The Clean Space initiative to support long-term sustainability of outer space activities

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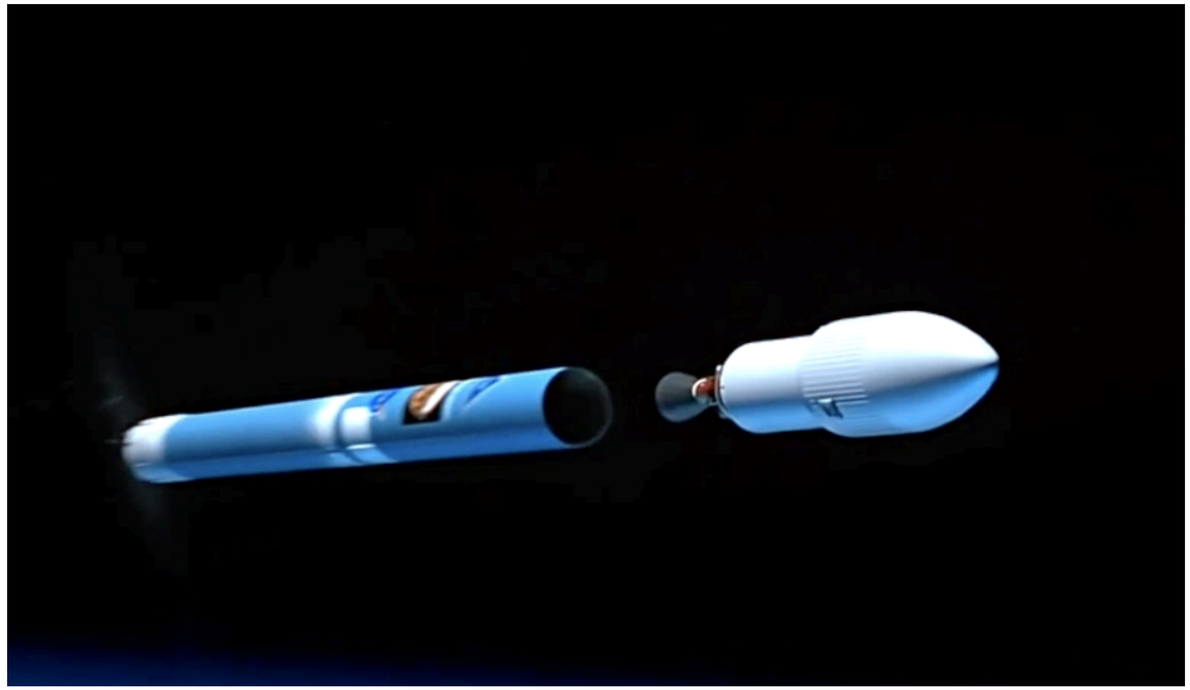
Aeronautics and Aerospace Department
von Karman Institute for Fluid Dynamics, Belgium

Credit: iStock illustration

60 years of space flight without much reusability

courtesy: NASA/JPL

60 years of space flight without much reusability



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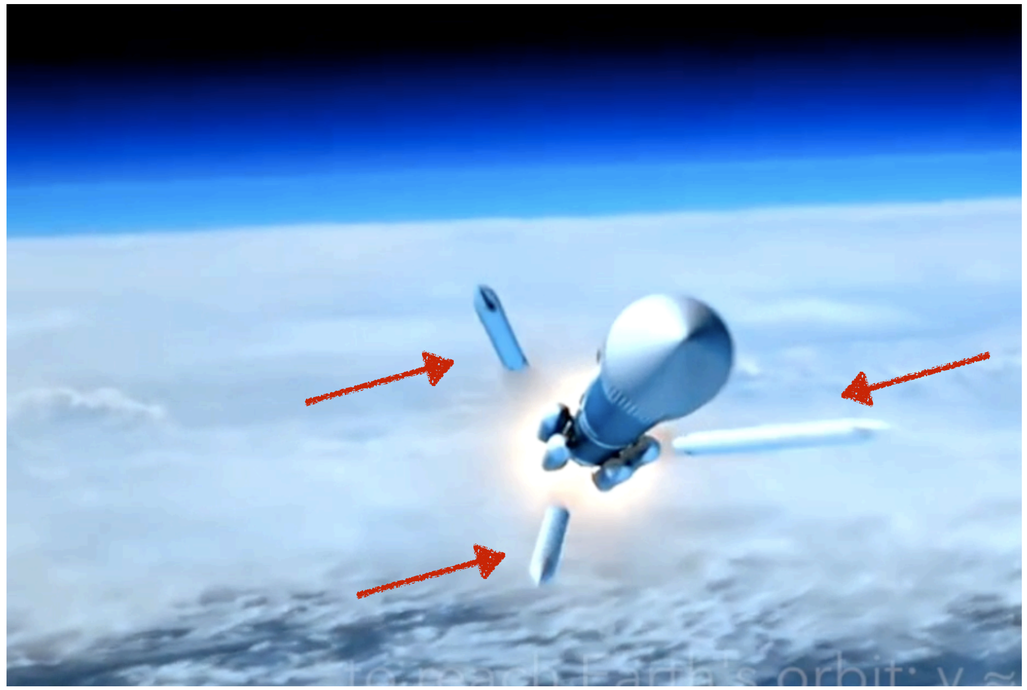

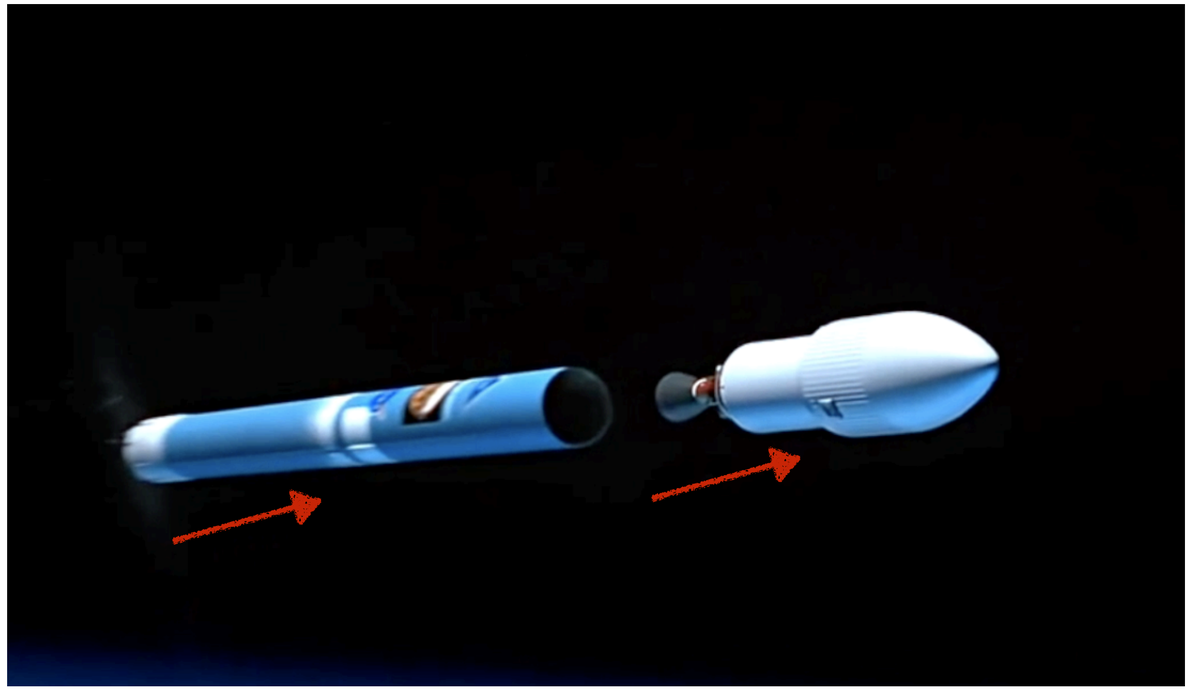

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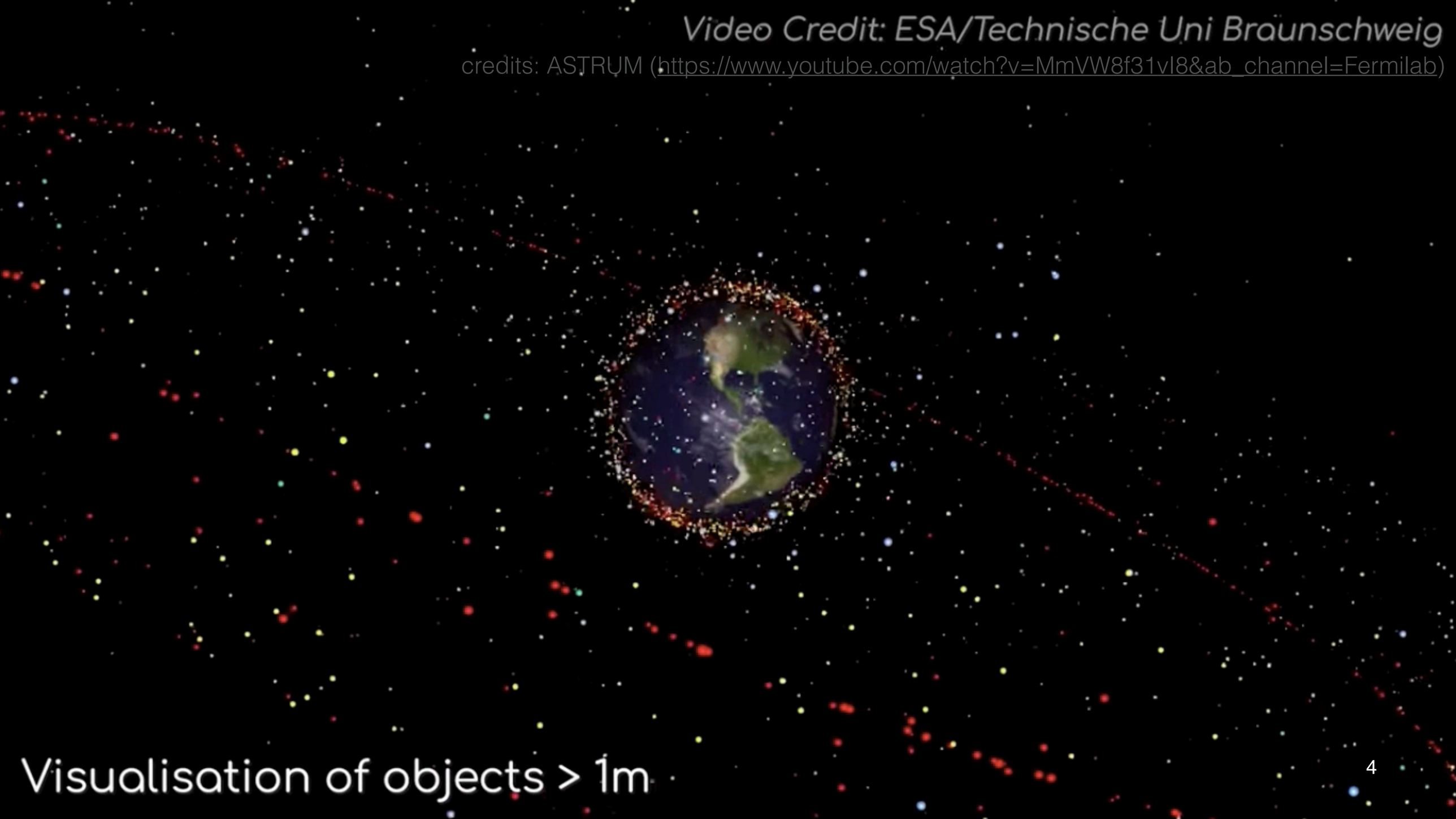
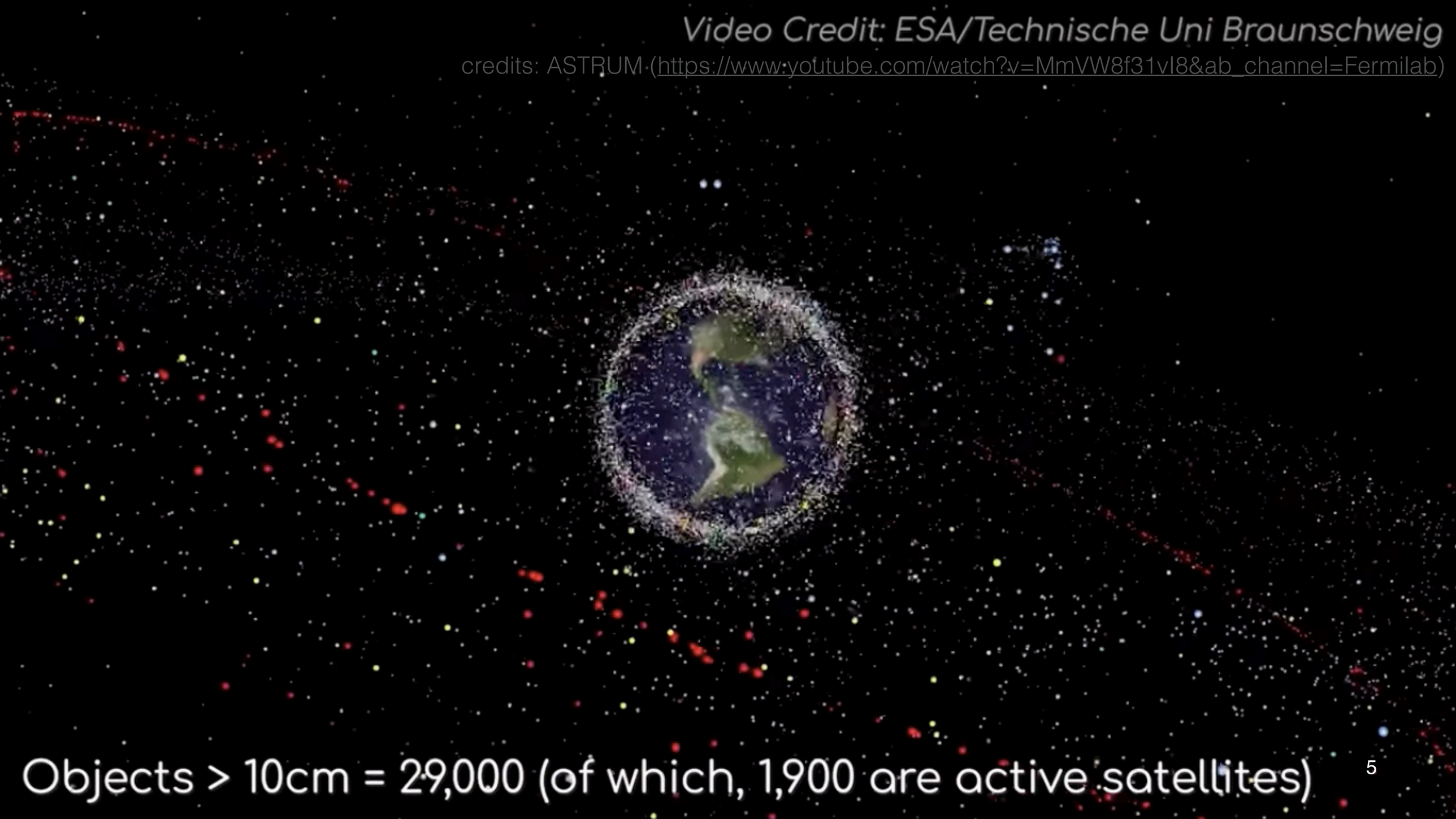

