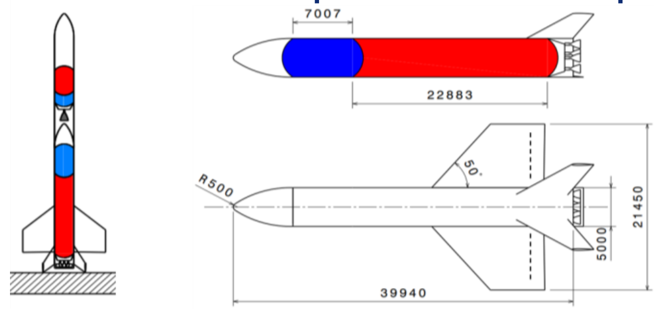
RESOLVE – INTRODUCTION
First stage, large launchers.

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

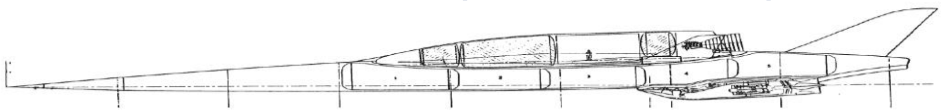
REusable Space transpOrtation fLight Vehicle Engineering

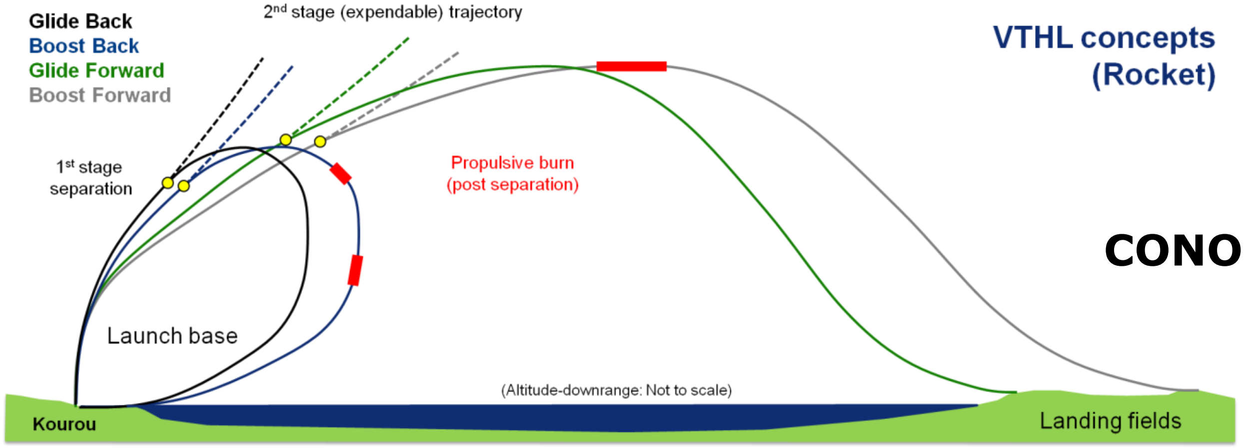
- Prime: DLR SART (Bremen, system design). DEIMOS: mission engineering (in particular vehicle sizing & trajectory optimization); Polaris (Structures).
- Objective: Trade-off of 2-stage launchers architectures with a reusable 1st stage that lands **horizontally**.
- Different technologies are investigated and compared in terms of subsystem impact and specifically in term of economic impact with respect to expendable missions.
  - **VTHL** concept vs **HTHL** concept
  - Airbreathing vs Rocket propulsion
  - Downrange Landing vs Return To Launch Site scenario

