An artist's impression using ChatGPT
https://chatgpt.com/s/m_6810023be8388191a0b5b8d2d285107f

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Designing a mission concept for atmospheric plume measurements during a rocket launch event

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Growth and impact of space travel

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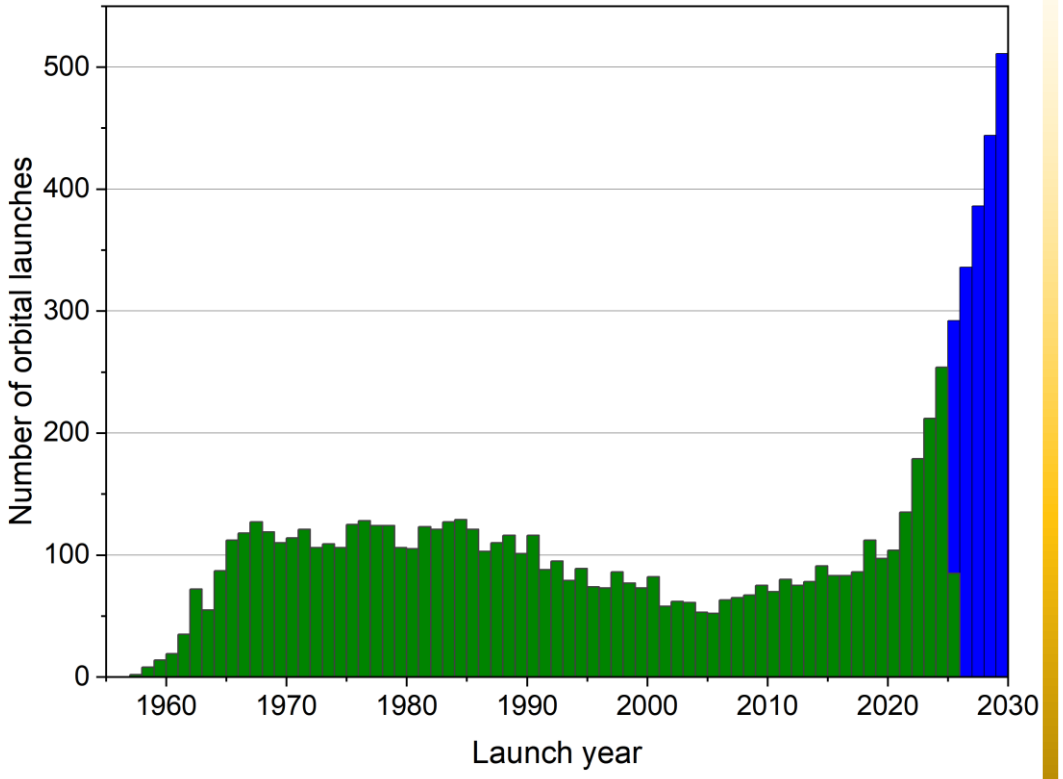
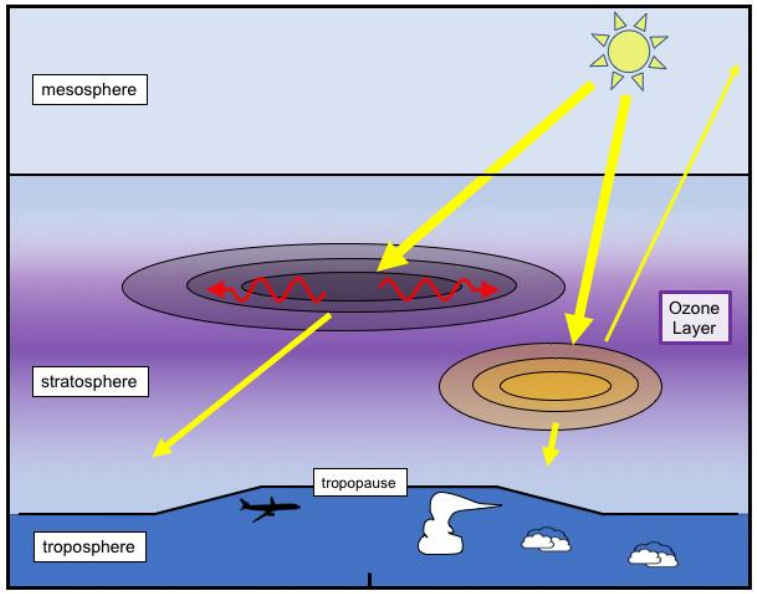
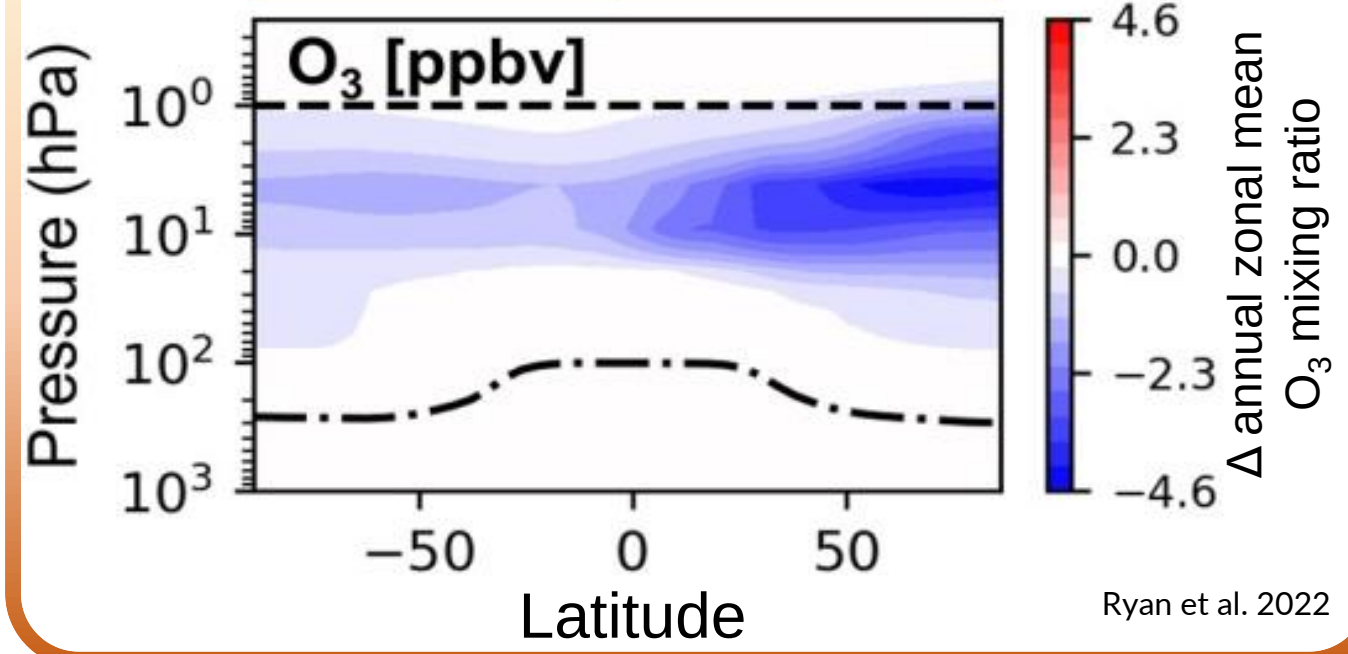