Video Credit: ESA/Technische Uni Braunschweig
credits: ASTRUM (https://www.youtube.com/watch?v=MmVW8f31vI8&ab_channel=Fermilab)
Visualisation of objects > 1m


Video Credit: ESA/Technische Uni Braunschweig
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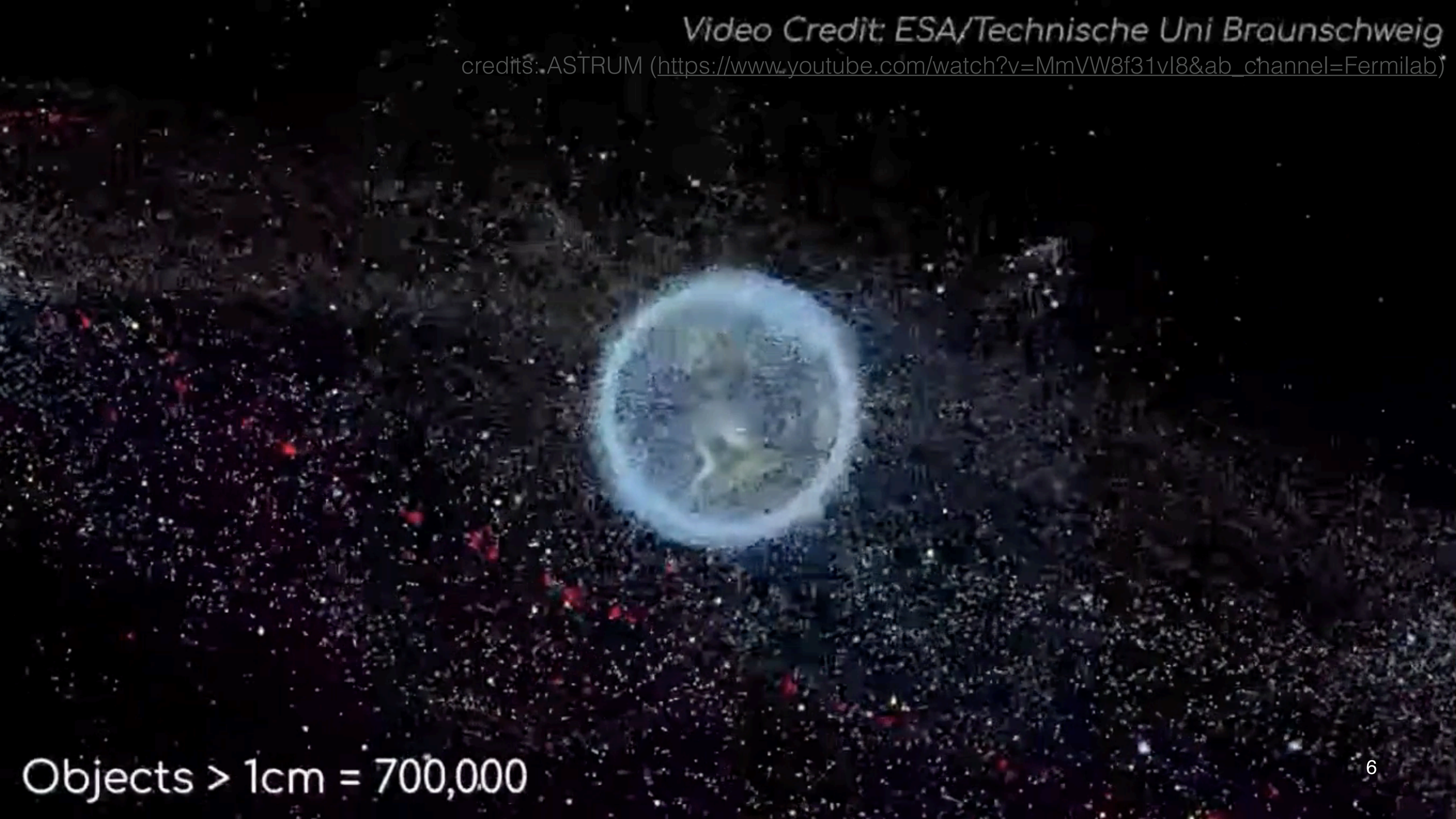
Objects > 10cm = 29,000 (of which, 1,900 are active satellites)



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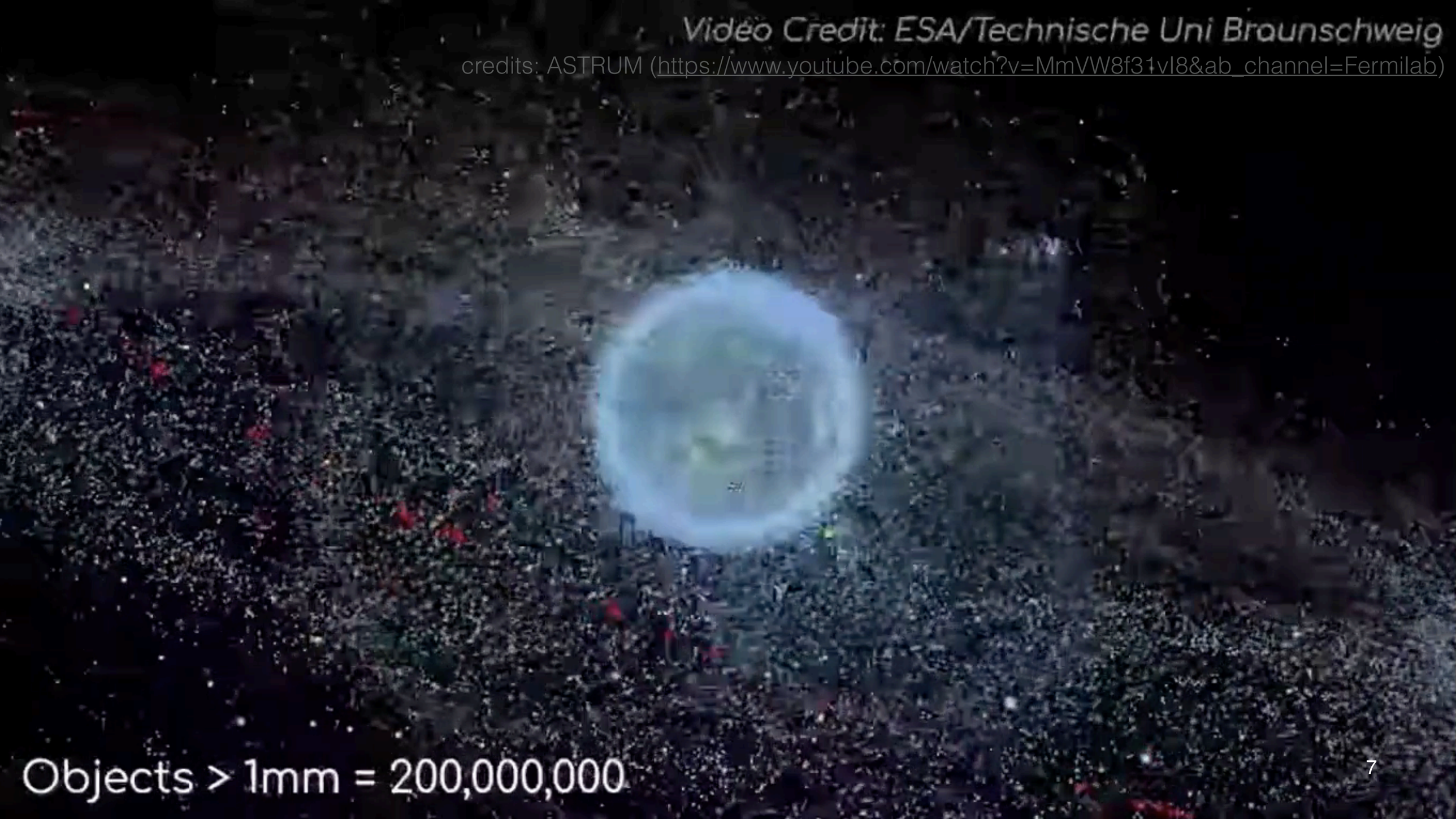

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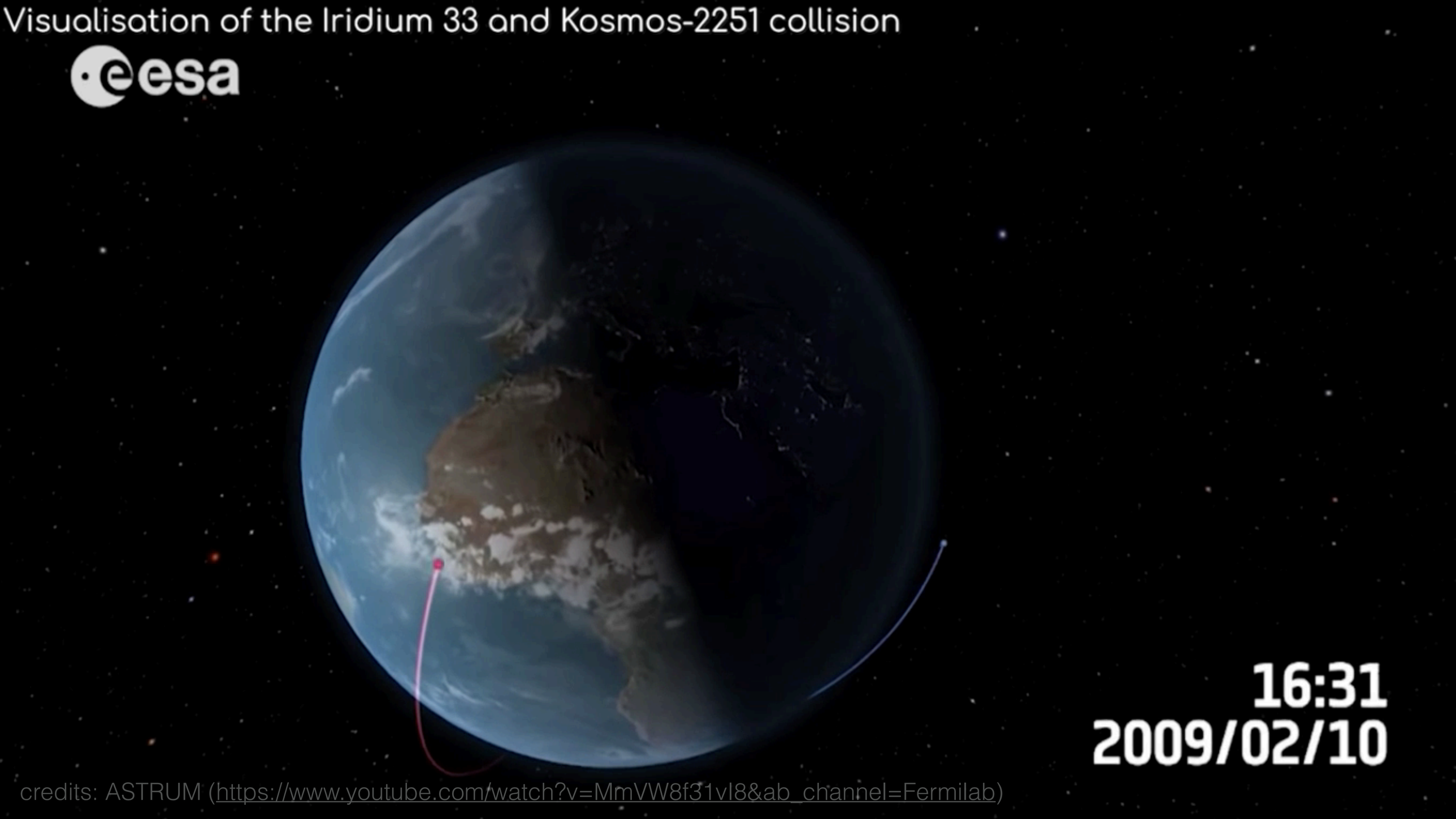
Visualisation of the Iridium 33 and Kosmos-2251 collision
esa
16:31
2009/02/10
credits: ASTRUM (https://www.youtube.com/watch?v=MmVW8f31vI8&ab_channel=Fermilab)


