Keynote speech #3

Chair: Prof. V. Wheatley - University of Queensland, Australia

A Summary of Hypersonic Flight Missions and recent Developments by Mobile Rocket Base

Frank Scheuerpflug - MORABA/DLR

HiSST 2025
22–26 September
Tours, France

DLR

A Summary of Hypersonic Flight Missions and recent Developments by Mobile Rocket Base

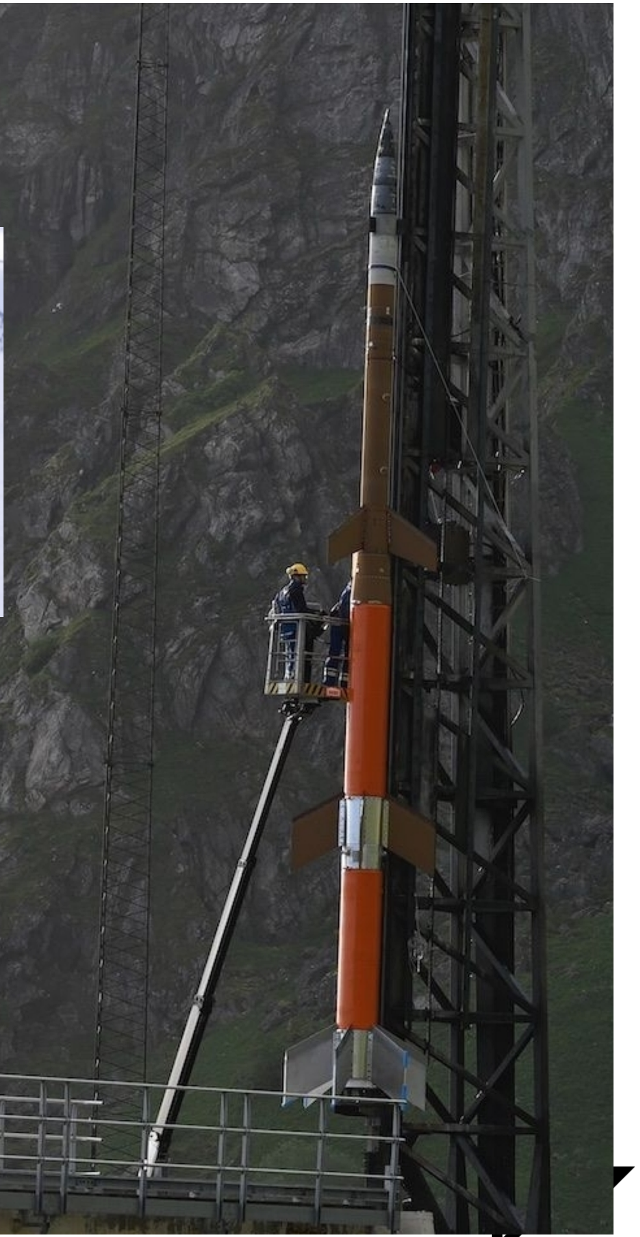
Frank Scheuerpflug

MORABA
MOBILE RAKETENBASIS

3AF Association Aéronautique et Astronautique de France
CEAS Council of European Aerospace Societies
4th International Conference on High-Speed Vehicle Science & Technology

Mobile Rocket Base (MORABA) of DLR

- We build and fly Sounding Rockets
- Up to 10 launches per year
- 60 people



Operational Sites Utilized by MORABA

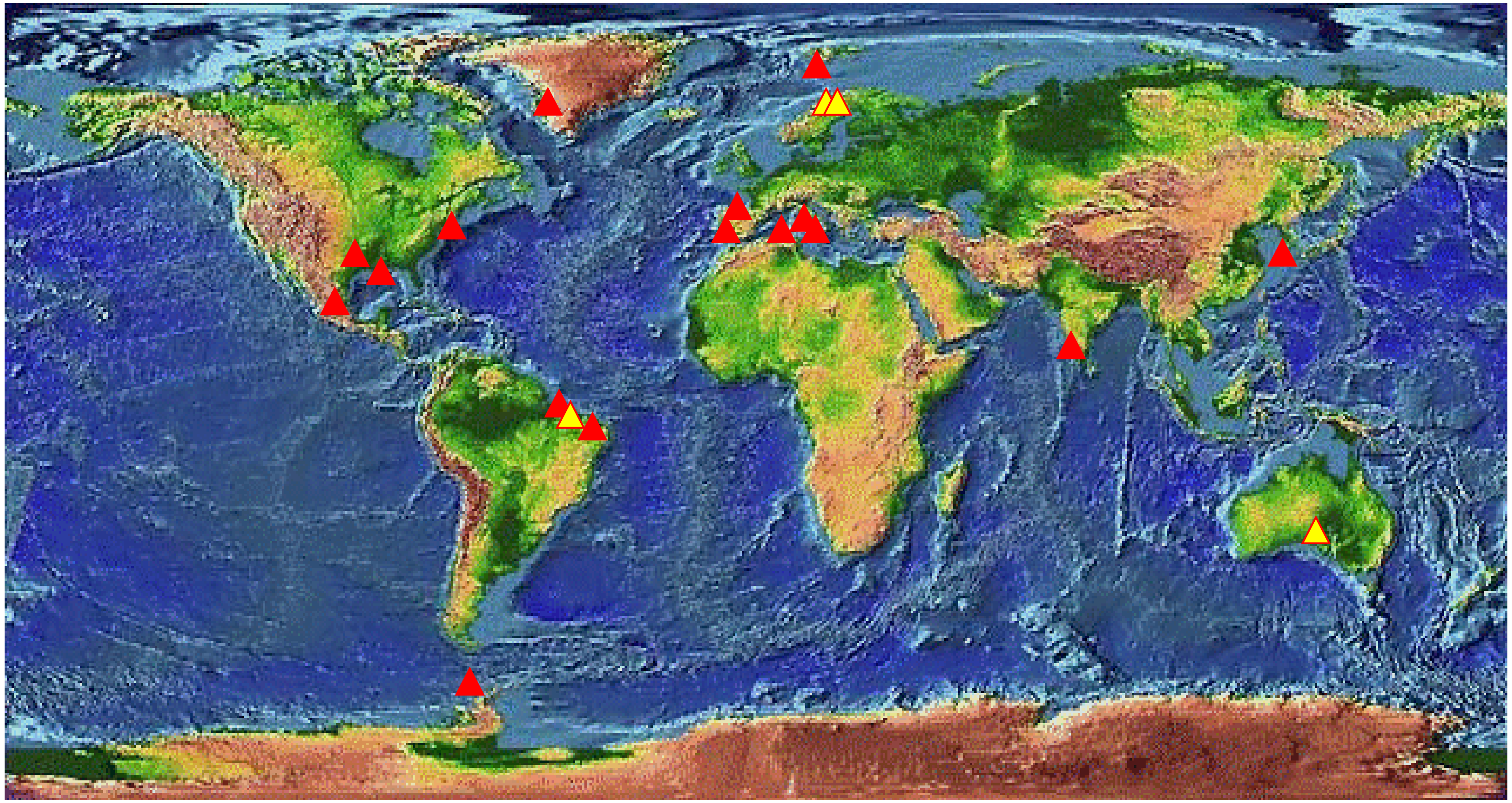
Huelva, Spain
Biscarosse, France
Perdas de Fogu, Sardinia

Greenland

Spitzbergen, Norway
Andenes, Norway
Kiruna, Sweden
Karystos, Greece
Kreta, Greece

Wallops Island, USA
Matagorda, USA
White Sands, USA
Palestine, USA

Kourou, French Guyana
Alcântara, Brazil
Natal, Brazil



Kagoshima, Japan

Woomera, Australia
Coober Pedy, Australia
Koonibba, Australia

Adelaide Island, Antarctica

Thumba, India

Traditional Research Domain of Sounding Rockets

Research Domains

- Atmospheric Physics
- Research under Microgravity
- Astronomy
- Student Education