Mc Dowell 2025, https://planet4589.org/space/gcat



Ross & Vedda 2018



Ryan et al. 2022

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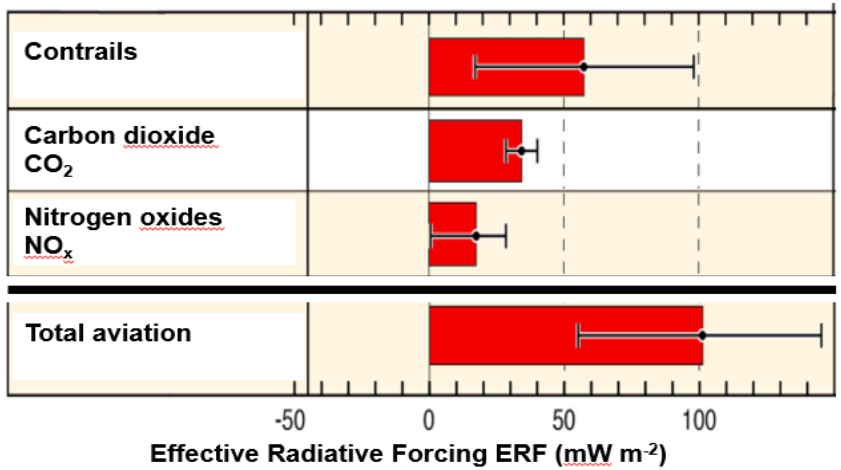
Questions requiring measurements

photo of the launch of Ariane 5ES
taken from ISS, ESA, Paolo Nespoli, 16 February 2011

1) How do launch/reentry emissions impact the atmospheric composition, dynamics and climate?
→ ozone depletion, cloud formation

