

ESA Sustainability Workshop
M. Strotkamp, J. Höffner; 2026/03/10

Autonomous multi-purpose lidar for atmospheric impacts of space transportation



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Development of Compact Resonance Lidar Systems

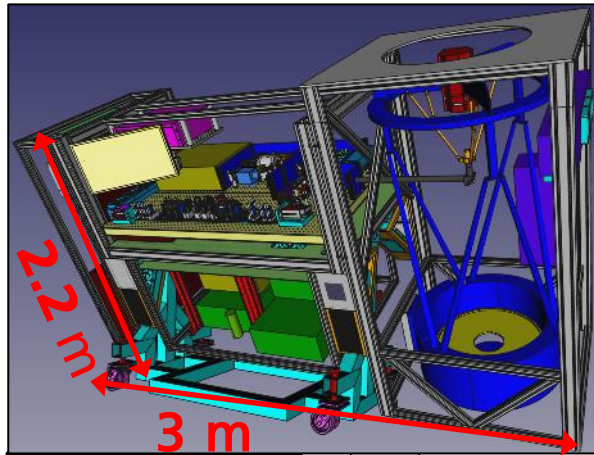
OLD system:
transportable **K/Fe**-lidar



1989-2020

- 10'000 kg
- 30 kW
- 40 m³

First Prototype:
K-lidar demonstrator



2015-2018

- 1'500 kg
- 1 kW
- 10 m³

VAHCOLI:
autonomous **K**-lidar
multi-FOV



2018-2022

- 500 kg
- 0.5 kW
- 1 m³



EU project EULIAA:
autonomous **UV**-lidar array
with multiple FOV

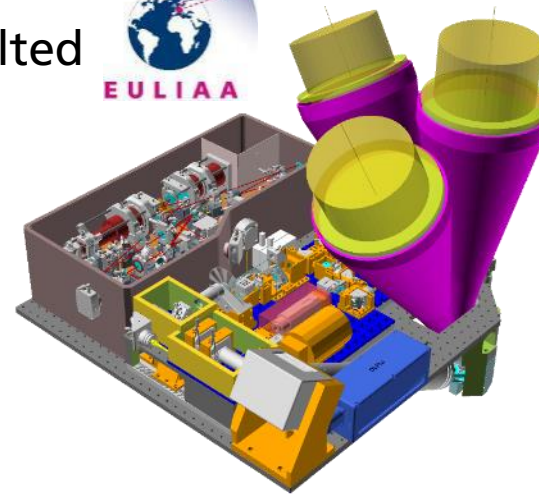
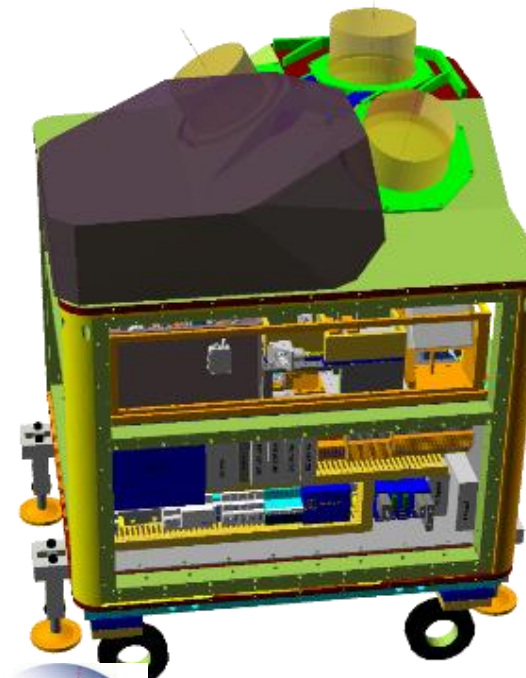


flashlamp-pumped

diode-pumped

Compact lidar instrument

- **Mobile system** for easy deployment (even by helicopter) and operation (1m^3 , $< 500\text{ kg}$, $< 650\text{ W}$)
- Modular lidar instrument with structural elements from 3D-printed carbon-reinforced plastics
- **Central platform** (aluminum BB) with all lidar subsystem referenced and attached to it
- **Customized laser** as lidar transmitter
- **Scanner** to address different lens telescopes
- **Three FOV** via lens telescopes (1x vertical, 2x tilted 30°) for vertical and horizontal winds
- **Daylight capability** even close (5°) to sun
- **Real-time lidar control and data processing**
- **Polarization-dependent measurements** for aerosol characterization and classification
- **Safety-measures for autonomous operation**



