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Satellite Constellations as an Issue in Space Law

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ABSTRACT

Satellite constellations constitute significant threat to ground-based optical astronomy as well as radio astronomy. Thousands of satellites are planned to be placed in low-Earth orbit (LEO), and several hundreds of them are planned for higher orbits such as MEO. International astronomical community has been discussing the issue with its all dimensions; need for proper regulations, national space policies, and international agreements. This contribution is intended to define the issue and its impact on astronomical observations.

Keywords: Satellites, low-earth orbit, space debris, light pollution, space-law

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1. Introduction

The first artificial satellite was sent to orbit in 1957. Sputnik-I was a very simple satellite sending inside and outside temperature of the nearly 80 kg spacecraft. Since then, 9031[1] satellites and space vehicles have been sent to the Earth orbit up till 2019.

Orbit of satellites can be considered in three categories; low-earth orbit (LEO), medium-earth orbit (MEO), and geostationary (or geosynchronous) orbit. Figure 1 demonstrates these orbits projected onto 2D plane centered at Earth.

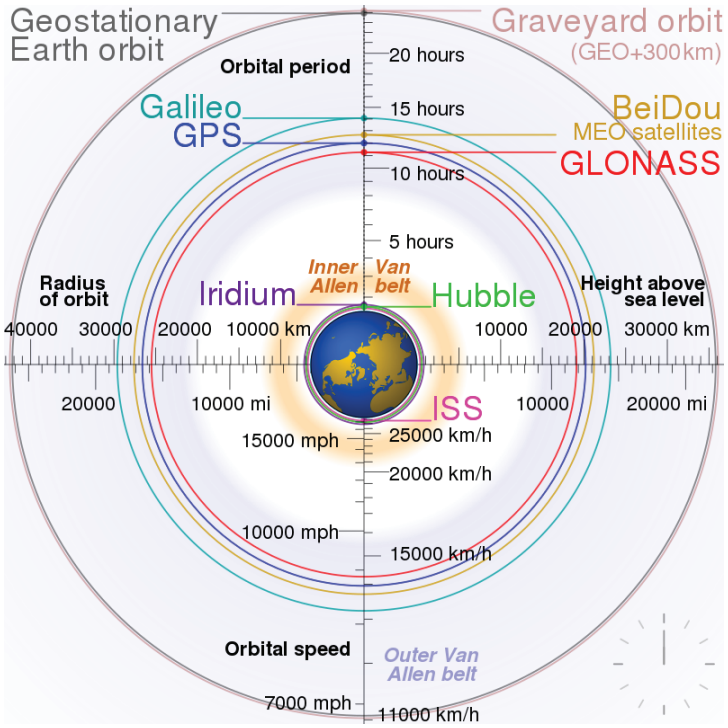


Figure 1. Comparison of satellite navigation orbits around the Earth. ©Wikipedia

Purposes of those satellites are various such as Earth observation, global positioning or navigation, communication, and the military. In general, TV/radio communication satellites are located in geostationary orbits whereas Earth observing satellites are located mostly in LEO.

2. Satellite Constellations

A constellation of satellites is a group of satellites working for a specific purpose in coordination with each other. The well-known example of satellite constellations is the global navigation satellite systems (GNSS). The pioneer of GNSS is the US GPS satellites, a network that contains 31 satellites. Russian GLONASS system (24 sats), European Space Agency's GALILEO (22 sats), and China's BEIDOU (33 sats) are amongst other GNSS systems currently in operation.

Another example of constellations is used for communication via satellite phones. Iridium is the pioneer of the field with 76 satellites. Thuraya (3 sats) and Inmarsat (13 sats) are also used for satellite communication.

1 https://www.unoosa.org/oosa/osoindex/index.jspx

Nowadays, companies are designing and launching large constellations to provide global broadband internet connection. SpaceX's StarLink is the pioneering project which foresees to launch 42k satellites in LEO. A list of planned satellite constellations is given in Table 1.

Major competitors of StarLink are OneWeb (~6000 sats), Amazon/Kuiper (~3000 sats), and GuoWang (13k sats). Together with other smaller scale projects there expected more than 70k satellites in Earth orbit until the end of the 2020s. In 2020, 1263 satellites were launched to the orbit, and in the first five months of 2021 the total number of launches was 911. When compared to 9031 satellites between 1957-2019, that was a very dramatic increase in satellite launches.

