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19 December 2022

Dear Space Agency Leaders,

Reducing risks from uncontrolled reentries of rocket bodies and other space objects

The uncontrolled reentry of space objects presents a significant, cumulative, fast-growing risk to human beings around the world. Uncontrolled rocket bodies are of particular concern. We call on your agencies, working with your states' foreign ministries, to initiate multilateral negotiations on a *controlled* reentry agreement, starting with rocket bodies. Recognizing that such negotiations take time, we further call on each of your states to unilaterally commit to a national controlled reentry regime.

In 2021, approximately 65 percent of launches to low Earth orbit (100 to 2000 km above the surface) resulted in an uncontrolled rocket body reentry. Depending on the materials, masses and sizes of its components, approximately 10-40 percent of the dry mass (i.e., not including liquids and gases) of any such object will survive reentry. Although most of the debris pieces are small, even a small piece could be enough to kill a person or critically damage an aircraft. The International Association for the Advancement of Space Safety estimates that an "impact anywhere on an airliner with debris of mass above 300 grams would produce a catastrophic failure, meaning all people on board would be killed."

Uncontrolled reentries from Chinese spaceflight launches have been prominently covered in Western news reports. In 2020, pieces of a Long March 5B rocket damaged buildings in the Ivory Coast. In early 2022, two smaller rockets scattered debris across India. In July 2022, the breakup of another Long March 5B was visible from the ground in Borneo, and sizable pieces were later found. On November 4, 2022, another Long March 5B reentered over the Pacific Ocean southwest of Guatemala. However, while the Long March 5B is of note due to its mass (the core stage is about 20-tonnes), China is not the only actor allowing rocket bodies to reenter in uncontrolled ways. In 2016, a US SpaceX Falcon 9 second stage was abandoned in orbit, reentering over Indonesia with two refrigerator-sized fuel tanks reaching the ground intact. In 2018, a number of smaller titanium pressure vessels from a Russian Zenit upper stage reached the ground in Peru.

Some states have adopted a safety threshold of one predicted casualty per 10,000 launches, above which controlled reentries are supposed to be required. But this threshold is arbitrary and not widely accepted internationally, and even those states that use it have often waived the requirement when compliance is deemed to be unreasonably expensive. The US Air Force, for example, waived orbital debris mitigation standard practices (ODMSP) in over half of the launches conducted on its behalf from 2011 to 2018.[1] Most importantly, the 1-in-10,000 threshold does not account for cumulative risks from all launches over a period of time. The risks from uncontrolled reentries are growing quickly as space activities increase and the global population grows.

[1] We do not know the reason for any given ODMSP waiver.

Conservative estimates place the casualty risk from uncontrolled rocket body reentries as being on the order of 10 percent in the next decade.[2] These estimates do not include 'low-probability high-consequence' events such as debris striking an aircraft in flight, nor do they take into account the way space use is changing. This research also found that states at low latitudes – i.e., many of the states of the 'Global South' – face disproportionately high casualty risks due to the distribution of orbits of abandoned rocket bodies.

Moreover, as the frequent use of waivers suggests, the 1-in-10,000 threshold itself is increasingly difficult to meet. The figure below shows the maximum casualty area that a reentering object can have and still meet the 1-in-10,000 threshold as a function of the object's orbital inclination. The casualty area is the sum of the cross sections between each piece of lethal debris and a person on the surface of Earth. This could comprise a single large piece of debris, or many small pieces. A typical casualty area for a rocket body is larger than 10 m^2. Some, such as the Long March 5B, will have much larger casualty areas.

When the 1-in-10,000 threshold was first adopted, casualty areas of 10 m^2 could plausibly have been achieved. But as shown in the figure, because of population growth, both current and future, casualty areas will now need to be well below 5 m^2 for many inclinations to keep the casualty risk less than 1-in-10,000. The figure also confirms that, because the orbital inclination sets the latitudes that a reentering object can reach, reentries of large objects with moderate to low inclinations – like the Long March 5B rockets being used to construct the Tiangong space station – are of particular concern.

