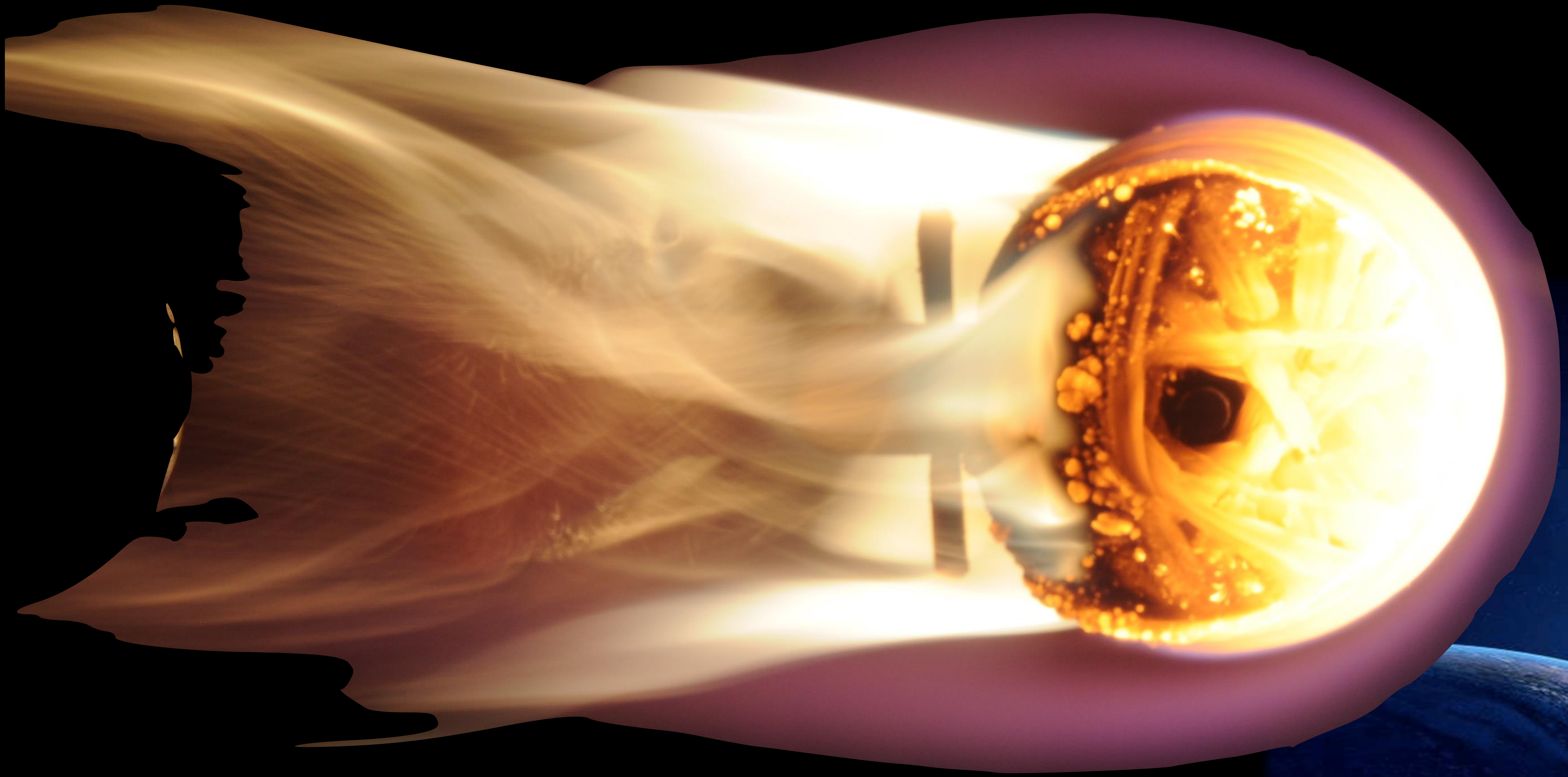
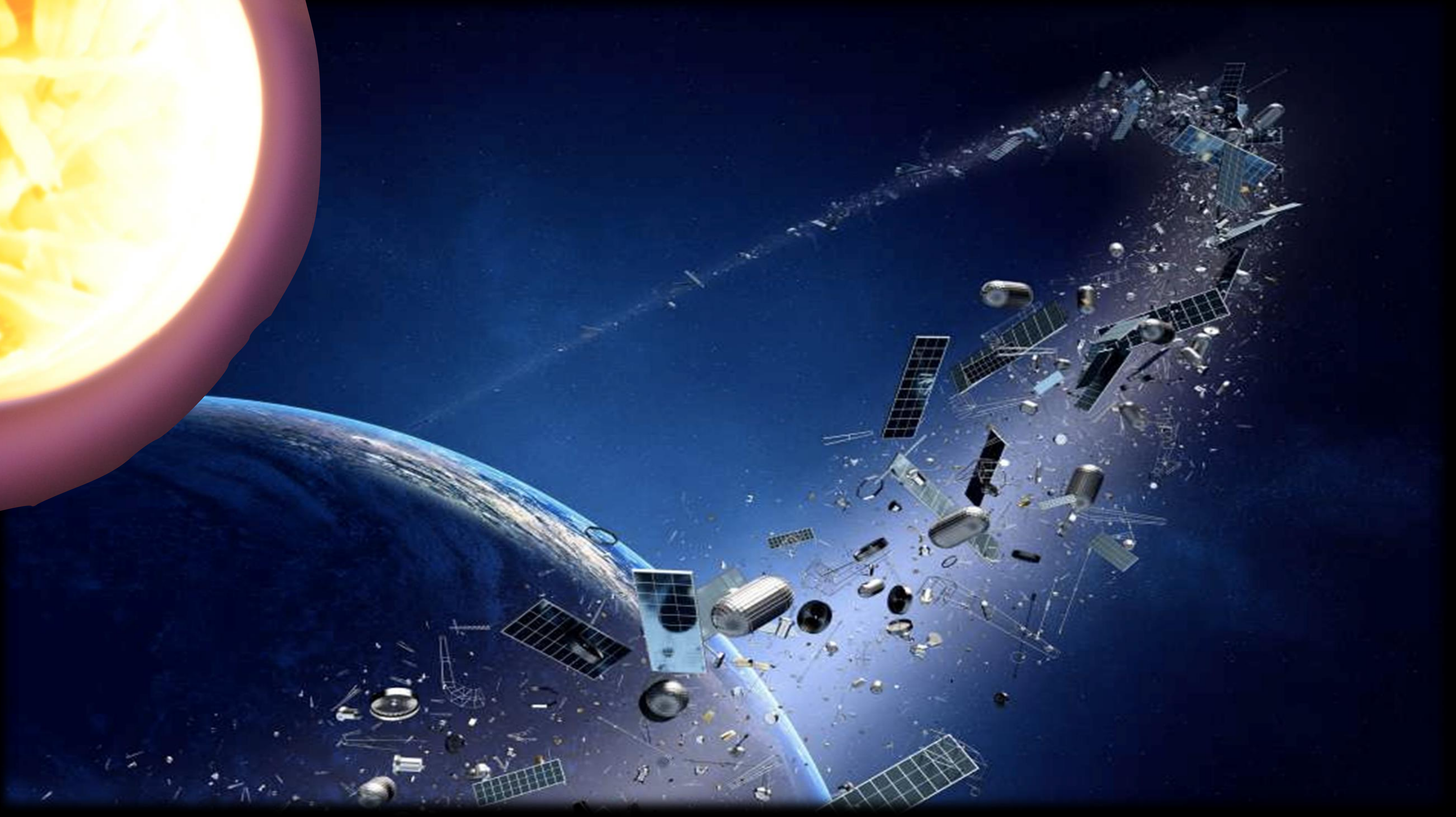
Burning up satellites in the lab

VKI's contribution to the clean space initiative in the world-largest inductive plasma wind-tunnel



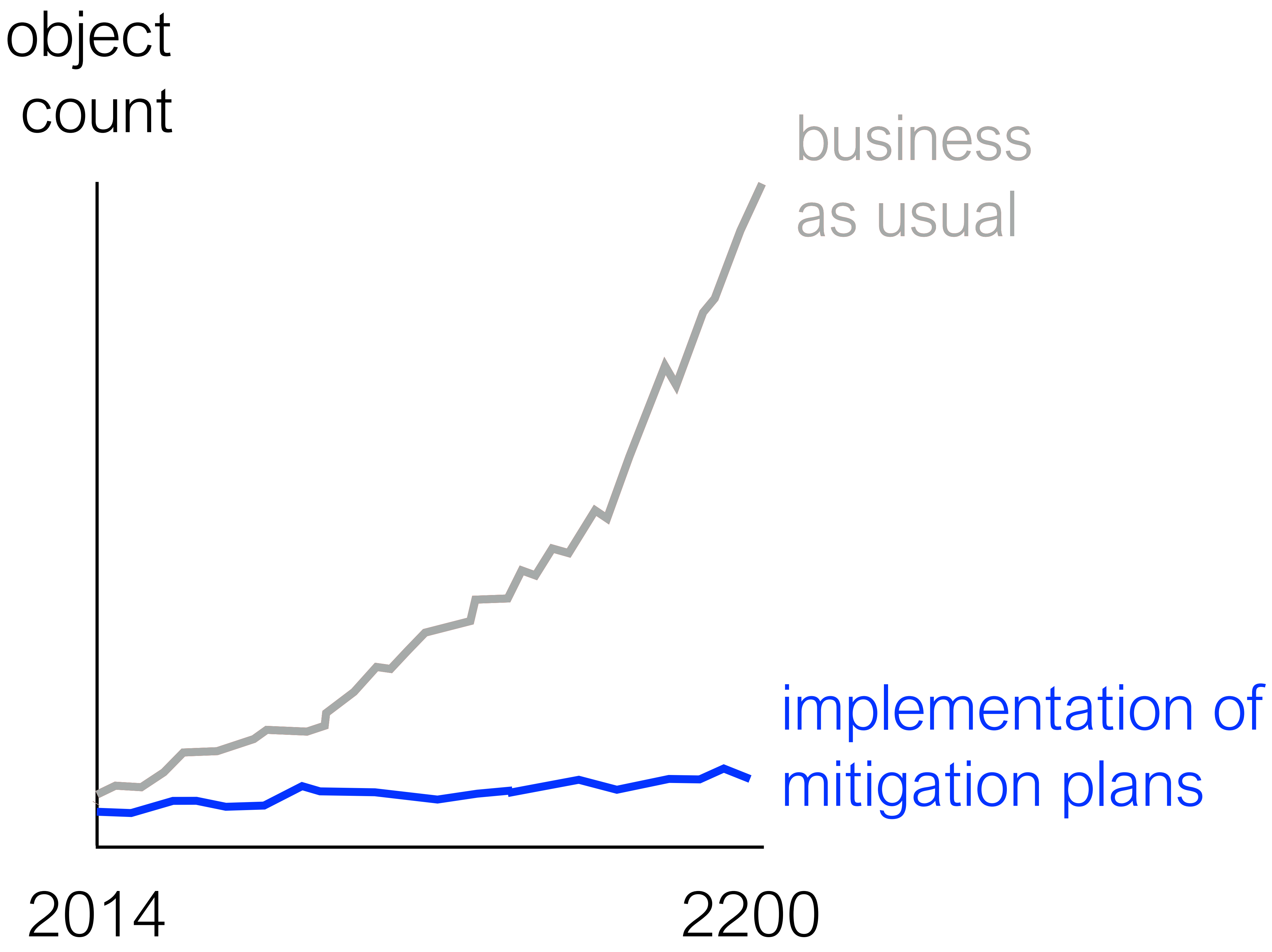


B. Helber (bernd.helber@vki.ac.be)
Aeronautics and Aerospace Department
von Karman Institute for Fluid Dynamics

Certain orbits may become inaccessible if we do not act NOW

Video Credit: Warner Bros, Gravity (2013)