Table 1. List of planned satellite constellations (ESO Report COU-1928, 2020)

Constellation (Registering Nation)	**Altitude (km)**	**Number of satellites**
Starlink Generation 1 (US)		
	5,50	1,584
	1,110	1,600
	1,130	400
	1,275	375
	1,325	450
Starlink Generation 2 (US)		
	328	7,178
	334	7,178
	345	7,178
	373	1,998
	499	4,000
	604	144
	614	324
	360	2,000
OneWeb Phase 2 (US, UK)		
	1,200	1,764
	1,200	23,040
	1,200	23,040
Amazon Kuiper (US)		
	590	784
	610	1,296
	630	1,156
Sat Revolution (Poland)	350	1,024
CASC Hongyan (China)	1,100	320
CASIC Xingyun Lucky Star (China)	1,000	156
CommSat (China)	600	800
Xinwei (China)	600	32
AstromeTech (lndia)	1,400	600
Boeing (US)	1,030	2,956
LeoSat (Luxembourg)	1,423	108
Samsung (Korea)	2,000	4,700
Yaliny (Russia)	600	135
Telesat LEO (Canada)	1,000	117
Total		96,437

With all these numbers taken into account, it can be seen that commercial satellite constellations consisted of 35% of the satellite launches in the 2010s, whereas these constellations will constitute 70% of the satellite launches by 2029 (Euroconsult, 2020).

Putting satellites in orbit is not the end of the story. Especially, with large number of satellites (i.e. satellite constellations), there needs to design replacement operations for malfunctioned or

dead satellites. In order to keep constellation working properly, operators need to replace older satellites with spare satellites. However, what is going to be done to older satellites is not clear. Obviously, it is not sustainable to keep old satellites in orbit, which is increasing the space debris. ESA and Airbus designed a conceptual study called "shepherd concept" to bring down dead satellites to the Earth by using a collector satellite (Fig. 2).

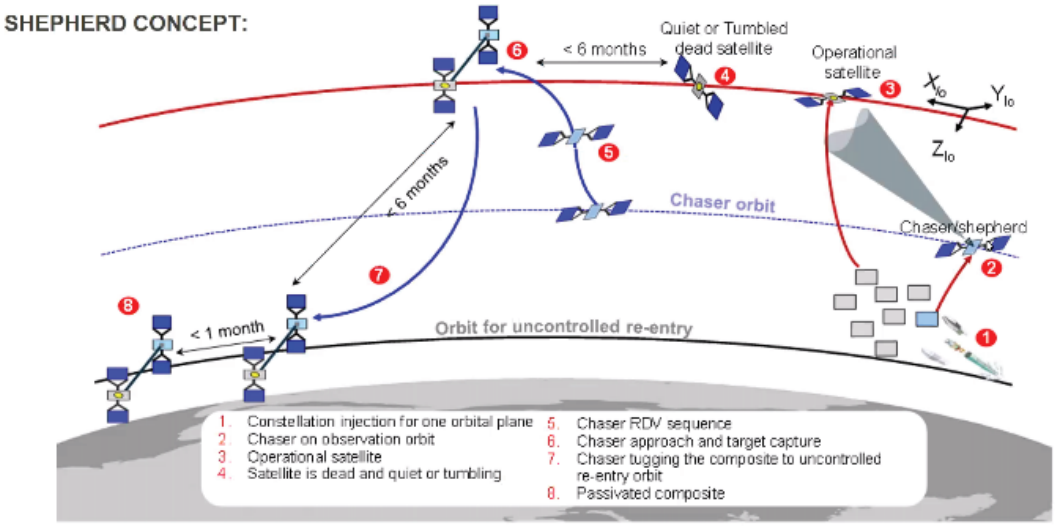


Figure 2. A conceptial strategy (i.e. shepherd concept) to recover malfunctioned or dead satellites (Courtesy of ESA-Airbus)

Significant increase in the number of satellites in orbit threats other satellites, telescopes, and space stations. Risk of satellite collisions increases with the number of satellite in orbit. In Fig. 3 monthly average number of objects larger than 10 cm in orbit is shown as a function of year. Two steep increases in the number of objects, thus space debris, in 1996 and in 2009 are due to the collisions of satellites or spacecrafts.