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esa
16:59
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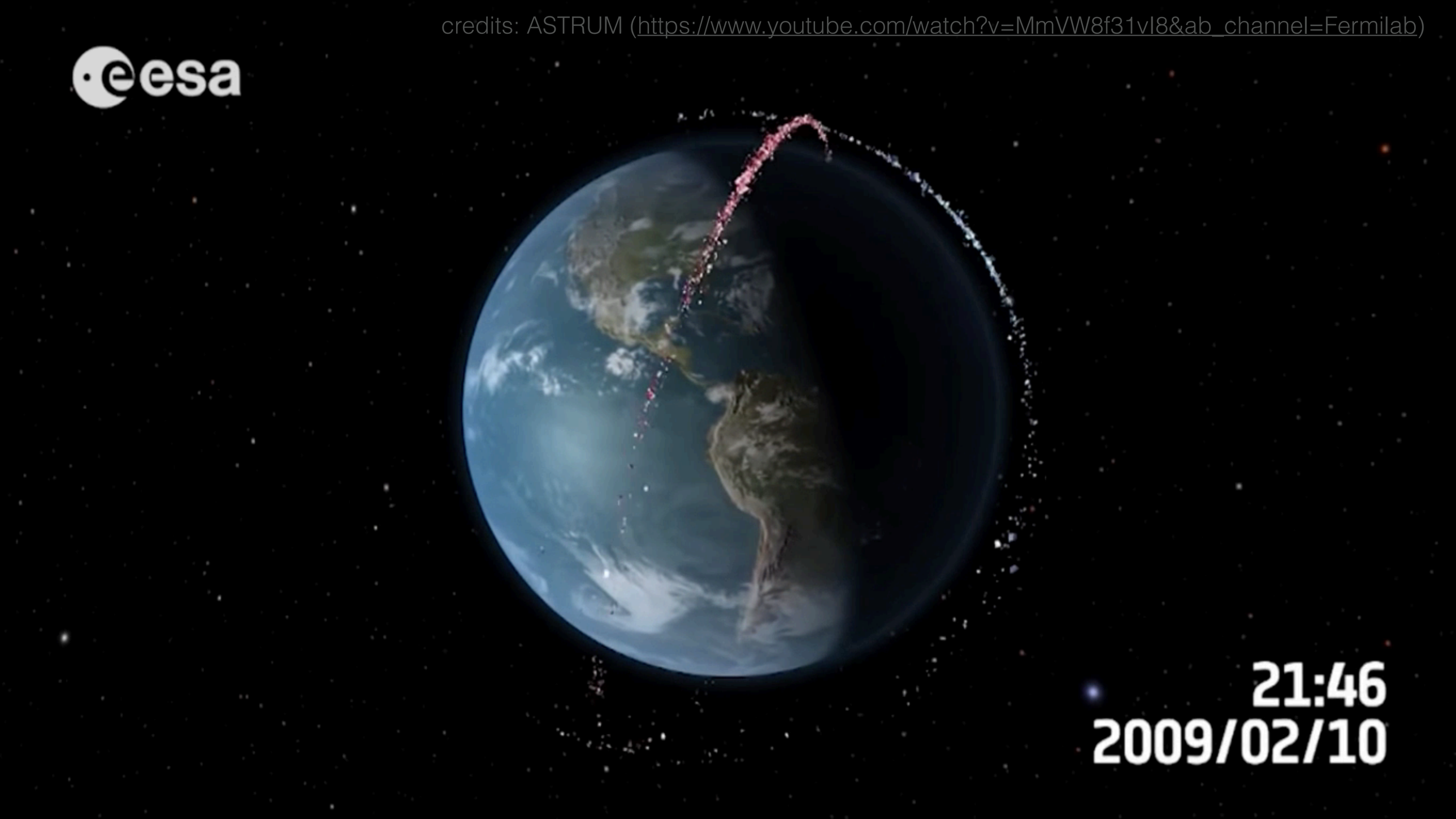
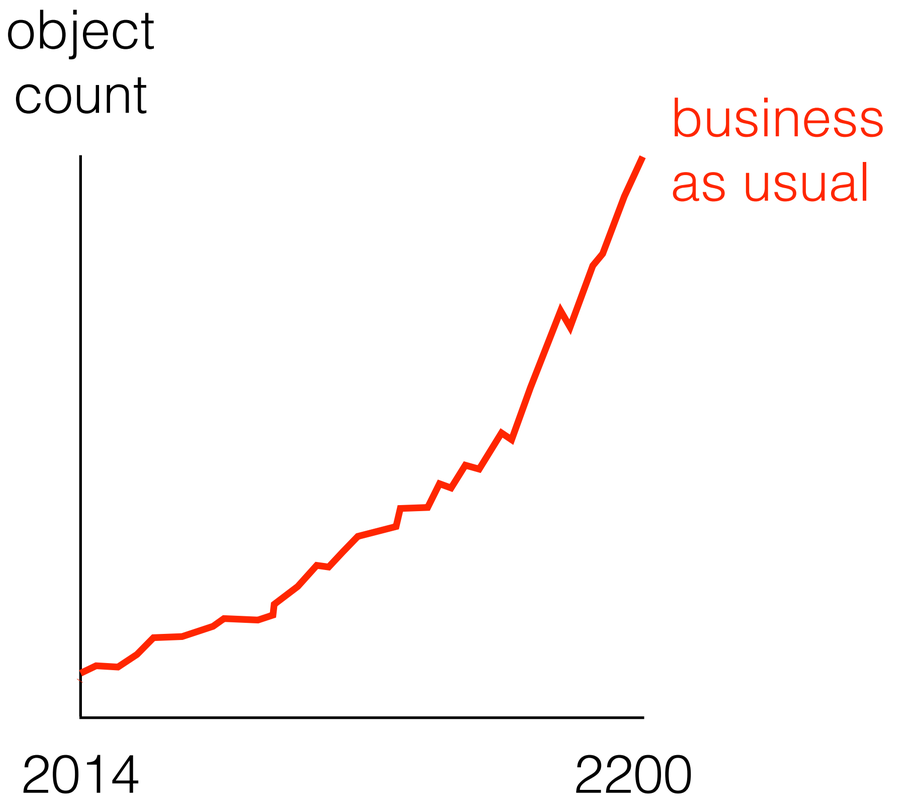


If we want to sustain outer space activities we cannot continue with business as usual



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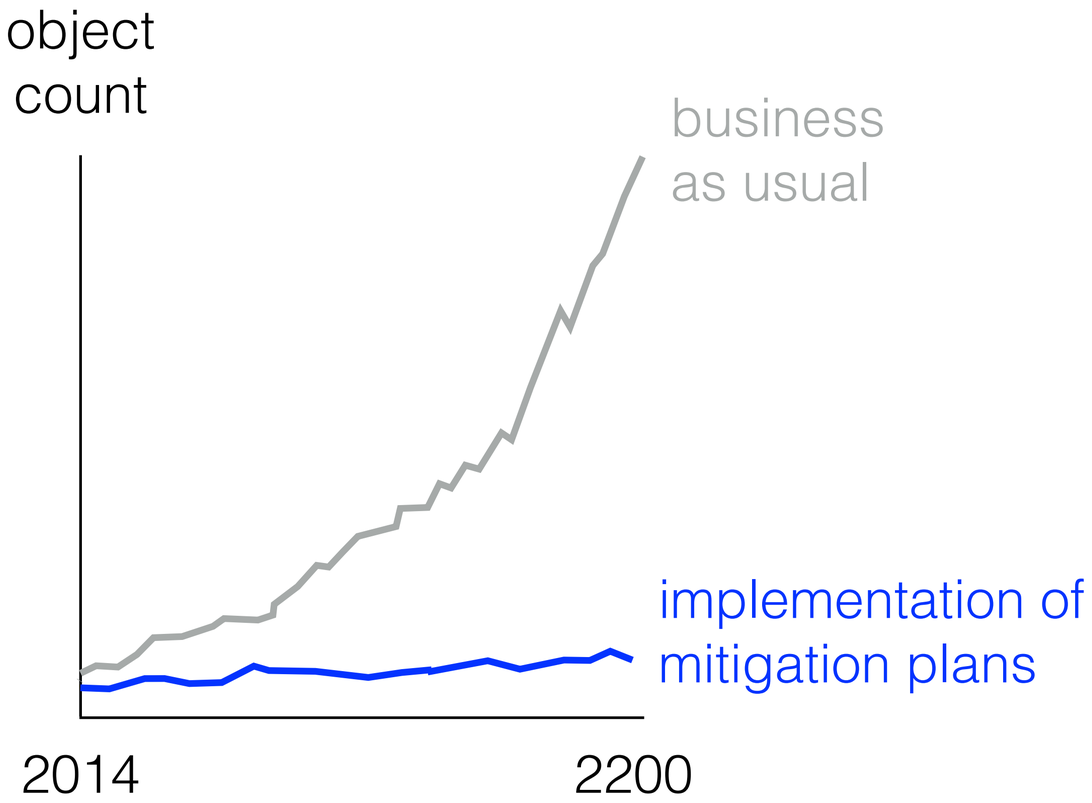


Mitigation of space debris: The clean space initiative

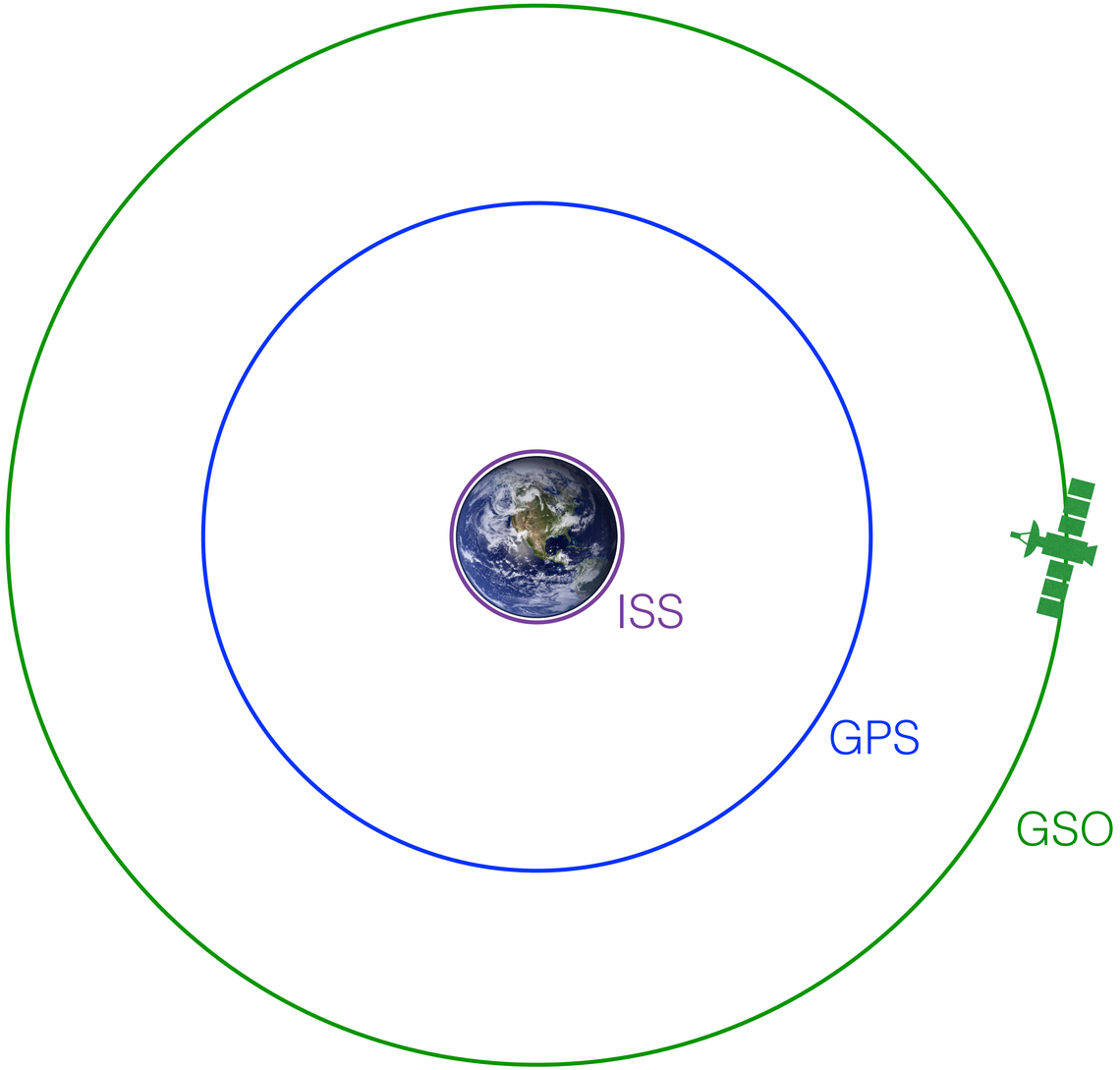
Cross-cutting technology theme 2012

Passivation after service: deplete all energy reservoirs (batteries, fuel, venting,…)