Mission CONOPS

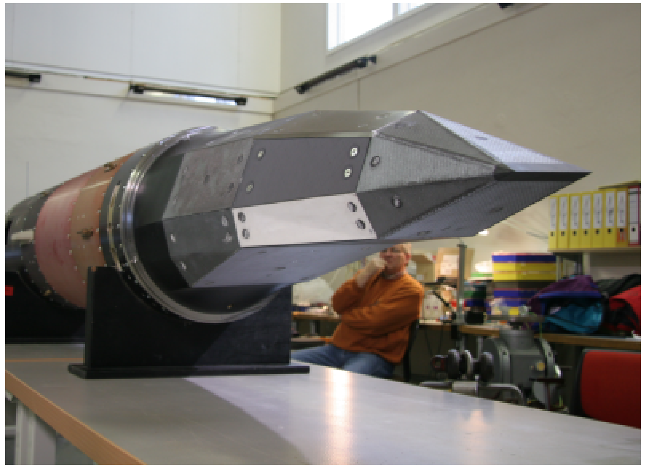
- Unguided Solid Rocket Vehicle
- Steep, parabolic trajectory
- Parachute Recovery

TEXUS 1, 1977

TEXUS 60, 2024

Outline

Traditional microgravity payload



First hypersonic payload SHEFEX I

I. Mission Designs in Hypersonics Research

II. Some Adjustments of Launch Vehicles

III. Overview of hypersonic research missions done 2005 - Now

Adjusted Mission Designs for Hypersonic Research

SHEFEX II Payload Rollout, Andøya 2012

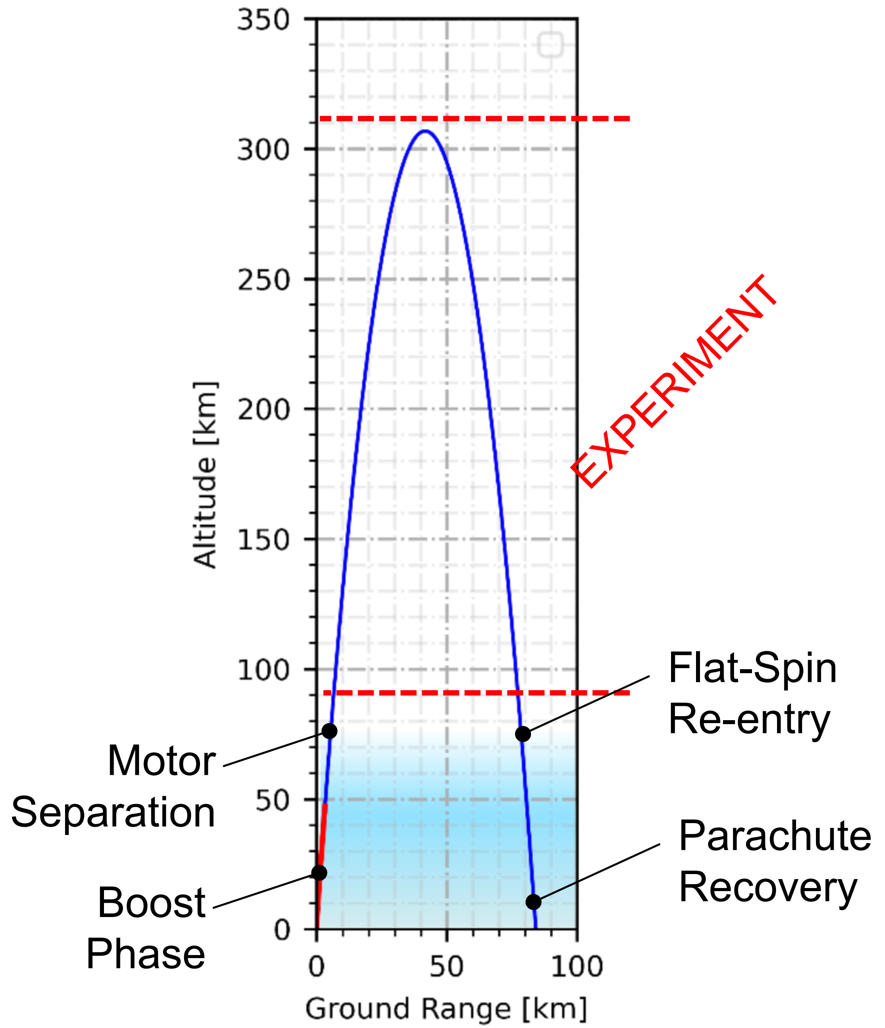
Up-and-Over Mission Design

- Quick Atmospheric Passage
- Two Experiment Windows during atmospheric crossing
- Optional exo-atmospheric cold gas maneuver to re-align vehicle with reentry vector

➡ Low Load Level

➡ Measurement time typically 30 s

➡ Rapid change in atmospheric flight conditions



Hypersonic Missions using Up-and-Over Trajectory Designs

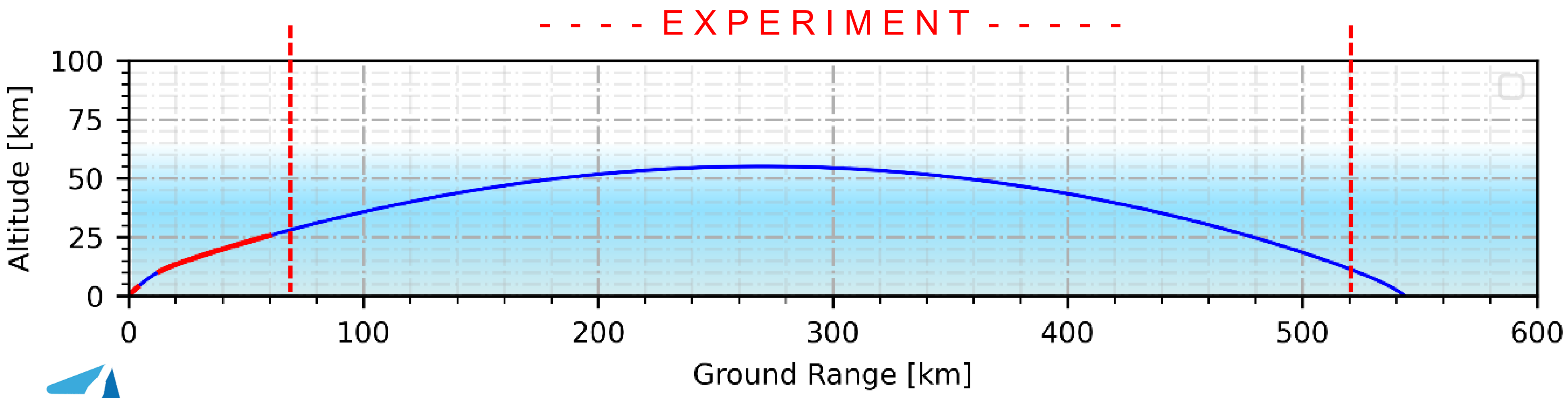
SHEFEX-I	HiFIRE-5	HIFiRE-3	SCRAMSPACE	HIFiRE-7	HIFiRE-5B	ROTEX-T	BOLT-1	HIFLIER	SOAR	BOLT-1B
10/2005	04/2012	03/2013	09/2013	03/2015	05/2016	07/2016	06/2021	10/2023	11/2023	09/2024
Andøya	Andøya	Andøya	Andøya	Andøya	Woomera	Esrange	Esrange	Esrange	Andøya	Andøya
Partial Success	2nd stage ignition failure	Success	Booster Failure	Success	Success	Success	2nd stage Instability	Success	Success	Success