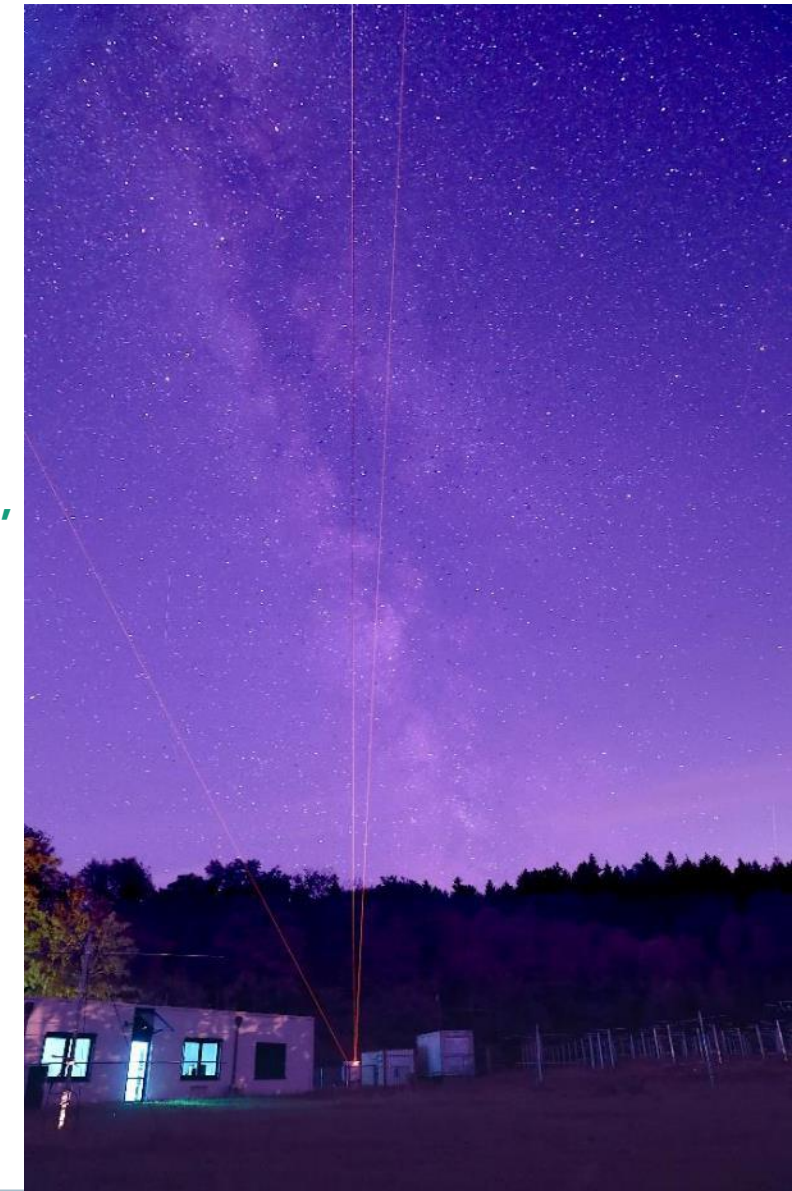
Application of mobile lidar at launch pad

Measurements of wind and launcher propellant contaminants

Placement of a mobile lidar in close proximity to launch pad

Local wind and temperature conditions important for operators at spaceports

Multi-purpose lidar technology superior with higher altitudes, continuous live data, greater area coverage, detection of turbulence



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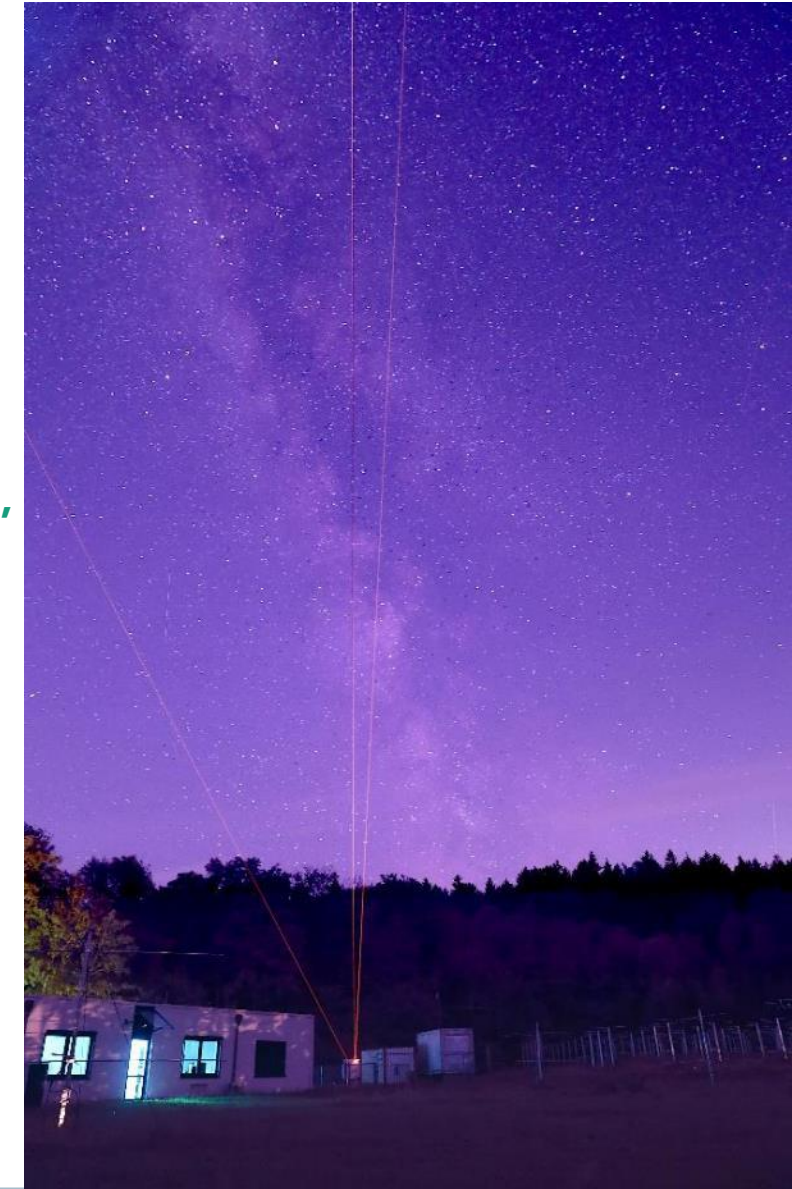
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Measurement of aerosols from rocket propellant with lidars