Dispose new satellites within 25 years of mission completion

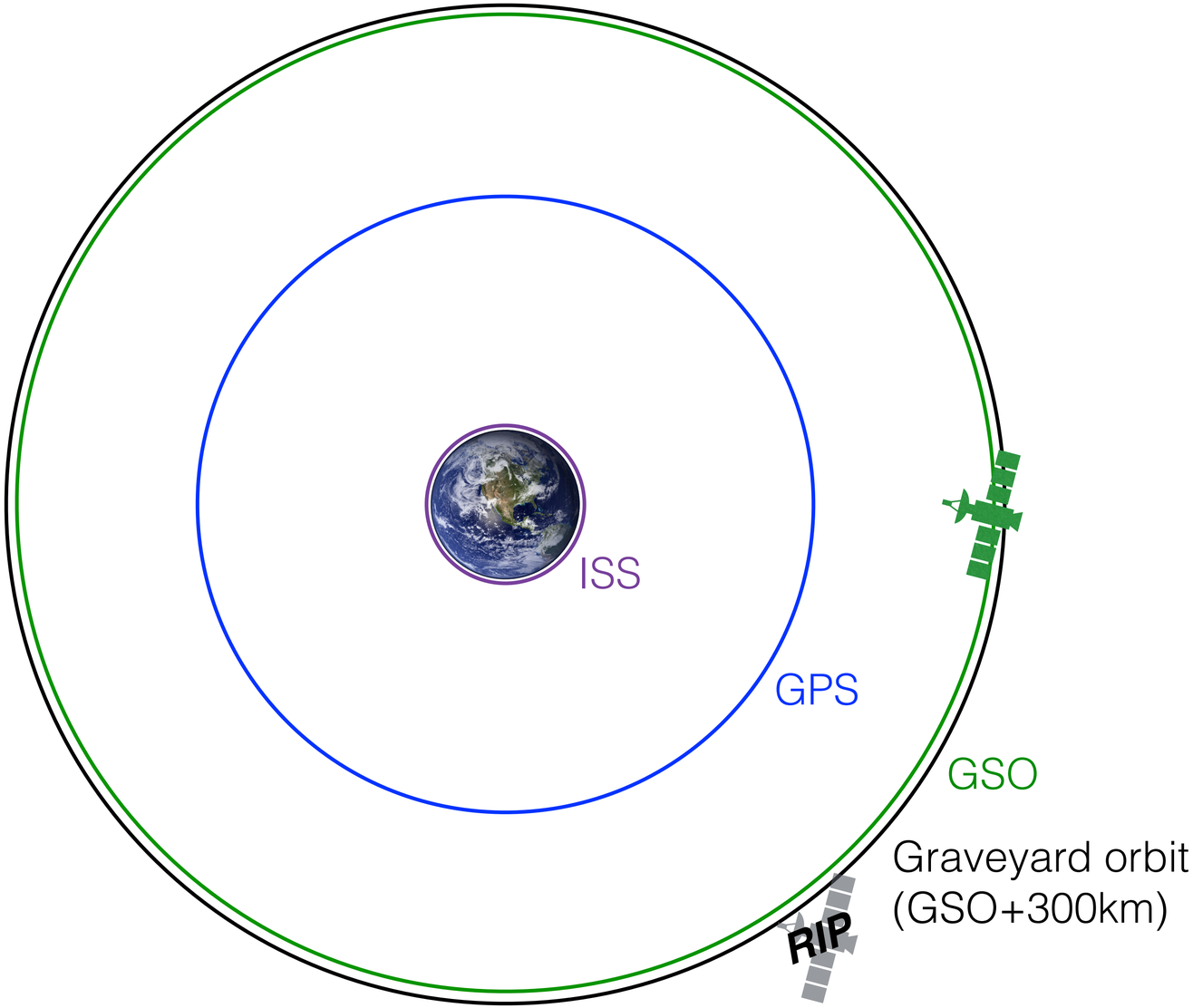
Geostationary orbit: ‘Re-orbit’ to graveyard

Satellite graveyard



Satellite graveyard

de-orbiting requires Δv = 1500 m/s
lifting to graveyard Δv = 11 m/s
orbital lifetime: 10^6 years



Satellite graveyard: not practical for small constellations

Increasing number, micro satellites and
megaconstellations require new approaches

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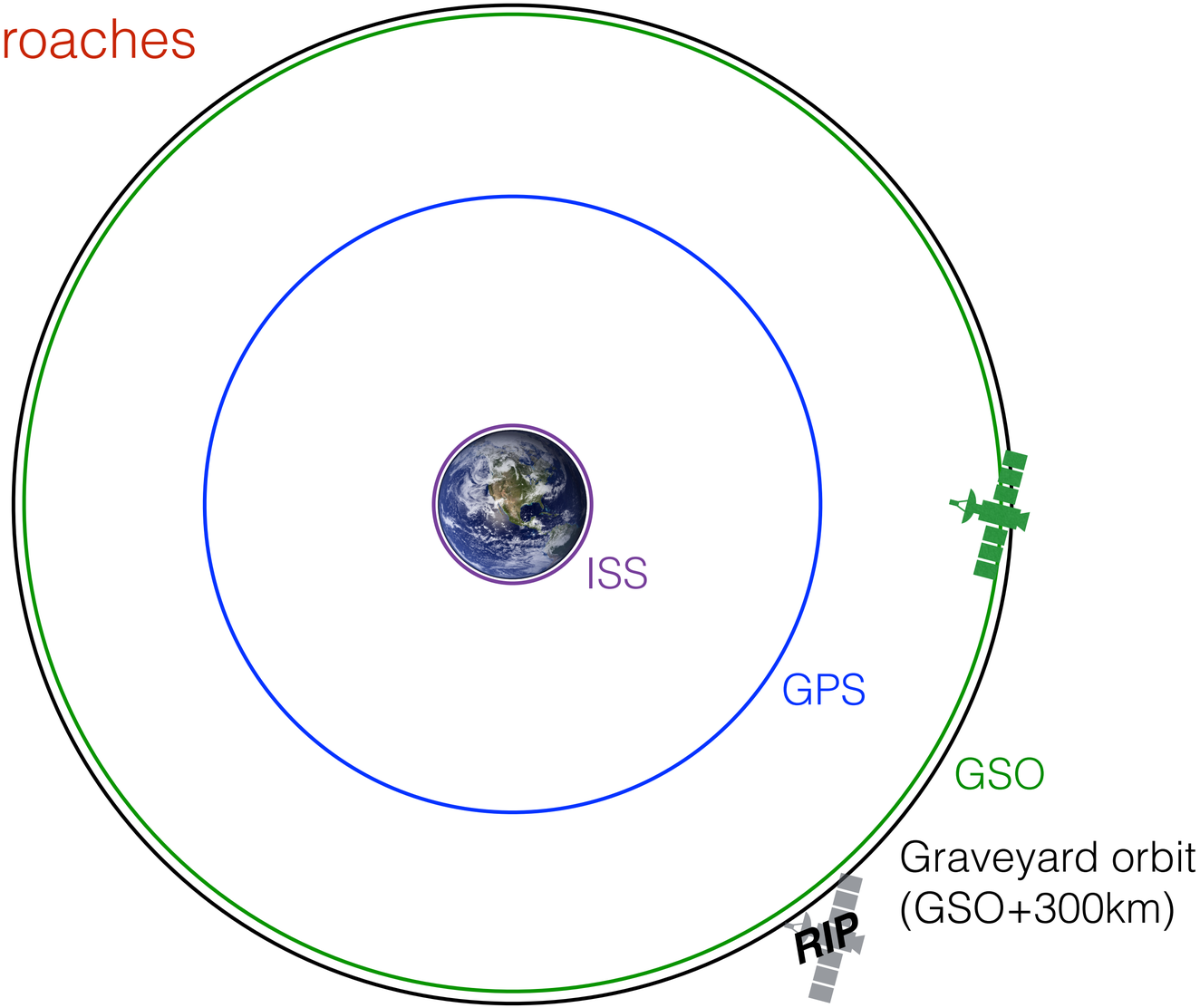
lifting to graveyard Δv = 11 m/s

orbital lifetime: 10^6 years



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Geostationary orbit: ‘Re-orbit’ to graveyard

Operational orbit: below 2000 km —> **Design for Demise**

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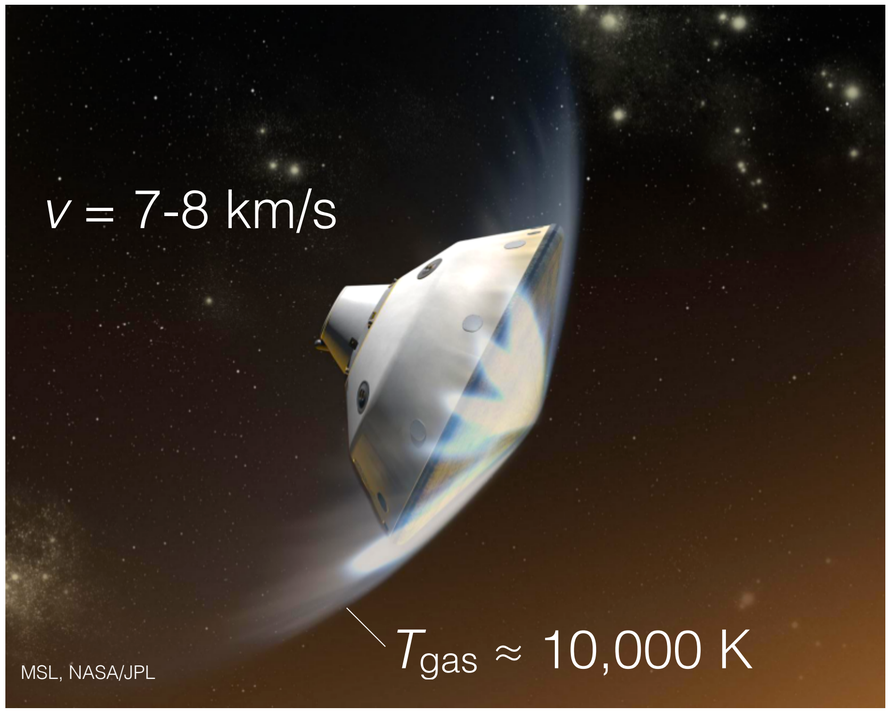
Dispose new satellites within 25 years of mission completion

Geostationary orbit: ‘Re-orbit’ to graveyard

Operational orbit: below 2000 km —> **Design for Demise**

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



Conventional space missions:
Survive the reentry at maximum heat flux

Design for Demise:
Destroy at minimum heat flux

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)

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

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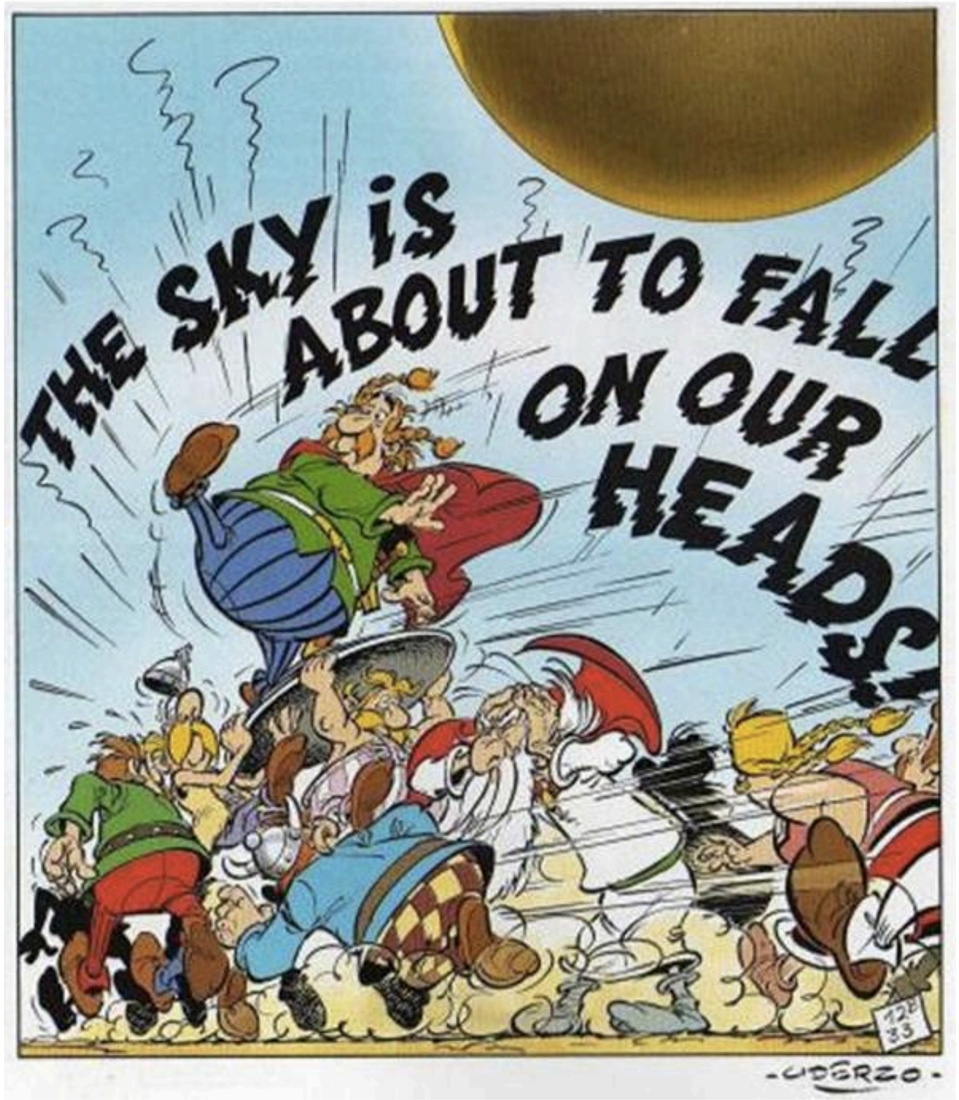
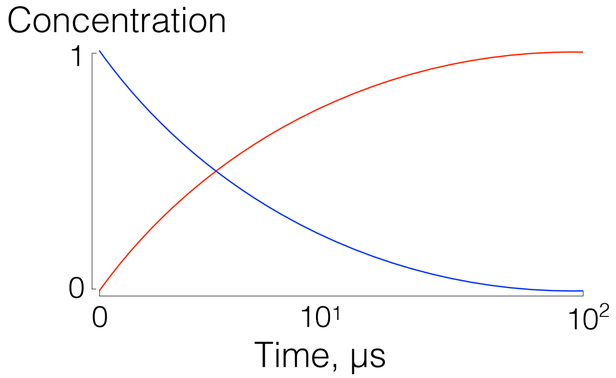


