Recent Detection of Reentry Debris in Stratospheric Aerosol and Science Implications

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Introduction

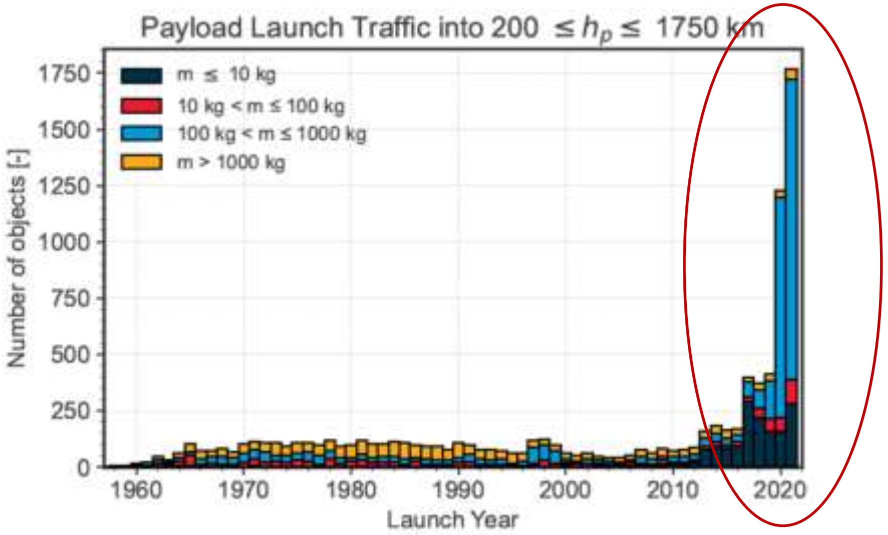
- Impact of space industry emissions on climate and ozone have been of scientific interest since the 1990s

- Spaceflight emission sources

  - rocket engine combustion (launch vehicle)
  - reentry vaporization (satellites and upper stages)

- Until recently the scientific focus was limited to launch emissions

- Reentry emissions are increasing faster than launch emissions and the science focus is changing as well