Monitoring throughout the atmosphere over long time

Mesospheric aerosols (80 – 90 km altitude), like noctilucent clouds (NLC), measured regularly via lidar at day- and nighttime by EULIAA

Fortunate coincidence during EULIAA validation campaign at Andøya facility close to launch pads in Norway



Andøya Space, 69°N Norway

Facility

Norwegian island Andøya at 69°N

European launching facility for easy access to polar and Sun-synchronous LEO

Arctic Lidar Observatory for Middle Atmospheric Research (ALOMAR)

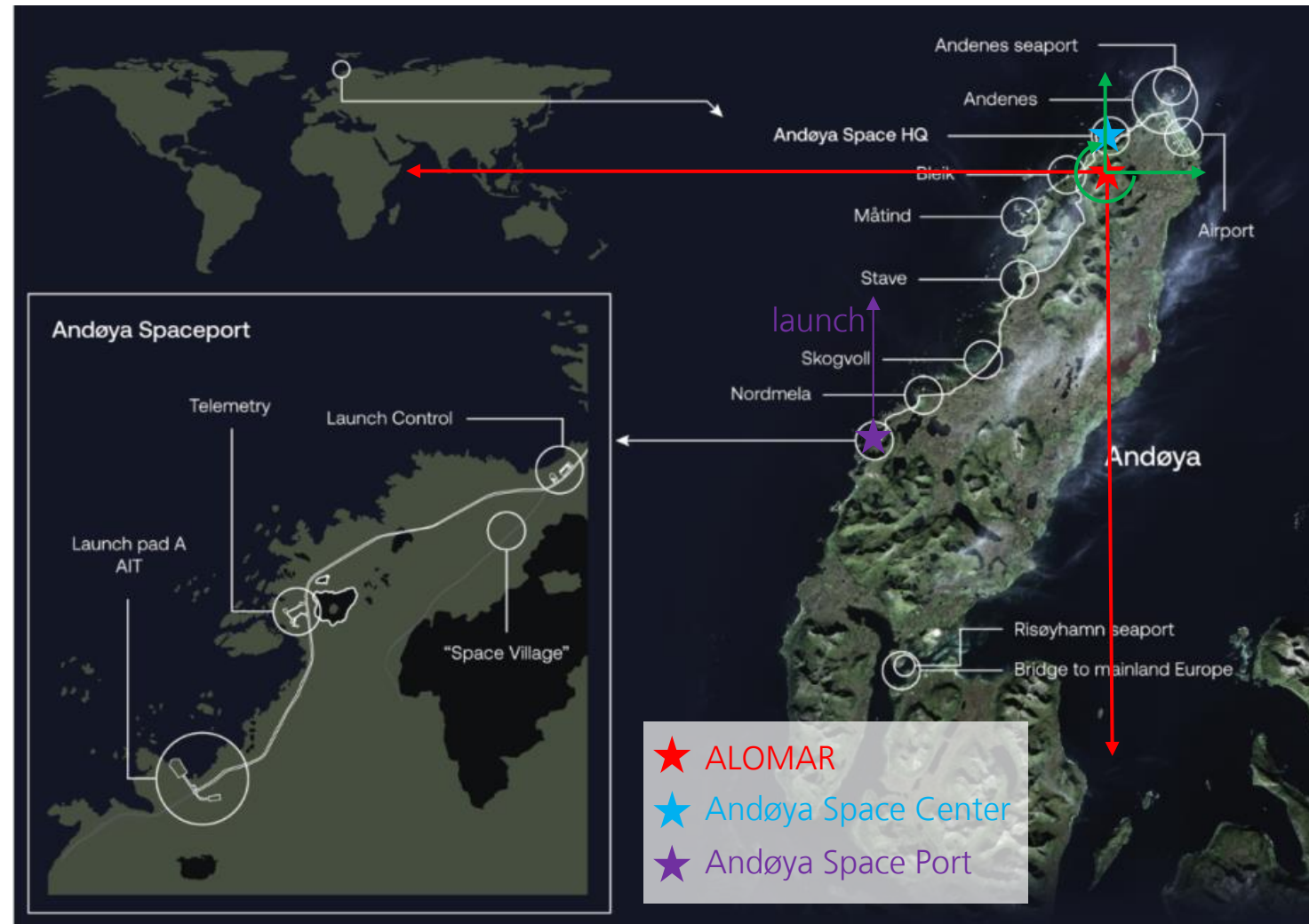
Andøya Space Center with suborbital launcher capability for sounding rockets (2 km)

