SUSTAINABLE USE OF SPACE AT AURORA PROPULSION TECHNOLOGIES

ABSTRACT

We are committed to promoting sustainable use of space at Aurora Propulsion Technologies. We want to proceed a dialogue towards finding workable solutions to the challenge of the fair and responsible use of outer space with all our partners who believe in the same values. We need a holistic and systematic approach to aim for sustainable use of space, when we design, produce and provide services for our customers. This document is prepared to explain and declare our approach to various dimensions of sustainable use of space to all stakeholders in this context.

PROBLEM STATEMENT AND BACKGROUND

Space industry and economy have substantially changed from the 1960s. Especially the last decade has witnessed a steady, rising contribution of the space industry to the overall economy. According to the Space Foundation's annual report [1], the sector reached US$ 423.8 billion in 2019 from US$ 323 billion in 2015. Growth of the private industry in a previously government-dominated industry has contributed to this growth. Other factors responsible for this growth could be the increasing reliance of our daily lives on services from Space, the privatisation of the space market and the lower cost of deploying smaller and distributed missions in orbit. So this growth improves human-life quality but also contributes to overloading the space ecosystem at the same time. The forecasts return a stronger growth over the following years, up to US$ 720 billion by 2030 (according to the Space Foundation's estimates; Paladini, 2019). Besides the satellite segment where our company operates represents the biggest share, accounting for about 75% of worldwide 2019 revenue [2]. On the other hand, this growth contributes to overloading the space ecosystem. Carrying capacity of Earth's orbital regions is limited yet space traffic is continuously increasing which causes the enduring space debris problem. We see a close connection between space debris and sustainability which will be covered at the end of this document, in more detail. Still there are other dimensions to consider to have a complete holistic view on sustainability, as explained in the following section.

AURORA'S VIEW ON THE PROBLEM

The most obvious trigger to focus on sustainable use of space might be the accelerated growth of space debris resulting from steep increase in space flight traffic, yet there are more issues to consider to have a balanced stand point on sustainability. Let's summarize the sustainable use of space with discussions combining environmental, legal, social, economic, and technological aspects to explain what it actually means for Aurora.

1. Environmental Aspects of Sustainability

Outer space has become a fundamental resource to human beings, which needs to be protected to preserve its benefits. Current space flight activities are mainly concentrated in Earth orbits. However, deep space exploration has been of interest to space nations since the dawn of the space age. In recent years, new initiatives focusing on extraterrestrial exploration have risen also with focus on Mars. Missions to Mars could not only help in searching for life [3], but also represent a deep interest of human beings to explore and expand. Though most of the space flight activities already respect the Principle of Planetary Protection (PPP) (to avoid forward and backward contamination), debris is produced all over our solar system and beyond (Voyager space probes [4]). Human-made objects in orbit sooner or later become debris unless they are disposed of right away. Hazards from the outer space environment either natural (space weather and asteroids) or artificial (space debris and the growing number of satellites launched to orbit) pose a rising risk to space flight activities. The awareness for space sustainability and space safety has seen a continuous increase in recent years and does not stop at the Earth's sphere of influence.

The environmental impact of space missions and the sustainability of space activities should be evaluated carefully. We can understand what our present use of space will mean for future generations by only using this approach. At Aurora, we strive to maintain humanities access to space by promoting the study of natural space hazards and their mitigation. We are also leading the way taking concrete steps to enable us and our customers to reduce their impact on the space environment. We address the space debris problem by three principles; Firstly, using less resources and materials on the ground and in space. Secondly, conserve, reuse and recycle materials already sent to space. Thirdly, clean up, by enabling the effective removal of space objects from orbit. With these three principles Aurora Propulsion Technologies aims to address the environmental dimension of sustainability for us and our customers.

2. Legal Aspects of Sustainability

Space has been treated largely as open territory, a commons belonging to no State, and therefore open to exploitation by any State which represents the tragedy of the commons.

It is a global commons with little governance beyond the four UN treaties [5] and the regulations of the International Telecommunication Union. Government officials and the general public have come to realise that space activities must be subject to greater caution and care than seemed necessary recently. Status of International Agreements relating to Activities in Outer Space can be found here [6].