Supressed Mission Design

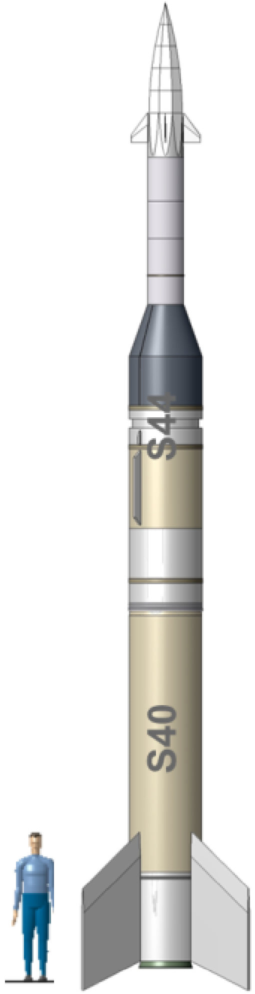
- Shallow launch angle (65-75°)
- Gravity Turn before second stage ignition

➡ Long & steady hypersonic conditions (typically 3 min)
➡ No Cold Gas Re-alignment required

➡ Payload recovery expensive (often prohibitively)
➡ High telemetry bandwidth and transmission power required to obtain data
➡ High Thermal Loads (!!!)
➡ Trajectory dispersion can become challenging

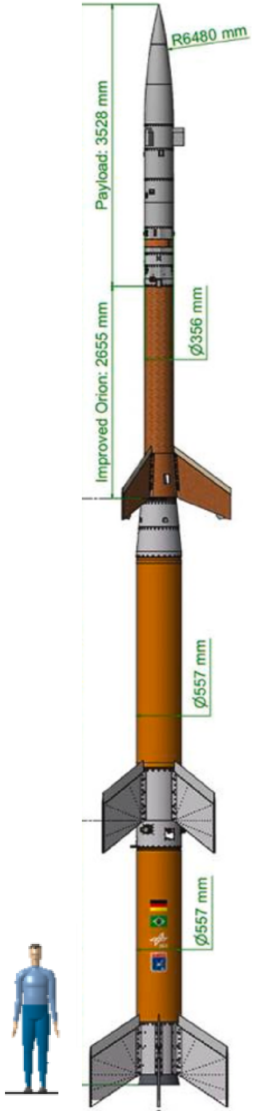


Hypersonic Missions using Suppressed Designs



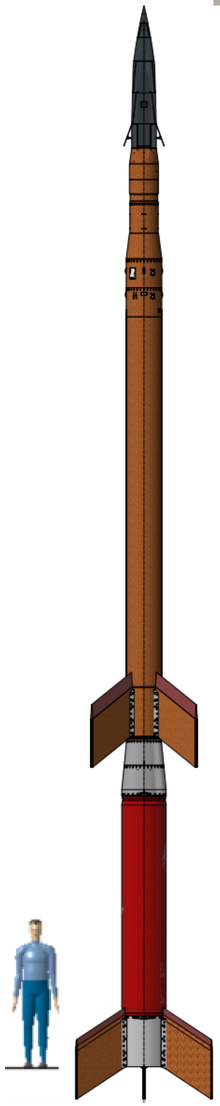
SHEFEX-2
06/2012
Andøya
Success

Payload	710 kg
Ground Range	800 km
Apogee	177 km



STORT
06/2022
Andøya
Success

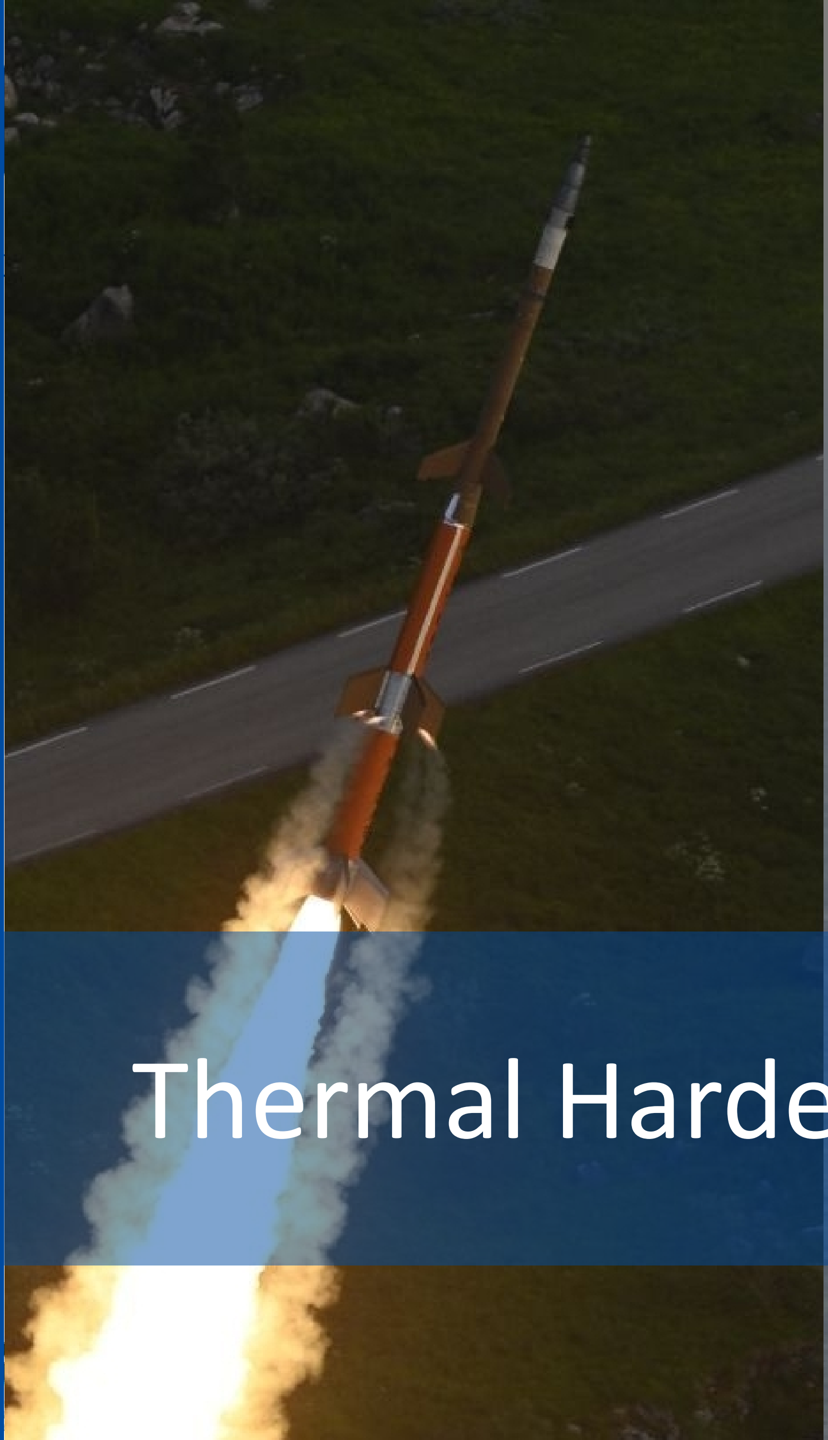
Payload	200 kg
Ground Range	370 km
Apogee	38 km