VTHL Rocket Propulsion Concept

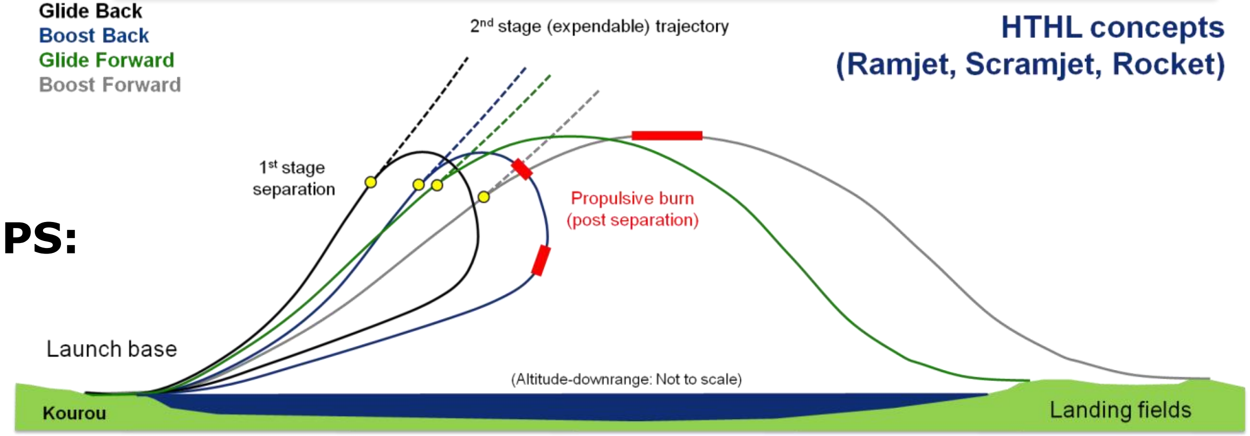


HTHL a/b Propulsion Concept





CONOPS:



RESOLVE – DEIMOS ACTIVITIES
First stage, large launchers.

DEIMOS Space activities:

- ❑ Advanced optimization:
  - Mission & system (MSOL)
  - Trajectory (TSOL)
- ❑ High fidelity simulation core (SC)

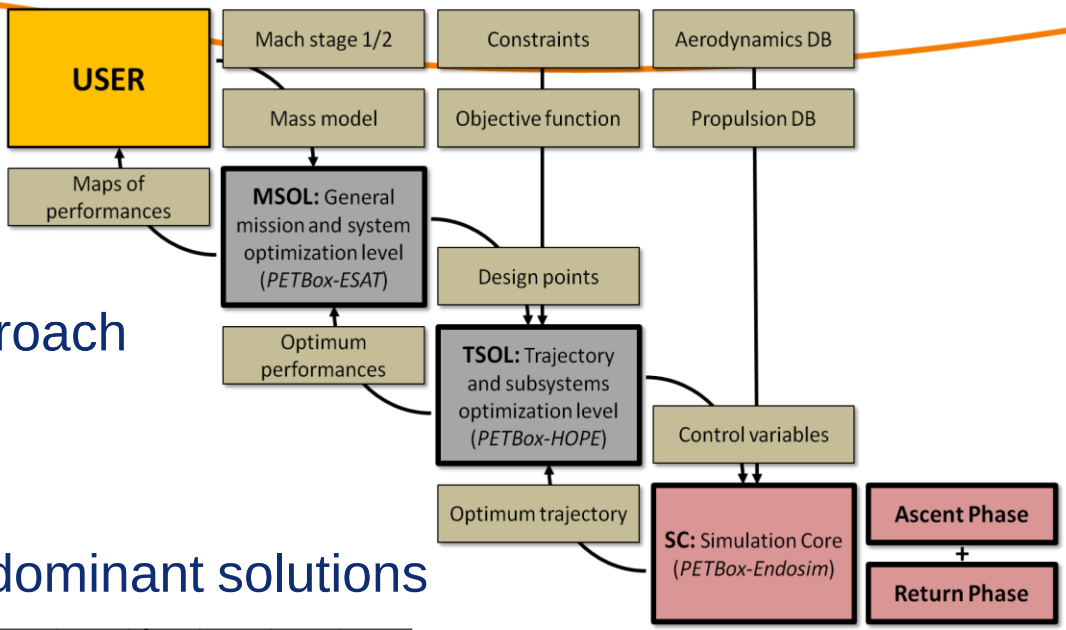
Optimization objectives:

- ❑ Achieve the lightest vehicle that puts the right payload in the right orbit;
- ❑ Bring the reusable first stage to the desired landing field;