This realisation has led to several initiatives to improve the governance of Earth orbital space. Unfortunately there are only some guidelines following the previously mentioned awareness so legal enforcement is falling behind and tackling national/international barriers of legal aspects. There is no binding law enforcement not to create space debris or to clean the existing space debris. There are some guidelines (voluntary) developed by the UN, ESA, NASA and US Government and some national regulations in Australia, Denmark, France and Canada. We need better space traffic monitoring capabilities first and then increased data interoperability, sharing and transparency before expecting any hard regulations on space debris in near future. As far as we understand, the EU is expected to focus on SSA, space traffic management on EU level and development of debris removal technologies without a legal enforcement basis. Besides it is believed that ESA already has good guidelines in place but the level of adherence to them is rather low. On the other hand, there is a stronger push from the USA towards a new regulatory environment for space. New safety disclosure requirements for applicants seeking licenses and U.S. market access is expected in the near future which is good as we believe current soft regulations are not able to govern exponentially increasing constellations especially operated from the USA.

3. Social Aspects of Sustainability

According to John Rawls, justice is the primary virtue of social institutions, just like truth is the basic scale for any system of thought. Justice provides invulnerability to every human being and we all have the responsibility to ensure it.

How can we ensure that space actors use the precious outer space resource responsibly and fairly? Let's define the 'fair and responsible use' first: The term "fair" implies that the developed States with major technological resources in accessing and using outer space act in ways that do not impede the ability of less fortunate States to take part in the many benefits that operating in outer space can provide. It may further imply that the developed States should assist the less developed ones in accessing the benefits of space activities. This is a basic tenet of the UN Office of Outer Space Affairs (UNOOSA), which works to broaden the capacity of developing States in space technology and we as Aurora support this view of UNOOSA. We enable advanced space technologies to be accessible in a fair manner globally to aspiring teams building their spacecraft. Many developing nation spacecraft are small to conserve on launch costs, Aurora products enable these smaller space ventures to achieve mission capabilities only accessible by larger spacecraft in the past. We also welcome payloads from all over the world on our test flights to support teams taking their first steps in space with In Orbit Demonstration flights.

The term “responsible” points out the duty to maintain certain standards of behaviour. So responsible behaviour implies that developed and developing States must all adhere to the obligation to treat the commons of outer space in such a way to ensure sustainability of outer space activities into the future. We at AURORA ensure de-orbiting and collision avoidance capability are accessible by everyone. We empathise with future generations and respect their ability to use and benefit from space. Here our approach is not predicting the future debris, but respecting the future generations.

Another dimension of social aspect is ethical trade in sourcing. By ethical trade we refer to the practices that follow codes of conduct, and ensure that labour rights of workers are respected in our operations. We care about contributing towards sustainable economic and social development in developing countries through our purchasing preferences and we promote fair trade in our procedures.

4. Economical Aspects of Sustainability

According to the Space Foundation’s annual report [1], the sector reached US$ 423.8 billion in 2019 from US$ 323 billion in 2015. Growth of the private industry in a previously government-dominated industry has accelerated this growth. The forecasts return a stronger growth over the following years, up to US$ 720 billion by 2030 (according to the Space Foundation’s estimates; Paladini, 2019). Besides the satellite segment where our company sits represents the biggest share, accounting for about 75% of worldwide 2019 revenue [2].

This big economy carries some responsibilities. According to the United Nations sustained and inclusive economic growth can drive progress, create decent jobs for all and improve living standards. This decent work and economic growth is one of the 17 Sustainable Development Goals set to promote prosperity while protecting the planet [13]. We at Aurora, are building a workplace and network of partnerships that share the value of the UN and promote inclusive, diverse workspace and do our best to create sustainable and decent jobs.

Another dimension of economics is the value created on Earth by space activities where Aurora supports companies and other organizations aiming to create value in satellite operations which would serve modern life such as navigation systems, traffic management, crop yielding, weather forecast etc. improving quality of life on earth.