Andøya Space Port for orbital launchers (Isar Aerospace) on same island (25 km)

Annually up to 30 missions/ 1,500 kg payloads

EULIAA lidar:
fixed LoS (vertical, S & W)

RMR-lidar:
two steerable LoS



Andøya Space, 69°N Norway

EULIAA lidar instrument at ALOMAR



First validation site within European field campaign of EULIAA

Rayleigh-Mie-Raman (RMR) lidar for wind and temperature for 25-90 km, aerosols 3-100 km, density 30-120 km, with two steerable LoS

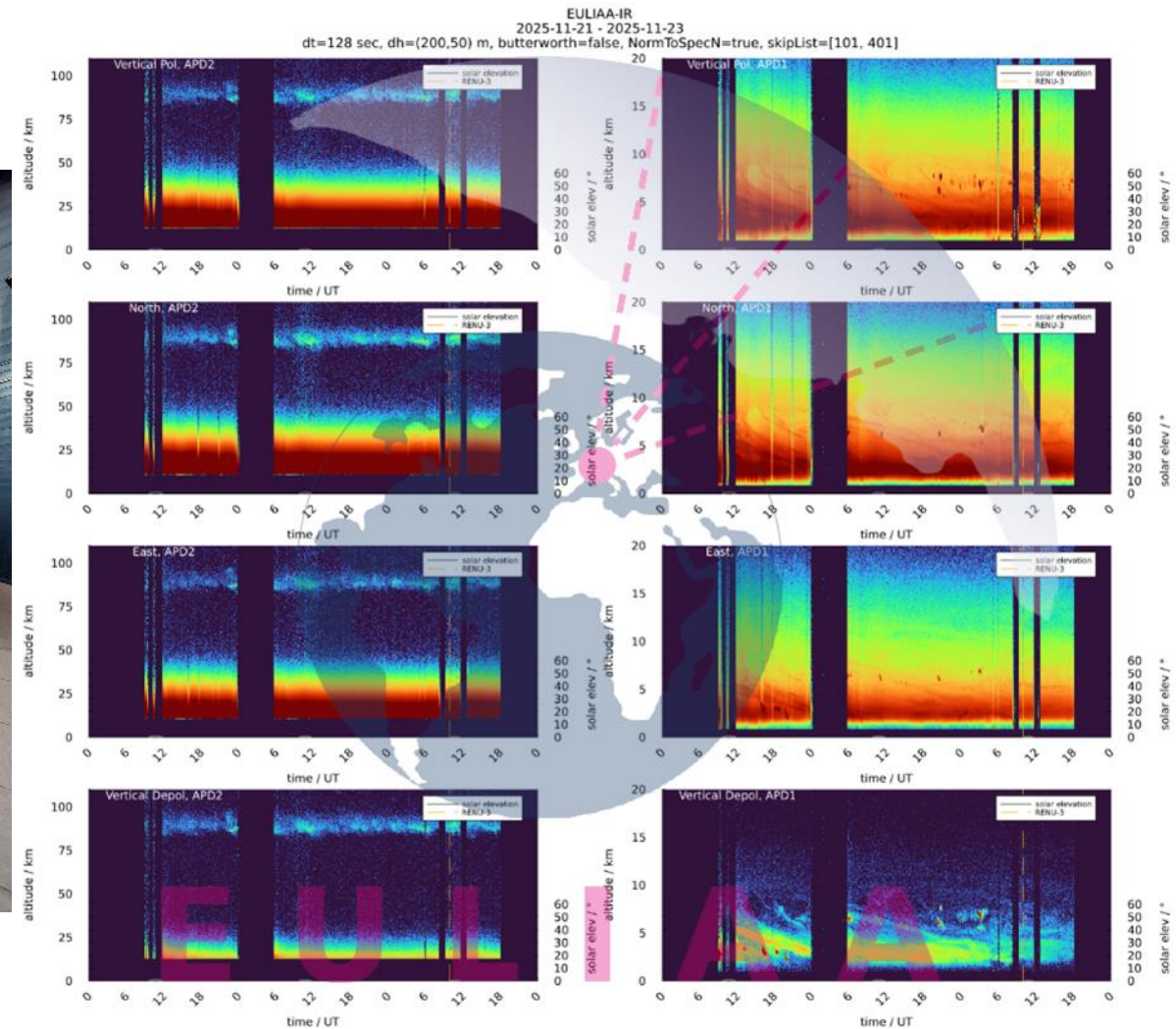
Aerosol lidar (Troposphere)

Regular radiosondes up to 35 km

Radars (Troposphere to Mesosphere)

EULIAA-IR lidar instrument with three fixed LoS, depolarisation & Potassium capability at ALOMAR

