RETALT - RETro propulsion Assisted Landing Technologies

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RETALT

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HORIZON 2020 PROJECTS

RETALT Team

DLR:	Project coordination, ceference configuration, CFD and testing, AEDB and ATDB, health monitoring of base area TPS
ALMATECH:	Landing mechanism, structural design and control surfaces, manufacturing and test of components, TVC structures and mechanisms
AMORIM:	Thermal protection of the structures with cork-based TPS materials
CFS Engineering:	CFD for aerodynamic loads and control surface efficieny, AEDB, dissemination
DEIMOS:	Flight dynamics and GNC
MT Aerospace:	Structural concept and design, design and manufacturing of a landing leg, hardware for aerothermodynamic tests

Introduction

Recovery Concept	Benefits	Drawbacks
VTHL Vertical Take-off Horizontal Landing (Space Shuttle, Buran, LFBB, Hermes, X-37) 	• Aerodynamic breaking happens without additional propellant. • Use of efficient air-breathing engines (turbojets) is possible. • High L/D increases downrange (necessary for fly-back) and provides precise landing (big side range is necessary for suborbital flight landing) • In-air-capturing could reduce fly-back propellant mass	• Many additional elements are necessary (wing, control surfaces, landing gears, air-breathing engines…), they increase system mass, size, complexity and costs. • Runway is necessary • High wing impact on the ascent aerodynamics • High normal structural loads • Trimming and CoG control is challanging • Problems with multi-staging and packet (parallel) configurations
VTVL Vertical Take-off Vertical Landing (Falcon 9, New Shepard, DC-X) 	• Only small changes on the current rocket design are necessary (landing legs and fins) • No runway is necessary (comparable to heliport/helipad) • Precise landing is possible • Mainly axial loads • Downrange landing version reduces descent propellant	• Additional elements are necessary (legs, control surfaces, reaction control) • Additional propellant is necessary (Toss-back, deceleration, landing) • Throttling of engines is necessary • Drone-Ship is necessary for the downrange landing

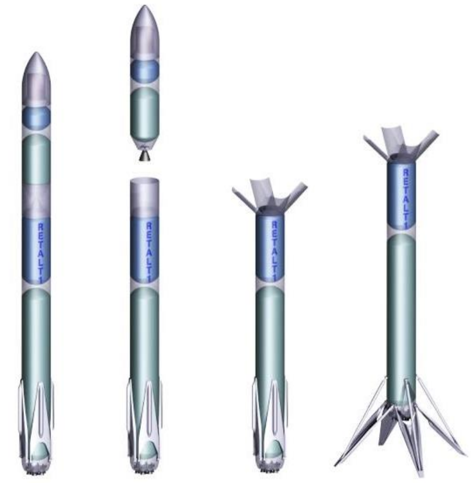
Main goals

- Investigate the Launch system reusability technologies of
  - Operational launch vehicle
    Vertical Take-off Vertical Landing (**VTVL**) Two Stage To Orbit (**TSTO**)
    (similar to Falcon 9)

  - Future launch vehicle
    Vertical Take-off Vertical Landing (**VTVL**) Single Stage To Orbit (**SSTO**)
    (similar to DC-X)

Concept

- RETALT 1:
    - TSTO VTVL RLV
    - 30 t to LEO
    - 7 engines (Vulcain 2): LOX/LH2
    - Aerodynamic Control Surfaces: Interstage sections (base line), grid fins (for comparison)
    - Breaking: Retro propulsion



- RETALT 2:
    - SSTO VTVL RLV
    - Smaller payloads to LEO of suborbital missions
    - Aerodynamic control surfaces: Fairing Sections (base line), Grid fins (for comparison)
    - Breaking: Retro propulsion, capsule like shape

Detailed goals

- Understanding of complex aerodynamics and aerothermodynamics
- Reliable aerodynamic data base for Flying Qualities Analysis and Guidance Navigation Control
- GNC Concept
- Overall concept of Structures and Mechanisms
- Concepts for Structure and Mechanisms for landing legs and aerodynamic control surfaces
- Development of TPS for base area
- TRL 5 for Aerodynamics, Aerothermodynamics, Structures and Mechanisms
- TRL 3 for GNC concept