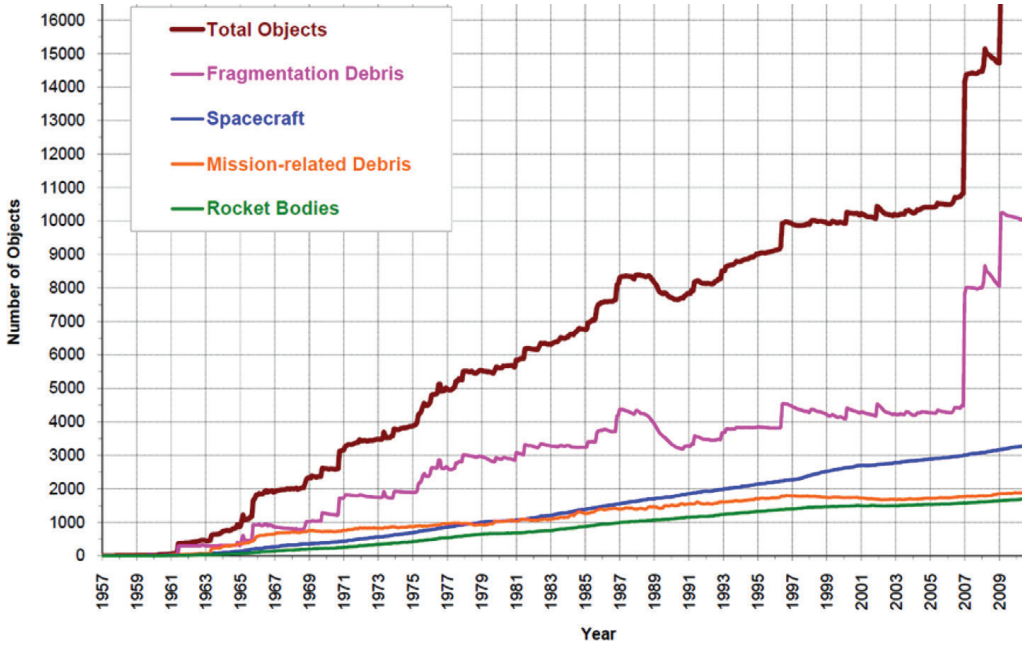


Figure 3. Monthly number of objects in Earth orbit larger than 10 cm detected and catalogued by the U.S. Space Surveillance Network (Englert et al., 2014)

3. Impact on Astronomy

From the beginning of designing satellite constellations, nobody was expecting a significant negative impact on astronomical research. Deployment of the first sets of Starlink satellites made astronomy community in the world shocked due to their brightness. Communications between the SpaceX and the astronomical community revealed that even the company was not expecting such an impact. However, SpaceX showed an affirmative intention to reduce the brightness of their Starlinks. Nevertheless, SpaceX is not the only aerospace company planning satellite constellations, and the technical characterics of others are unknown for the moment.

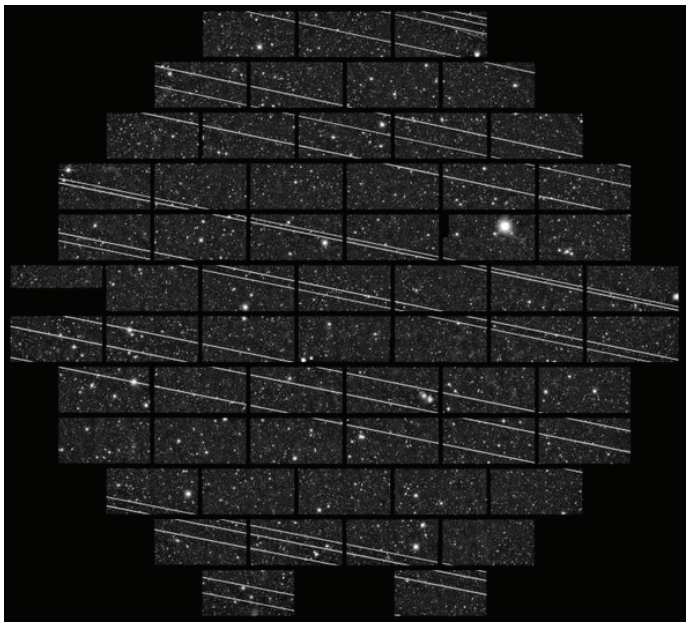


Figure 4. Starlink satellites' trails on the image taken by the CTIO 4m telescope at Chile. Credit: CTIO, NOIRLab, NSF, AURA and DECam DELVE Survey