Rayleigh-Mie-Resonance for 3-120 km



Andøya Space, 69°N Norway

Rocket launch monitored with EULIAA & RMR lidar instrument at ALOMAR

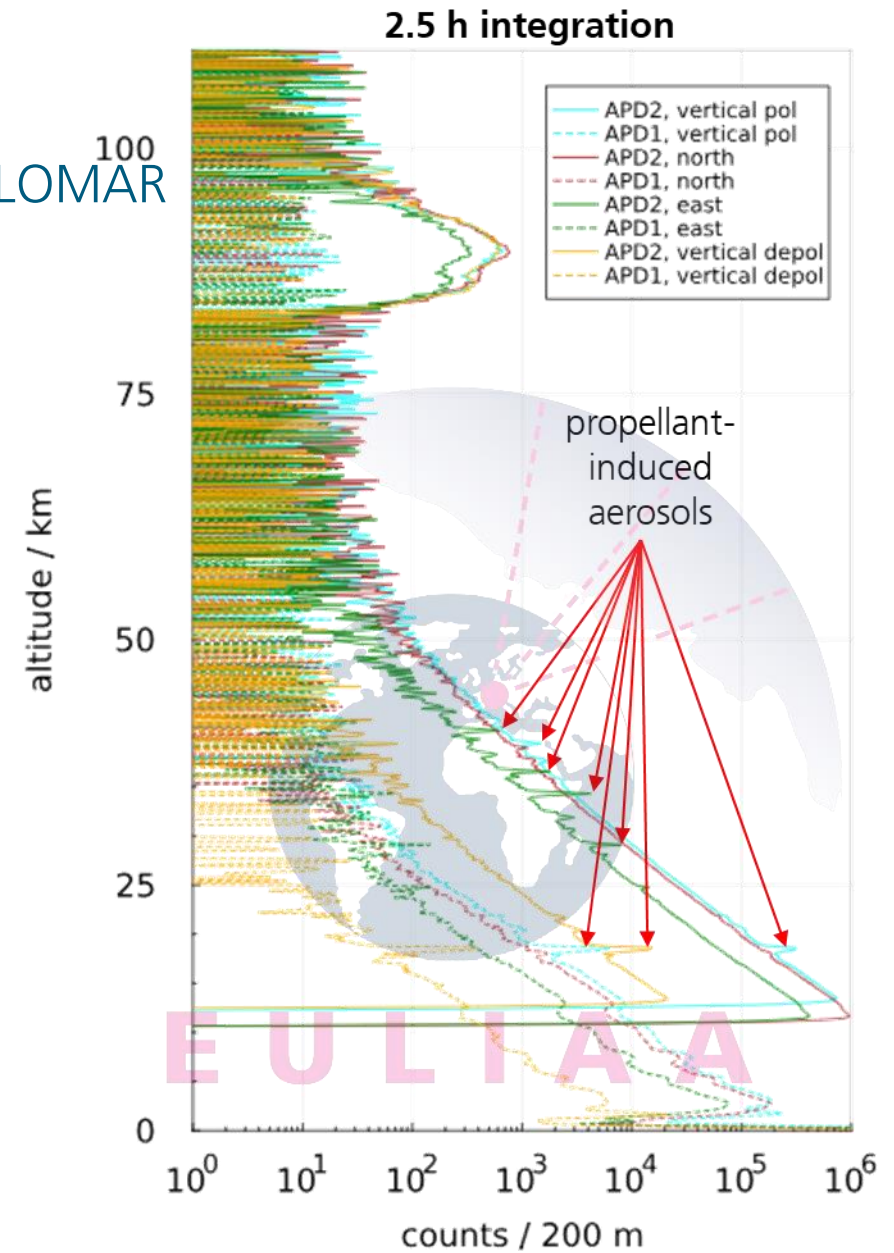
RENU-3: Rocket Experiment for Neutral Upwelling