5. Technological Aspects of Sustainability

Fair and responsible use of space is not only part of the social view of sustainability. It is also about "space security and issues in space and on the ground, such as access to data or technology. The applications of space technology to societal development is strongly correlated in our age. Space applications are part of modern life, even in many developing countries without space programmes. So, what does the concept of "fair and responsible use of space" mean for emerging space countries that do not have space programmes? This is why we need to consider the particular needs and challenges facing developing countries in applying space technology. Space is a globalised environment. Other than certain nation states, independent actors such as multinational firms, universities, academic consortia and non-governmental organisations are increasingly being active in either operating satellites or utilising data from them. Space applications support environmental security, disaster management and human security and form one of the cornerstones of the Information Society. These issues are global issues and every nation should have the opportunity to solve these problems with accessibility of space. We at Aurora support the accessibility of space by all nations even if they do not have their own technologies. Besides from a technology point of view, we at AURORA address three principles of sustainable use of space with a toolbox of our technologies. The first principle, ‘Use Less Resources' is achieved by designing our product as small and compact as possible to minimize the amount of material sent to space as well as the energy needed to get it there. The second, “Conserve, Reuse and Recycle” is achieved by designing our micro thrusters to allow all satellites, regardless of size, the capability of collision avoidance and build the capability of proximity and docking operations enabling the refueling, inspection, maintenance and refurbishment of spacecraft to re-use them for further missions after their originally planned work is complete. The third principle, “Clean up” is enabled by our line-up of Plasma Brake deorbiting products that allow satellite builders to guarantee the eventual deorbiting of their spacecraft. Following these principles we focus on technologies enabling sustainable use of space such as development of deorbiting solutions and water- based thrusters since deorbiting solutions would help tremendously to reduce the space debris and cost efficient miniature thrusters would enable sustainable operations in attitude and orbit control of satellites.

Recent calculations estimate around 12,000 objects measuring over 10 cm in size, 200,000 objects between 1 and 10 cm and 35,000,000 objects between 0.1 and 1 cm in LEO. Particles measuring less than 0.1 cm are even more abundant. For almost any size of object in space, man-made pollution represents a greater risk than the meteors which are part of the natural space environment.

There have been an increasing number of launches of space assets by dozens of nations and operators, mostly for communications and entertainment (TV) purposes but also to provide increased services for the public in general (crop yielding or navigation systems) and for the military in particular. Space Situational Awareness (SSA) programmes monitor the threat from human-made objects: other satellites and space vessels, anti-satellite weapons (ASATs) as well as space debris, including the awareness of threats from asteroids, solar flares and other “astronomical threats” In particular, this raises questions regarding the trade-offs between actions that may improve military capabilities, but actually threaten civil and/or commercial capabilities. At Aurora, we are aware that SSA has both civilian and military perspectives, which are difficult to separate one from another. Both civilian actors and military actors have roles to play in SSA. We at Aurora support and enable the SSA and space traffic management operations by enabling space craft movement, monitoring, as well as the ability to act in space traffic management situations. We develop technologies that in the future will enable better understanding of astronomical threats, mitigate them or even make use of phenomena such as the solar wind.

6. Space Debris

Aurora shares below standpoints on the issue of growing space debris:

1. Understanding of the risks associated with a present-day space mission and the adherence to space debris mitigation guidelines are important to incentivise good behaviour.
2. Better space traffic monitoring capabilities and increased data interoperability, sharing and transparency on space debris are prerequisite to have sustainable solutions on space debris problems.

According to [7], the below growth tendency is anticipated for the future. The evolution of the number of objects larger than 10 cm and the cumulative number of catastrophic collisions, i.e. collisions leading to the complete destruction of target and impactor, are shown in Fig. 1 and Fig. 2: the dark line represents the mean value over all the Monte Carlo runs and the light coloured lines indicate the outcome of the single run. This representation was selected to visualise the variability across the single runs without introducing standard deviation bands as they may be not representative of the result distribution [8].