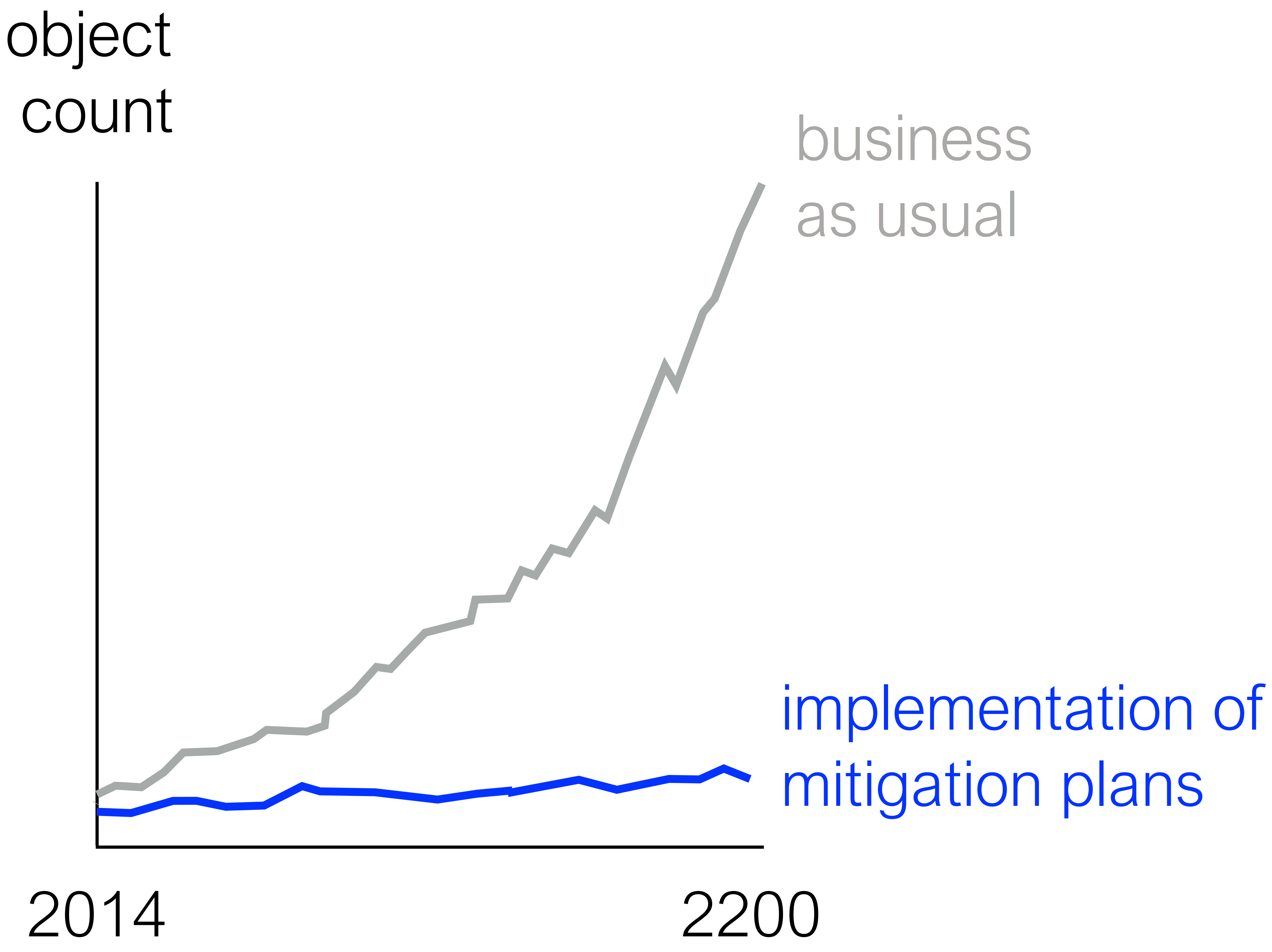
If we want to sustain outer space activities we cannot continue with business as usual



New regulations (2023)

- ESA's Zero Debris approach
- LEO disposal phase 25 → 5 years
- Probability of successful disposal must be >90%

If we want to sustain outer space activities we cannot continue with business as usual



New regulations (2023)

- ESA's Zero Debris approach
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<u>Design for Demise</u>

→ HOW?

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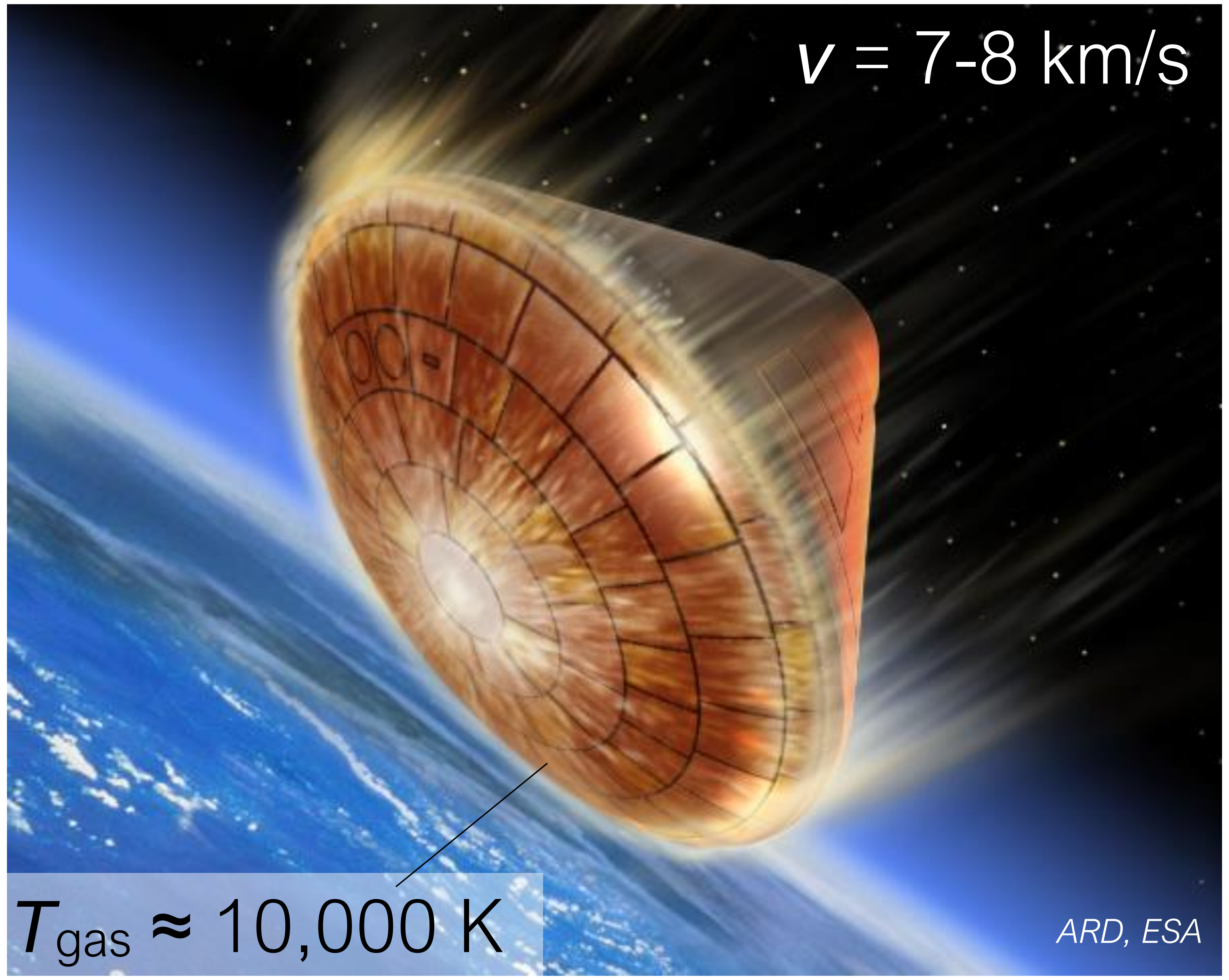
Courtesy: NASA/JPL

Design for Demise (D4D): From survival to destruction De-obitation, decay, and burn-up



Since the start of space flight:
Survive the reentry at maximum heat flux

Design for Demise:
Destroy at minimum heat flux (tumbling)

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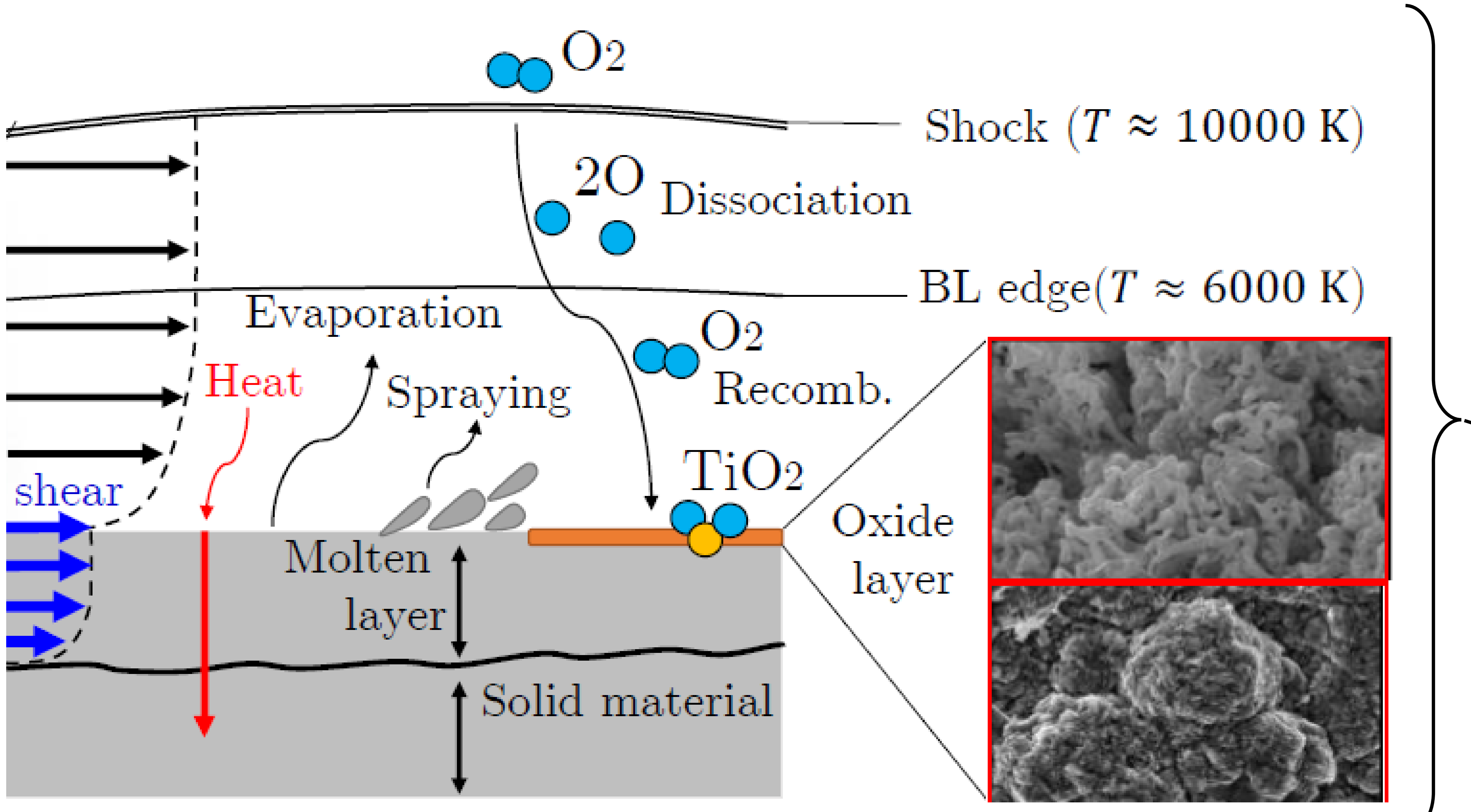
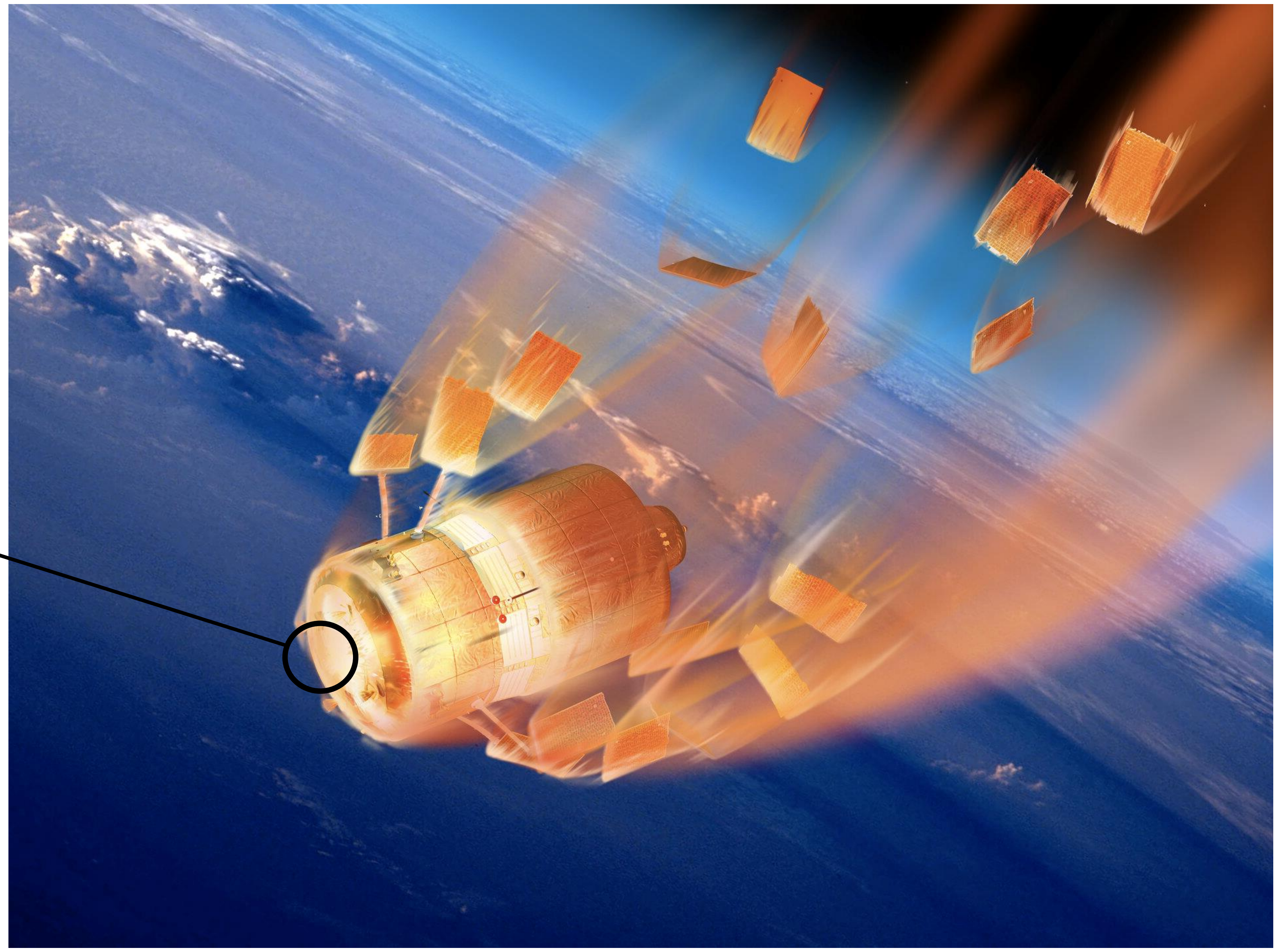
Design for Demise (D4D): From survival to destruction De-obitation, decay, and burn-up