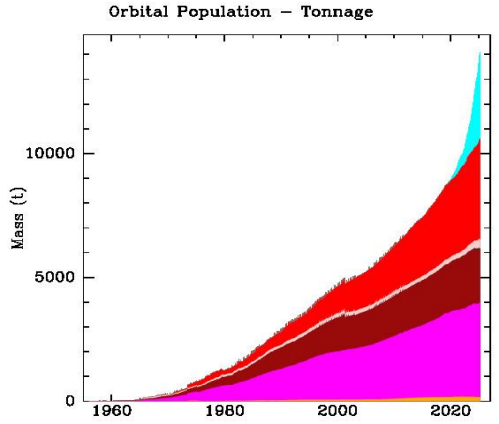
2) What is the role of current and future propellants?
→ CH_4, C_3H_8, RP-1

ERF from aviation



Lee et al. 2021

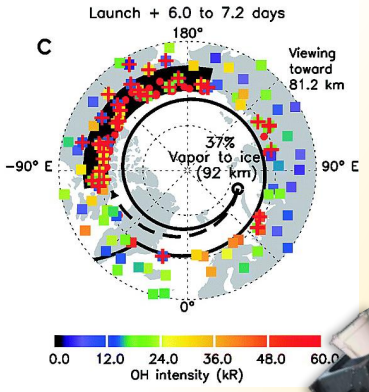
3) What are the effects of space debris on stratospheric aerosol and ozone?



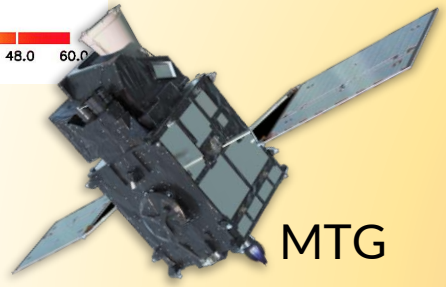
Orbital mass

Mc Dowell 2025

Stevens et al. 2003



A comprehensive approach



OH
PMC

MTG

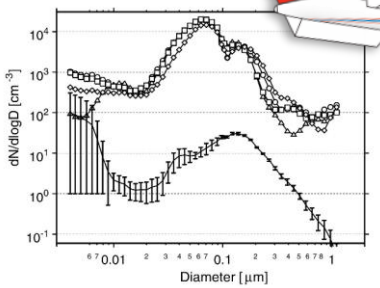
GHG

Clouds
Aerosol

EarthCARE

Chemistry
Gases

Aircraft

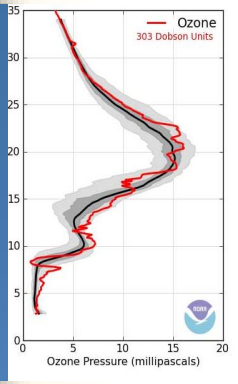


Schmid et al. 2003

Sounding
rocket

Debris
Dynamics

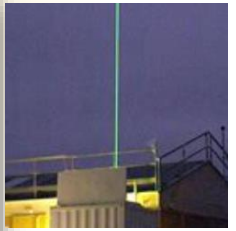
T O_3



Balloon

Gases

Ground



Aerosol

Image credits:
Isar Aerospace
ESA
NASA
NOAA
DLR

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How to get a plane into the plume