ATHEAt
Happening Now
Andøya

Payload	250 kg
Ground Range	530 km
Apogee	54 km

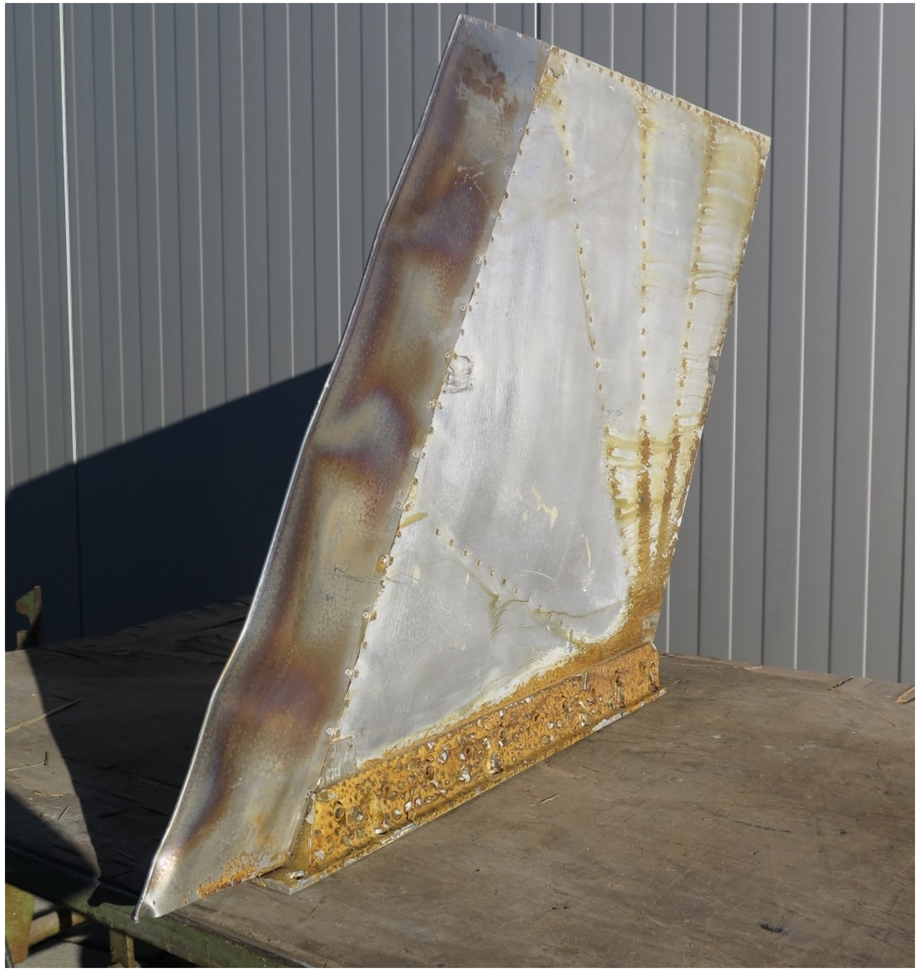
Thermal Hardening



STORT Launch, Andøya June 2022

Thermal Hardening of Flight Structures

Leading Edge buckling due to kinetic heating during the descent of SHEFEX I, October 2005

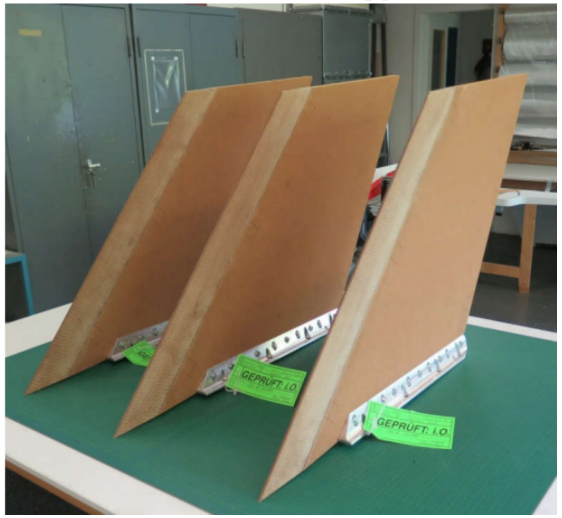


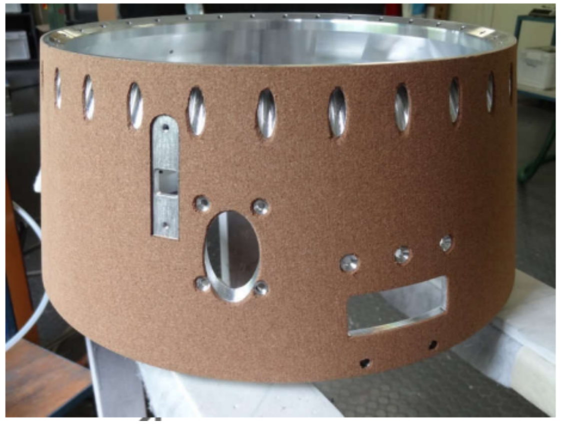
Heritage fin recovered from standard Micro-g Mission (TEXUS 48, 2011)

Thermal Hardening of Flight Structures

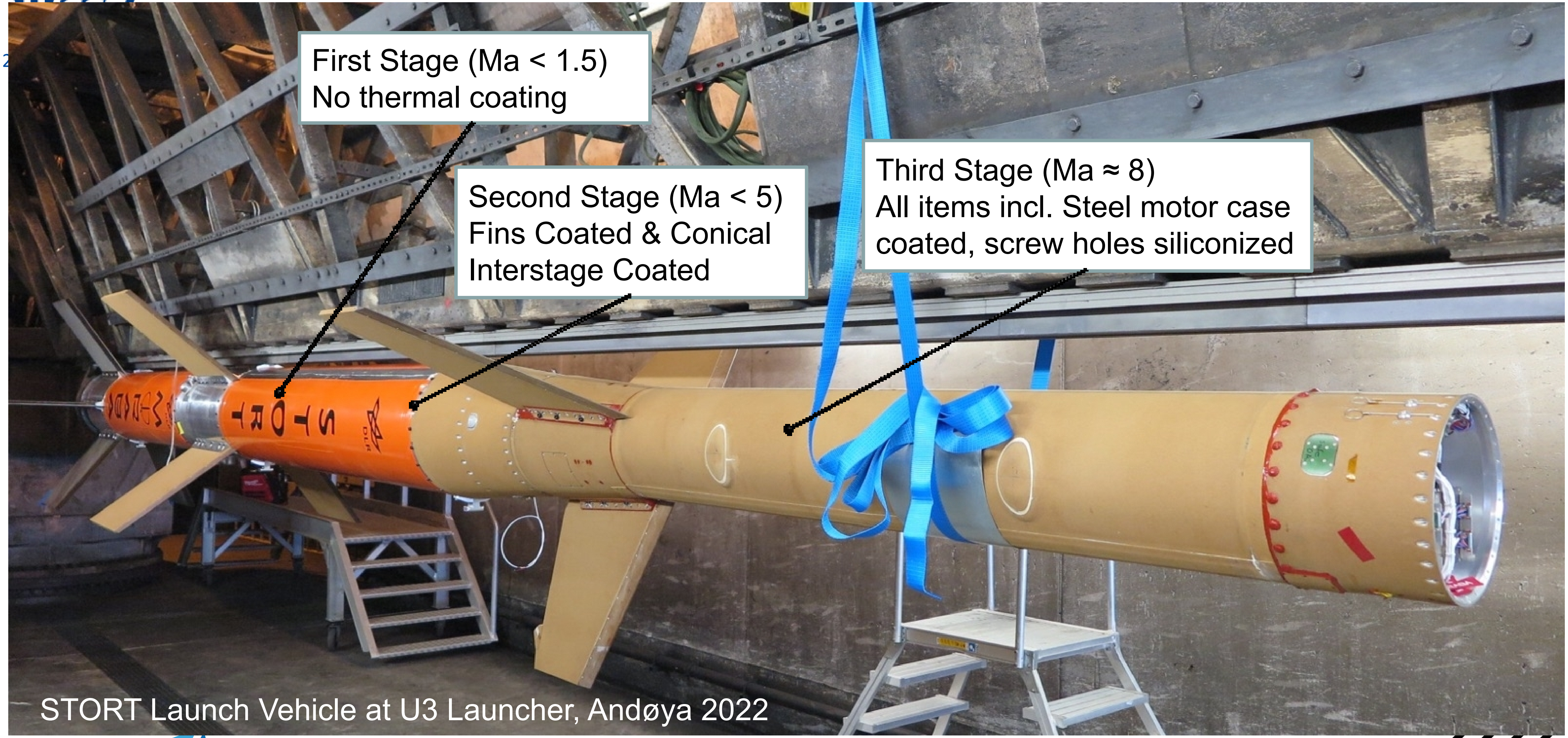
Cork Tree - Quercus Suber ([Wikipedia])