Courtesy: Fagnani (2023)



Design for Demise:
Destroy at minimum heat flux (tumbling)

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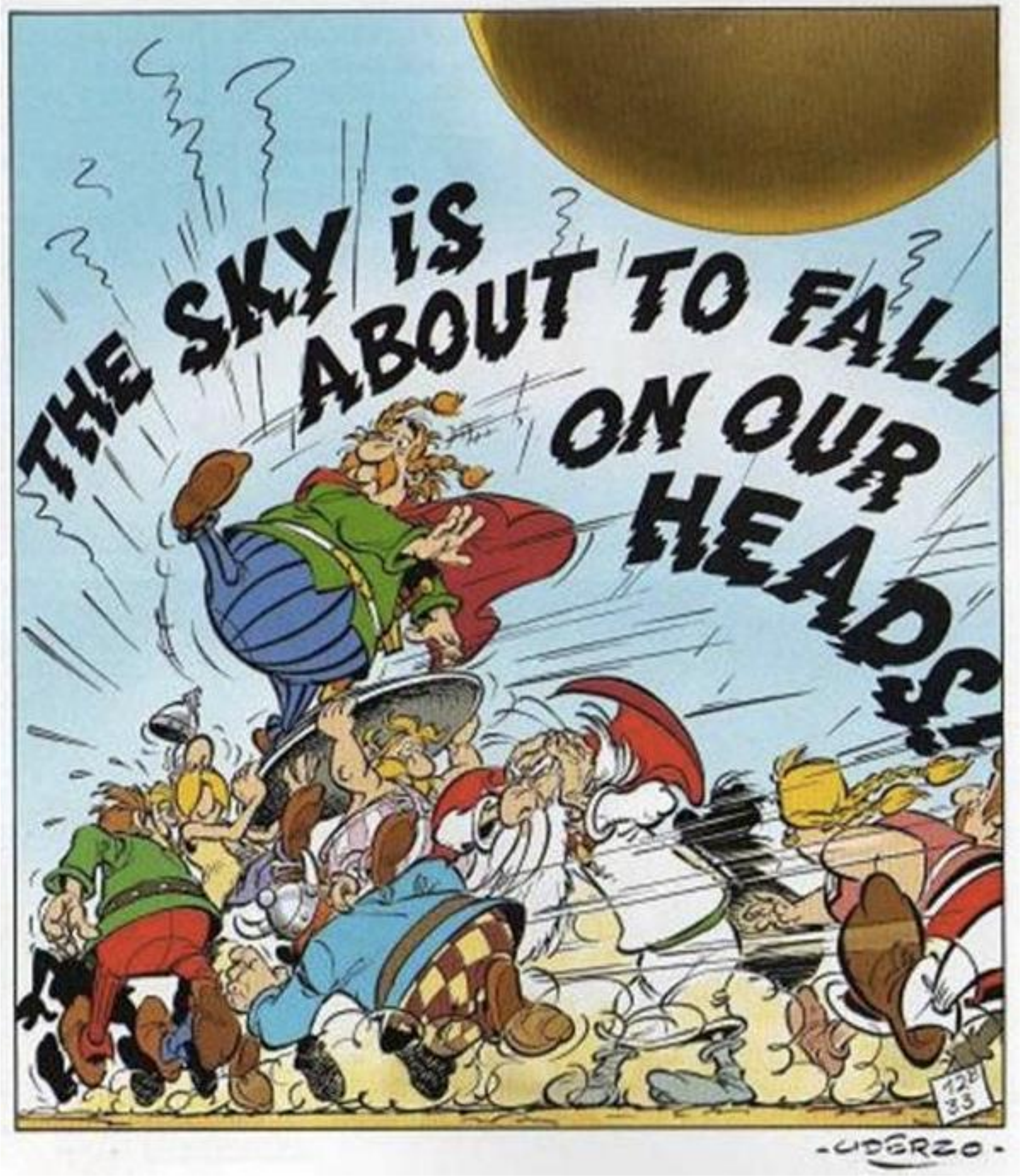
Design for Demise (D4D):
De-obitation, decay, and **burn-up gone wrong**



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Design for Demise (D4D):
De-obitation, decay, and **burn-up gone wrong**

propellant tank of a Delta 2 rocket (1997)
credit: NASA

Delta-V rocket COPV

COPV of the AVUM upper stage (2016)

Agena rocket pressure sphere
Source: Rolf Arvidsson

Ariane V rocket piece
https://www.reddit.com/r/space/comments/17pnk2/a_massive_chunk_of_the_ariane_v_space_rocket/

Delta 2 rocket titanium sphere (1990)

nice collection:
https://eclipsetours.com/paul-maley/space-debris/

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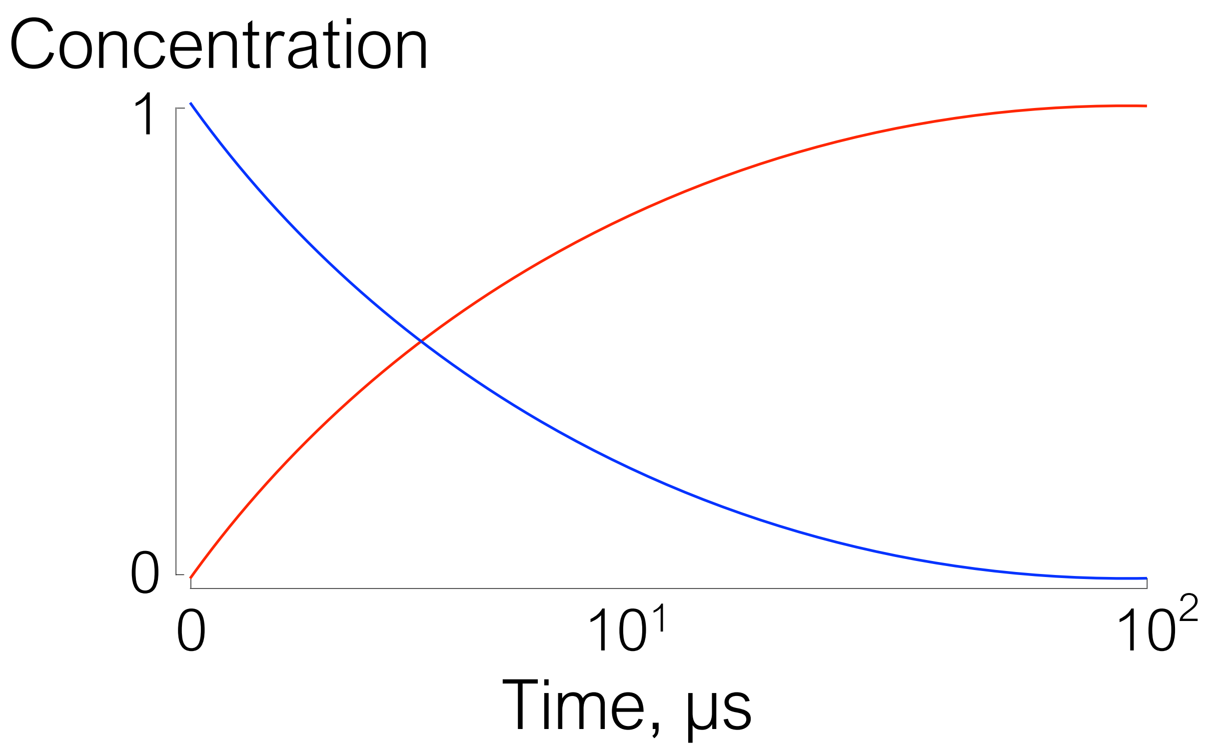
Design for Demise (D4D):
Common tools for engineering prediction

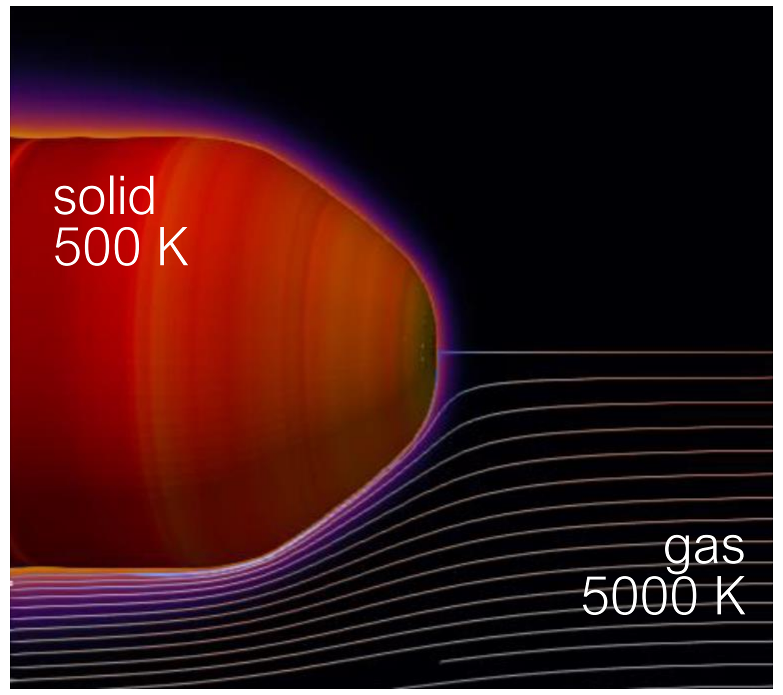


model identification

Physicochemical models

Experimental data

verification



validation

Computational methods

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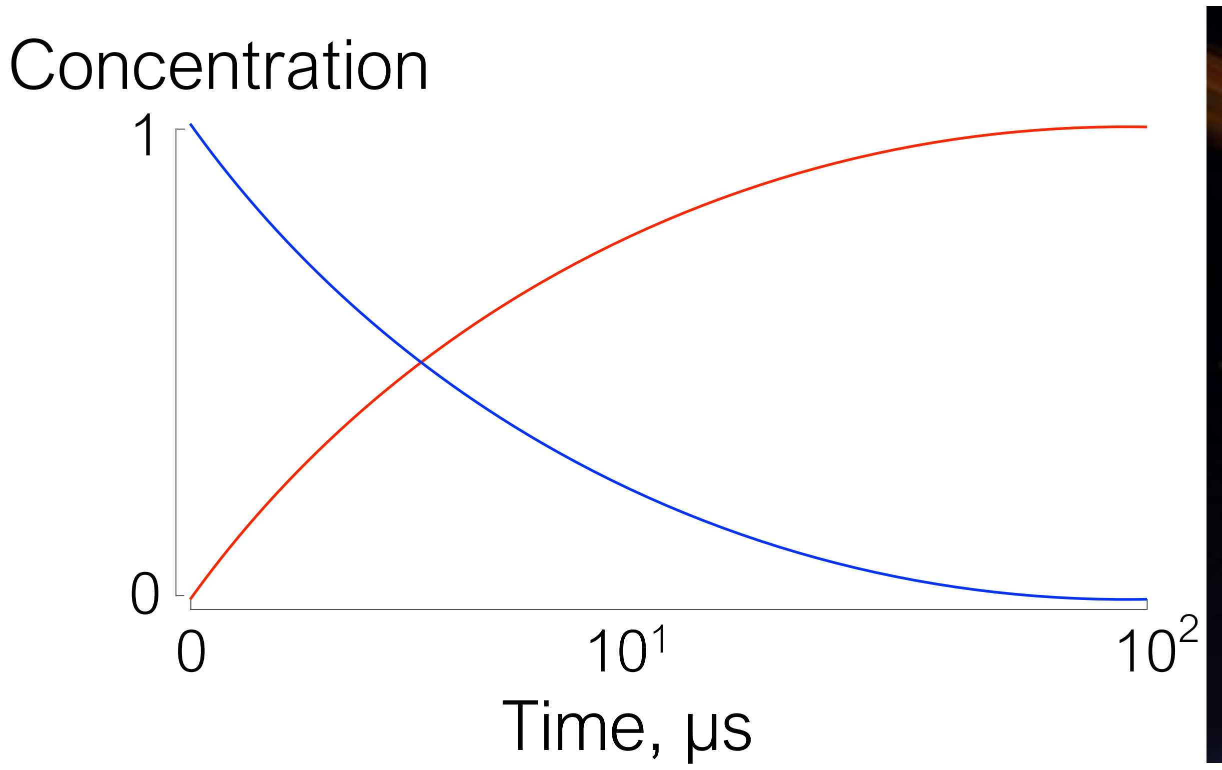
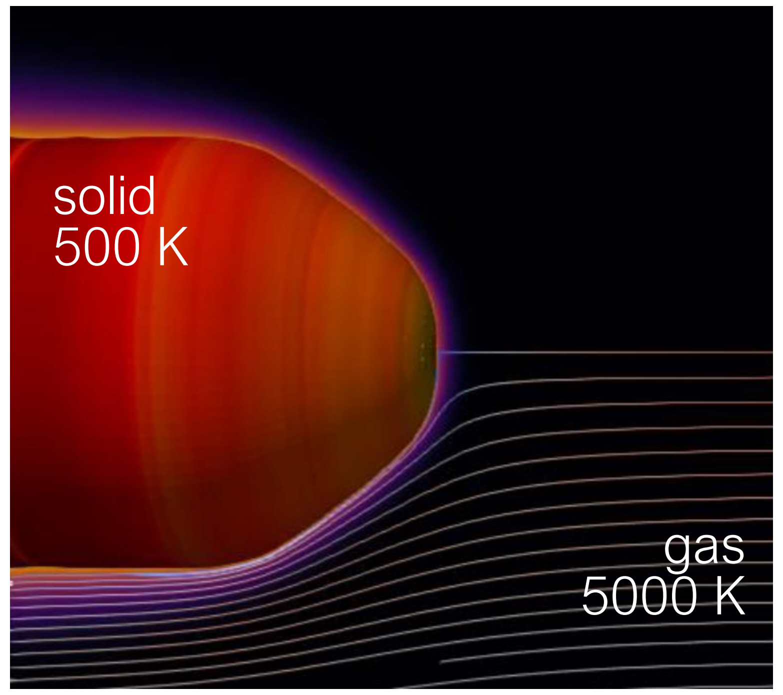
Design for Demise (D4D):
Common tools for engineering prediction