Aerodynamic and Aerothermodynamic Experiments

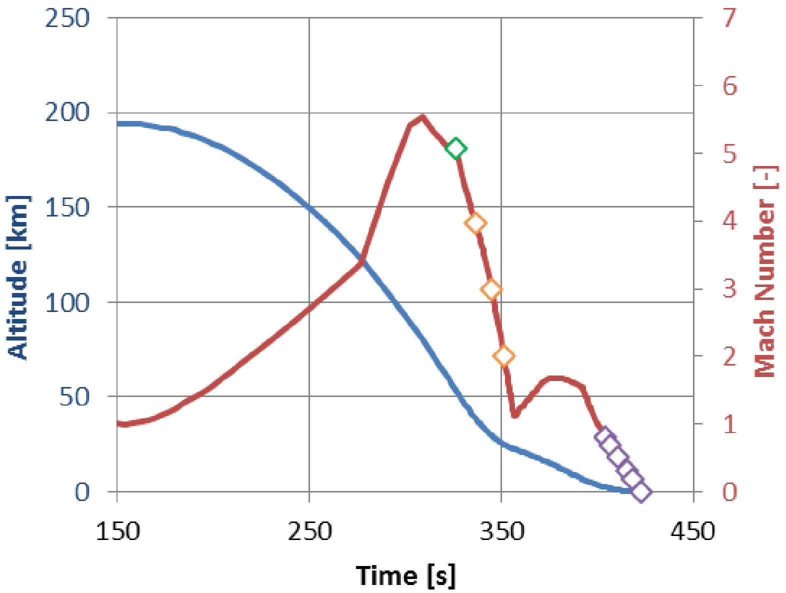
- Provide data for CFD validation wrt
    - *Aerodynamic Loads*,
    - *Aerothermal Loads*
    - *Control Surfaces Efficiency*
- Investigate impact of retro propulsion on flow structure and resulting force and moment coefficients
- Assessment of efficiency of novel control surface design (interstage and fairing sections)
- Hot plume for detailed understanding of flow-flow interaction
- Heat loads on structural elements and TPS
- Qualification of TPS and Health Monitoring System (HMS)
- Contribution to AEDB/ATDB for GNC and flight dynamics, TPS and landing structures

Planned Wind Tunnel Tests

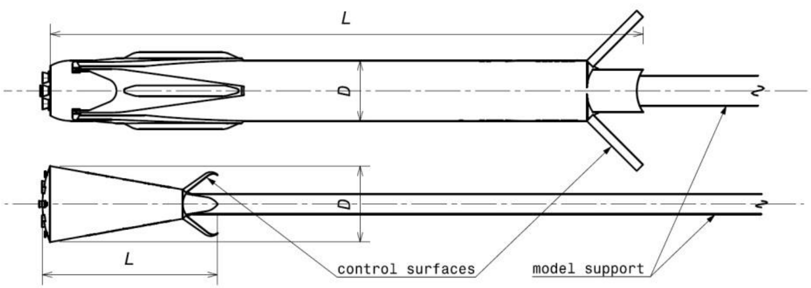
Full Configuration

- H2K / TMK
  - Mach 7.0 … 2.0
  - Propulsive medium: pressurized air
  - Strain gauge measurements
- VMK
  - Mach 0.9 … 0.3
  - Propulsive medium: GH2/GO2
  - ➢ Plume of up to 115 bar and 3600 K stagnation conditions
  - Wall pressure measurements, PIV
- Additional tests for control surface efficiency in TMK

Type	Wind tunnel tests			
Test focus	Aerodynamic		Aerothermal	
Wind tunnel	H2K / TMK		VMK	
Configuration	RETALT1	RETALT2	RETALT1	RETALT2
Scale	1/100	1/100	1/80	1/80
Length (L / mm)	600	220	750	330
Diameter (D / mm)	60	100	75	150



Exemplary Falcon 9 descent trajectory with relevant test cases in the H2K, TMK and VMK.



