AAS Statement on the Atmospheric Impacts of Spacecraft Reentries and Launches

Adopted 27 September 2024

The American Astronomical Society (AAS) is gravely concerned about the impacts of emissions and residual effects from extensive space launches and space object reentries on Earth's sky and upper atmosphere. Tens of thousands of new satellites are planned to be launched and then replaced regularly in order to indefinitely maintain steady-state populations of large satellite constellations, often referred to as megaconstellations. The replacement process will involve disposing of retired satellites by ablation in the mesosphere and stratosphere, and launching new satellites to replace them. The AAS is concerned about the potential impacts of the continuous launching of new spacecraft and vaporizing old ones on our atmosphere, and in turn on ground-based astronomy. We call on policymakers to secure funding for scientific research on the aggregate effects of a growing number of launches and reentries on the Earth's climate and ozone layer, and on regulators to incorporate the results of such research into their licensing of space activities.

Re-entry of spacecraft into the atmosphere at the end of their lifetimes has become a common practice to mitigate the crowding of low Earth orbit (LEO) and the generation of orbital debris. For example, the FCC now requires satellite operators in LEO to dispose of their satellites within 5 years of completing their missions, usually by having them reenter the atmosphere. In planning for spacecraft reentries, the "design to demise" principle, which involves satellites fully burning up in the atmosphere, has been advocated for and adopted by many space operators to minimize the risk of uncontrolled re-entries that bear casualty risks and the potential to damage homes and infrastructure (**Byers et al. 2022**). While this approach to endof-life satellite disposal helps reduce debris in orbit, and minimizes damage from uncontrolled reentries, the choice to instead burn up satellites in the atmosphere may pose a significant risk to the Earth's climate and the ozone layer, through the resulting alteration of atmospheric chemistry.

A single large satellite constellation, composed of 42,000 satellites, with steady state replacement on a five year cycle[1] would require 23 satellites to be launched and deorbited each day. Given existing rocket capacity to carry 20-50 satellites, this would require launches every 1-2 days[2]. Moreover, with a typical satellite weighing of order 1000 kg, and being primarily metallic, the steady state injection of metals into the stratosphere by vaporization of satellites would be at least 8000 tons per year. This would exceed the natural injection of metals into the stratosphere by meteoroids. For example, the aluminum deposition from satellites would be more than double the natural injection by meteoroids, which are less than 1% aluminum by mass (**Schultz & Glassmeier 2021**, **Boley & Byers 2021**).

Recent measurements show that metallic inclusions from current rocket and satellite re-entries are already present in at least 10% of stratospheric background aerosols (**Murphy et al. 2023**). This fraction will soon increase quickly, as the many planned satellite constellations are deployed and these satellites begin to reach the end of their short lifetimes. The effects of the expected increase in reentry rates and associated metal pollution are completely unknown.

Pollution from reentries could potentially increase the opacity of Earth's atmosphere (**Keith 2000**), further impacting ground-based optical and infrared astronomy that is already plagued by satellite streaks. The lithium deposition from re-entries will exceed natural deposition by at least two orders of magnitude (**Boley & Ostapenko 2023**)[3], and could induce an airglow that increases the night sky brightness, limiting our ability to study faint astronomical objects. The magnitude and severity of these effects are still uncertain and need ongoing research to better understand. This pollution could also cause ozone depletion and modify the properties of the naturally occurring sulfate aerosols that play a role in maintaining Earth's climate, and further research is urgently needed to understand the severity of the impacts. Reentry shock waves will also cause atmospheric chemistry changes, with significant production of nitrogen oxides (NOx), which could also contribute to ozone depletion (**Ryan et al. 2022**).

The atmospheric effects of reentries could also be compounded by the launches that are needed to replace the deorbited satellites. While the CO2 emissions from an individual launch will not necessarily be significant, launches deposit large amounts of black carbon, or soot, into the stratosphere, which would lead to an increase in the stratospheric temperature, potentially increasing ozone depletion (**Maloney et al. 2022**). Launches also deposit considerable water vapor into the mesosphere, leading to the formation of mesospheric clouds (**Voigt et al. 2013**), further impacting ground-based astronomical observations. Both ascending rockets and deorbiting secondary boosters **create holes** in the ionosphere, which create a temporary, but bright, induced auroral effect. Frequent launches and reentries of large rockets may begin to consistently impact our ability to carry out astronomical observations.

We recommend that regulators and policymakers seriously and substantively consider the issue of atmospheric pollution from satellite launches and reentries. We call on policymakers to provide funding to conduct urgent scientific research in order to provide stakeholders with a timely assessment of all spaceflight emissions and their effects. Such research will require coordination with satellite operators and manufacturers to incorporate accurate projections of re-entry rates and data regarding the metallic composition of satellites. We further urge regulators to incorporate the results of this research into their licensing of space activities. This could include setting a cap on the flux of reentry aerosols into the stratosphere that is informed by scientific research on reentry emissions and changes to the global atmosphere. While such research is being carried out, we strongly encourage abiding by the precautionary principle.

---

[1] See, e.g. **Baccelli et al. 2024** and **https://www.space.com/spacex-starlink-satellites.html**. For an analysis of current SpaceX Starlink operational lifetimes, see **https://planet4589.org/space/plots/starlife/index.html**.

[2] Even for a Starship rocket, which could carry up to 150 tons of payloads to LEO (**https://www.spacex.com/vehicles/starship/**), this would require launches approximately every 4 days for a single satellite constellation with 42,000 satellites weighing 1000 kg each.

[3] The daily flux of lithium from meteoroids is $5x10^{-5}$ tons/day, while for 42,000 satellites with a lifetime of 5 years that have a mass of 1000 kg each, with 0.3% lithium, largely in batteries, the flux would be 0.07 tons/day.

Want to submit content for the AAS website and biweekly Digest? Read our Posting Guidelines and then click the button below:

Submit Content

Contact the Communications Department if you have any questions.