Sounding rocket with 4 stages (2.8 t of APCP) and >450 km altitude

Launch at 2025/11/23 09:52:37 UT

Daytime with ~0° solar elevation

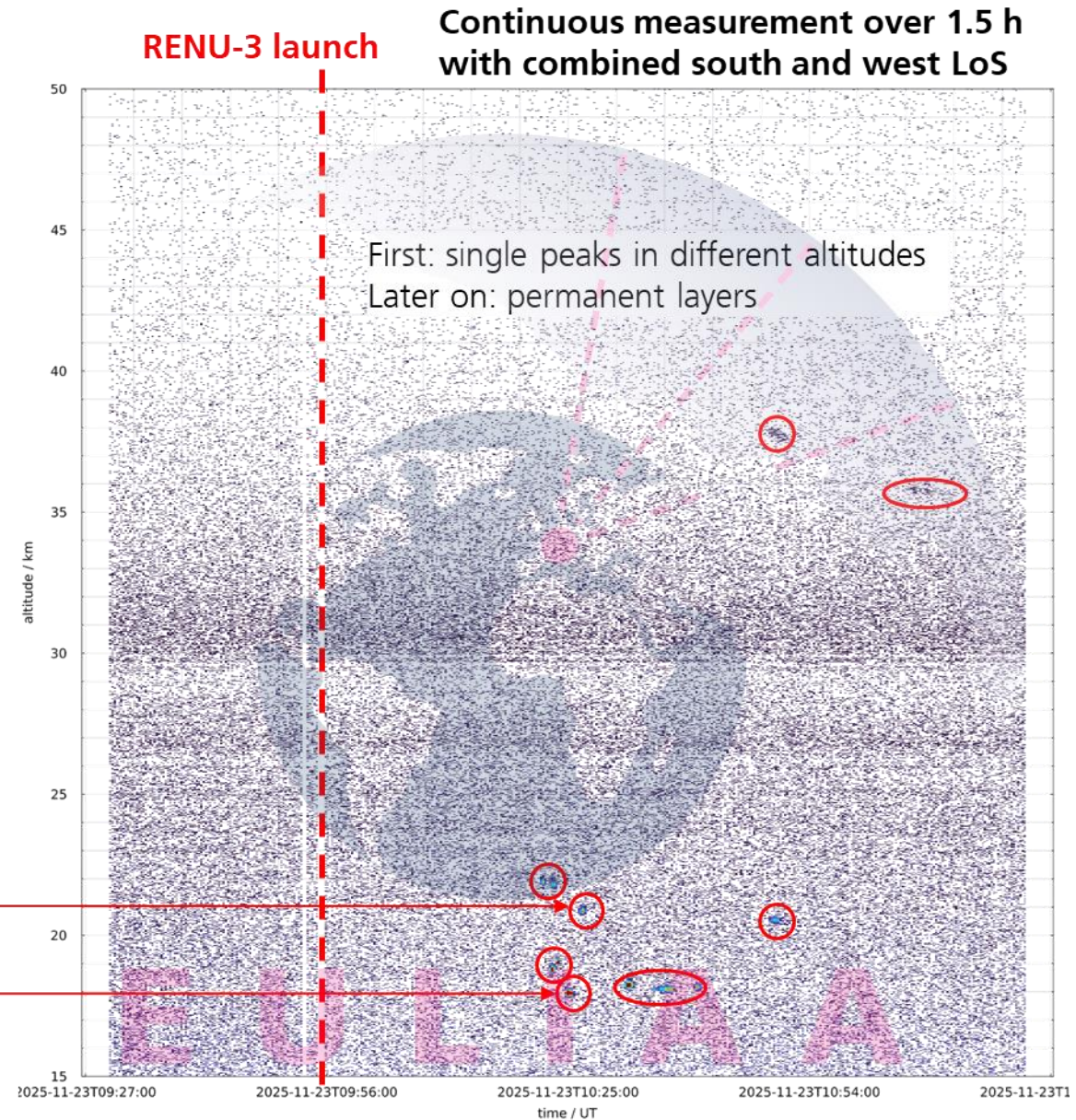
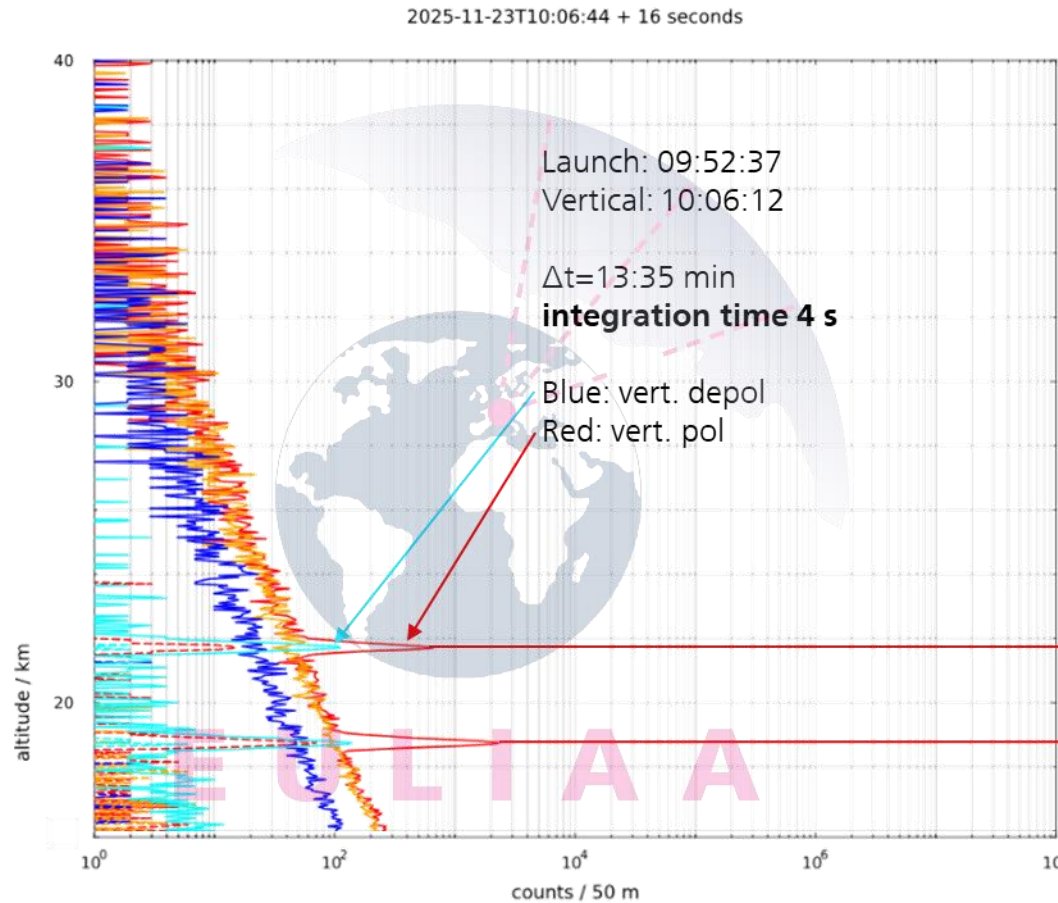
Measurement of aerosols throughout the stratosphere over several hours