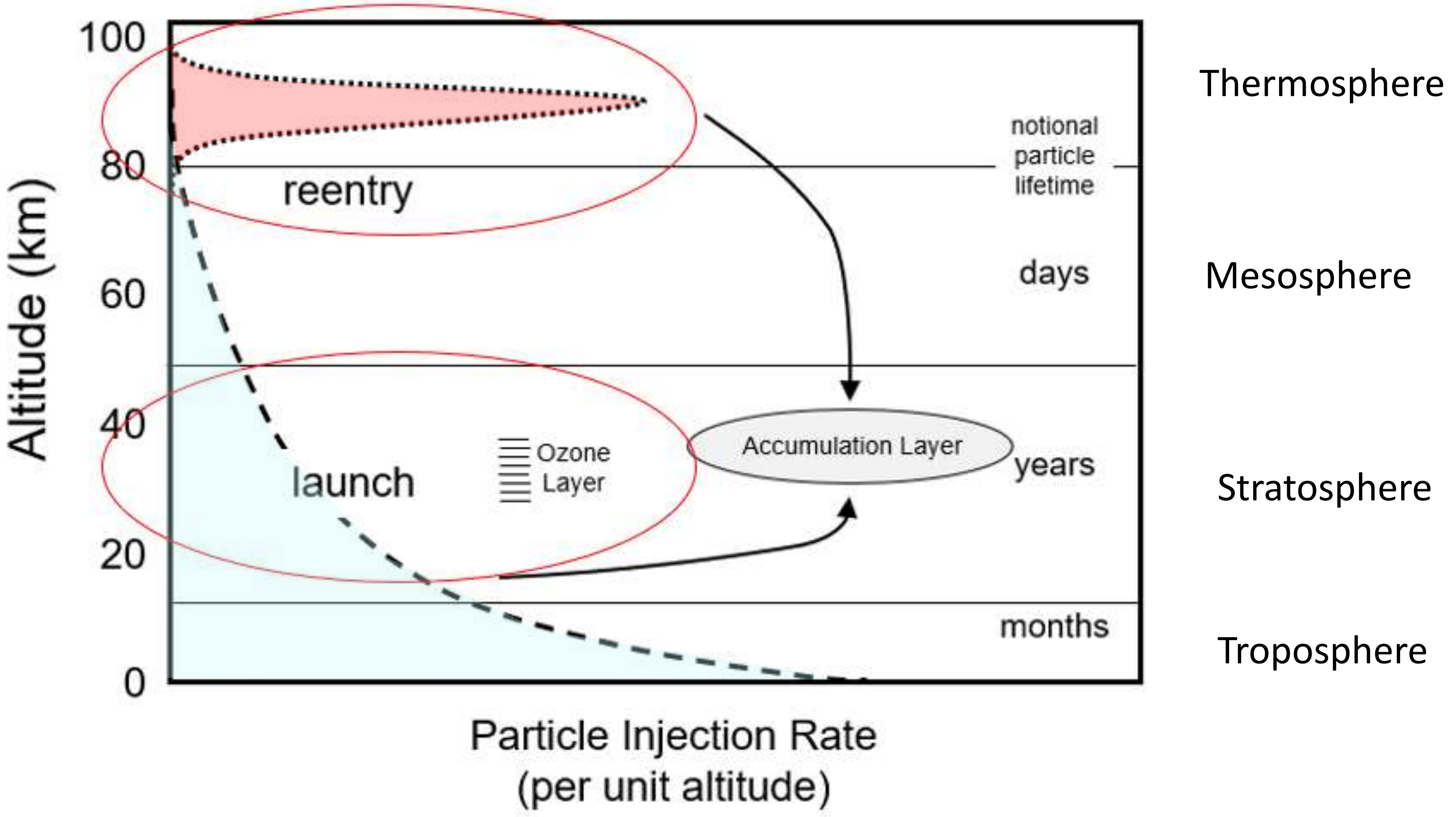


most will reenter
in next several years

↑3X by 2030

↑10X by 2030

Phenomenology of Space Industry Emissions



Recent Scientific Publication

- NOAA PALMS instrument has flown on multiple aircraft since 1998 (Particle Analysis By Laser Mass Spectrometry, Daniel Murphy PI)
- PALMS measures the composition of aerosol particles from 100 to 5,000 nm, and can operate on high altitude aircraft that reach the lower stratosphere.
- Aerosol particles make up the nominal background of small (0.1 µm) sulfuric acid particles in the lower stratosphere
- Recent high latitude measurements revealed unusual metallic inclusions, different from what is from meteoric ablation in the background sulfate particles
- These inclusions included a variety of metals and alloys that are commonly and uniquely used in satellites and upper stages

Metals from spacecraft reentry in stratospheric aerosol particles

Daniel M Murphy [1,2], Maya Abou-Ghanem [1], Daniel J Cziczo [2], Karl D Froyd [1,3], Justin Jacquot [2], Michael J Lawler [1,3], Christopher Maloney [1,3], John M C Plane [4], Martin N Ross [5], Gregory P Schill [1], Xiaoli Shen [2]