Cork Coating on Schiaparelli Mars Sonde (ESA)

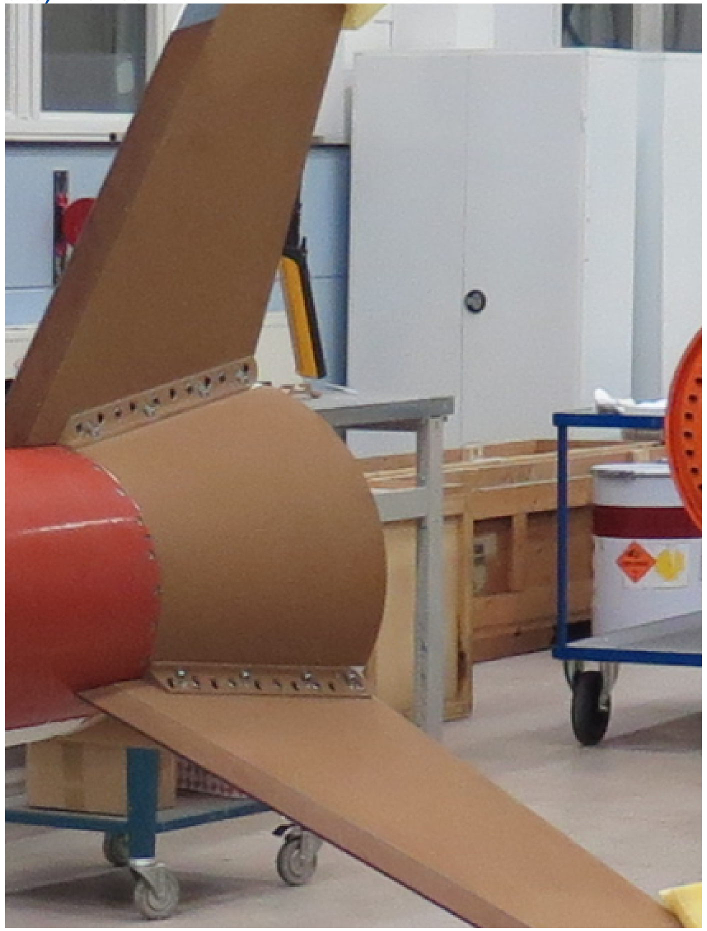


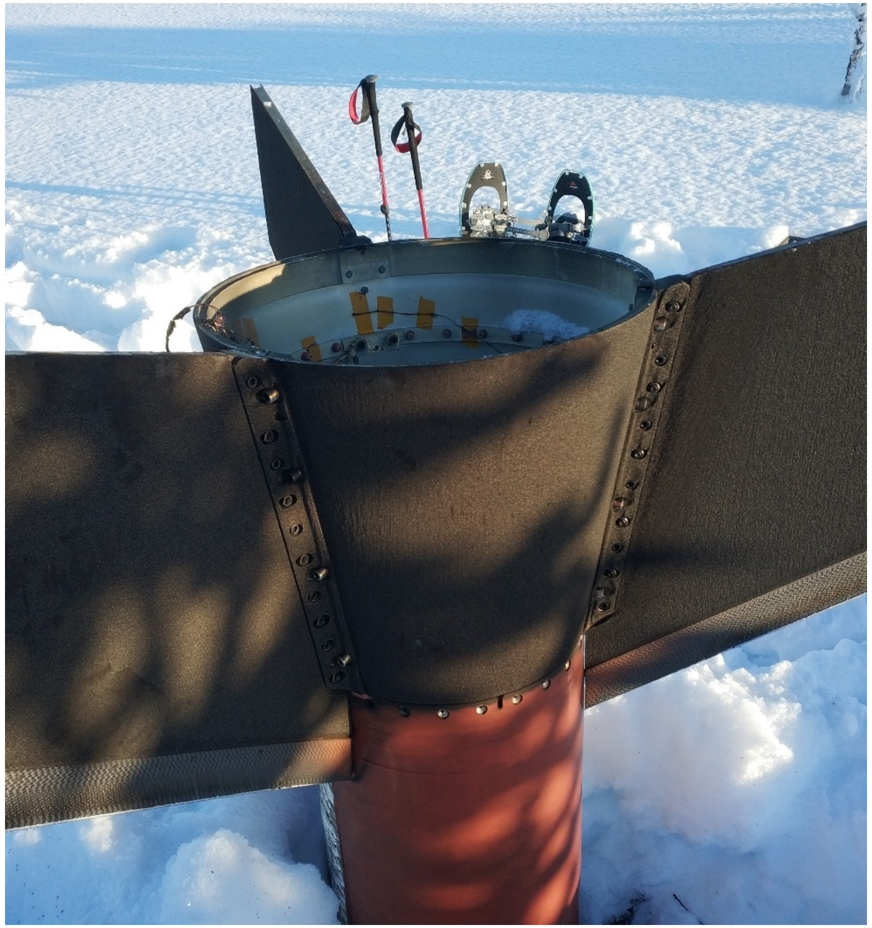


Various primary structures coated with cork


First Stage (Ma < 1.5)
No thermal coating
Second Stage (Ma < 5)
Fins Coated & Conical
Interstage Coated
Third Stage (Ma ≈ 8)
All items incl. Steel motor case
coated, screw holes siliconized
STORT Launch Vehicle at U3 Launcher, Andøya 2022

Thermal Hardening of Flight Structures





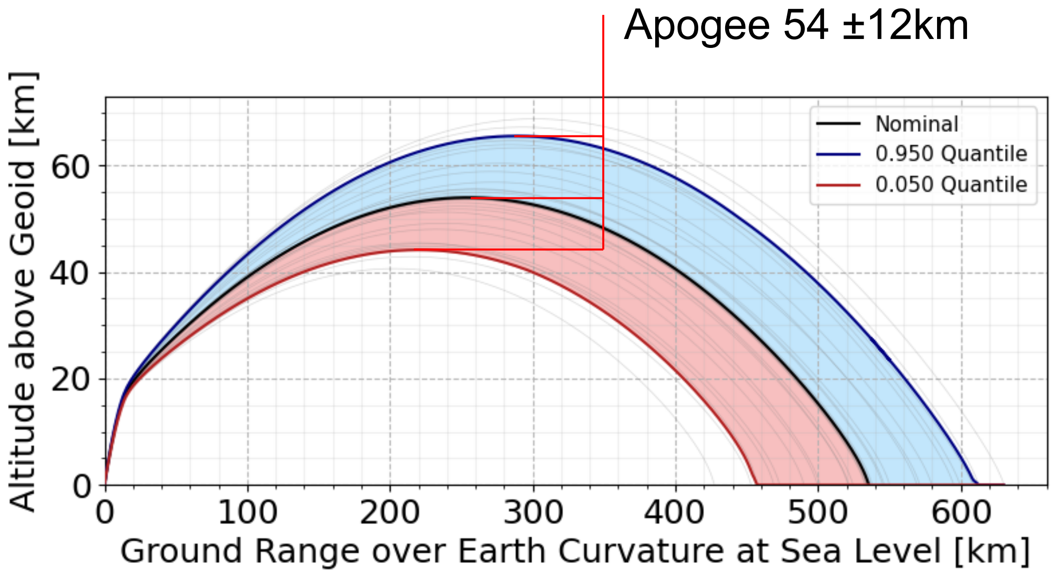
Footage fin and tailcan assembly structures from MAPHEUS missions