Physicochemical models

Experimental data

verification



validation

Computational methods

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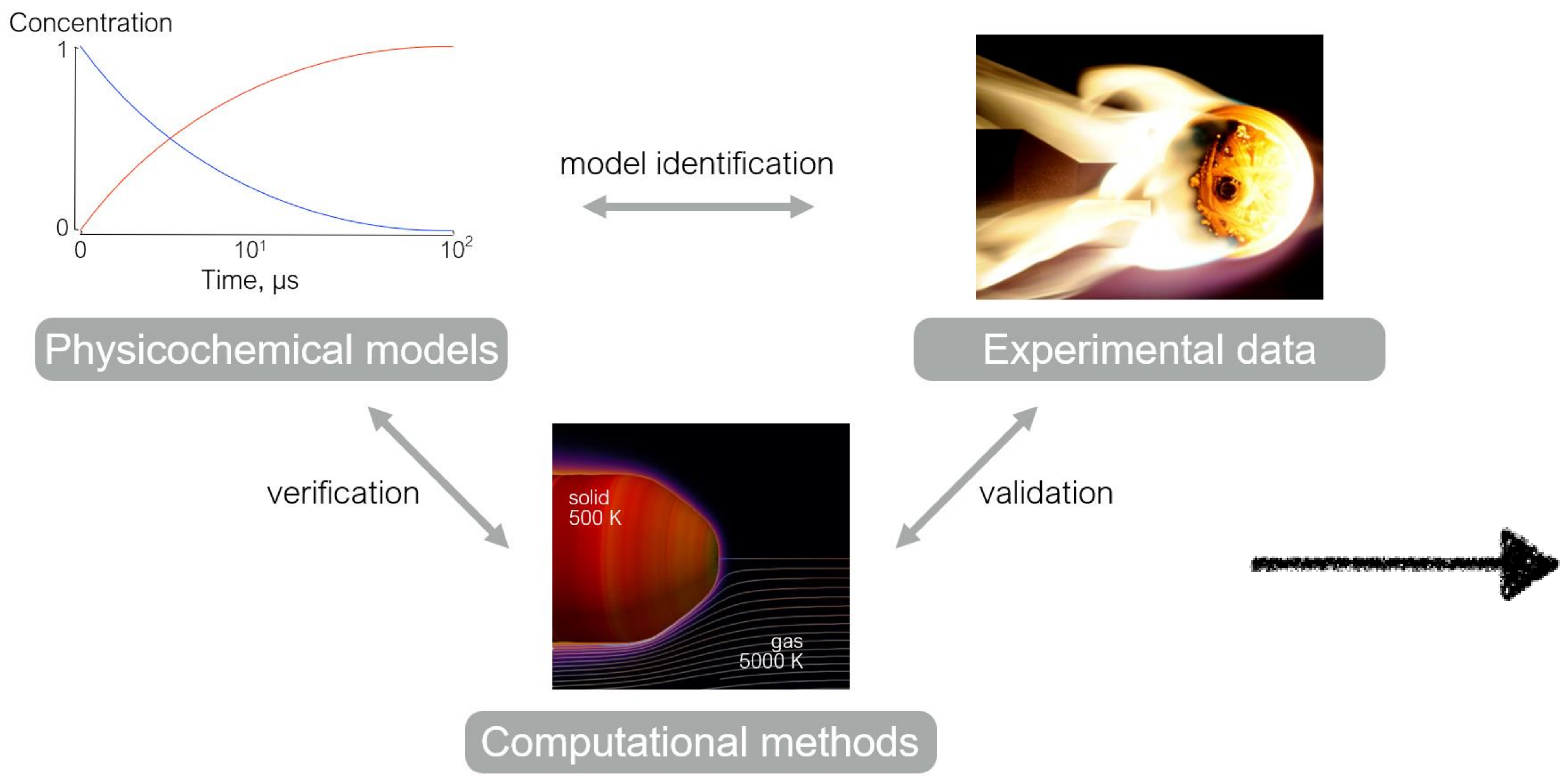
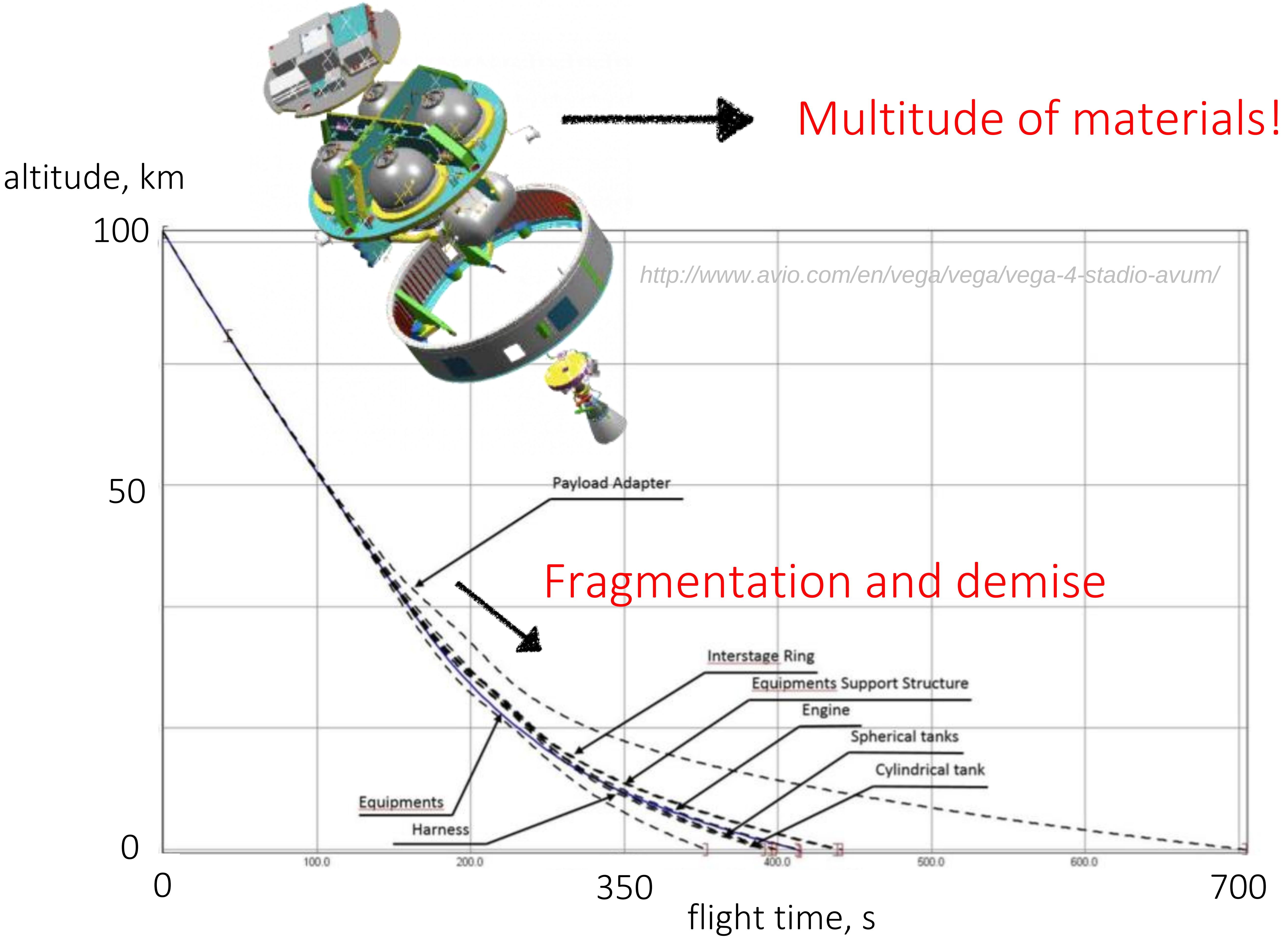
From high-fidelity tools to engineering correlations along the trajectory

AVUM upper module reentry and fragmentation prediction





ESA DRAMA simulation
(Debris Risk Assessment and Mitigation Analysis tool)

von KARMAN INSTITUTE FOR FLUID DYNAMICS

von Karman Institute for Fluid Dynamics

- Non-profit international educational and scientific organization
- Experimental and numerical R&D
- Three departments:
  - Aeronautics and Aerospace
  - Environmental and applied fluid dynamics
  - Turbomachinery & propulsion
- Staff, Post-Doc, PhD, bachelor/master thesis, internship

EDUCATION

Training in Research through Active Research

RESEARCH AND CONSULTING

LECTURE SERIES

von KARMAN INSTITUTE FOR FLUID DYNAMICS

Aeronautics and Aerospace Department

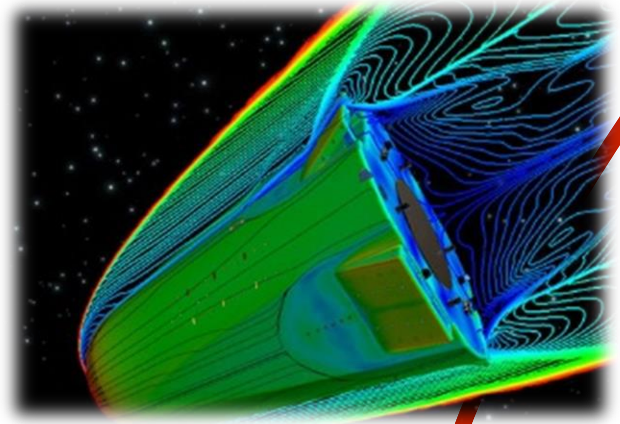
Research expertise groups at VKI

Rarefied and Plasma flows

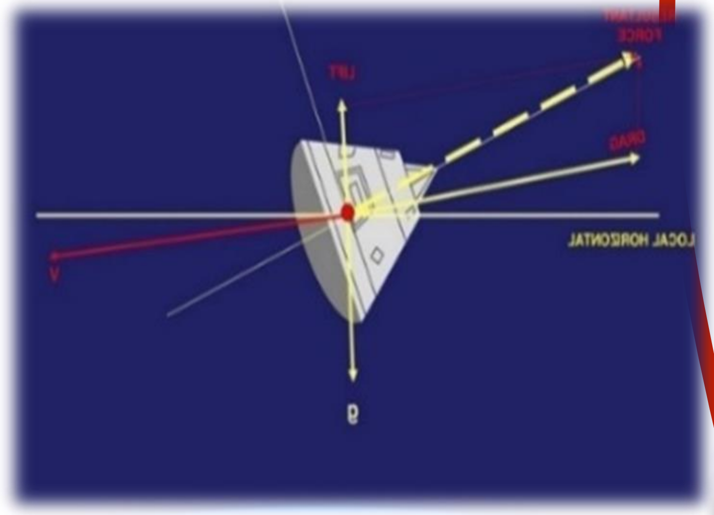
- TPS characterization
- Space debris demise
- Multi-physics modelling
- Non-equilibrium flows
- Uncertainty Quantification