RETALT1 and RETALT2 wind tunnel models for use in the H2K, TMK and VMK facilities

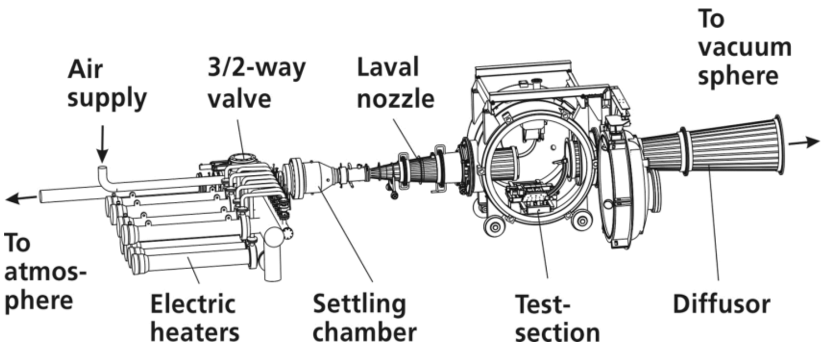
RETALT DLR

Aerodynamic Wind Tunnel Experiments

Wind Tunnel Facilities - Hypersonic Wind Tunnel Cologne (H2K)

- Blow down facility (pressure-vacuum) with several Laval nozzles for fixed Mach numbers
- Reynolds number adjustable by variation of total pressure and total temperature
- Available Diagnostic Techniques:
  - 6 components balances
  - High Speed shadowgraphs and Schlieren
  - Oil flow techniques
  - Infrared Thermography
  - Particle Image Velocimetry
  - Tracking methods
  - Pitot and heat flux probes

H2K wind tunnel, with test section open

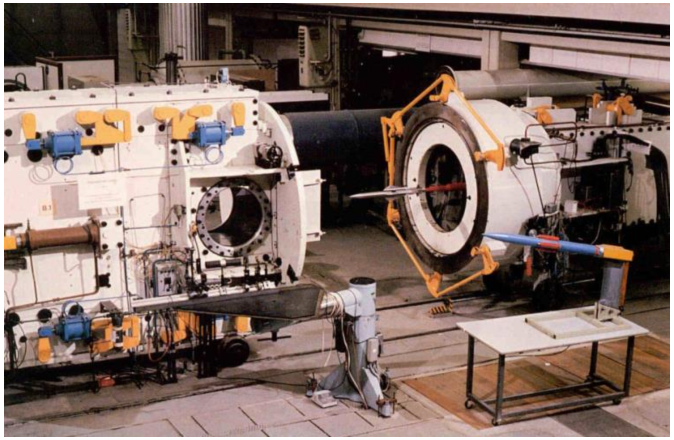


Facility Attributes	
Mach Numbers	5.3, 6.0, 7.0, 8.7, 11.2
Reynolds Numbers	2 to 20 x 10^6/m
Test Section Area	π/4 x (600 mm)²
Total Pressures	2.5 to 55 bar
Total Temperature	1100 K (max)
Typical Run Time	30s

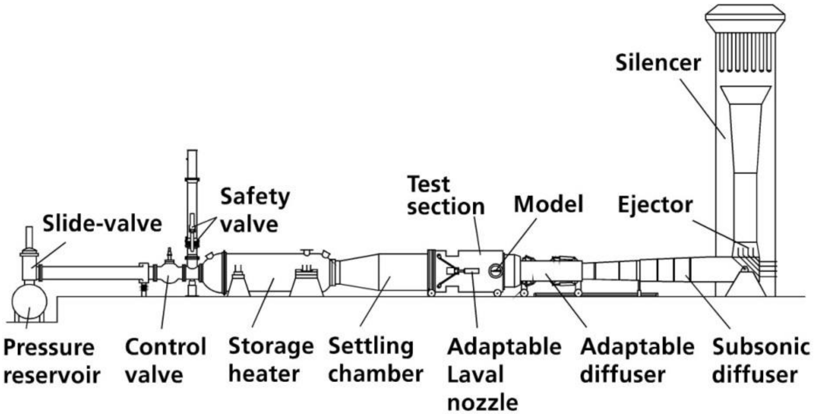
Aerodynamic Wind Tunnel Experiments

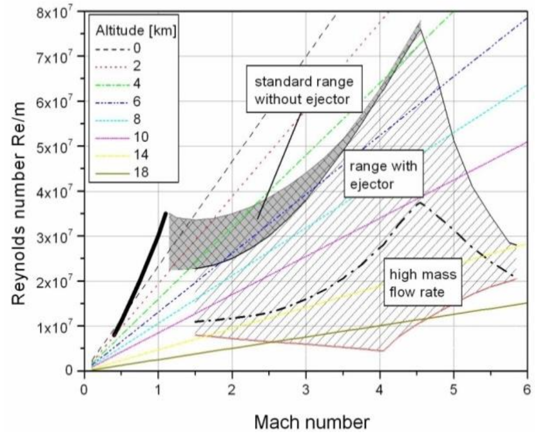
Wind Tunnel Facilities - Trisonic Wind Tunnel (TMK)