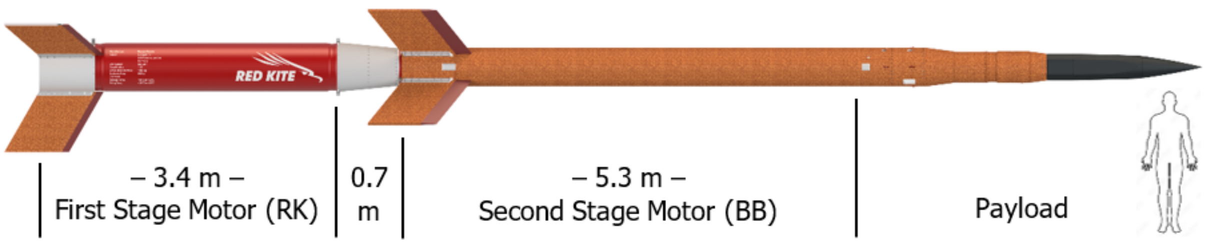
Dispersion Mitigation

Red Kite Testflight Vehicle in Assembly Hall, Andoya Aug 2023

Dispersion Mitigation

- Trajectory dispersion can become problematic, especially in suppressed mission designs





ATHEAt vehicle (slated for launch in Oct 2025)

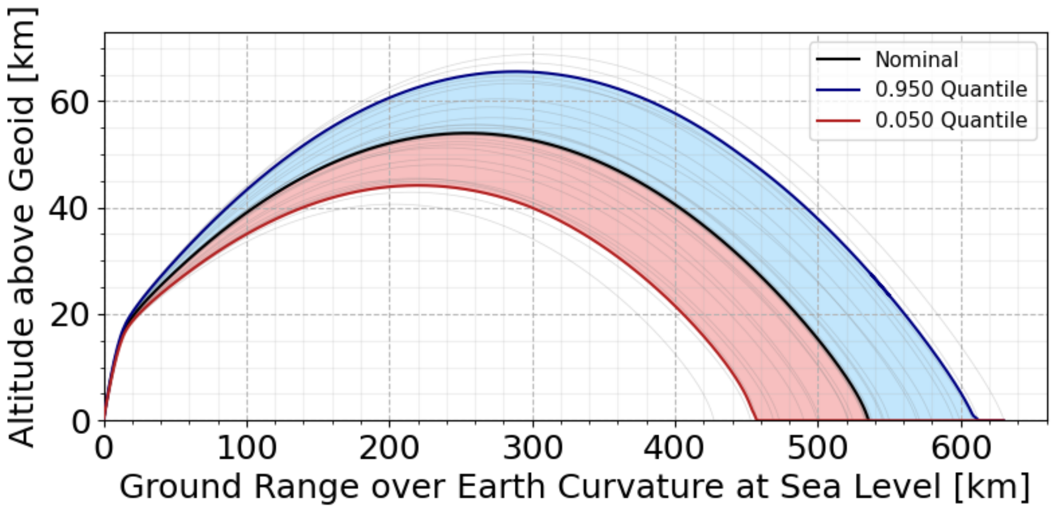
Dispersion Mitigation: Autonomous Upper Stage Ignition

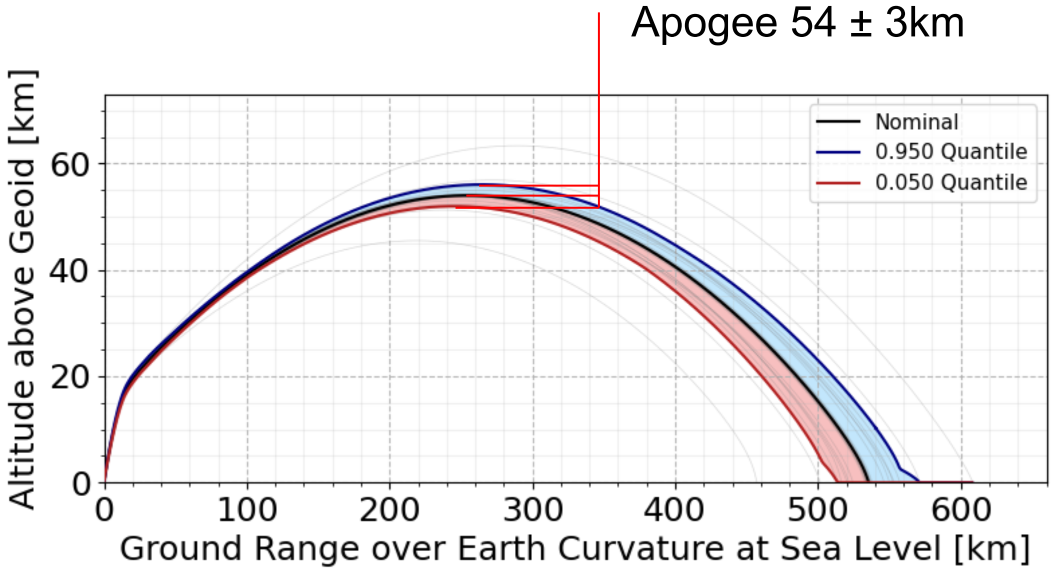
- Mitigate by making the ignition time of the last stage a function of the flight state after first stage burnout:

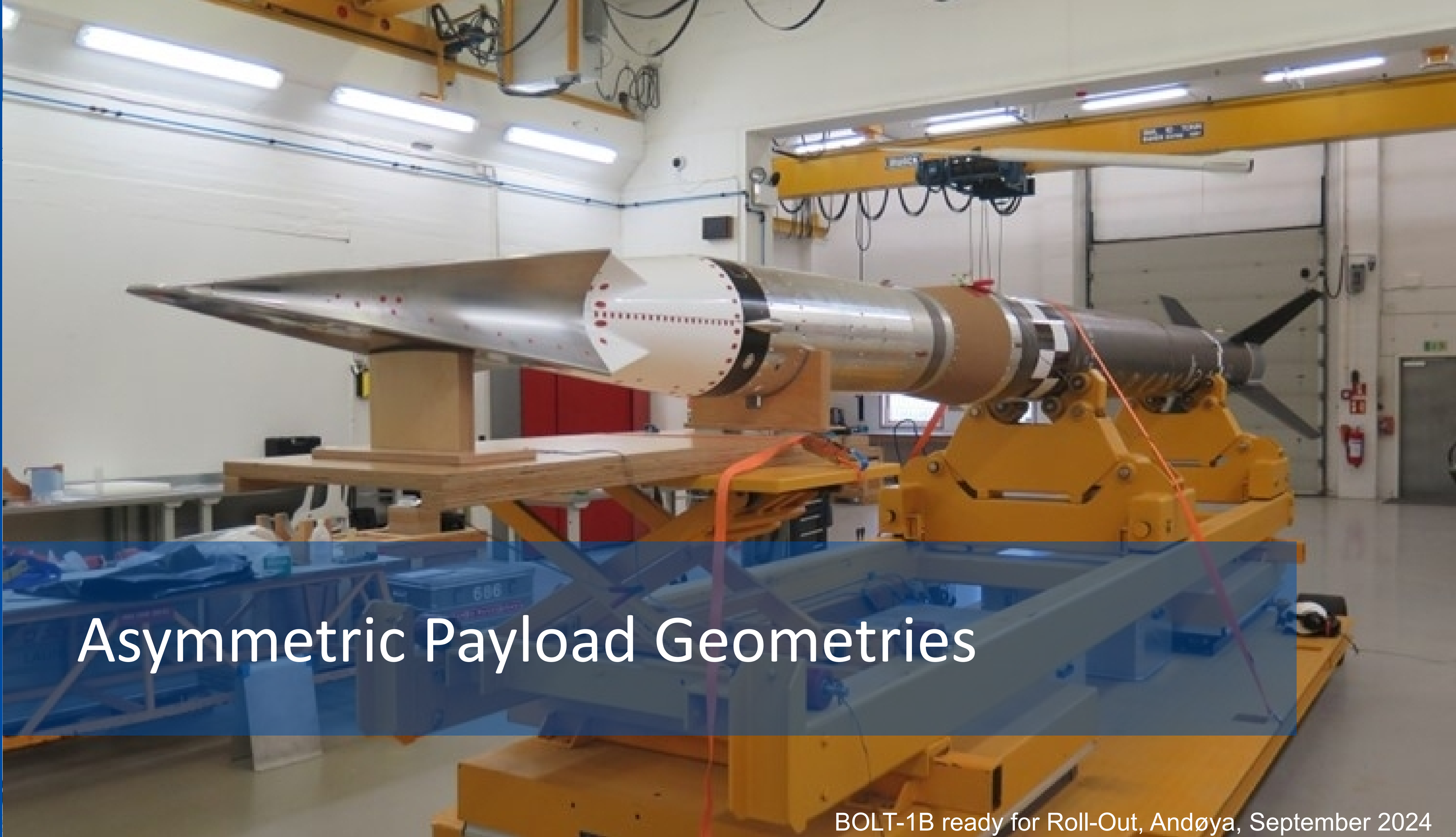
$$\text{Ignition Time (Upper Stage)} = f\begin{bmatrix}\overrightarrow{pos}\\ \overrightarrow{vel}\\ \overrightarrow{att}\end{bmatrix}^{\substack{after\\ burnout\\ first\ stage}}$$