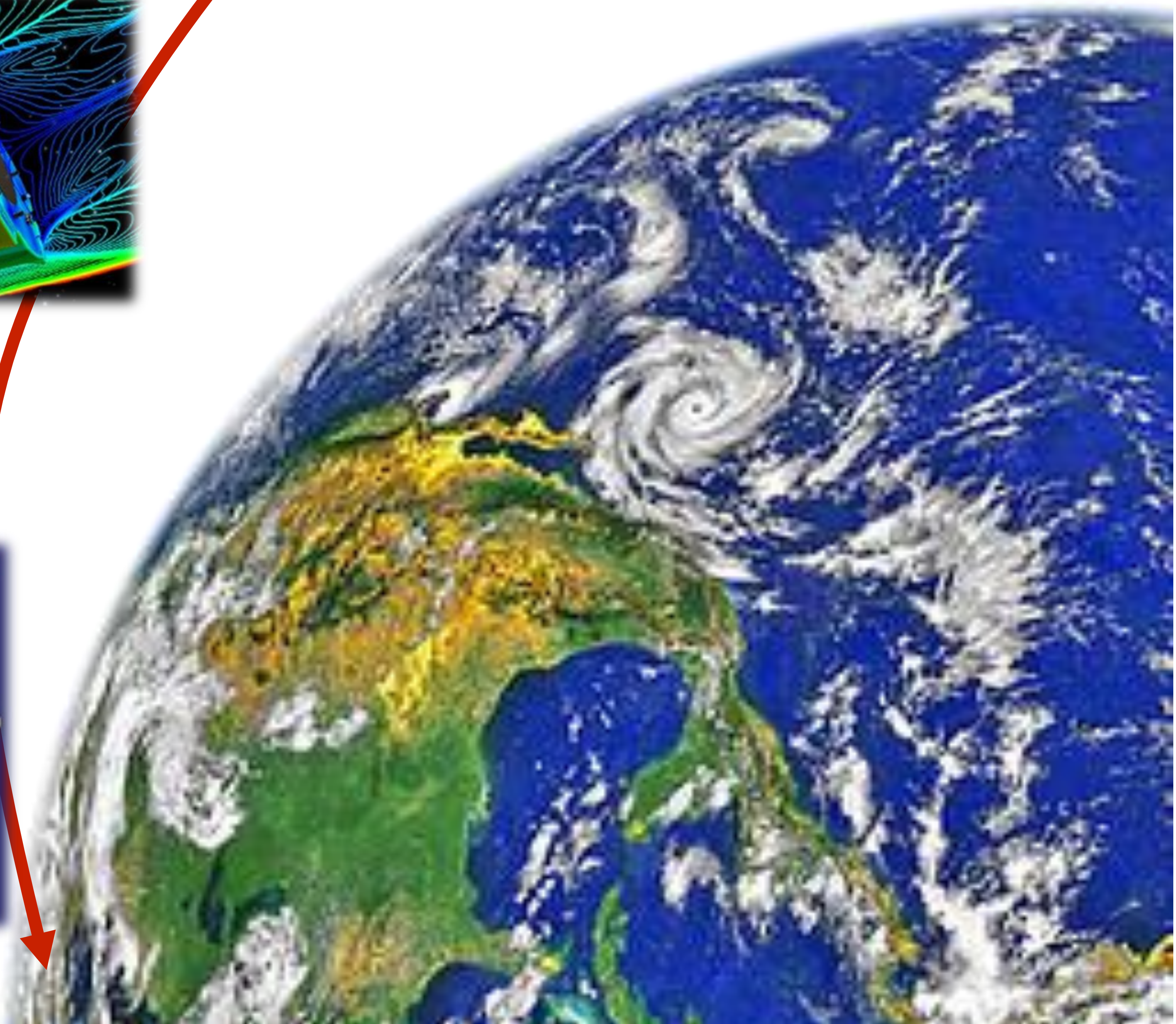
Aerothermochemistry

Aerothermodynamics



Aeronautics & Aerodynamics





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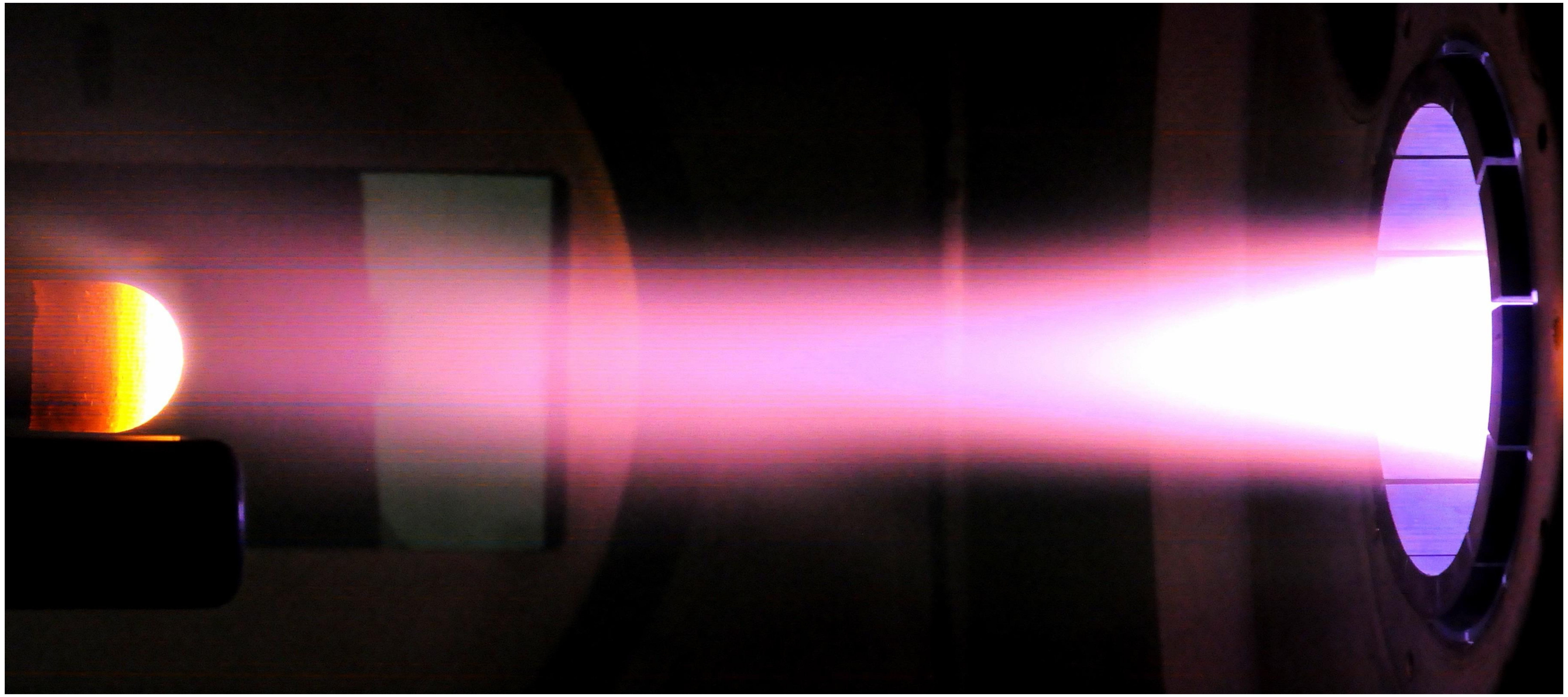
Research Group: Aerothermochemistry



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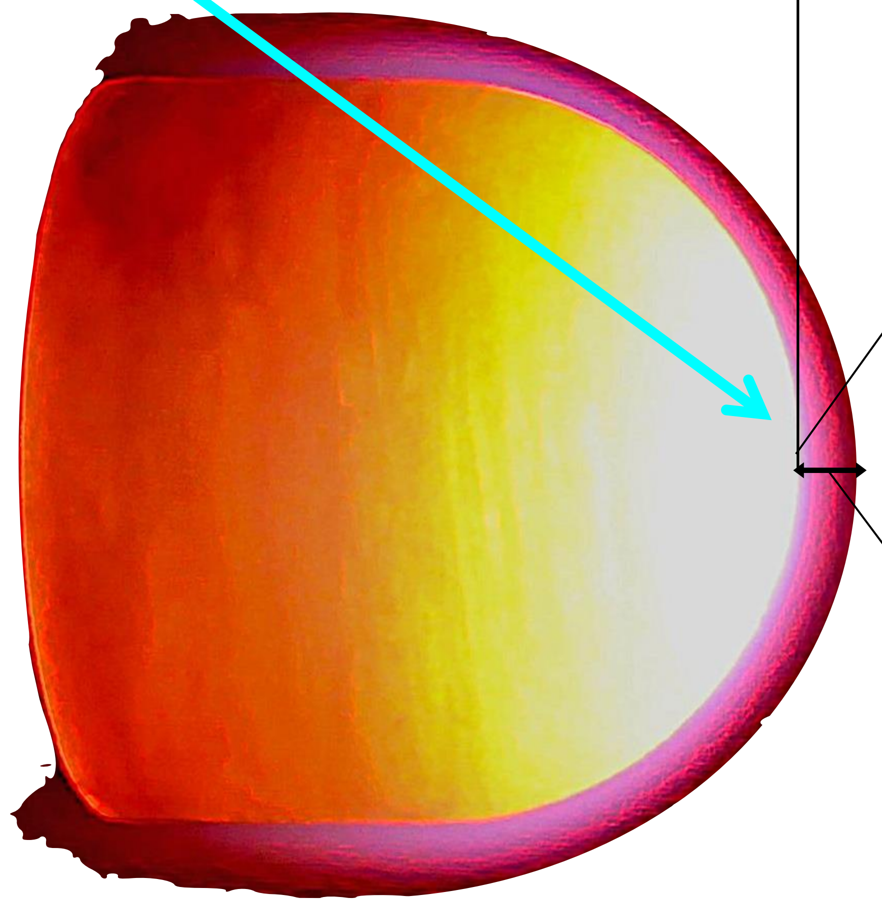
What are we interested in?

Material response

temperatures
melting, vaporisation
recession rate
micro-degradation

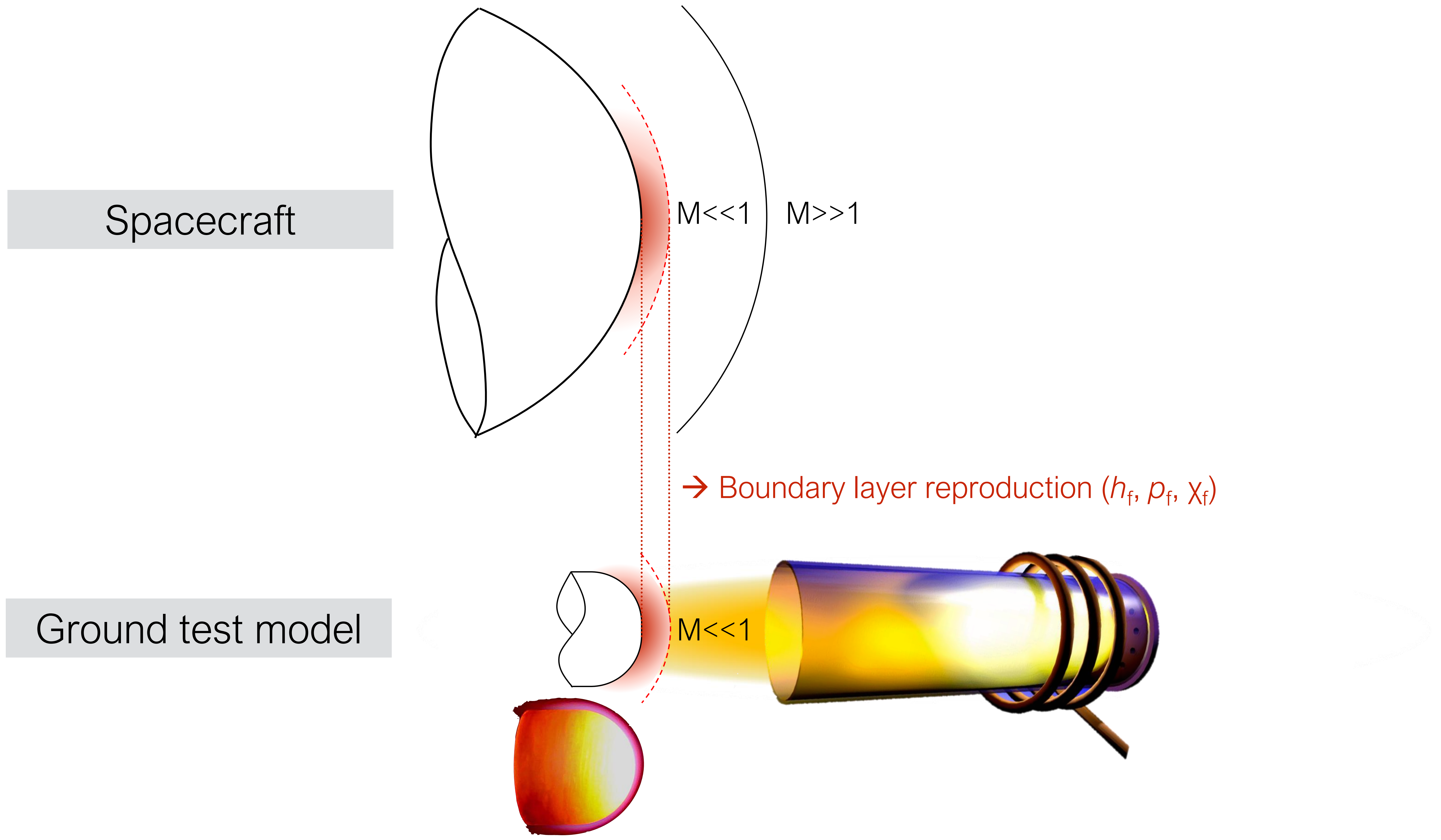
Gas phase

boundary layer temperatures
gas composition
surface reaction products
boundary layer size