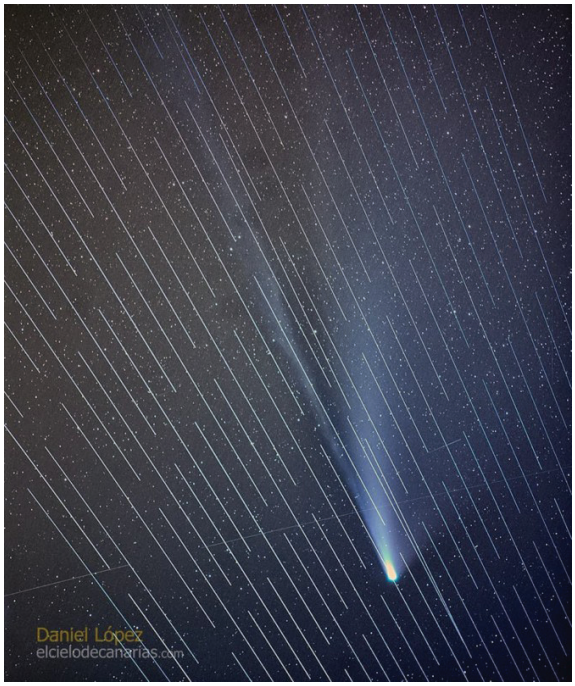


Figure 5. Comet NEOWISE and trails of Starlink satellites. © Daniel Lopez

The biggest impact on astronomical research from the satellite constellations is to ruin scientific images. This is true especially for large field of view imaging surveys and/or telescopes such as SDSS, Rubin Observatory, and VISTA.

Modern astronomical surveys are conducted with a robotic fashion from the observing to the data analysis phases. Such satellite trails will have a huge impact on the outcomes of those surveys (e.g. Figs. 4 and 5). Currently, the IAU and the respecting bodies are discussing the possibilities of image reduction and analysis methods to eliminate such trails. Even with machine-learning techniques, this is not a trivial task, and this impact will degrade the science output of those telescopes/surveys.

Due to the material used for the coating of the satellites, the effect of the trails will be visible in optical and near-infrared wavelengths. However, the effects of satellites are not limited to this. There is a significant thread exists for the radio astronomy as well. Communication and data transfer of hundreds of thousands satellites in LEO will interfere with radio telescopes. Currently, the biggest concern is for the Square Telescope Array (SKA) Observatory, LOFAR, VLA, and the ALMA radio telescope arrays. One practical solution for radio astronomy would be to stop radio communications of satellites over those radio observatories. Nevertheless, this solution is not approved, and even more is not enough. There expected to be large interference even with stopping radio communications when the observatories are at the line-of-sight with satellites. IAU is leading a discussion to be presented to the ITU and to the UN-COPUOS regarding the allocation of radio frequencies and safeguarding radio astronomy from the Earth.

Hainaut and Williams (2021) showed that thermal radiation impact or naked-eye visible satellites will be negligible for telescopes in Chile, mostly for ESO telescopes. Imaging surveys, especially those with a large field of view, and long exposure observations will be affected by satellite constellations significantly. For a given time, approximately 5000 satellites will be over the horizon of Paranal (site of the VLT telescopes).

Besides their impact on large field of view imaging surveys, satellite constellations affect the observations at twilight and lower altitudes. This is mostly important for detecting and monitoring the near-Earth objects which have a potential threat for the Earth. Thus, due to the thousands of satellites, telescopes dedicated to the monitoring of such objects may fail to identify any orbital disturbances, close-by passages to the Earth.

4. Conclusions

In the light of international agreements, it is not possible and not feasible to prevent satellite launches and orbiting for any reason. However, for the sake of the future astronomy, we need to find ways to mitigate their impact on astronomy and space sciences. In this regard, close collaboration and communication between the two communities is quite important. International bodies such as ITU, IAU, and UN-COPUOS should play a role in finding a common ground for discussions. In particular, putting satellites in LEO or higher orbits creates an important difference where the latter impacts astronomical observations severely for a longer duration. On the other hand, putting many satelllites in LEO orbit requires a good handling and maintenance scheme to prevent satellite collisions and the increase in space debris.

In order to reduce their effect on observational astronomy from the ground, satellites certainly should be as faint as possible. Starlink typical brightnesses can be seen in the Figure 6. Those first sets of satellites were as bright as they could be seen with naked-eye. Communications between the Starlink and the astronomical community led to a common ground that Starlink's can be fainter with an average brightness of 7 magnitude. However, this situation is not certain for the other satellite manufacturers.