- Implemented on-board
- No flight termination equipment required

➡ **Precise achievement of target flight conditions**



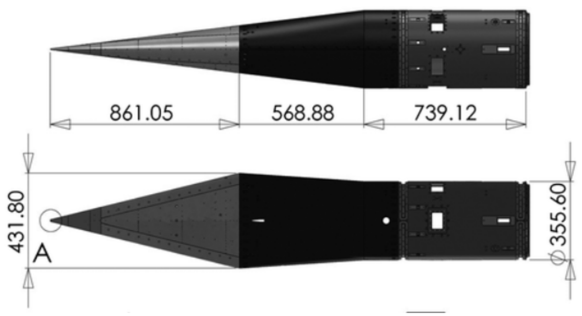




Asymmetric Payload Geometries

BOLT-1B ready for Roll-Out, Andøya, September 2024

Asymmetric Payload Geometries



HIFiRE 5 elliptical forebody [15]

HIFiRE 5b payload mated with Improved Orion second stage

HIFiRE 5B on launcher, May 2016

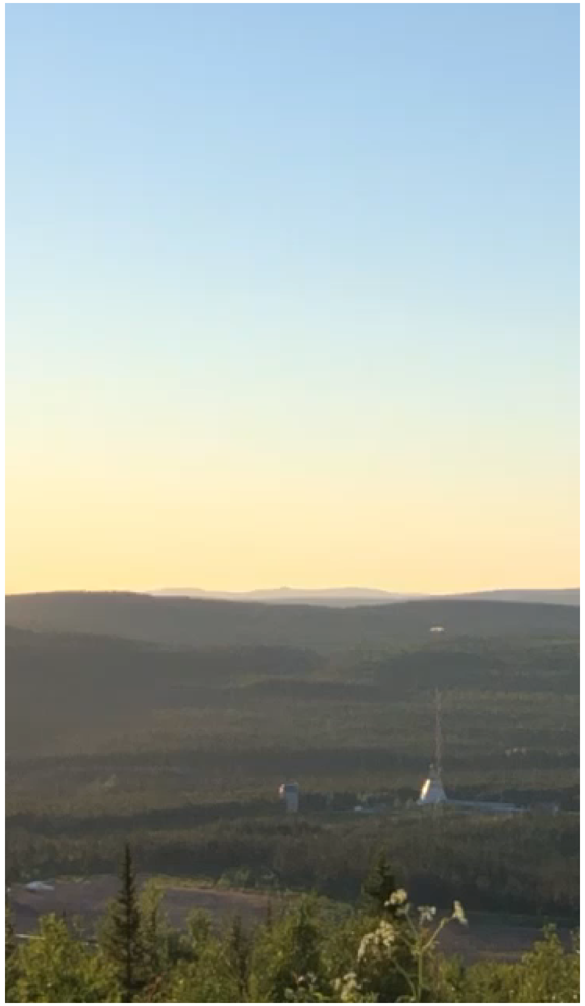
Asymmetric Payload Geometries

BOLT I forebody during environmental testing

BOLT I leaving the launcher (1000 fps), Esrange 2021

- Nominal first stage burn
- Cork screw motion upon first stage sep
- Apogee 78 km (vs. 264 planned)
- Mach 3 (vs. 7 planned)

Asymmetric Payload Geometries



BOLT I launch captured from
Radar Hill

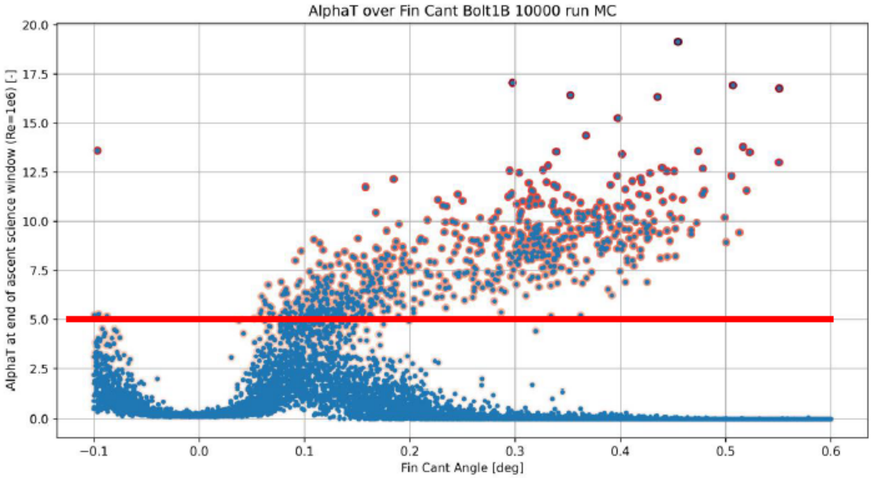
Asymmetric Payload Geometries

BOLT I impact site

Asymmetric Payload Geometries

HiSST 2025
22–26 September
Tours, France

- BOLT 1 Failure triggered the (tedious!) expansion of flight dynamics modelling to asymmetric configurations
- We changed launch vehicle configuration and flew successfully.



Monte Carlo Analysis of a BOLT 1B-like configuration showing clear non-linear behaviour in some runs.