1.2 MW Inductively Coupled Plasmatron

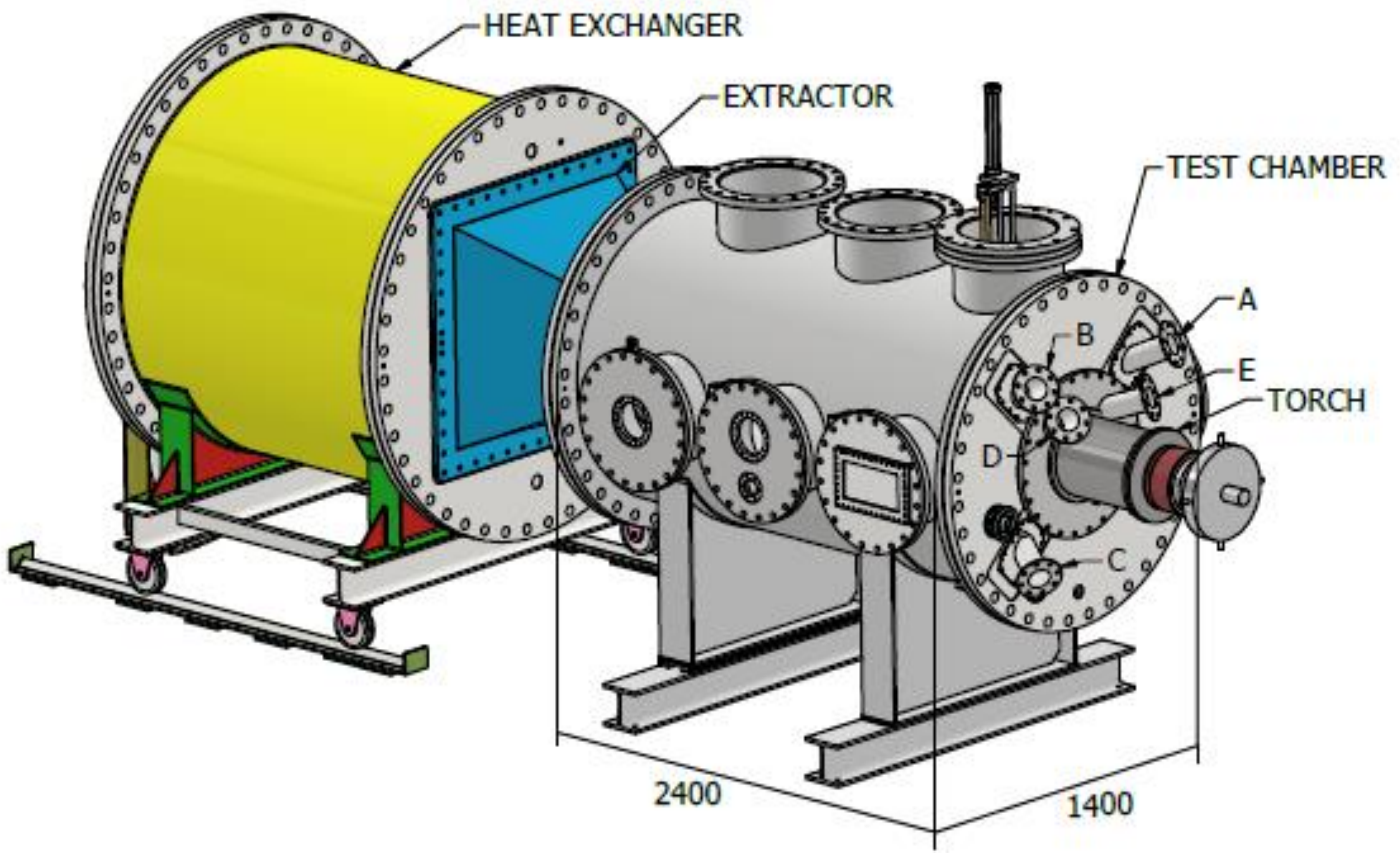
Subsonic plasma flow to recreate a high temperature, reactive boundary layer

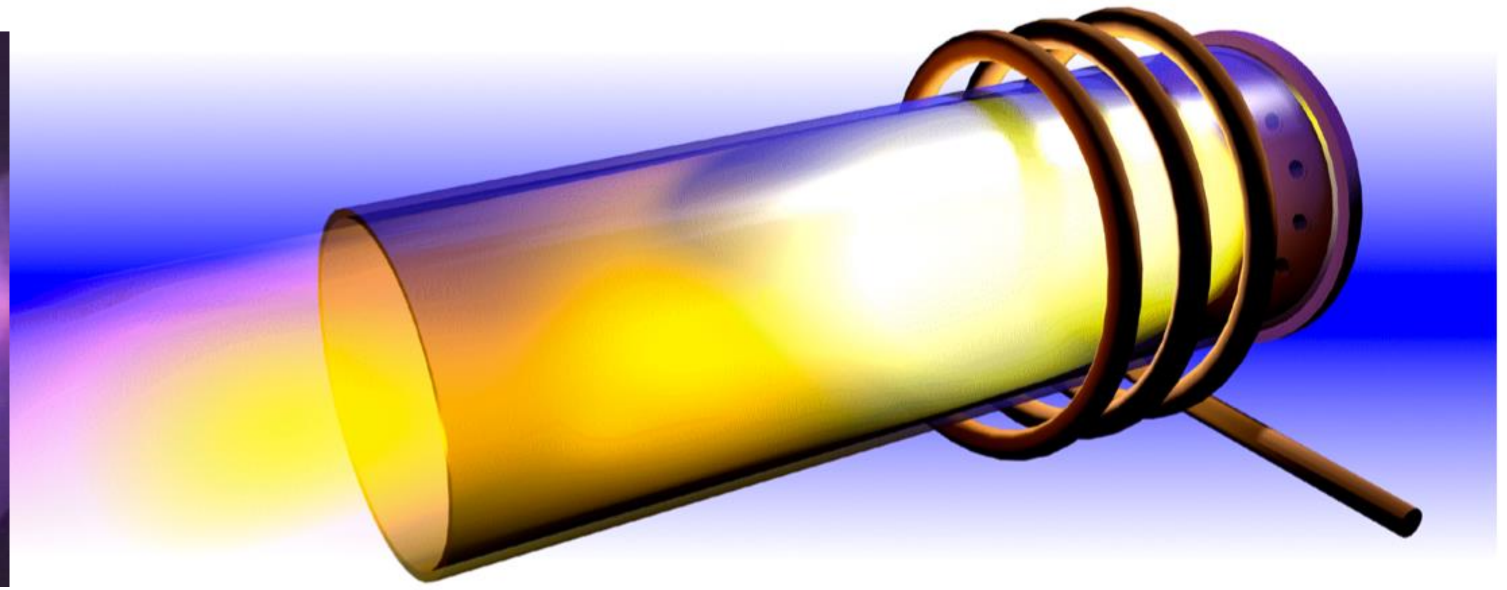


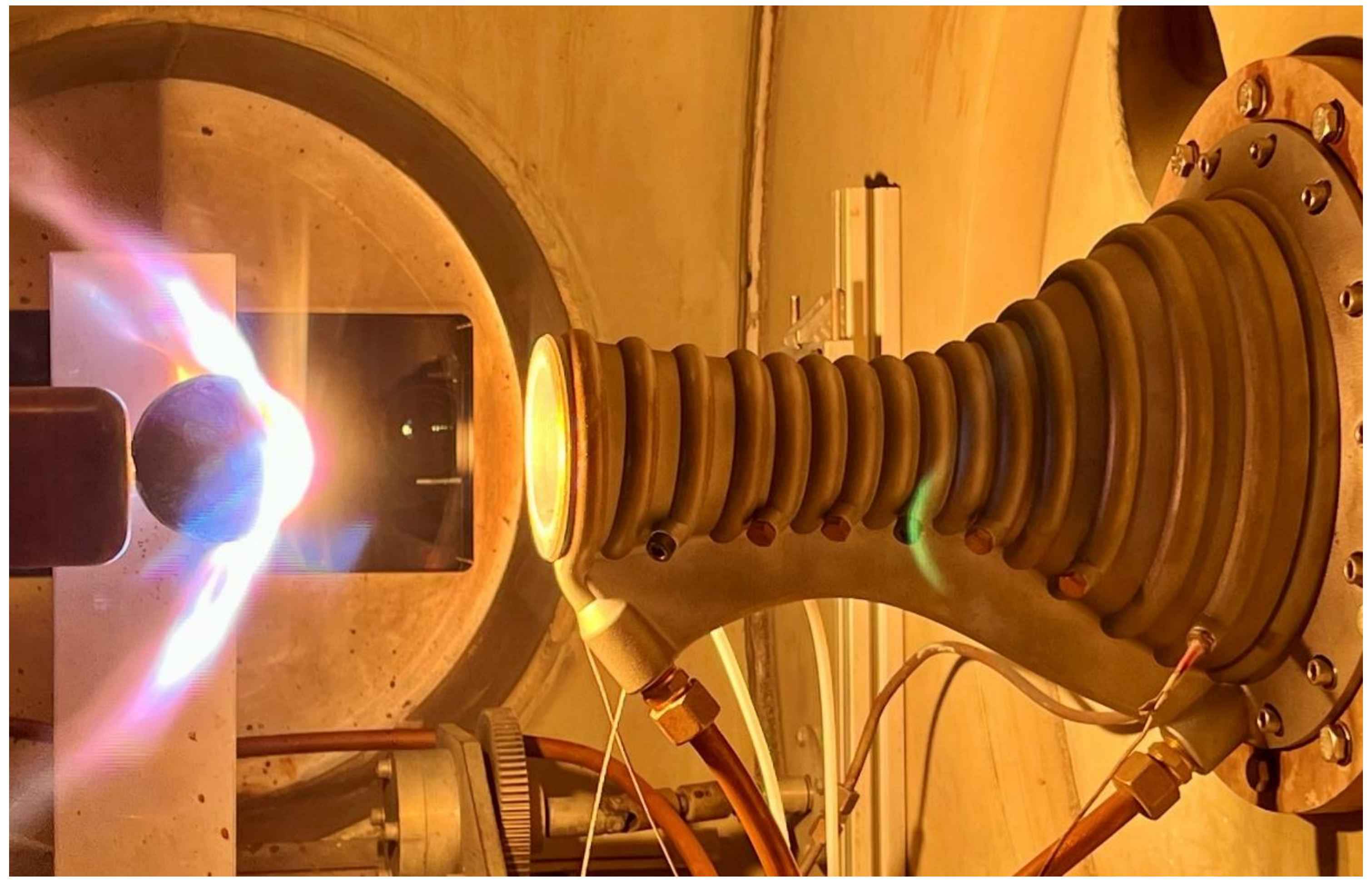
Kolesnikov. Fluid Dyn., 28(1):131–137, 1993.