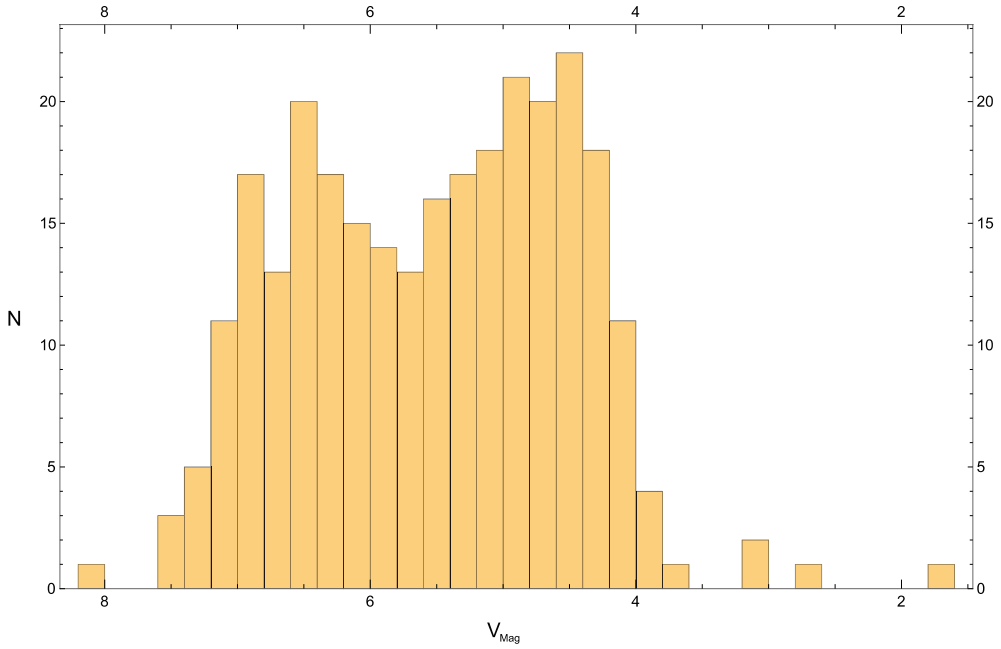


Figure 6. Brightness distribution of firs sets of Starlink satellites

After several meetings, workshops, and symposias, it is clear that a strong collaboration is needed. Here, the astronomical community is not trying to prevent satellite launches, but seeks a moderation and international regulation for such an extensive orbiting. National legislation sometimes plays an important role for the regulation, but only a few countries have their own space law or related legislation. This puts UN-COPUOS in an important position to be a neutral and objective moderator for this topic. The issue of satellite constellations was discussed in the Scientific and Technical Sub-Committee in 2021 for the first time. Obviously, there is a long way for the common agreement. IAU and many related international organizations are making preparations for the COPUOS STSC in 2022. Once an agreement among the national representatives in COPUOS is reached, then the topic can be discussed in the General Assembly. The process is hard and takes a long time, but to save the future of astronomy and space sciences, this route needs to be followed.

In the meantime astronomical community prepares itself by developing tools to reduce/remove satellite impacts from images obtained with telescopes. Besides, establishing a common data centre and an office is under discussion with AAS, IAU, and related bodies. Knowing exact location of those orbiting satellites may help to take some precautions such as observation planning and scheduling accordingly, but this requires knowledge of satellite locations with a very high temporal resolution and precision.

References

Report of the 1st Satellite Constellations Workshop, *Impact of Satellite Constellations on Optical Astronomy and Recommendations Toward Mitigations*, 2020, AAS/NOIRLab/NSF.

IAU CRP document. *Recommendations to Keep Dark and Quiet Skies for Science and Society*, 2021, CRP-17, IAU/UN- COPUOS, 19 April 2021.

Englert, C. R. et al. (2014). Optical orbital debris spotter. *Acta Astronautica, 104*, 99−105

ESO Council Report. (2020). A Report on the Impact of Satellite Constellations, ESO/Cou-1928.

Hainaut, O. R. and Williams, A. P. (2020). Impact of satellite constellations on astronomical observations with ESO telescopes in the visible and infrared domains. *Astronomy and Astrophysics, 636,* A121.