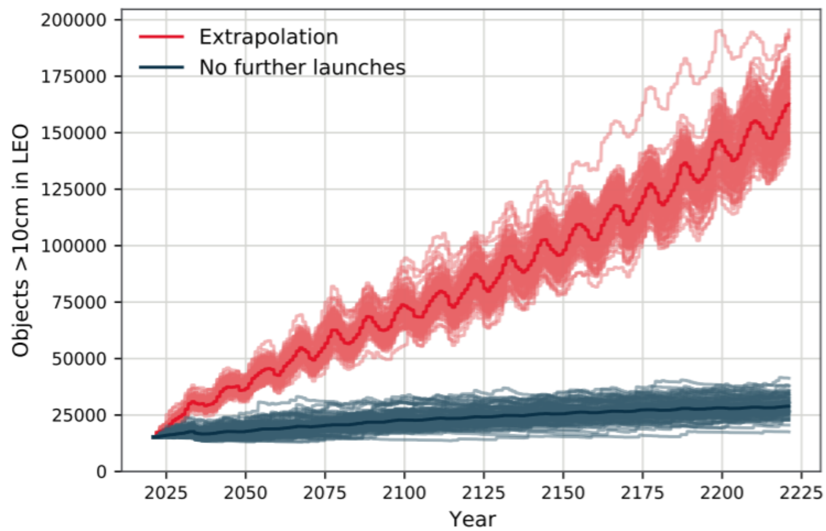

Fig 1:Number of objects in LEO_{IADC} in the simulated scenarios of long-term evolution of the environment.

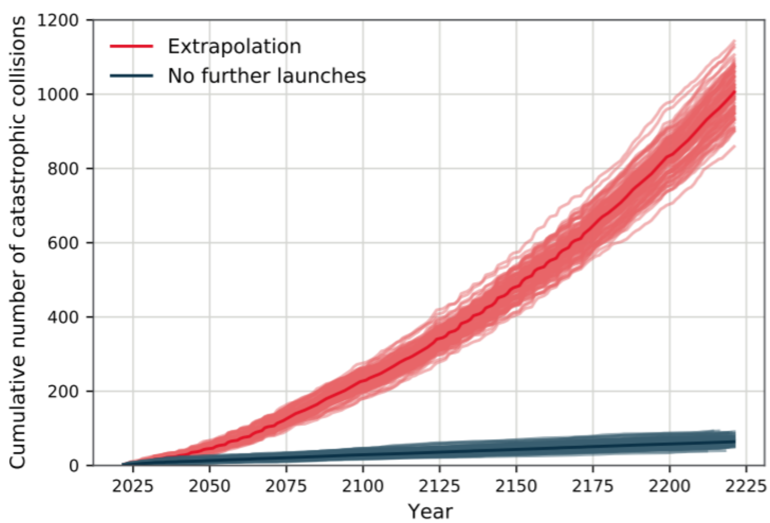

Fig 2: Number of cumulative collisions in LEO_{IADC} in the simulated scenarios of long-term evolution of the environment.

Policies to manage the increase in space traffic should be developed based on projections of the future orbital environment. In 2018, the Word Economic Forum issued a call for proposal to develop a so-called Space Sustainability Rating, a score representing a mission's sustainability as it relates to debris mitigation and alignment with international guidelines. Following this call, the European Space Agency, MIT, University of Texas at Austin, and Bryce Space and Technology have formed a consortium to design a rating able to encourage behaviours that are more responsible by promoting mission designs and operational concepts that are compatible with a stable evolution of the environment. List of potential elements affecting the sustainability of a mission is discussed in [9]:

Physical parameters
Spacecraft size and mass
Material selection
Bus selection
Shielding
Orbital parameters
Concept of operations
Mission objectives
Collision avoidance capabilities
Duration of operational lifetime
End-of-life strategy
End-of-life passivation
Mission related object generation
Launcher provider selection
Operational availability
External services
Space Situational Awareness
Identification
Trackability
Data sharing
Re-entry
Casualty risk
Oxone depletion
Land/water contamination
Spectrum
Spectrum use
Frequency interference
Processes
Registration
Standards
Verified mitigation plan
Economic aspects
Orbit value
Financial resources
Insurability

Table 1. List of potential elements affecting the sustainability of a mission

The dark blue curve represents the risk evolution in the case of a successful disposal, whereas the red curve indicates the case where the spacecraft is abandoned in its operational orbit in Fig 3.