Design for Demise (D4D): Common tools for engineering prediction



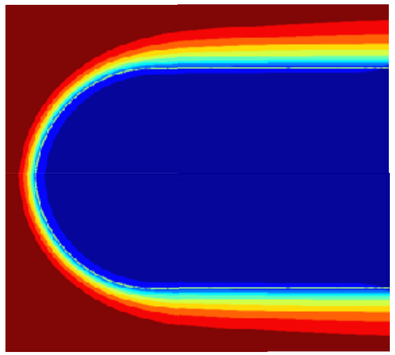
specific processes

Physicochemical models

Experimental data

verification

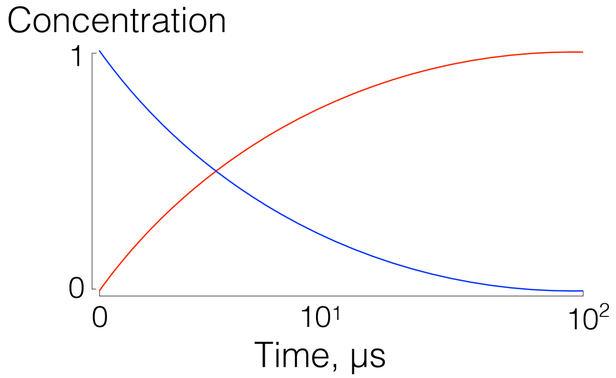
validation



Computational methods

AVUM upper module reentry and fragmentation prediction

From high-fidelity tools to engineering correlations along the whole trajectory



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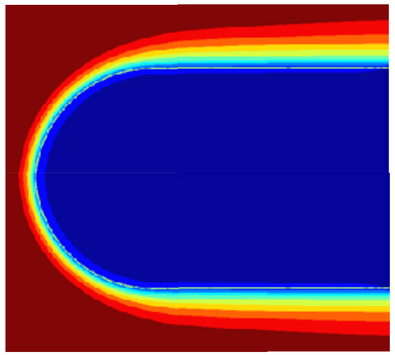

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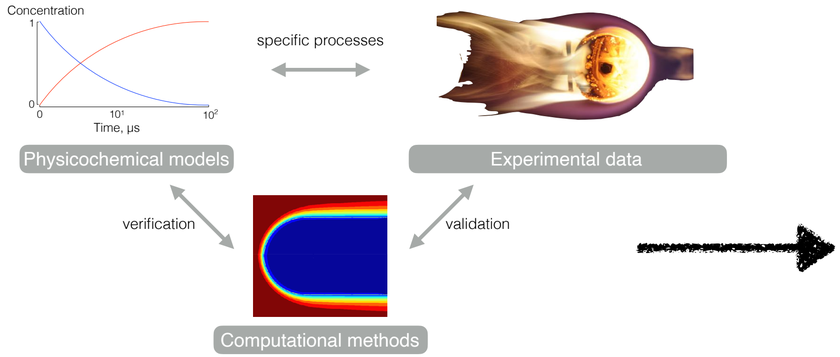

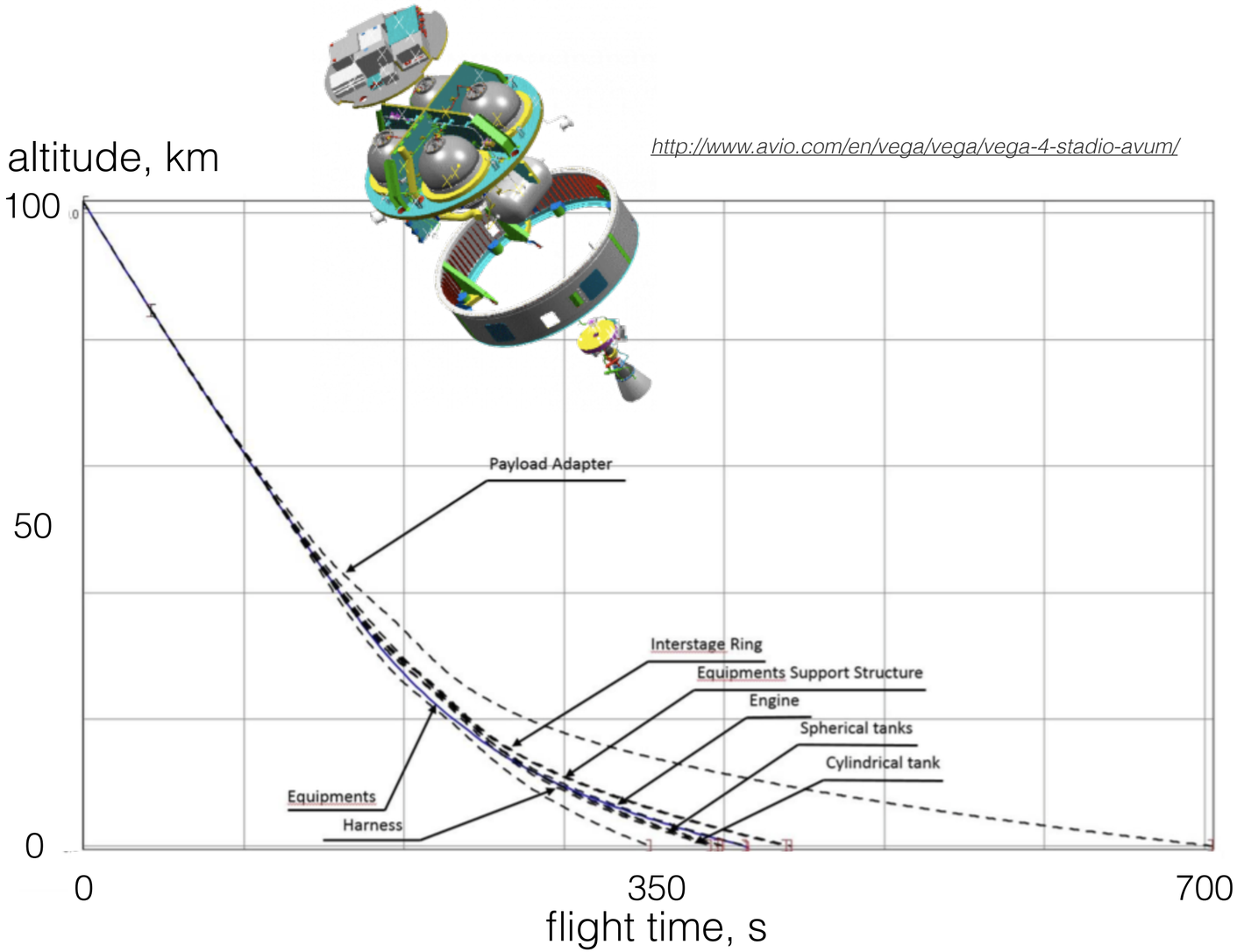

http://www.avio.com/en/vega/vega/vega-4-stadio-avum/

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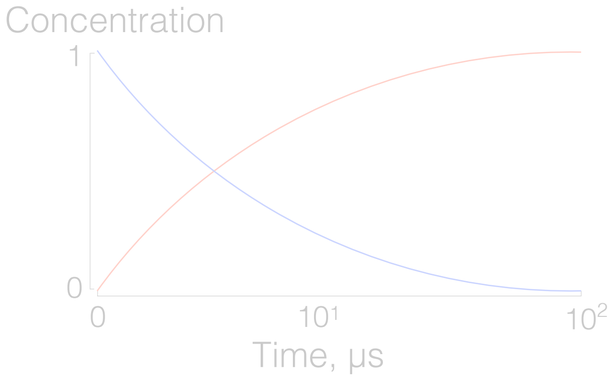

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Physicochemical models

Experimental data

my job

verification

validation

Computational methods

How did I end up here?

from Bad Boll, near Stuttgart, Germany

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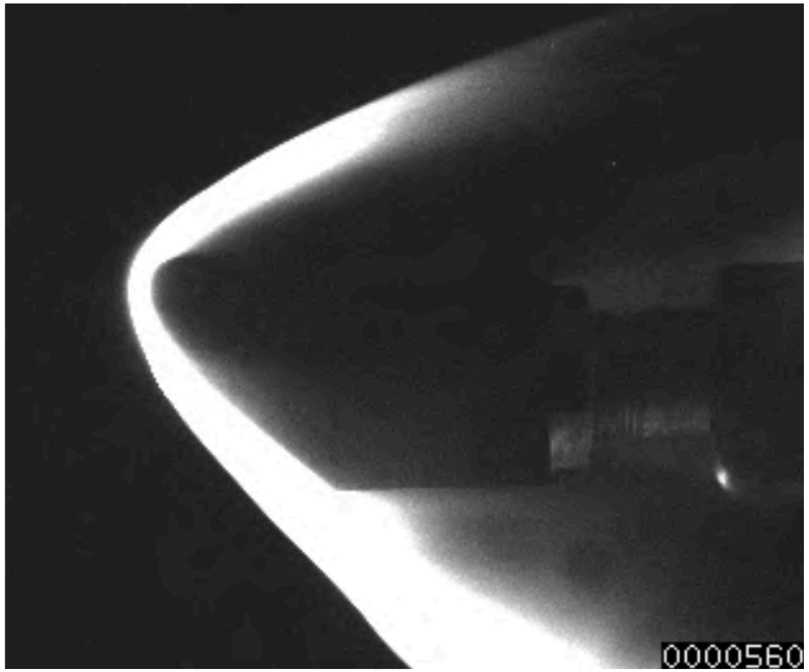

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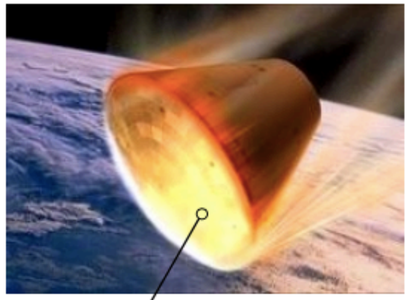

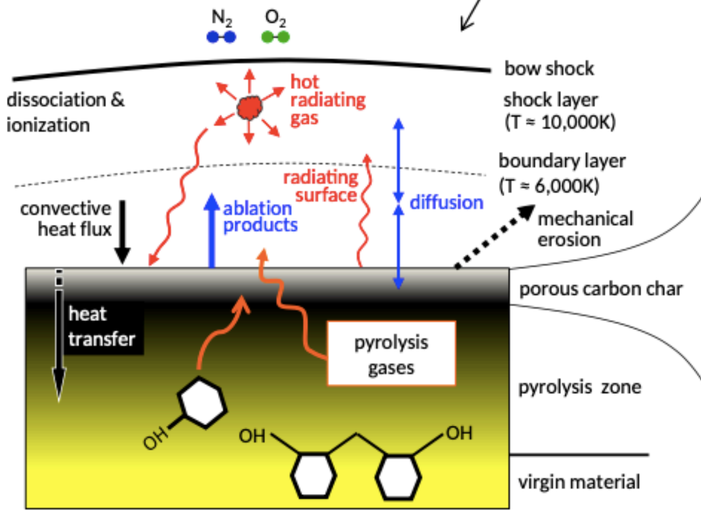

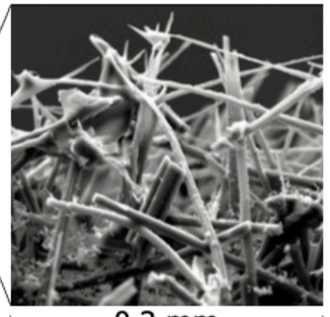

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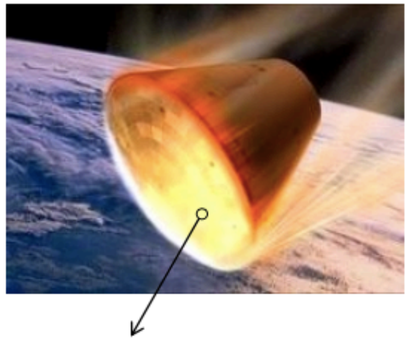