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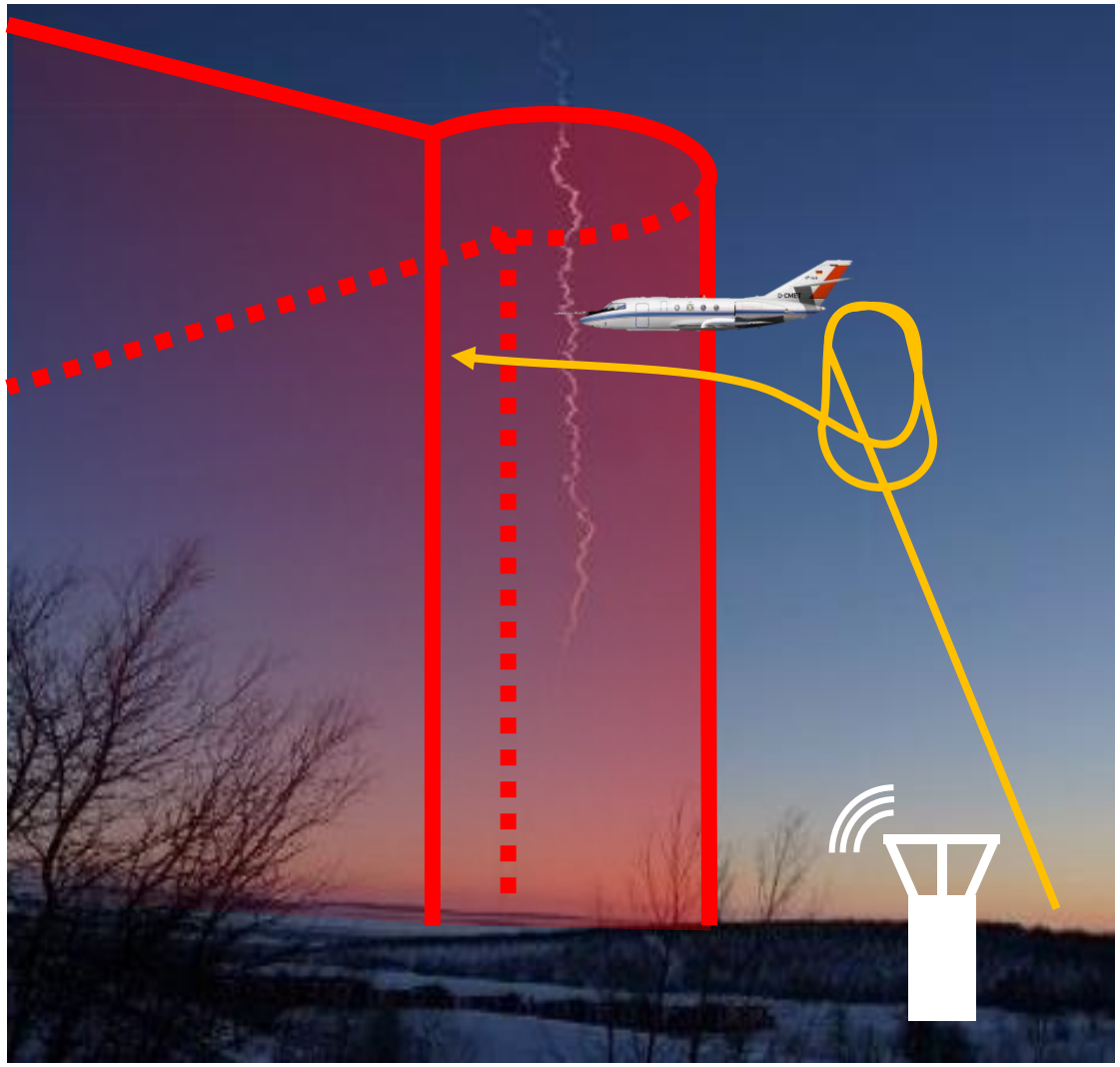
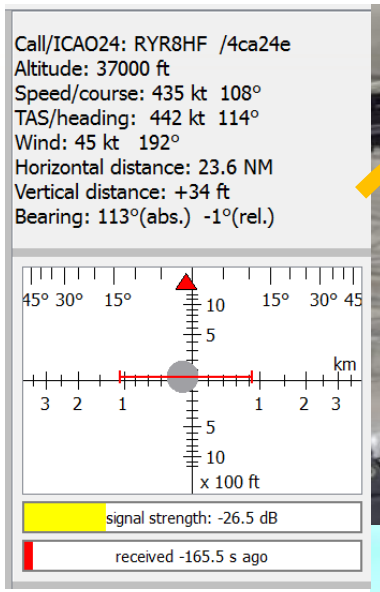
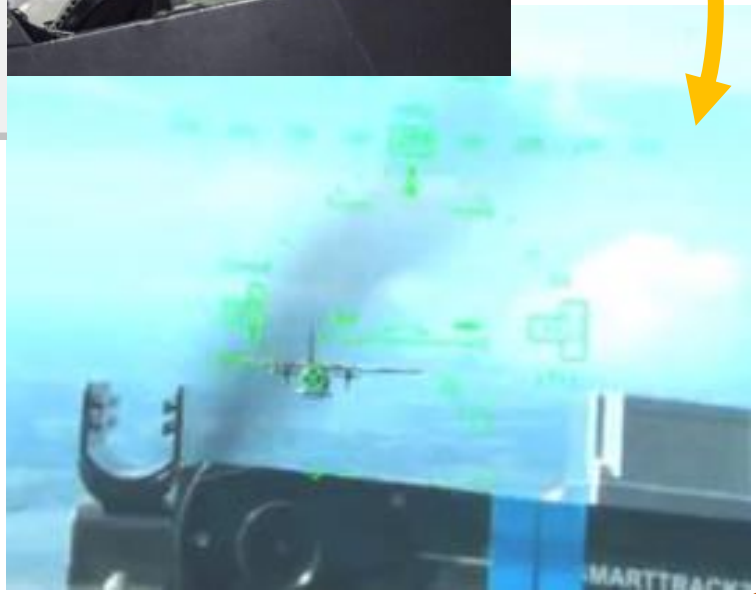