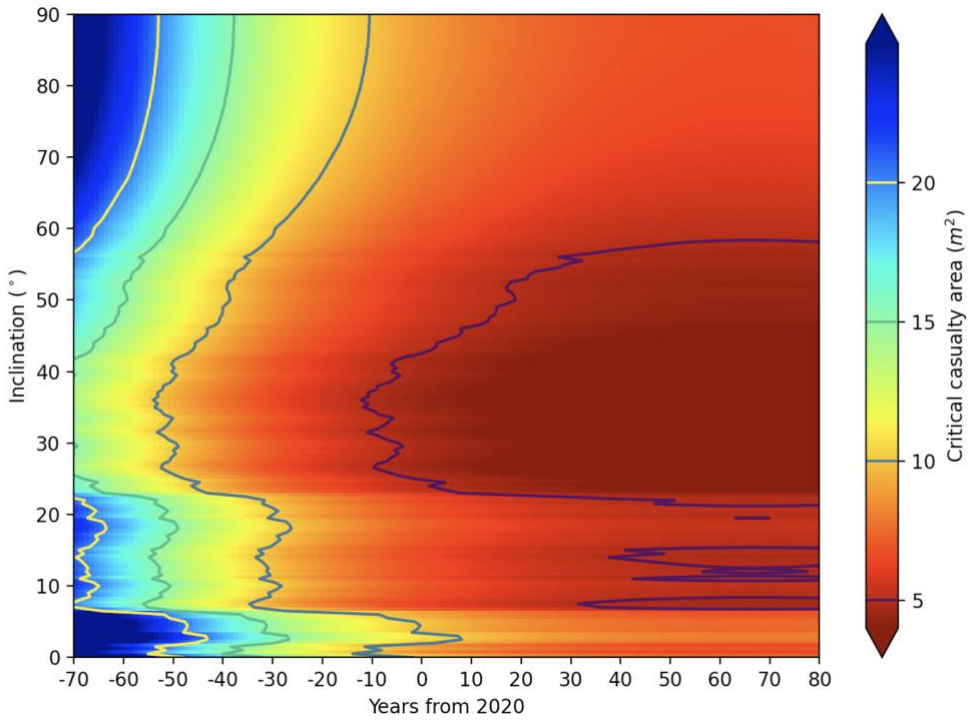

Figure. Heatmap showing the maximum casualty area for an uncontrolled reentry to meet the 1-in-10,000 risk threshold. Inclinations between 25-45 degrees include most of the United States, the Mediterranean region, central South Asia, and major cities in Brazil, Argentina, and South Africa. The situation, already serious today, will continue to worsen unless and until a controlled reentry regime is adopted. Image credit: Ewan Wright (see Byers et al. 2022). See also Lemmens et al. (2016).

[2] M. Byers, E. Wright, A. Boley, C. Byers, 'Unnecessary risks created by uncontrolled rocket reentries.' *Nature Astronomy* (2022). https://doi.org/10.1038/s41550-022-01718-8. Similar research, conducted independently and concurrently, corroborates this figure: C. Pardini, L. Anselmo, 'The Kinetic casualty risk of uncontrolled re-entries before and after the transition to small satellites and mega-constellations,' Journal of Space Safety Engineering, 2022. https://doi.org/10.1016/j.jsse.2022.04.003.

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Uncontrolled reentries of rocket bodies are usually preventable and therefore unnecessary. With re-ignitable engines (and some extra fuel), rocket bodies can be directed into remote areas of the ocean. Although all reentries risk damage to the upper atmosphere and marine environments, mandating controlled reentries is currently the best way to reduce casualty risks for the global population.

A controlled reentry agreement will require increased expenditures by some launch providers, at least in the short-term – as they transition to new technologies and mission designs more quickly than they otherwise would. This latter point is important: eventually, change will come. In the 1970s and 1980s, proposals for a double hull requirement for oil tankers (which operate in another 'area beyond national jurisdiction') were successfully resisted by the global shipping industry. It was only after the 1989 Exxon Valdez oil spill that a transition to double hulls was required, first by the United States and then by the International Maritime Organization. With rocket body reentries, the only unclear thing is whether the major spacefaring states will require a safer approach *before* an accident occurs.

We therefore call for multilateral negotiations on a controlled reentry agreement.

Uncontrolled rocket body reentries constitute a collective action problem; solutions exist, but every spacefaring state must adopt them. A controlled reentry regime would raise safety standards worldwide and thus create a level playing field, including for new entrants. It would also be verifiable, given the transparency of Earth orbit to the ground-based radar and telescopes already used for space situational awareness and collision avoidance.

We also call on each of your states to show further leadership by immediately and unilaterally committing to a national controlled reentry regime.

Such a regime, which could include a transition phase, should apply to all government and commercial launches conducted, procured, licensed, or otherwise approved by your government.

Moreover, while this letter focuses on the casualty risks from uncontrolled rocket body reentries, uncontrolled satellite reentries are also of concern and may eventually dominate the casualty risk should tens of thousands of medium-sized to large satellites be placed into orbit. Thus, a reentry regime that starts with rocket bodies should soon be expanded to satellites to reduce all uncontrolled reentry risks.

Simply hoping that uncontrolled reentries will not cause harm is an unsustainable strategy. With leadership, cooperation and global goodwill, these preventable and therefore unnecessary dangers can be greatly reduced.

With thanks for your attention to this important matter, we are,

Yours sincerely,

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