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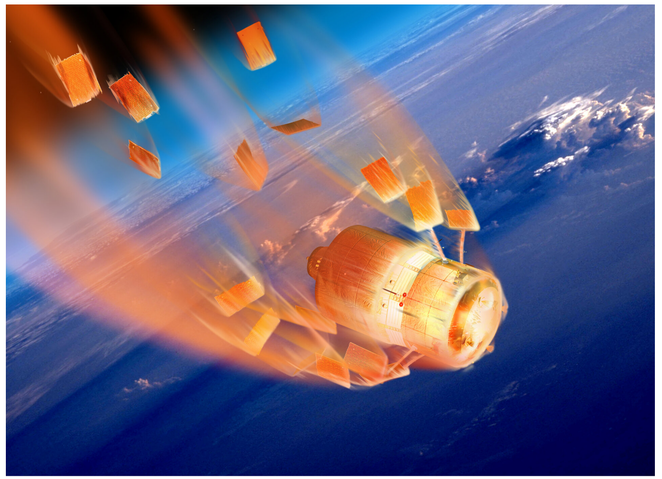
Thermal protection and space debris characterisation



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von Karman Institute for Fluid Dynamics

Training in **Research** through **Research**

Environmental and Applied Fluid Dynamics

Turbomachinery and Propulsion

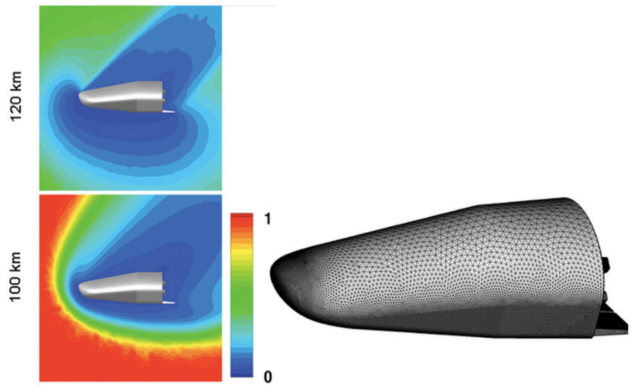
Aeronautics and Aerospace Department

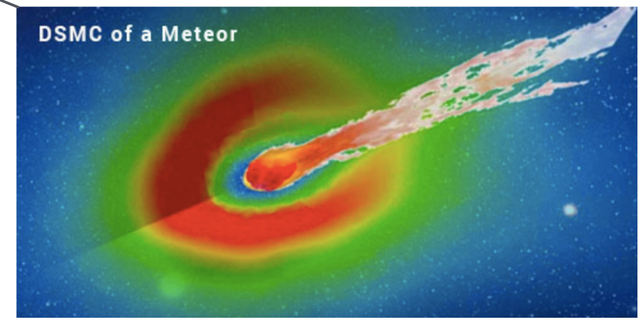
Aerodynamics and Aeronautics

Aerothermodynamics

Rarefied and Plasma Flows

Aerothermochemistry





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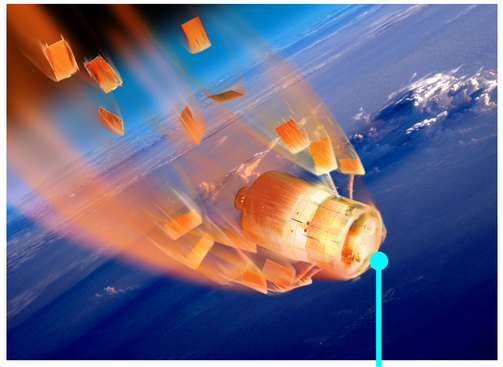
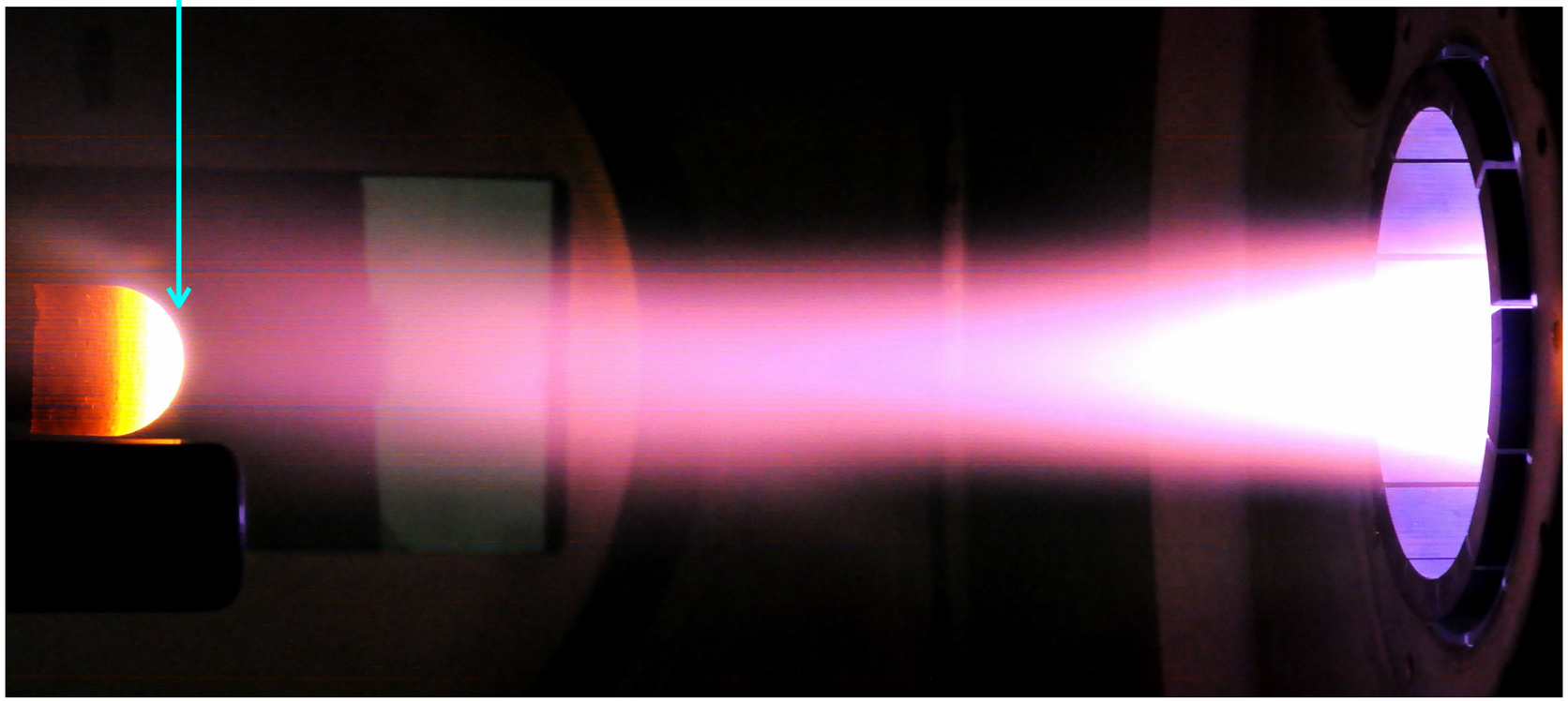
What are we interested in?





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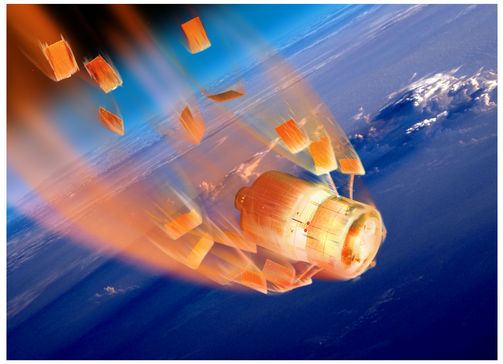
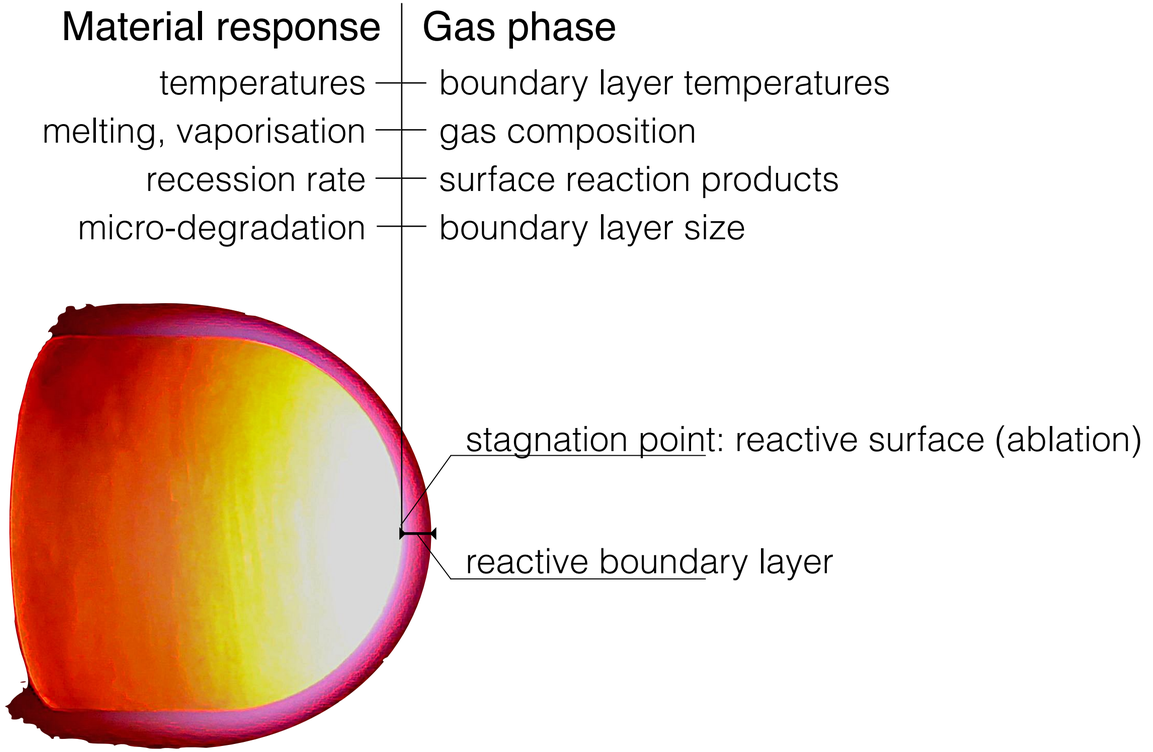
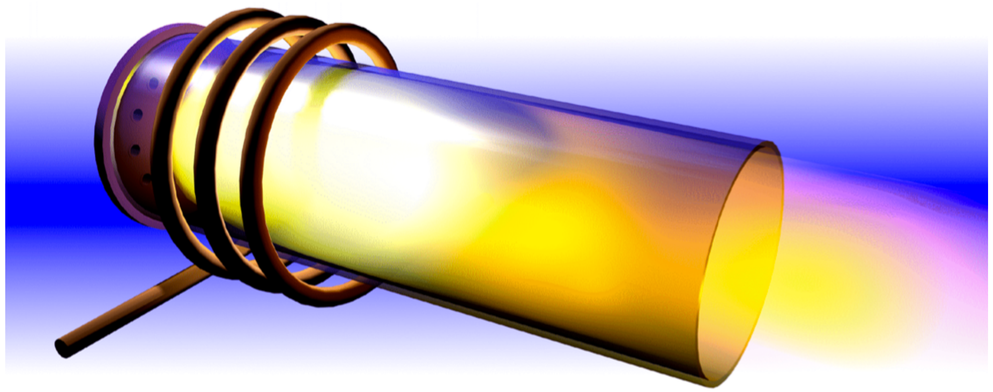
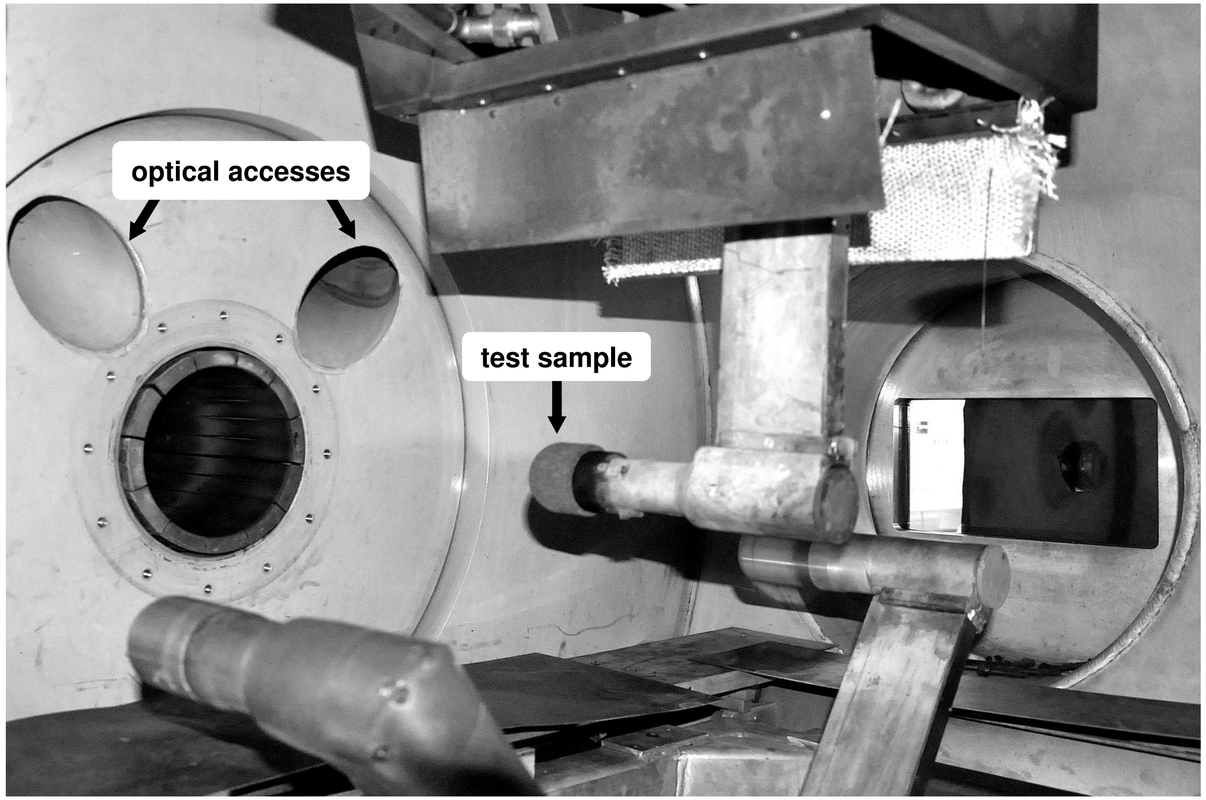