- Operation range:
  - Mach: 0.5 - 5.7
  - Reynolds number variation
- Measurement:
  - Aerodynamics (forces, moments)
  - Derivativa measurements
  - Schlieren imaging
  - Oil flow pictures
  - Temperature, pressure



TMK wind tunnel, with test section open





Performance map of Trisonic Wind Tunnel TMK

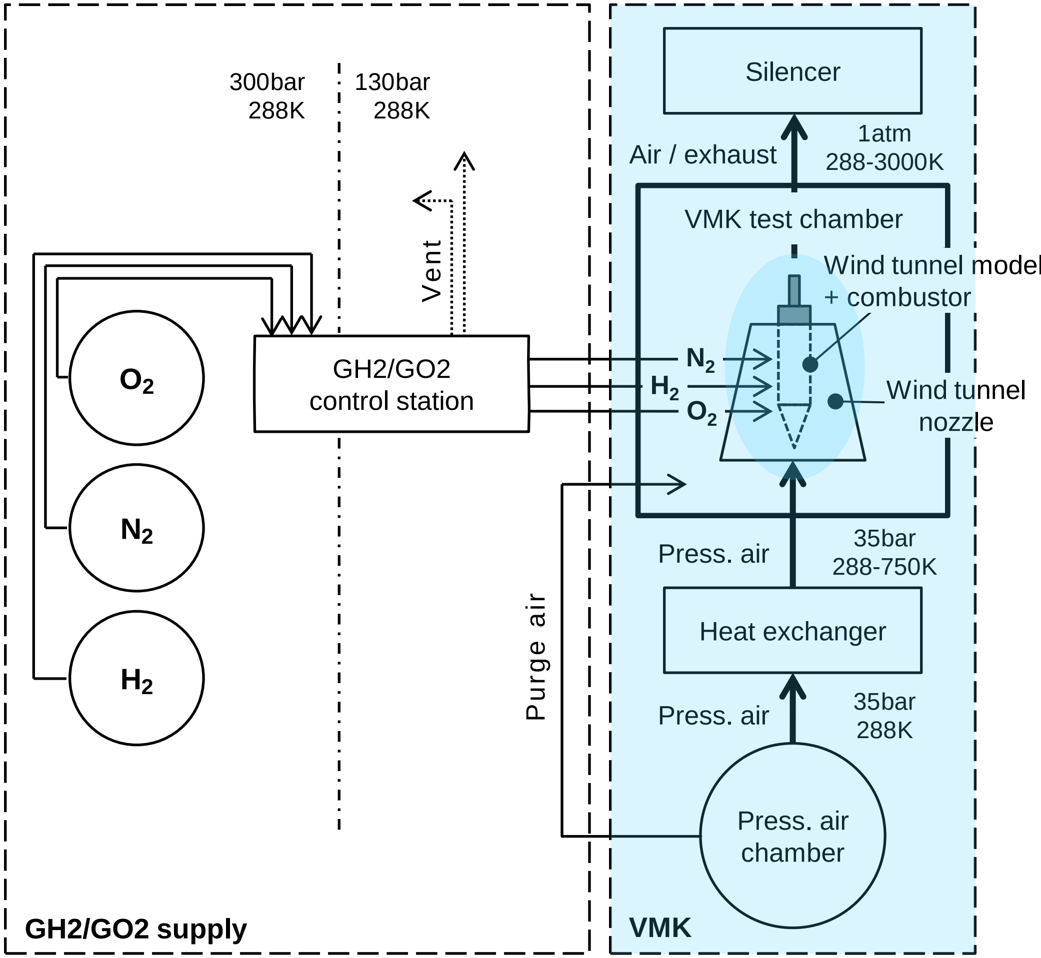
Aerothermal Experiments
VMK – GOX/GH2 Test Stand Infrastructure