Affiliations + expand

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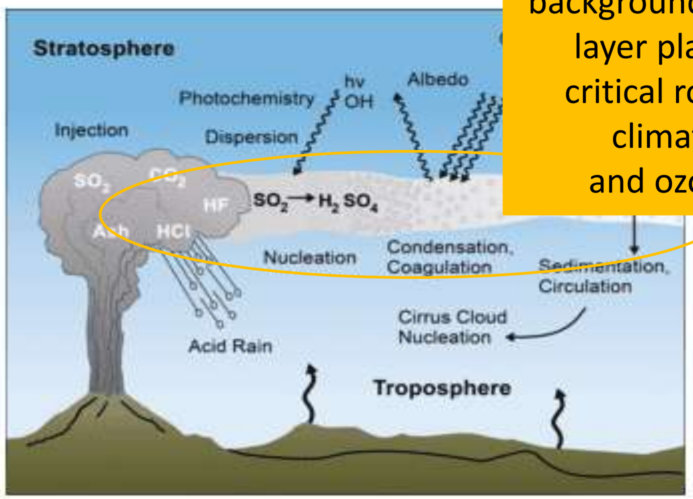
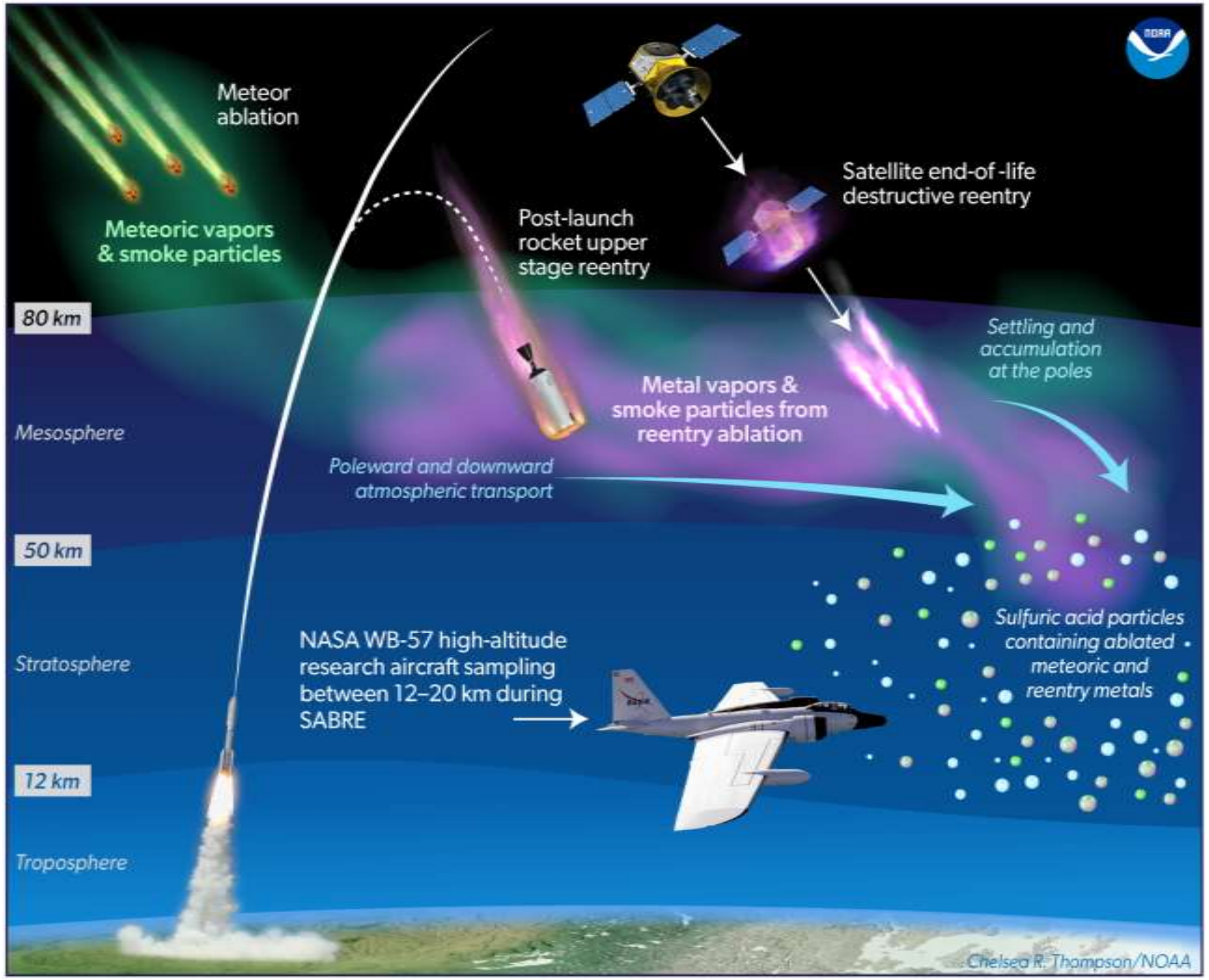


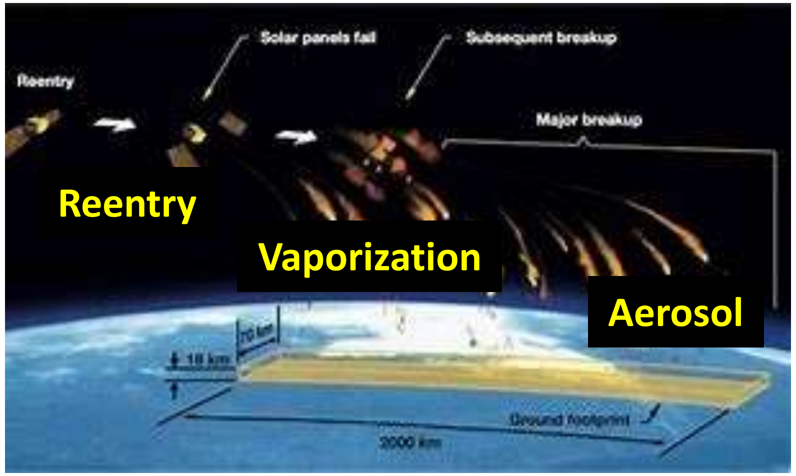
background H_2SO_4 layer plays a critical role in climate and ozone

Interpretation

- Detected the presence of reentry vaporization products (elemental) in stratosphere background particles
- Approximately 10% of all particles measured contain detectable levels of reentry products
- Data indicates presence of reentry vaporization, but not absolute amounts
- Specific spacecraft source identification cannot be made since most space vehicles use similar alloys
- Effects of the metallic inclusions on the optical and chemical properties of background aerosol is unknown



Some Implications of the Data



- Data validates the proposed particle production process: destructive reentry → vaporization → stratospheric aerosol

- Pervasiveness of reentry material (10% of background) provides key data point for reentry analysis tools (e.g., SCARAB, ORSAT)