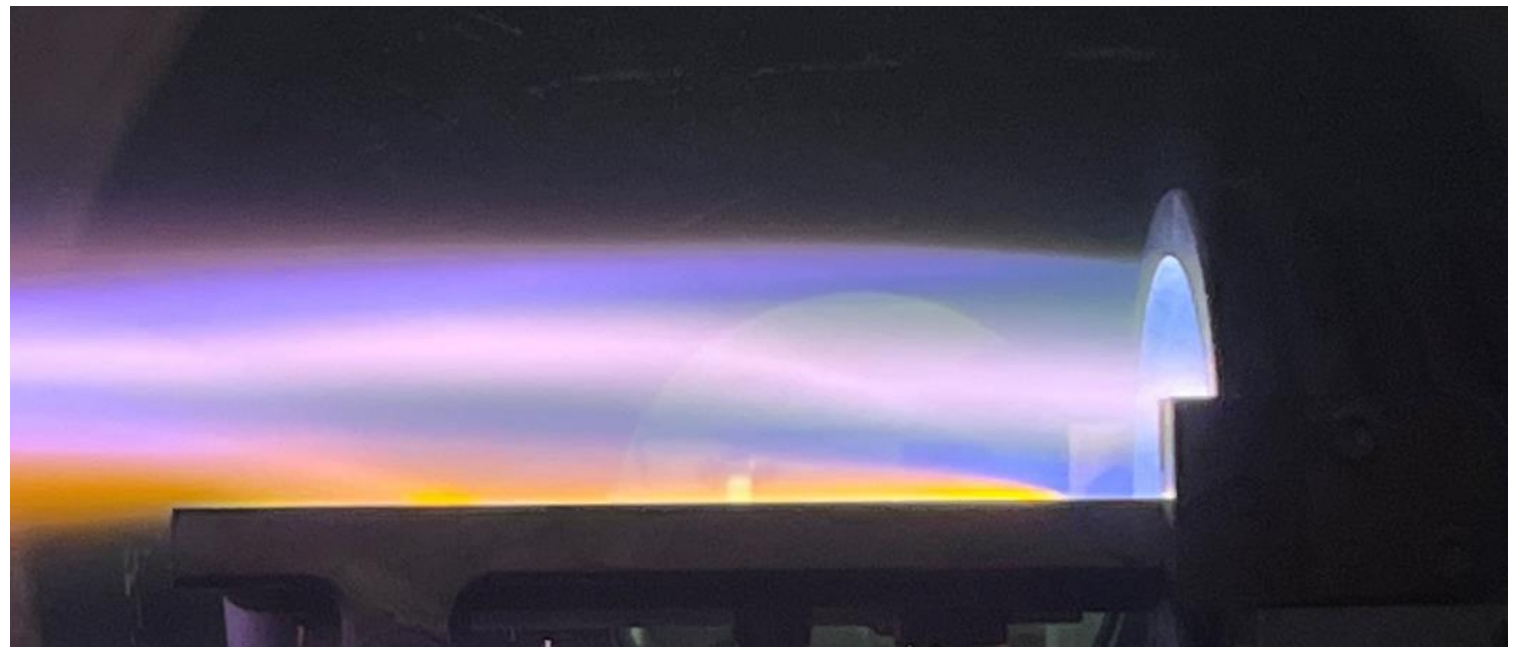
1.2 MW Inductively Coupled Plasmatron

Plasma-flow test bed to simulate reentry







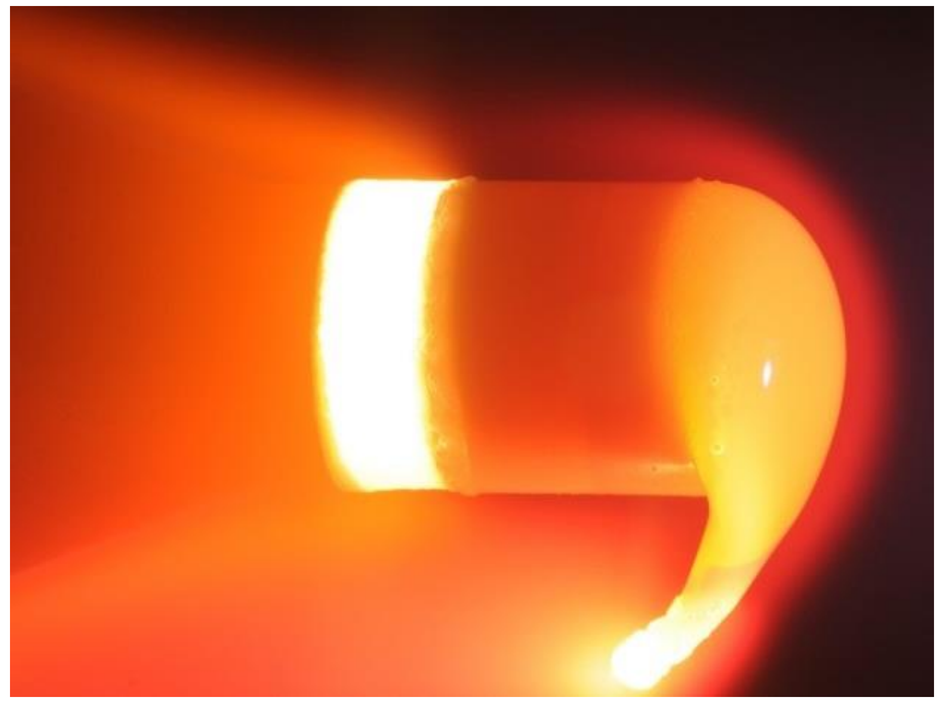


Gas	air, N_2, CO_2, Ar
Power	1.2 MW
Max. heat flux	15 MW/m^2
Pressure	10 hPa - 400 hPa

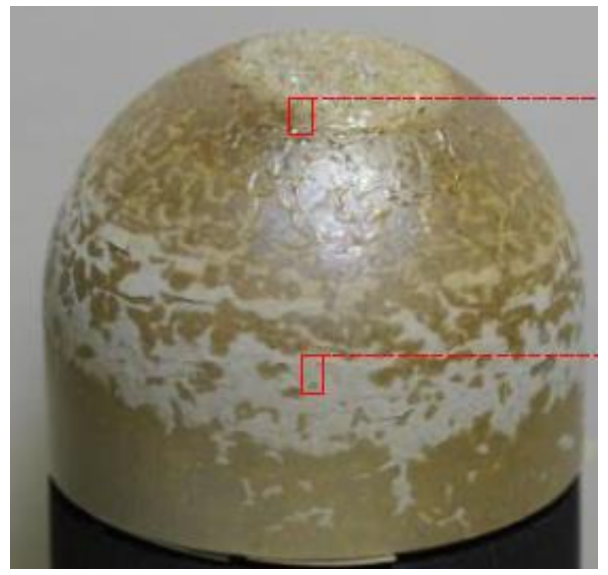
Which materials can demise?

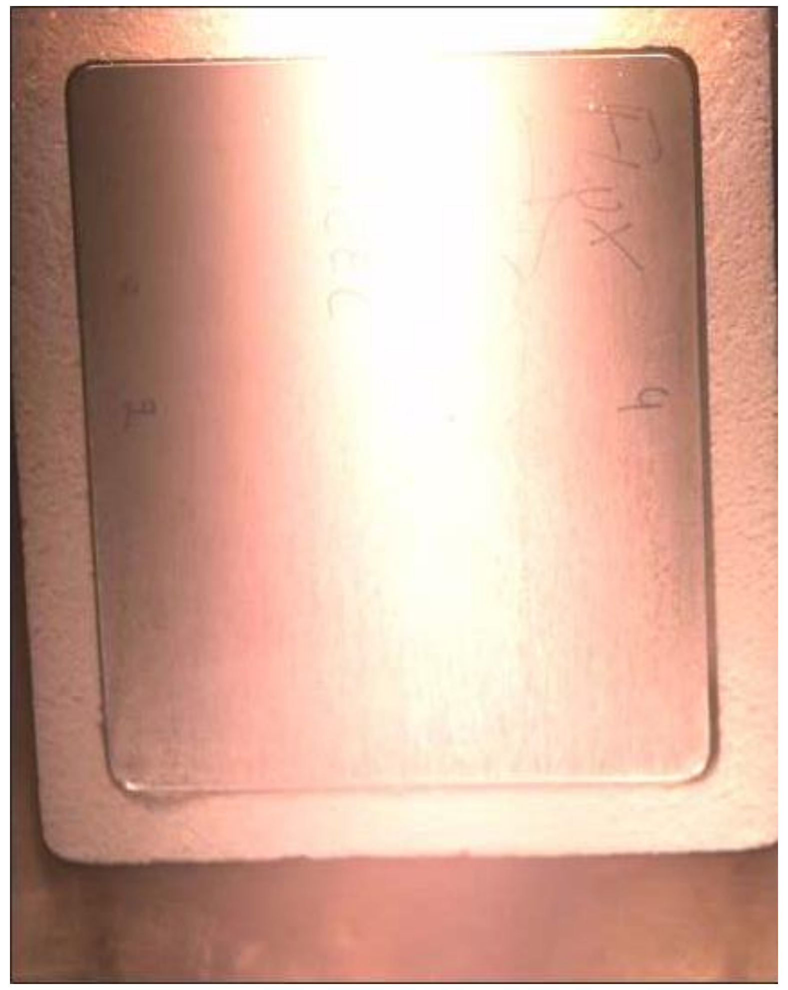
→ many are problematic (alloys, silicates, CFRPs,…)

Quartz ZERODUR®



Titanium Steel



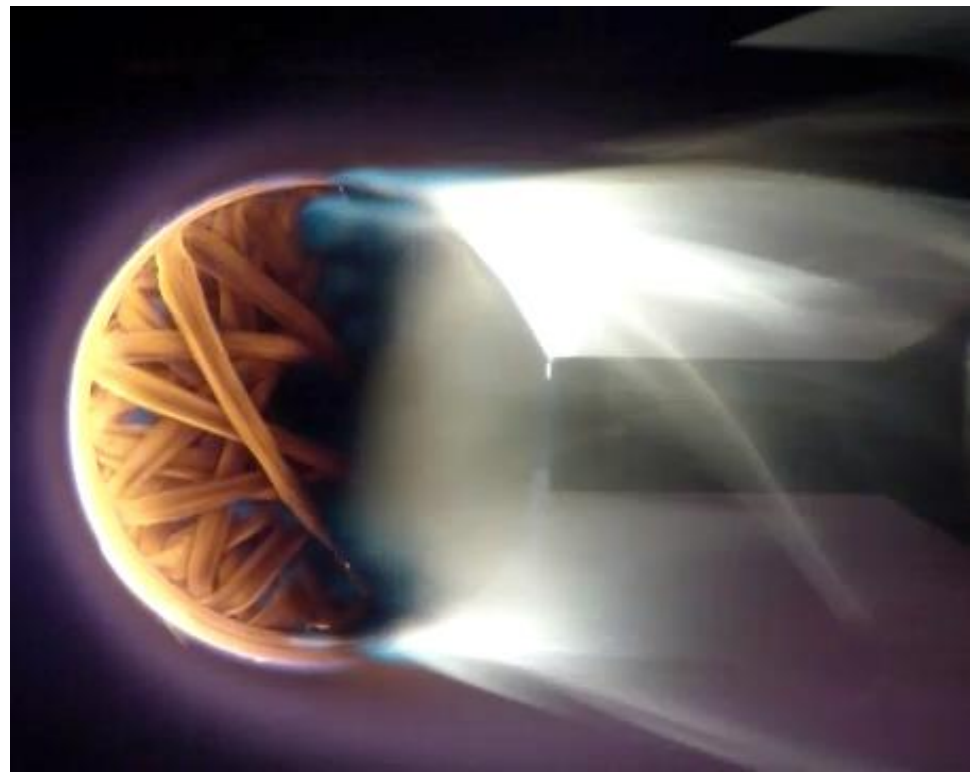


oxidation & freezing

CFRP

slow delamination

COPV



ABLACCOD GSTP
(Cenaero)
behaves like a TPS

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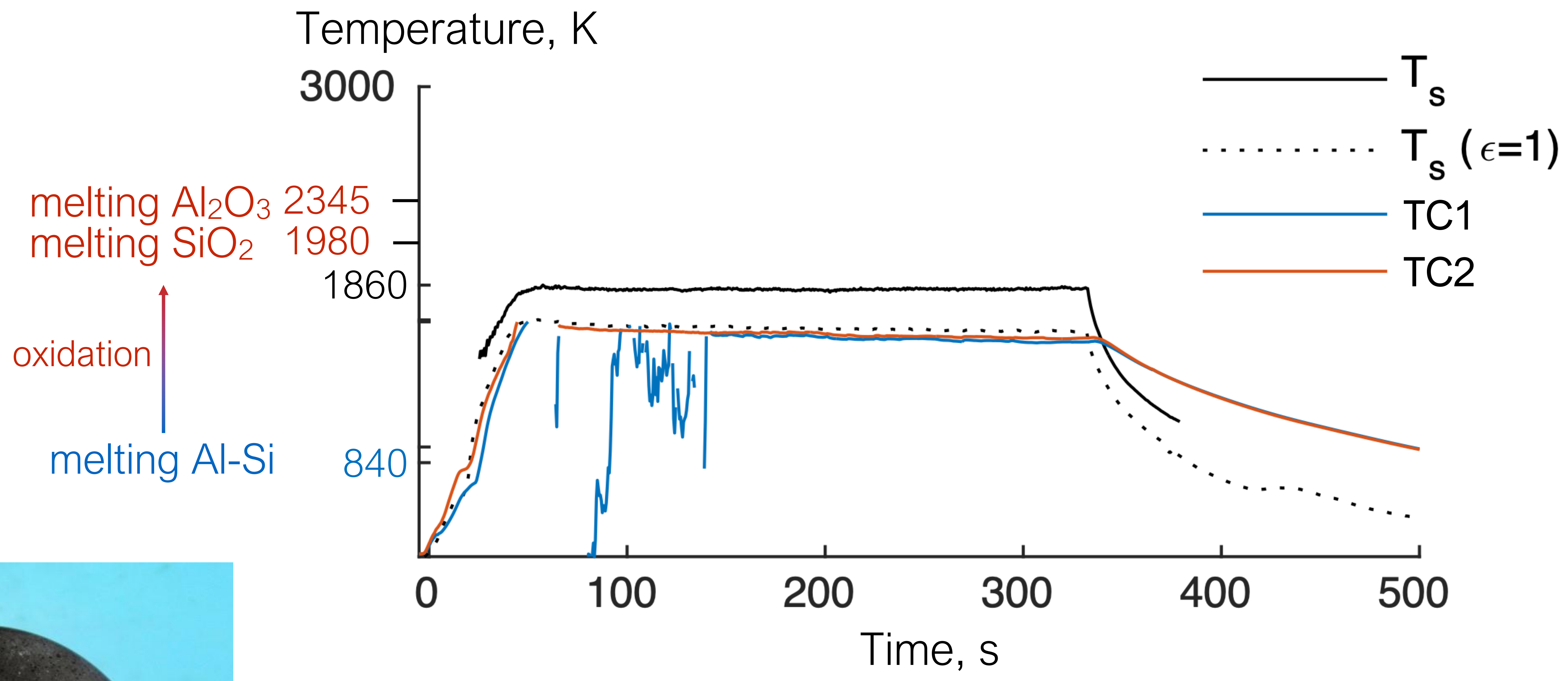
What about our *standard* satellite building material?