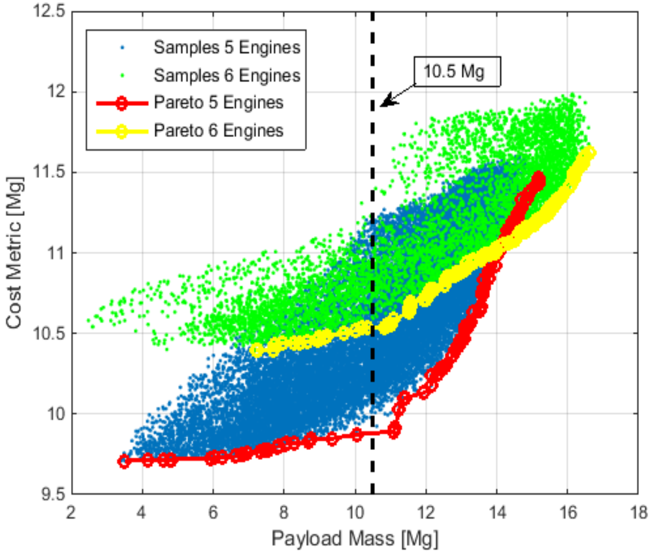
Multiple constraints, e.g., main ones:

- ❑ Guarantee that the vehicle has enough authority to perform the mission;
- ❑ Guarantee that the thermo-mechanical limits are respected and the subsystems are sized accordingly;
- ❑ Guarantee that the operative ranges of the propulsion subsystems are respected
- ❑ …

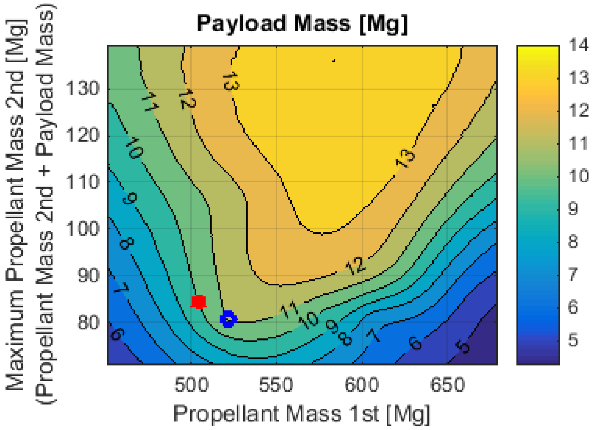
Approach



Pareto-dominant solutions



Performance maps



ASCenSIon: Advancing Space Access Capabilities – Reusability and Multiple Satellite Injection

deimos elecnor group

- **H2020 Marie Curie International Training Network**
- **Start: 2020; duration: 4 years**

