

# Food for thought

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**Abstract.** The space domain has undergone several changes in the last decade (aka “new space era”), and will continue to do so in coming years. This led to several challenges which should be recognized and tackled by all actors of this domain, including scientists.

**Keywords.** General

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Over the two thirds of a century since the launch of the first satellite, the space domain has evolved drastically in many ways. In this contribution, we propose some “food for thought” regarding several current issues, often requiring urgent consideration for action.

**Communication** A simple search on the word “space”, on internet or social media, usually yields answers linked to scientific discoveries in astronomy or space missions (with or without human beings). Such activities are of course important, but one should recognize that they represent a really tiny fraction of what is done in the space domain. The majority of space activities is rather linked to commercial or military uses. They are much less publicized, so that the public, politicians, or medias have a biased vision of space. Key issues (see below) can then be difficult to comprehend for them: communication regarding space therefore should evolve to better reflect the actual situation and its challenges.

**Sustainability** In a decade, the number of launches has more than doubled - there has already been about a hundred of them in the first half of 2023. In parallel, the satellites have become smaller. There is thus an exponential increase in the number of satellites. This has of course several consequences, especially regarding sustainability. First, having more objects in space implies an unavoidable increase in debris numbers and more generally an increase of the overall “orbital traffic”. Passive satellites and uncontrolled debris cannot escape collisions, further increasing the number of debris. In contrast, thanks to performant ground-based radars, collision alerts can be issued and avoidance maneuvers are then scheduled for working satellites. However, the number of alerts is increasing and will continue to do so in coming years (e.g. Starlink satellites had to swerve ~25 000 times between December 2022 and May 2023 - this currently represents a doubling of the number every six months). With every maneuver requiring energy, one may wonder when this situation will become untenable (one maneuver every month? every week? every day?) hence low orbit unusable, to the detriment of all. A second question is related to atmospheric pollution. Indeed, launches and satellite/debris re-entries are not without impact on the atmosphere (notably regarding the ozone layer and climate change). With more detailed simulations performed in this field, it is time to discuss what level of pollution would be deemed acceptable. Finally, there are also consequences for scientific activities. Indeed, satellites are a source of (optical) light and radio pollution. Some companies have

darkened their satellites, but that only prevents them from being visible to the naked eye: professional telescopes can still pick them up. Satellite strikes then renders images unusable, although the exact fraction of lost data depends on the nature of the telescope program (an all sky survey like that of the Vera Rubin telescope being more impacted than pointed observations with e.g. ESO telescopes). In a similar way, satellite radio emissions interfere with radiotelescope observations. Reversing the direction of observation, Earth observation satellites also suffer from satellites at lower orbits crossing their line-of-sight. For example, some humidity diagnostics could be affected by radio interference from satellites, impairing weather predictions. One may here wonder which limit for such interferences to scientific work could be accepted.

**Regulation** At the international level, things are still mostly ruled by the Outer Space Treaty from 1967, which has been signed by many countries, and in particular all space-faring nations. However, it is much less stringent than e.g. the subsequent Moon Treaty (ratified by only few countries) and it now appears quite outdated since it mostly considers space activities run by states and not by private companies. In the last decades, several countries (United States, Luxemburg, United Arab Emirates...) have adopted national laws which are clearly supportive of private space exploitation. However, many issues can only be solved by international agreements. Space debris constitute a good example: not only the consequences of collisions should be settled (who's responsible?) but also guidelines should be elaborated for debris removal (can one country evacuate the "debris" associated to another nation?). There is also the question of space tourists - there is an international agreement for state astronauts, but it does not account for the recent development of space tourism. Moreover, space weaponization is increasing, and becoming more mixed with private interests: e.g. some national "space forces" guidelines explicitly mention the defense of private interests of companies linked to that country, while some private services are now used by armies with consequences on the battlefields (e.g. the military use of Starlink in Ukraine, which was limited after a personal decision of E. Musk). Finally, space exploitation also causes problems. For example, water extraction in polar craters of the Moon attracts the attention from various countries with different interests (e.g. China and United States), laying the ground for future conflicts. More philosophically, one could wonder about the limits of exploitation: is it ethically acceptable to destroy a small asteroid to exploit it? or a big one? or to change the face of the Moon forever and for all terrestrial beings to see? or to fully use non-renewable resources (such as the lunar water), leaving nothing to exploit or study for the next generation?

As scientists and citizens, many questions related to the current and future space activities arise. Let's not be afraid of them and let's discuss them, to ensure everyone will enjoy space in the future.