Andøya Space, 69°N Norway

Rocket launch monitored with EULIAA lidar

Mie-signal up to 40 km for hours with development of layers



In-situ space debris residue monitoring with lidar

Ongoing ESA OSIP Project (activity #[4000150277](#))

New space creates a drastically improved input of aerosols and metals in the higher atmosphere from rocket starts and burned up space debris

Resonance lidar measurements for long-term development of tracer concentration of space-relevant materials

Decades of experience with natural metal-layers (Na, K, Fe, Ca) observation in MLT (60-130 km)

The screenshot shows a project dashboard for the activity "OVERCOMING ATMOSPHERE-BLINDNESS - IN-SITU RESONANCE LIDAR MEASUREMENTS OF RE-ENTERING SPACE DEBRIS ENABLED BY AN ALEXANDRITE LASER". The dashboard includes a navigation bar with tabs for Overview, Events, Reports, Assessments, Forum, Members, History, Approval workflow, and Milestone Payment Plan. Key information displayed includes: "RUNNING" status, "Prime contractor: FRALIN-KOFER GESELLSCHAFT", "Organisational Unit: TEC-AME", "Start date: 17 November 2026", "Estimated end: 17 September 2028", and "Duration: 10 MONTHS". The "Activity Type" is "Early technology development". A "Summary" section states: "As space activities increase, we need to safely remove old satellites from orbit to prevent overcrowding, but this process may pollute the atmosphere with metals. The idea is to develop advanced laser technology that can autonomously measure these metals in the atmosphere, helping us understand the environmental impact of space debris." The "Publications" section has a link for "Full description of idea from proposal". The "Objective" section explains the need for clean-space initiatives and the role of resonance lidar in measuring metal layers like Potassium, Sodium, and Iron in the Mesosphere and lower Thermosphere (MLT). A "Budget" section shows a total of 175000€.

In-situ space debris residue monitoring with lidar

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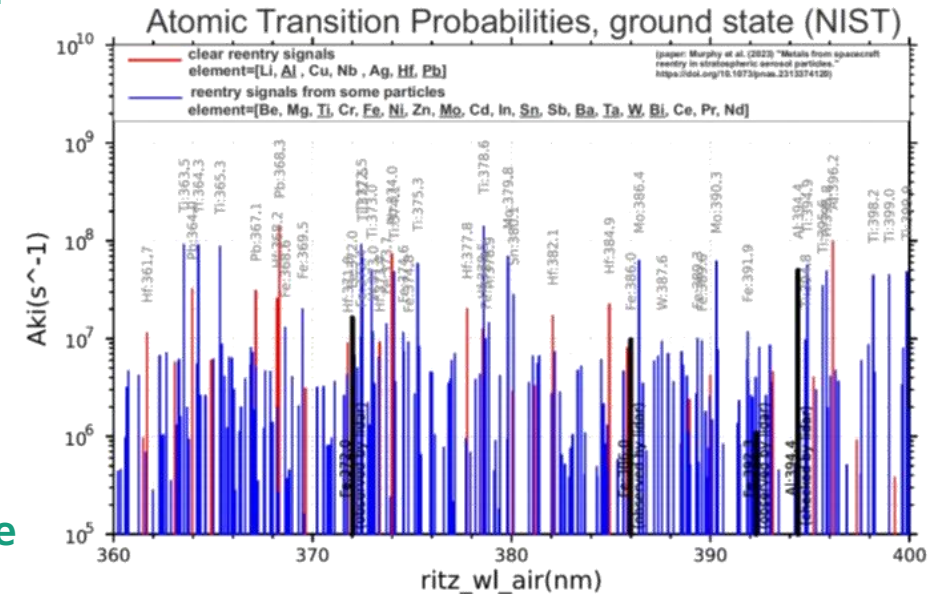
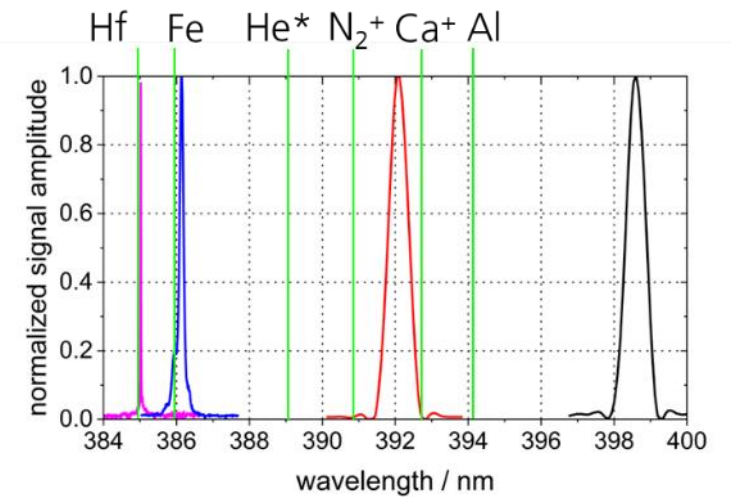
Tunable Alexandrite laser with optional SHG: 740-800 nm and 370-400 nm