1.2 MW Inductively Coupled Plasmatron

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

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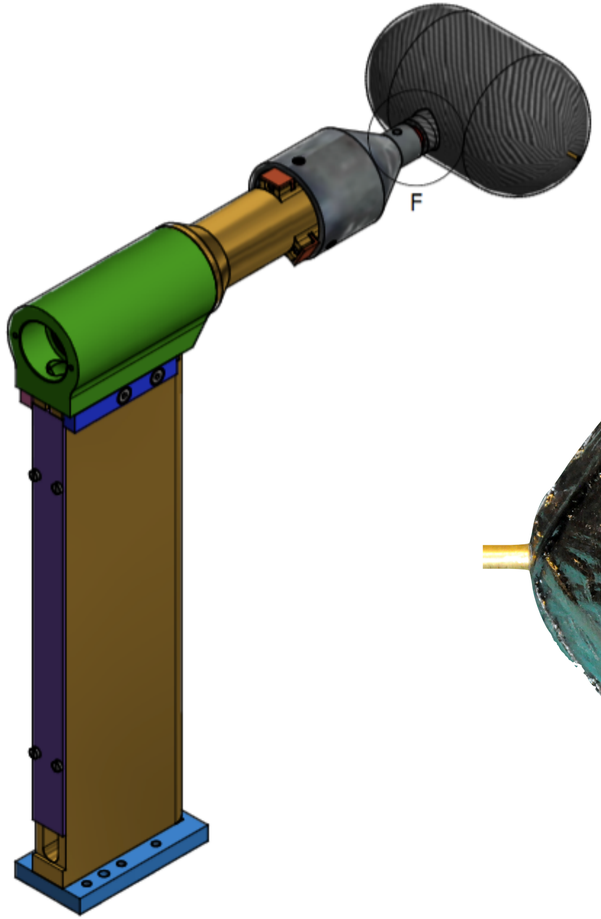
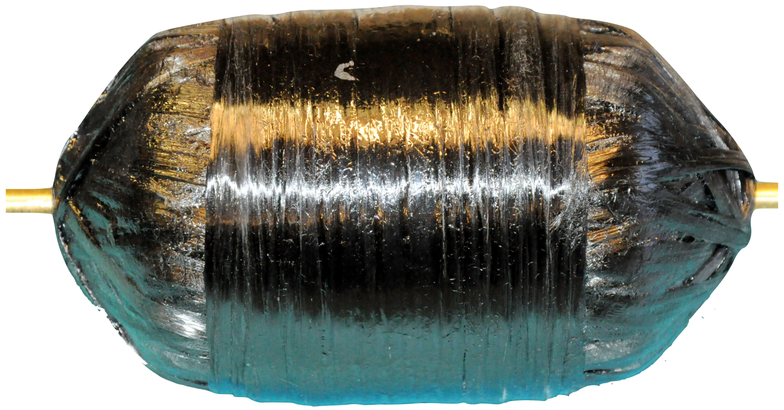
COPV testing: Titanium liner with carbon-fibre overwrap

ESA GSTP contract No. 4000125437/18/NL/RA





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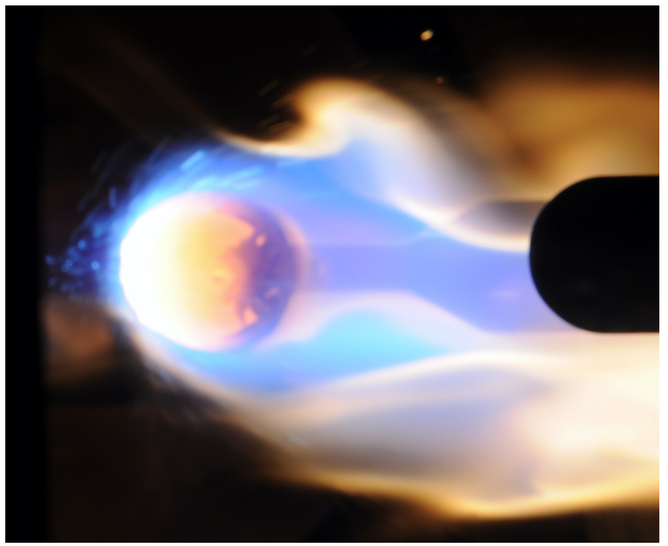

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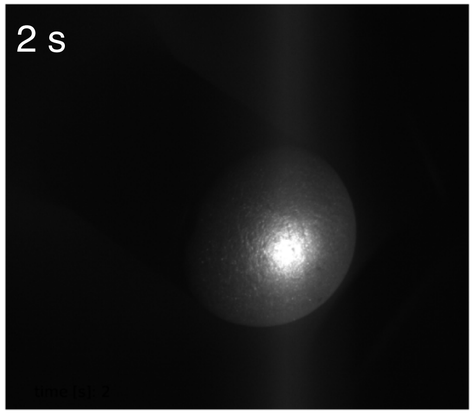
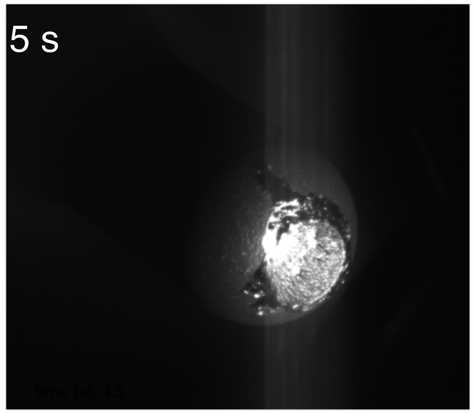
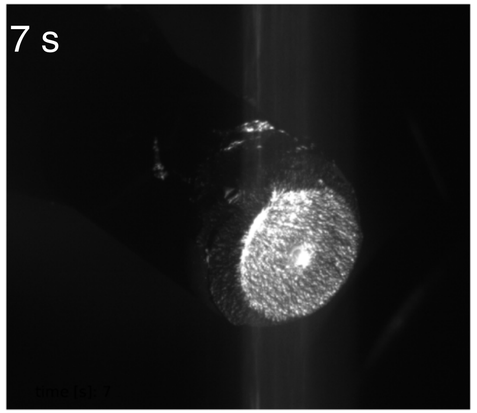
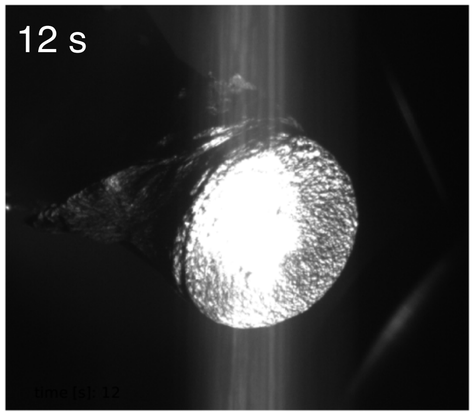
Al-Si hemisphere test (3D printable space material)

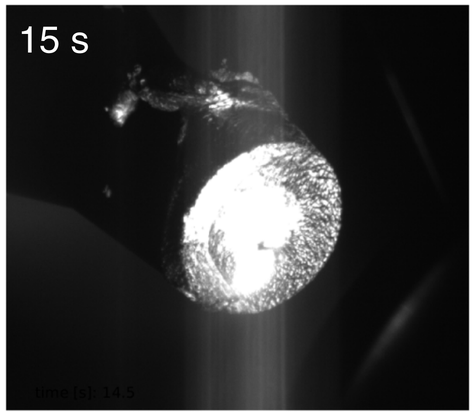
Heat up and then full demise

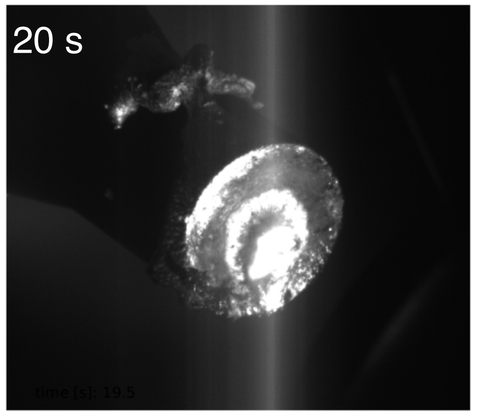




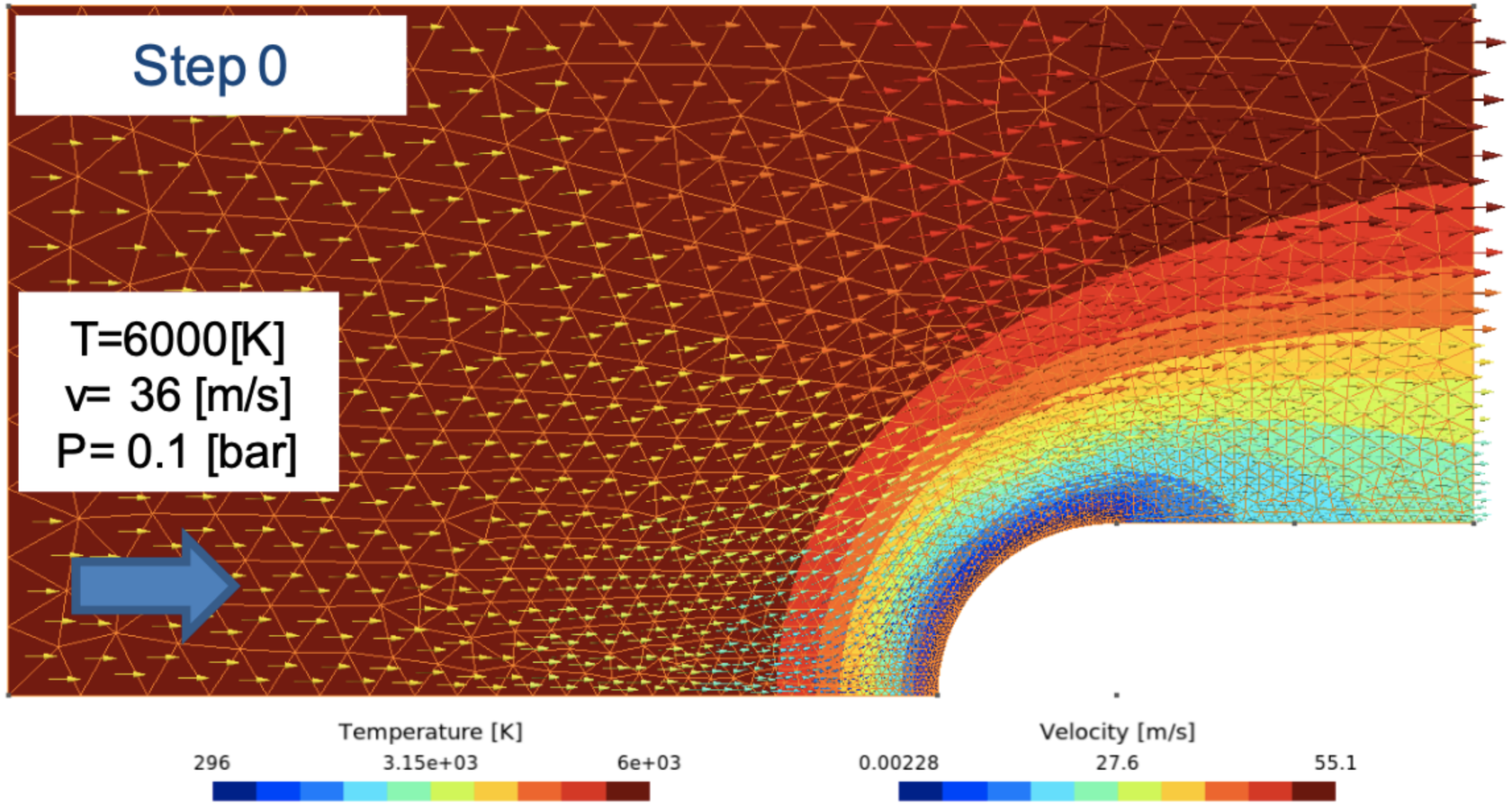








High-fidelity simulations help us to understand and predict the material demise



D4D activities at VKI

2015 Characterisation of demisable materials (**Fluid Gravity Engineering**, UK)

2016 Deorbitation “Design to Demise” Aerothermodynamic Aspects (**National Institute for Aerospace Research "Elie Carafoli”**, Romania)