Even aluminum silicate “freezes” again after oxidation (in the laboratory…)



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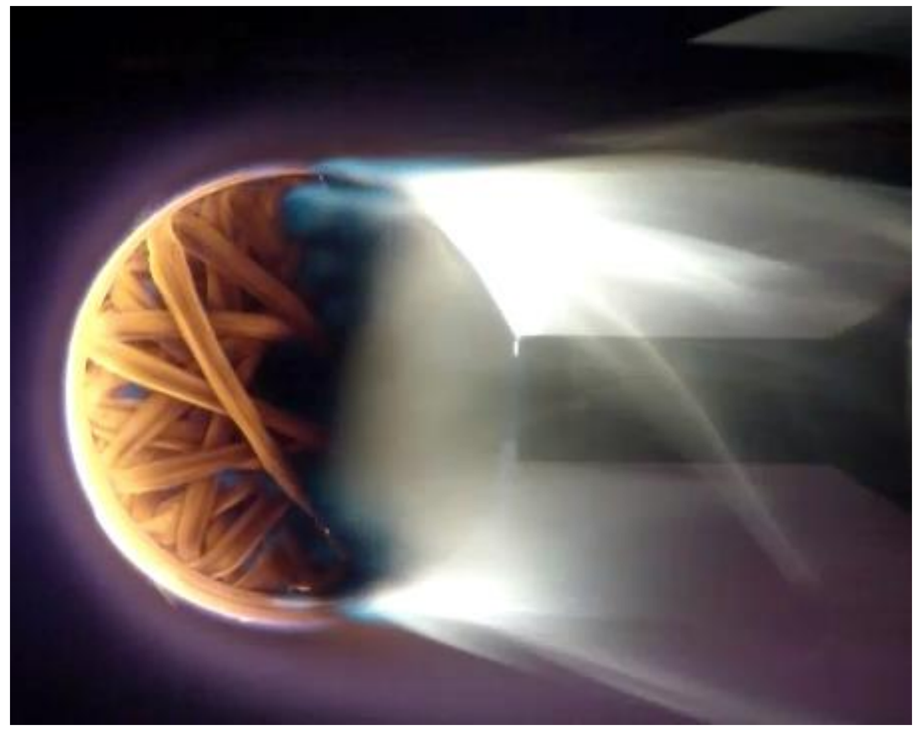
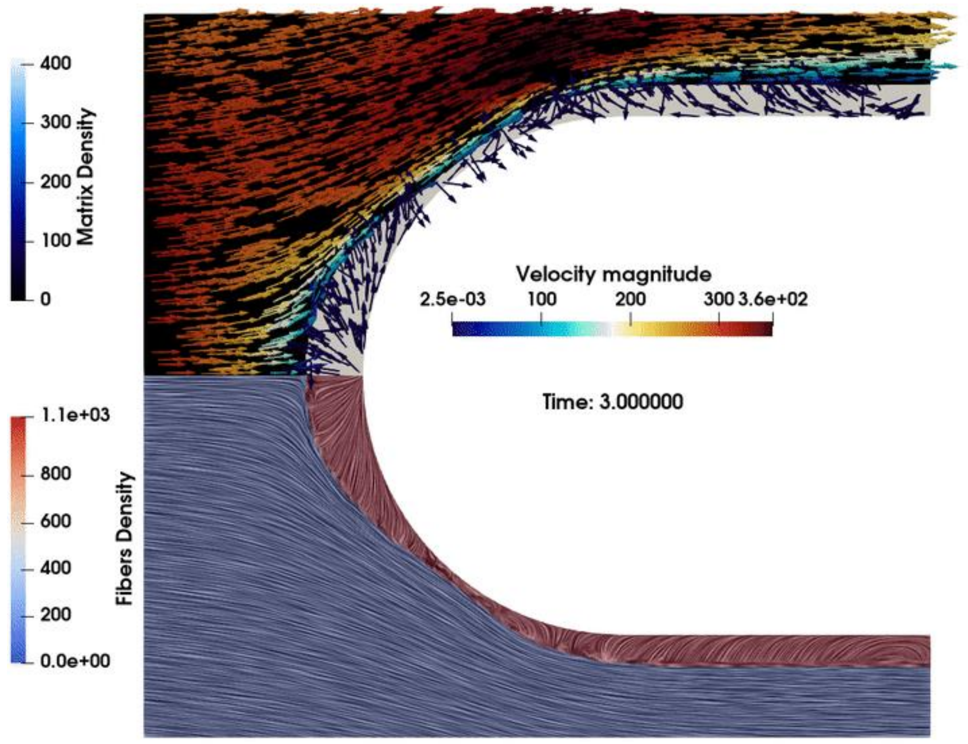
To-Do list for a *Zero Debris* approach

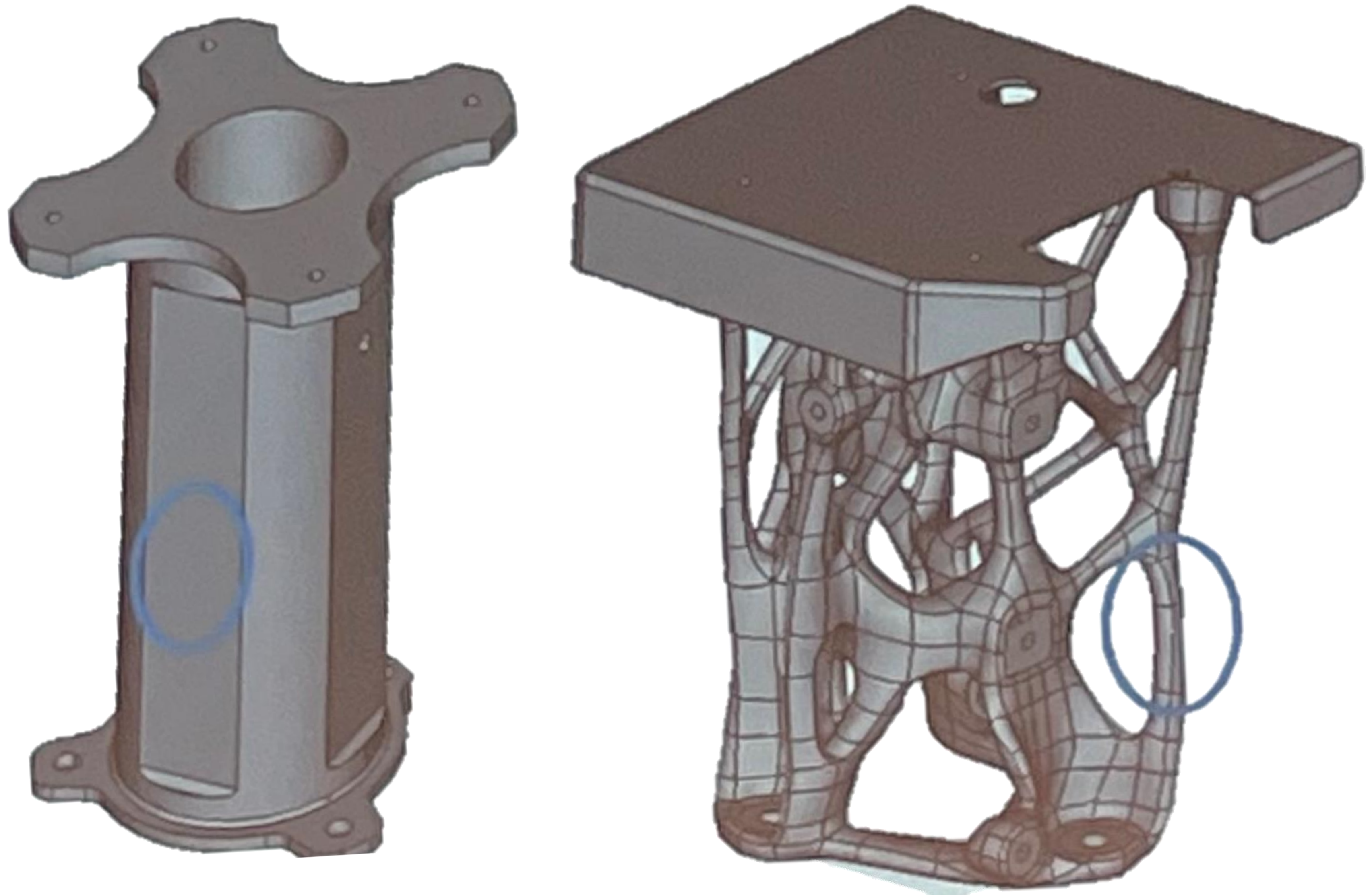
In general: Mutual agreement and definition of zero debris charter

More research
(experimental & numerical)





Redesign, especially metallic structures
(less thermal mass, more heated surface)
→ Additive Manufacturing



S. Galera, CNES

Adoption by industry!

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Academic programs at VKI

Your possibilities:

Short-training internship (3-6 months): undergraduate or visiting PhD

Final year and master thesis (3-6 months)

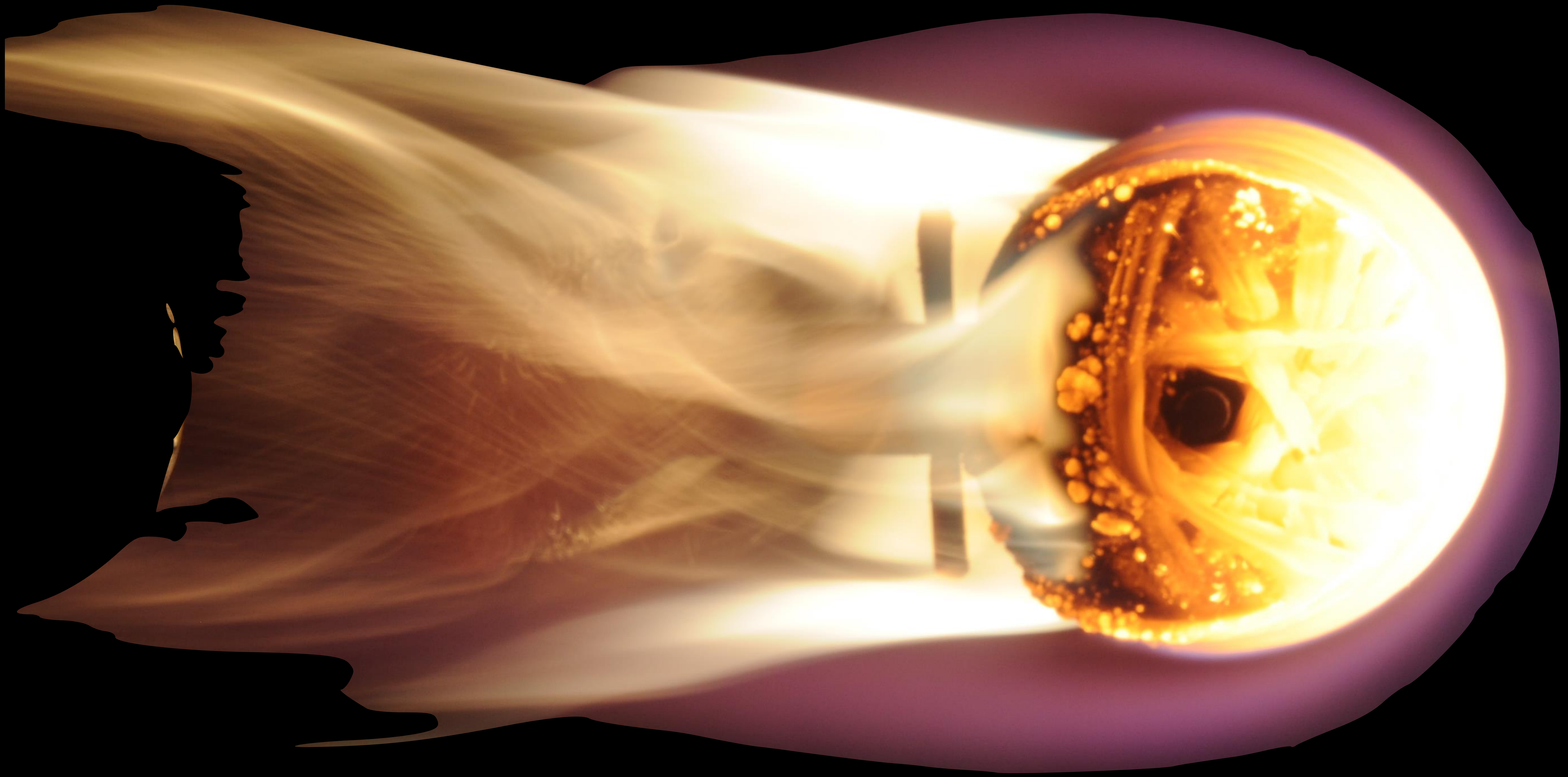
Research Master in Fluid Dynamics (master-after-master, October – June)
(30-35 students)

Doctoral program (together with European University)
(40-60 students)

Post-doctoral program

https://www.vki.ac.be/
bernd.helber@vki.ac.be

Visit our booth!



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