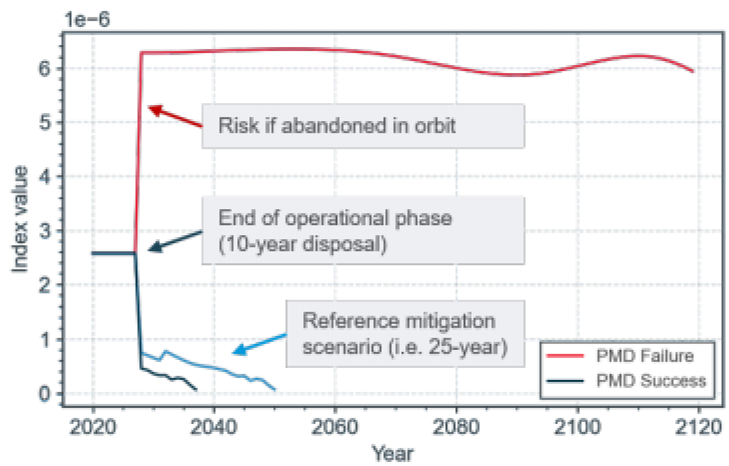

Fig 3: Index evolution in three mitigation scenarios

Long time behaviour seeks to cultivate an attitude of care for the future, however near or far off it might be, so that we change our behaviour to take responsibility for it in the present. [10] Krznaric provides a slightly different view, based around the idea of being a 'good ancestor' [11]: "We want to be good ancestors and be remembered well by the generations who follow us." Rather than trying to predict the future, we must instead empathise with the future generations of space users and look back with that new awareness.

The evolution of the catalogued populations of objects in Earth orbits (typically 10 cm in size or larger) is shown in Fig. 4. As can be seen, there has been a considerable increase in the number of objects in the population since the mid-2000s, primarily as a result of the fragmentation of three spacecraft (Fengyun 1C in 2007; Iridium 33 and Cosmos 2251 in 2009) and a substantial rise in the release of small satellites in the Low Earth Orbit (LEO) region.

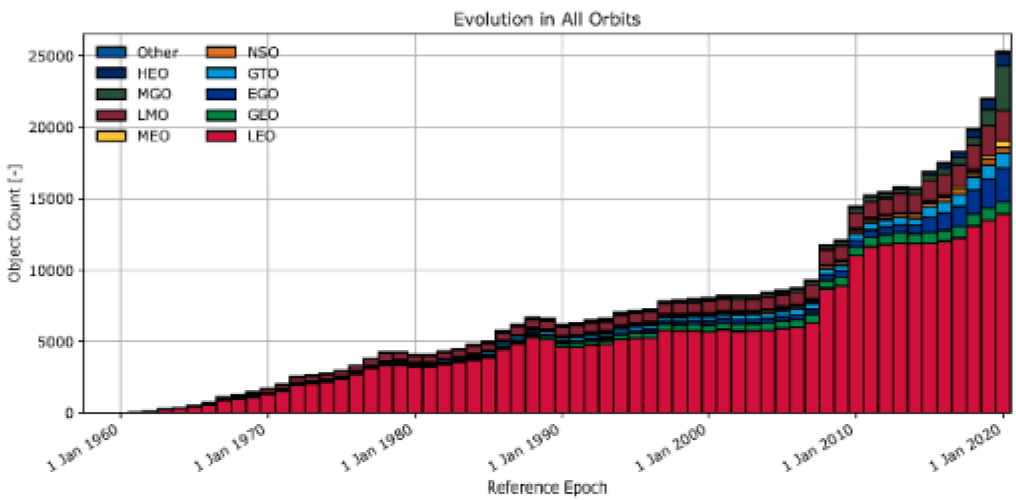

Fig 4. Evolution of the catalogued population of objects in Earth orbits 1957-2020 [12].