2017 Identification of ablation process in porous materials (**Cenaero**, Belgium)

Wind-tunnel experiments applied for hypersonic flows (DERISK) (**CNES**, France)

2018 Validation of Space Debris Demise Tools using Plasma Wind Tunnel Testing and Numerical Tools (**VKI**, Belgium)

2019 ESA Assessments to Prepare and De-Risk Technology Developments “Black Box Re-Entry Capsule for Satellites” (**VKI**, Belgium)

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Events and workshops:
Clean Space Industrial days (ESA)
Aerothermodynamics and Design for Demise (ATD3) Workshop (ESA, CNES)

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, 9 months)

Doctoral program

Post-doctoral program

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

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VKI plasma and demise team
(O. Chazot, T. Magin, A. Turchi, A. Fagnani, S. Mignano, D. Henneaux, A. Viladegut, B. Dias, G. Grossir, Z. Ilich, P. Collin, J. Freitas)

ESA technical officers
(L. Marraffa, L. Walpot, G. Ortega)

Cenaero colleagues
(P. Schrooyen, K. Cascavita)

The Clean Space initiative to support long-term sustainability of outer space activities

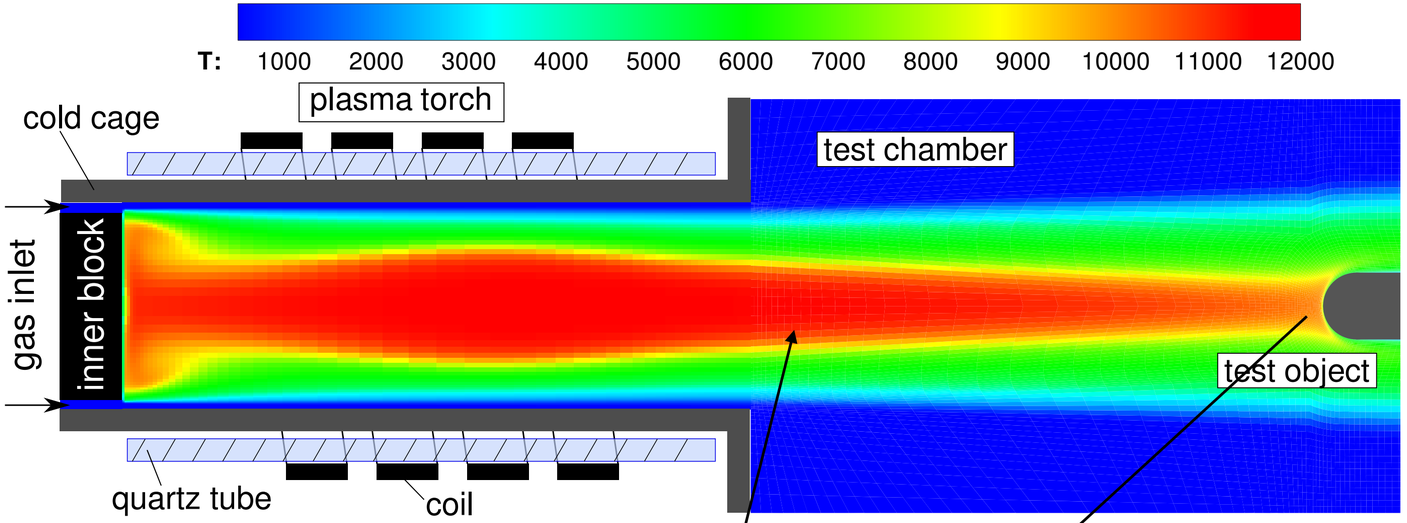
B. Helber (helber@vki.ac.be)

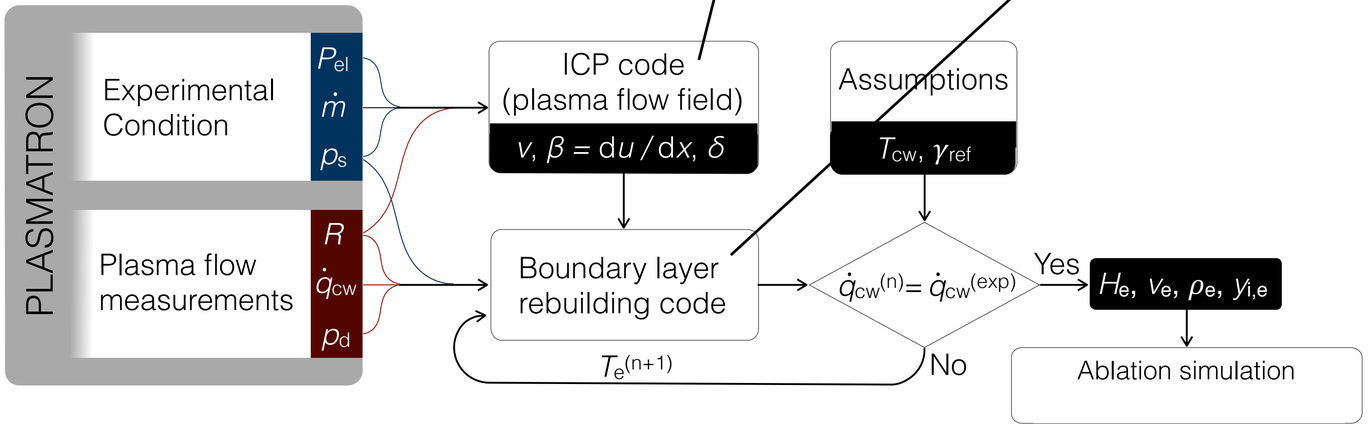
Aeronautics and Aerospace Department
von Karman Institute for Fluid Dynamics, Belgium

BACK UP

1.2 MW Inductively Coupled Plasmatron

Flow characterization with numerical simulations

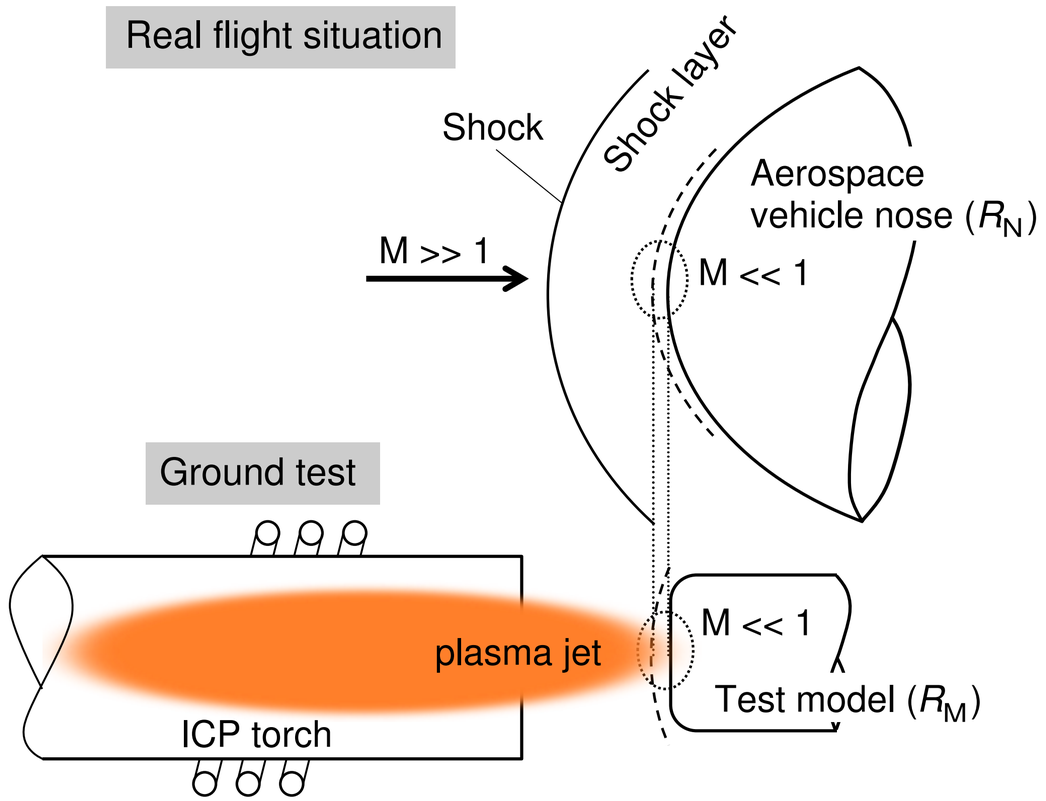




$$\dot{q}_{cw}^{(exp)} = \dot{q}_{cw}^{(num)} = \dot{q}_{cw}\left(\gamma_{ref}, T_{cw}, p_e, T_e, \delta, \left(\frac{\partial u}{\partial x}\right)_e, v_e \frac{\partial}{\partial y}\left(\frac{\partial u}{\partial x}\right)_e\right)$$

1.2 MW Inductively Coupled Plasmatron

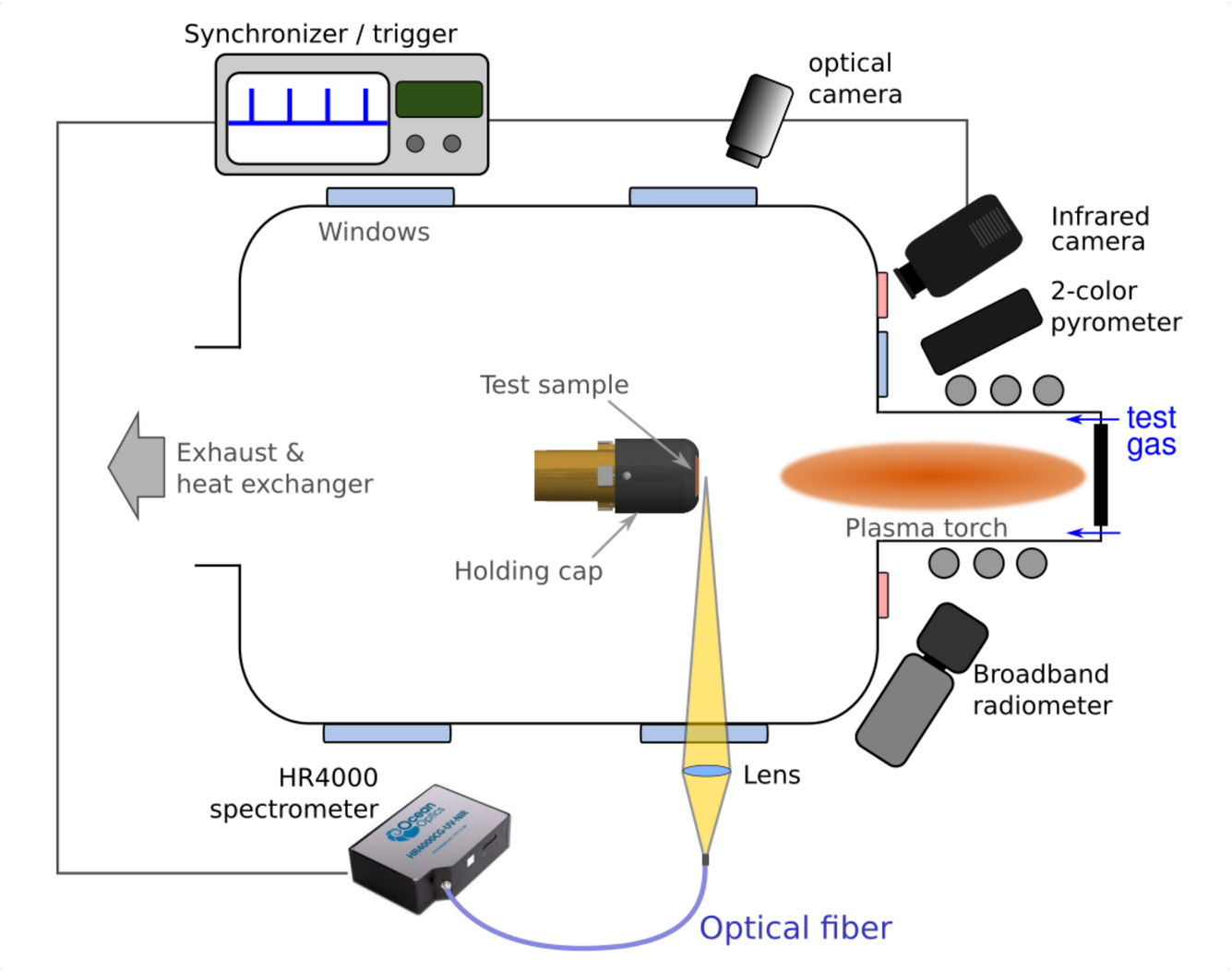
Local Heat Transfer Simulation methodology (subsonic plasma representing hypersonic flight)



$$H_e^f = H_e^t, \qquad p_e^f = p_e^t, \qquad \beta_e^f = \beta_e^t$$

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

Instrumentation in the Plasmatron and test observation



Material response	Gas phase
temperatures	boundary layer temperatures
melting, vaporisation	gas composition
recession rate	surface reaction products
micro-degradation	boundary layer size