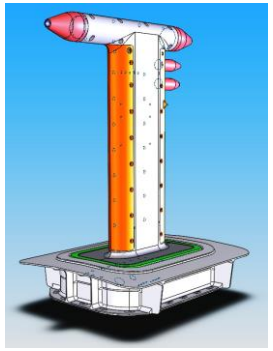




“Breadcrumb” tool
+
mixed reality goggles

Image credits: DLR, Varjo

Fast and precise aircraft instrumentation



Inlets

Meteorology (p, T, u, v, w) up to 100 Hz

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Cloud probes

Aerosol size and composition

Trace gas concentrations

CO CO_2 CH_4 H_2O NO_x NH_3 O_3

Image credits: DLR

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Adaptable plans

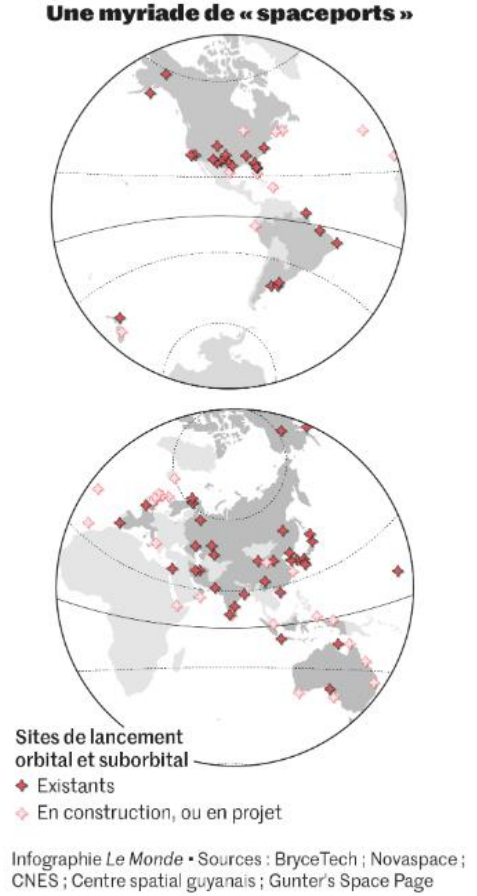
Different launchers

Duration/
Delays

Piggyback
options

Different aircraft …

… with other instruments



Launch site

Summary

- Adapt methods for high-resolution measurements of
  - exhaust plumes
  - impacted and background atmosphere
  - space debris
- Based on earlier work, link measurements to models (plume, GCM, CCM) and near field to far field
- Exploit synergies of exhaust and debris measurements, supporting life cycle assessment (LCA) capabilities

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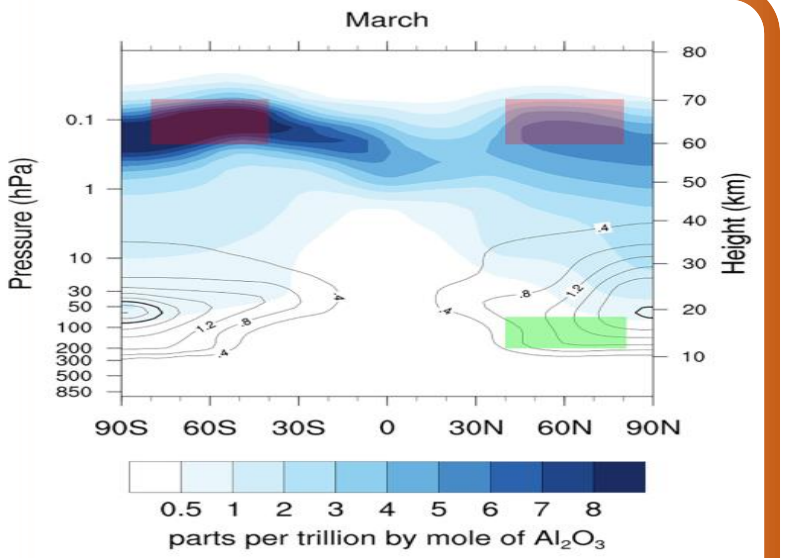
Kokkinakis & Drikakis 2022



Murphy et al. 2023