And the trend is expected to continue as in below Fig 5 according to [12]:

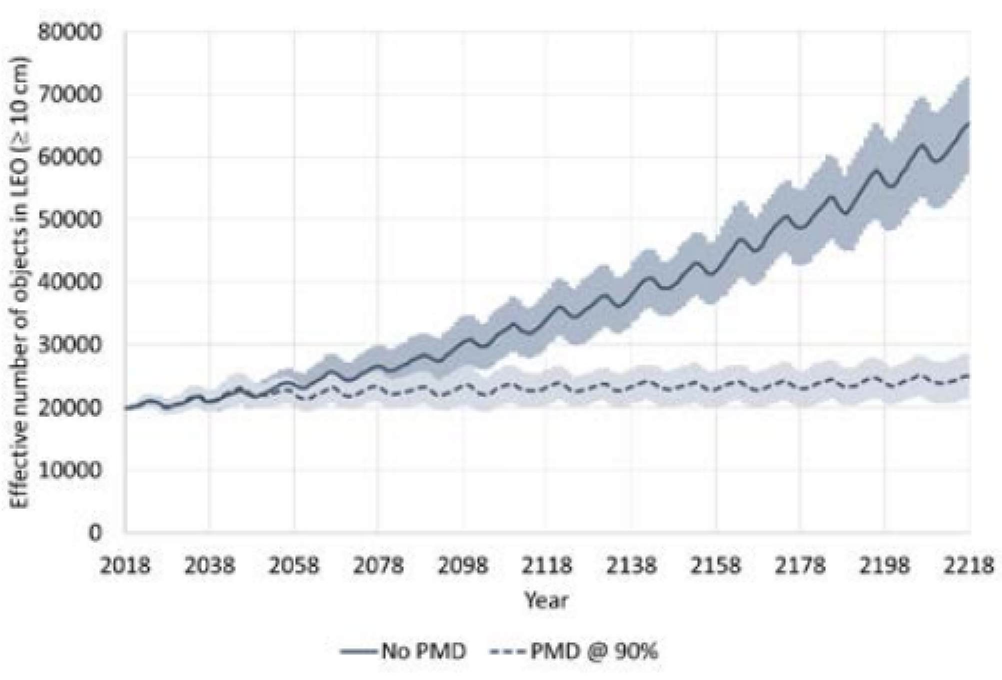

Fig 5. Effective number of objects predicted by DAMAGE (the Debris Analysis and Monitoring Architecture to the Geosynchronous Environment) for the two simulation cases. The shaded areas represent the 1-sigma variation.

In the first scenario, new spacecraft and rocket upper stages were assumed to achieve a 90% success rate with respect to post-mission disposal (PMD), targeting an uncontrolled reentry within 25 years by reducing the perigee altitude. A graveyard option above the LEO Protected Region was not permitted. In the second scenario, no post-mission disposals were performed. This study aims to present an understanding of how the space debris population will grow based on deep time thinking. They estimate even if we achieve high levels of compliance with the IADC space debris mitigation measures, it will reduce the growth rate substantially but it will still grow slowly, doubling in 730 years.

We at Aurora strongly support space debris mitigation measures of all kinds. We develop technologies for space craft manufacturers to comply with de-orbiting regulations and contribute towards the ability of future generations having access to a debris free space. We make every effort to enable the removal of our and our customer spacecraft from orbit once they have completed their missions and are seen unfit for re-use, orbital retrofitting or recycling in orbit.

CONCLUSION

At Aurora Propulsion Technologies, we aim to achieve the highest standards on sustainability when we design, develop and provide innovative solutions and when we conduct business with our customers, partners, investors and all the stakeholders. We make products that are sustainable on all these measures but also allow our customers to increase the sustainability of their products and spacecraft. This is why sustainability is a crucial value for our company and we would like to declare our statement on it. At Aurora we would like to emphasize how we ensure to achieve it in practice both with our daily operations and strategic long term decisions considering all the mentioned dimensions of sustainability in this document.

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