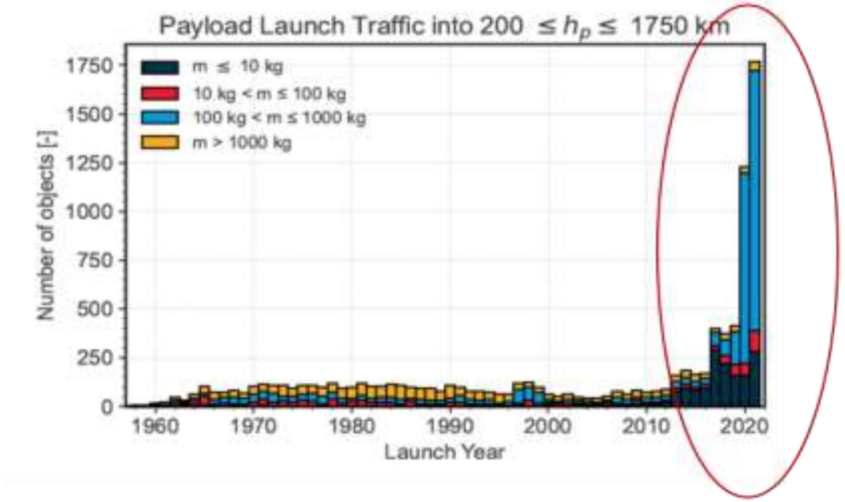
- Nothing definitive can be inferred concerning the impact of the metallic inclusions on background sulfate particle microphysics
  - Scattering properties
  - Chemical properties
  - Size distribution
  - Geoengineering processes

- In situ collection of sulfate particles for laboratory analysis of inclusions is possible and would be valuable

- The (a) production of particles and (b) the survival of components are two aspects of the same technical problem so that coordinated research is indicated

Future Reentry Emissions Will Grow

- The Large LEO paradigm assumes increased reentry flux
- Near-term reentry flux increase (2000 t/yr) is "baked in the cake" since 5000 satellites are already in orbit
- Far-term reentry flux increase (10 t/yr) can be predicted based on constellation licenses and stated plans
- Far-Term reentry particle production could approach the background meteoritic particle flux



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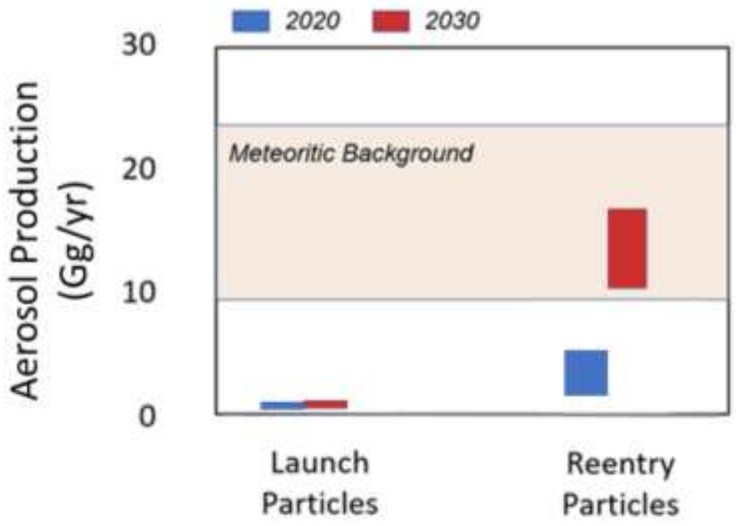

Questions

LIDAR
RADAR
IR Spectrometer
VIS imaging

- What do the new data imply about validation of reentry destruction / survivability models?
- What is the impact of metallic inclusions on sulfate particle microphysics?
- What remote sensing data can be collected against increasing reentries to improve models?
- What are the detailed scenarios for future reentry emissions?
- What are detailed physical/chemical process from space vehicle structure to stratospheric particle?
- What are the impacts of bare metallic reentry aerosols on global climate and ozone?

Summary

- Reentry vaporization is overtaking launch as the greatest source of spaceflight particle emissions.
- Reentry particle production has received little scientific attention compared to legacy launch emissions.
- Debris from spacecraft reentries were recently discovered as metallic inclusions in 10% of the background stratospheric aerosol layer.
- Increases in the number of LEO satellites could cause up to half of stratospheric sulfuric acid particles to contain metals from reentry. The impact on the properties of stratospheric aerosol is unknown.
- The impact of reentry metal on global climate and ozone is not known.
- The reentry particle production problem is tightly coupled to the reentry survivability problem.
- Path forward: Quantify reentry vaporization emissions
Determine impact on atmospheric chemical and radiative processes

Thank You

Questions?