BOLT 1B launched from U3, Andoya, Sep 2024

3AF Association Aéronautique et Astronautique de France
CEAS Council of European Aerospace Societies
DLR

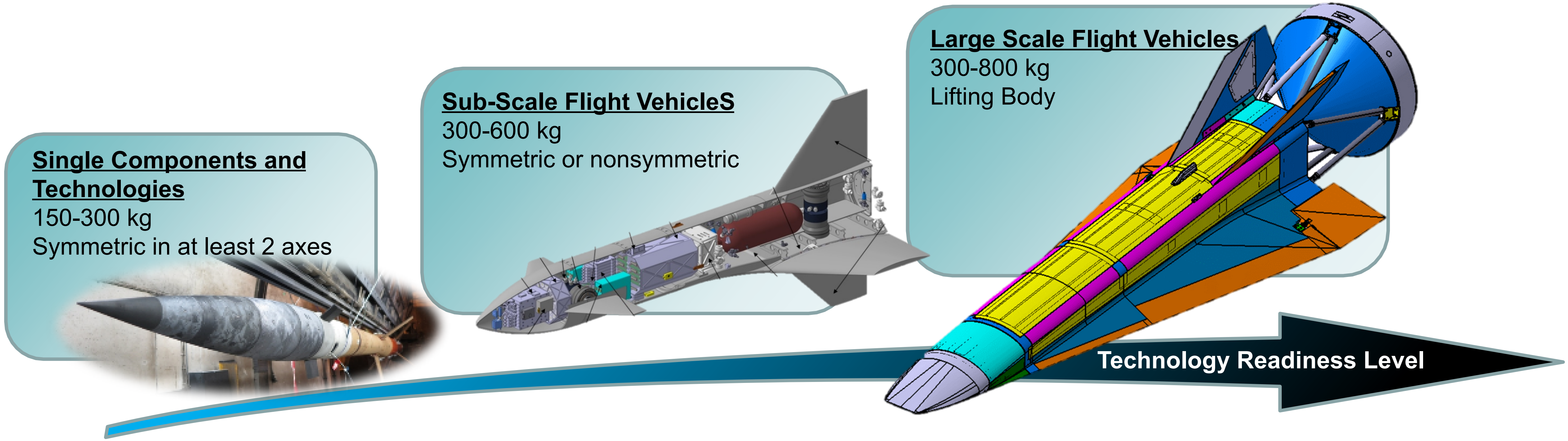
HIFiRE 4 launch vehicle, July 2017

HIFiRE 4 waverider [3]

Where things are going

Red Kite Testflight Vehicle in Assembly Hall, Andoya Aug 2023

Where are we going?

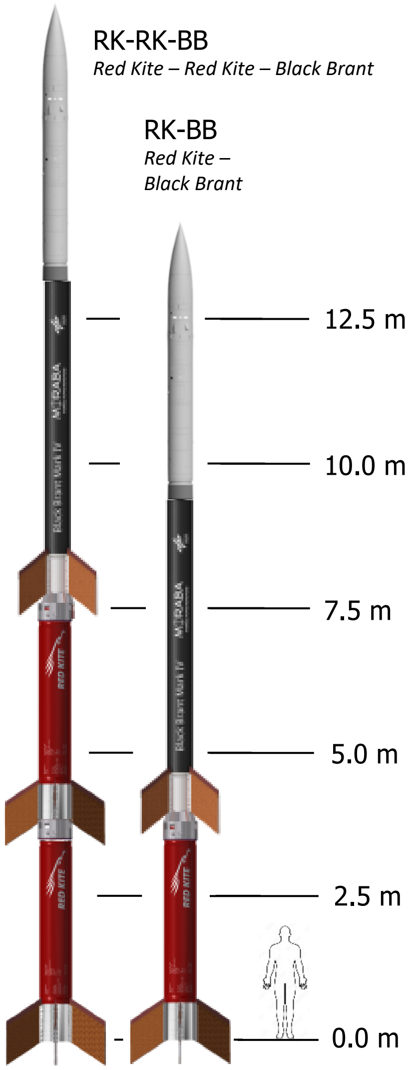


Where are we going?

<u>Single Components and Technologies</u>
150-300 kg
Symmetric in at least 2 axes

1. **<u>FASTER (> Ma 10)</u>**

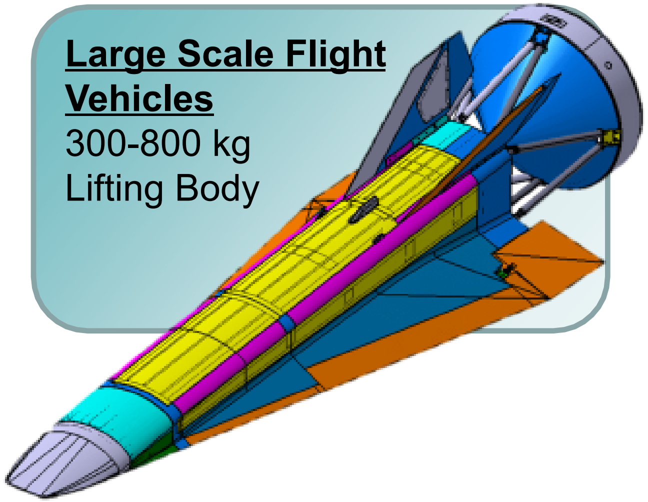
➡ Incremental further improvement using motors and subsystems we already have



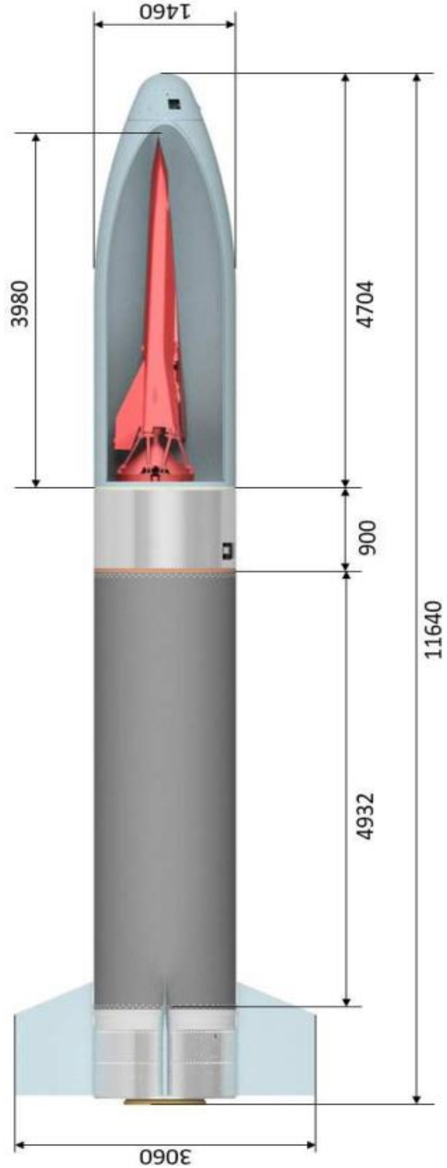
BLACK BRANT Mk4
- 30 s burn duration
- 1000 kg of composite propellant

RED KITE
- 12 s burn duration
- 900 kg of composite propellant

Where are we going?



S50 Motor
(12 ton composite propellant, 86s Burn Time)



VS-50 launch vehicle

2. Integrated Flight Vehicles

- Larger motors and

  Thrust vector guidance

Thrust Vector System Test

Conclusion

- 14 hypersonic testing missions since 2005 (**11 successful**)
- **Increasing demand** both in quantity and quality of launches
- Determined to pursue and **expand our activities** in the field


HiSST 2025
22–26 September
Tours, France
Thank you!
DLR
Contact
Frank Scheuerpflug
Mobile Rocket Base
Oberpfaffenhofen
D-82234 Wessling
Germany
Phone: +49 (0) 8153-28-3649
E-mail: Frank.Scheuerpflug@dlr.de
MORABA
MOBILE RAKETENBASIS
3AF
Association Aéronautique et Astronautique de France
CEAS
Council of European Aerospace Societies
4th International Conference on High-Speed Vehicle Science & Technology


HiSST 2025
3AF
Association Aéronautique et Astronautique de France
THE 4TH INTERNATIONAL CONFERENCE ON HIGH-SPEED VEHICLE SCIENCE & TECHNOLOGY
SEPTEMBER 22ND – 26TH 2025, TOURS - FRANCE
MBDA
ONERA
THE FRENCH AEROSPACE LAB
cea
CEAS
Council of European Aerospace Societies