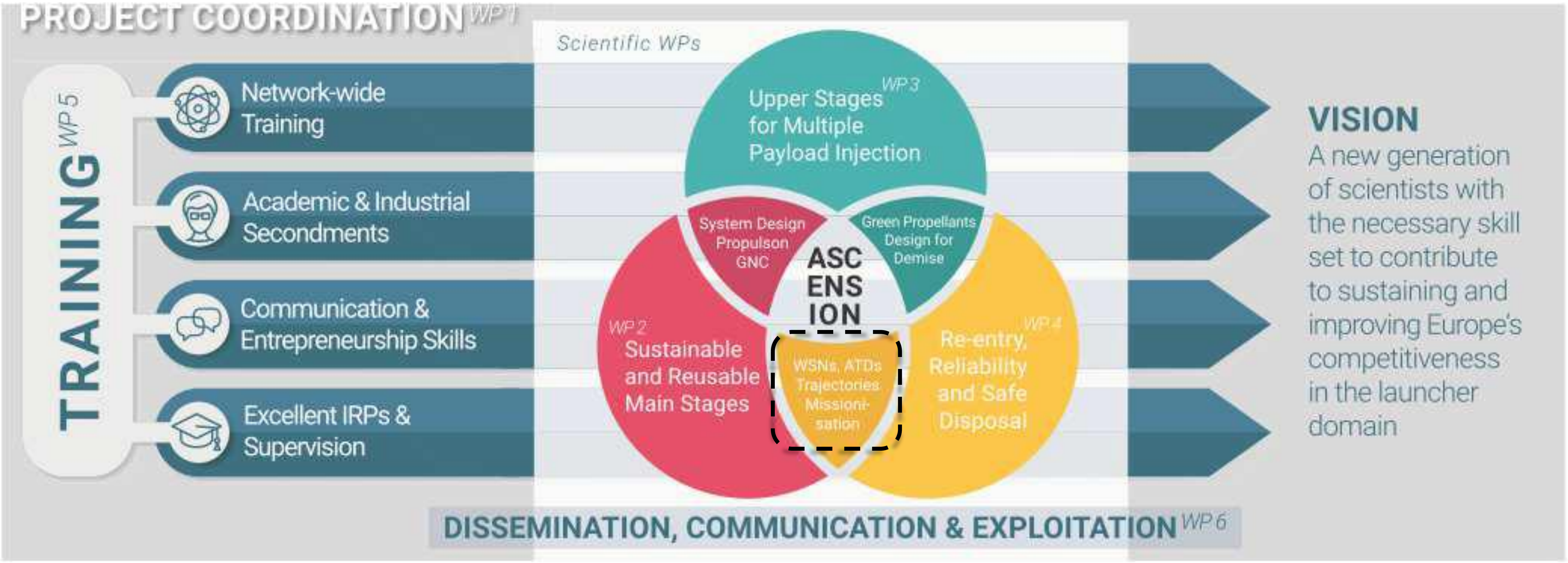
- Network Coordinator: Technical University of Dresden (TUD)
- 15 Early Stage Researchers (ESRs)
- 24 European Partners: 14 Associated and 10 Beneficiary Partners

OHB, arianeGroup, AVIO, WEPA Technologies, esa, RWTH Aachen University, ISAE SUPAERO, D-Orbit, Telematic Solutions, storyrunner, ESCP Business School, PTR, SpaceForest, Universität Bremen

HSB, Politecnico Milano 1863, Università di Pisa, DLR, deimos elecnor group, ONERA, Technische Universität Dresden, ULB Université Libre de Bruxelles, Sapienza Università di Roma, Technische Universität Braunschweig

- Board of External Advisors

ASCenSIon: Advancing Space Access Capabilities – Reusability and Multiple Satellite Injection



DEIMOS Space research topic:
"Mission analysis and GNC Missionisation for Re-entry Vehicles". Applicable to any launchers' stage.
Example of application: Falcon 9 1st stage (reusable, same hardware for multiple missions).

Conclusions

Wide DEIMOS Space expertise in multiple R&D projects on reusable launchers

- **DEIMOS is a key European actor in Mission Engineering and GNC for atmospheric flight**

- Multiple launchers classes and stages analyses
- Multiple Ascent and EDL strategies explored
- Different flight phases and subsystems involved
- CONOPS optimized to efficiently use drag, lift, thrust or other systems
- R&D improving knowledge, modelling and understanding of key technologies for launcher's reusability

- **Disciplines mastered: aerodynamics, flying qualities, trajectory design, trajectory performance, support to system design, guidance, navigation, control, descent and landing.**

- **Numerical tools to support analysis are continuously improved and validated.**

- **This expertise is applied also to expendable launchers applications (not shown here).**

More details available (website and funding):

- **RRTB: https://rrtb.eu/**

  This project has received funding from the European Union’s Horizon 2020 research and innovation program under the grant agreement no. 870340

- **EFESTO: http://www.efesto-project.eu/**

  This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 821801

- **Space Rider:**
  https://www.esa.int/Enabling_Support/Space_Transportation/Space_Rider_Europe_s_reusable_space_transport_system

- **RETALT: https://www.retalt.eu/**

  This project has received funding from the European Union’s Horizon 2020 research and innovation framework programme under grant agreement No 821890

- **RESOLVE: http://www.esa.int/**

- **ASCenSIon: https://ascension-itn.eu/**

  The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 860956.

Thank you!

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