- Add-on to our Vertical Wind Tunnel (VMK)

- GH2/GO2 Supply Facility
  - Gas supply station (300bar)
  - Control station (115bar, 470g/s)
  - Piping

- Wind Tunnel Model
  - Model support
  - GH2/GO2 combustor

- Safety Measures to enable combustion testing in VMK

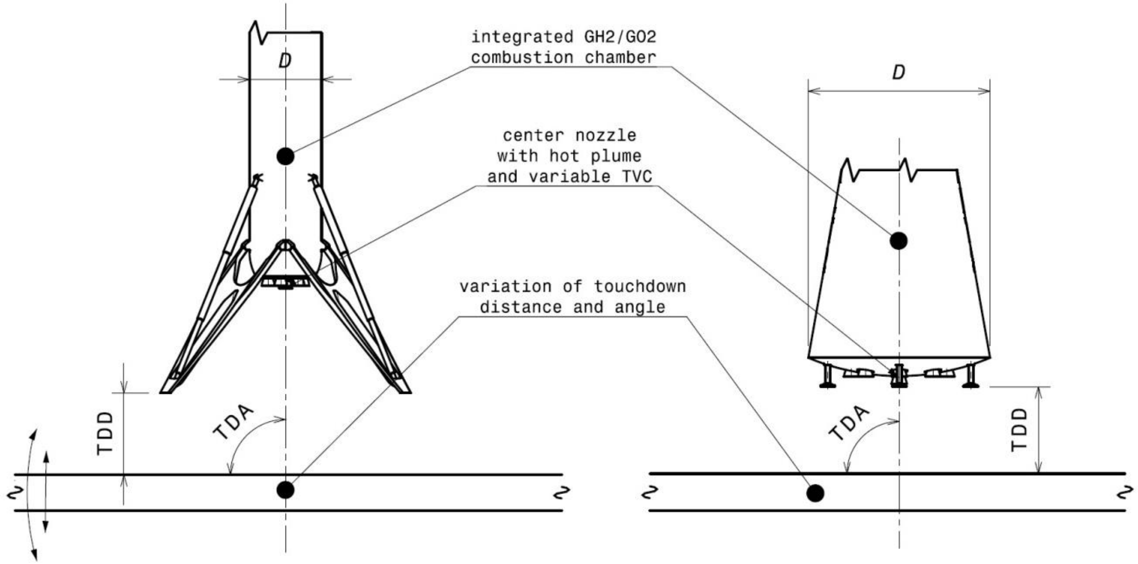


Planned Wind Tunnel Tests

Ground Effect Model

- GH_2/GO_2 combustion chamber integrated in model
- Larger scale
- Without surrounding flow
- For qualification of TPS and Health Monitoring System
- Variations of Touch Down Distance (TDD) and Touch Down Angle (TDA)
- Variable TVC

Type	Ground effect tests	
Test focus	Aerothermal	
Wind tunnel	VMK (static atmosphere)	
Configuration	RETALT1	RETALT2
Scale	1/30	1/30
Length (L / mm)	-	-
Diameter (D / mm)	200	250



RETALT1 and RETALT2 as base models for hot plume aerothermal impact tests

CFD Analyses

- Rebuilding of WT-Tests (Code validation, support of WT and model setup, improved interpretation and analysis of experimental data).
- Extrapolation to flight scales.
- Generation of inputs for Aerodynamic and Aerothermal Databases. Provision of mechanical and thermal loads.
- Analyses and assessment of control-surface efficiency.

Control of uncertainty by:

- Application and cross-check of different codes (TAU and NSMB)
- Closely coupled analysis methodology between CFD and WT results

Conclusion

- Together with the other two European projects CALLISTO and RETRO. RETALT will generate an important expertise in VTVL technologies in Europe.
- Our industrial partners ALMATECH, AMORIM, CFS Engineering and DEIMOS have very complementary expertise and allowed defining an interdisciplinary study logic within RETALT.
- The definition of reference trajectories is ongoing and required an intense discussion.
- Since the topic is quite new in Europe, a lot of young and highly motivated scientists are interested joining the team.
- Ground tests are very challenging and require very careful preparation.