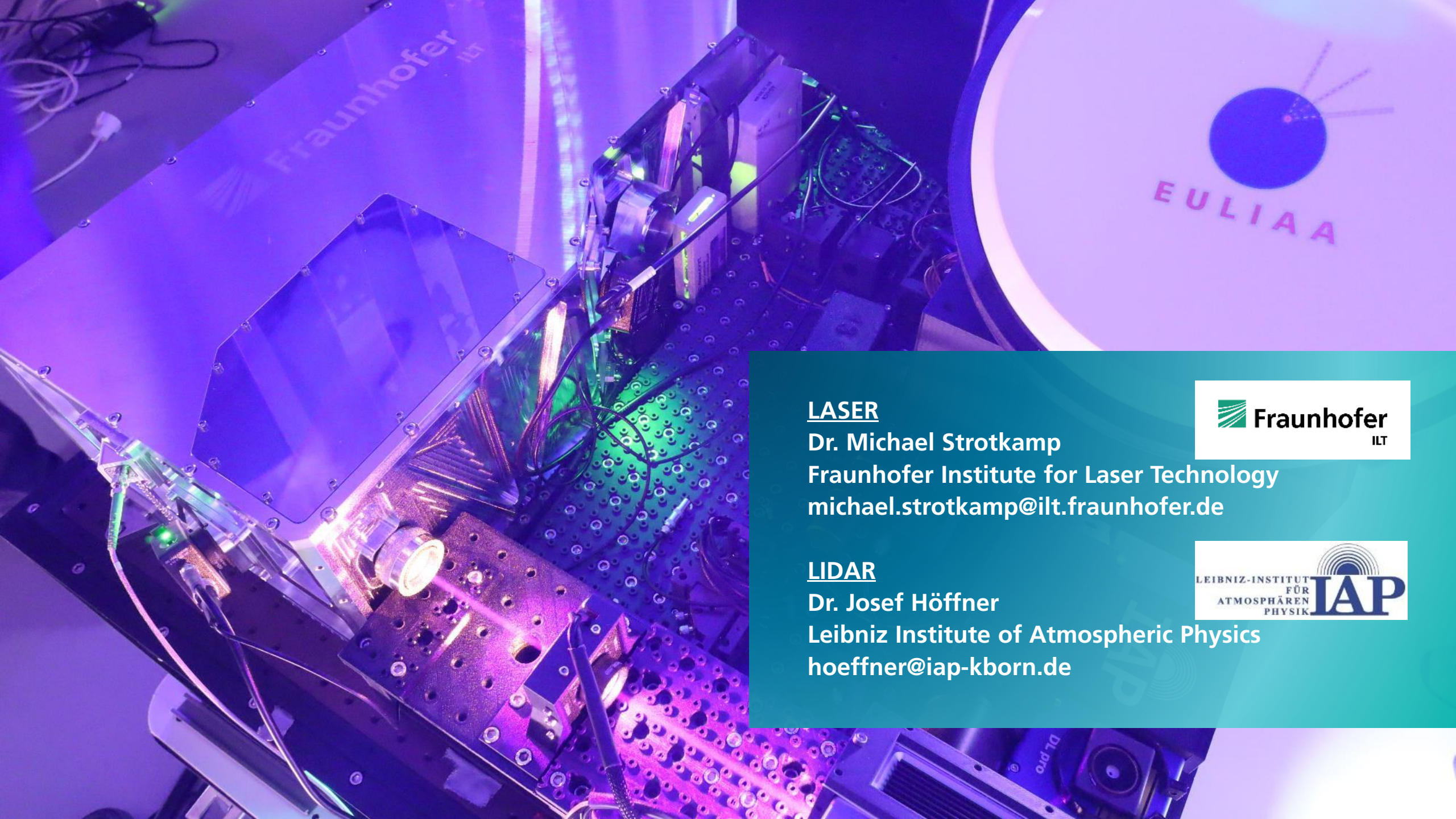
Several potentially relevant metals with reentry origin within tuning range

Possibility to address resonance lines for different metals with same setup

Long-term objective:

Resonance lidar to autonomously monitor various metals as tracer for space debris residue over long periods





LASER

Dr. Michael Strotkamp

Fraunhofer Institute for Laser Technology

michael.strotkamp@ilt.fraunhofer.de



LIDAR

Dr. Josef Höffner

Leibniz Institute of Atmospheric Physics

hoeffner@iap-kborn.de

