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Long-term sustainability of outer space activities

Report on the implementation of the Guidelines for the Long-term Sustainability of Outer Space Activities in the European Space Agency

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[1] A/AC.105/C.1/L.392

ESA

Report on the Implementation of the Guidelines for the Long-term Sustainability of Outer Space Activities in ESA

1. Introduction

In June 2019, the Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space were adopted (A/74/20, para 163 and Annex II). The Committee encouraged States and international intergovernmental organizations to voluntarily take measures to ensure that the guidelines are implemented to the greatest extent feasible and practicable. In view of this, ESA, to which major space activities are entrusted with shared responsibilities across Member States, wishes to present the implementation status vis-à-vis the guidelines.

The CRP is structured along the 21 guidelines which are recalled by their title in the order of appearance in A/74/20. Each of the individual guideline is paired with a paragraph of past and present ESA activities that are considered achievements and actions in the spirit of and in response to the guidelines.

It should be taken into account that the actions, products, services and achievements listed hereunder are presented in concise form and their description is limited to the outmost key aspects. It should also be considered as a "snapshot" on the current situation.

2. Mapping to Policy and Regulatory Guidelines (Part A)

Guideline A.1: "Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities"

As an international intergovernmental organisation, ESA is not subject to, nor can it enact, national space legislation (NSL). However, it actively supports Member States, on their individual request, in the establishment and implementation of NSL through technical and legal advice. Furthermore, as a responsible space actor and spacecraft operator, ESA also has its own legal and regulatory framework for outer space activities, developed and implemented at different hierarchical levels under the ESA Convention:

1.) Acceptance of international obligations: ESA declared acceptance of the Rescue Agreement, the Registration Convention and the Liability Convention (as an international intergovernmental organisation, it is not possible for ESA to be a party to or declare acceptance of the Outer Space Treaty);

2.) ESA's internal legal framework reflecting Guidelines 1-3, inter alia through the:
   - Resolution on the Agency's legal liability

- ESA Space Debris Mitigation Policy (incorporating ISO 24113)
- ESA Space Object Registration Policy
- ESA Safety Policy on Nuclear Power Sources
- ESA Re-Entry Safety Requirements
- ESA Planetary Protection Policy
- ESA Frequency Management framework
- ESA international agreements, programme legal frameworks and implementing rules (e.g. on space assets ownership, specific liability provisions, cooperation and coordination duties, etc.)

Guideline A.2: "Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities"

ESA's internal legal and regulatory framework is described under Guideline 1 above. In order to implement this framework – which includes its further development and amendment as necessary – ESA considers a wide variety of legal, political, programmatic, technical and scientific elements, and profits from its experience as a space actor and operator, as well as from constant dialogue and cooperation with its member states and international partners,

As a major example, ESA's internal instruction (ESA/ADMIN/IPOL(2014)2) is compliant with the provisions of the UN General Assembly resolution 68/74, the Space Debris Mitigation Guidelines and the IADC guidelines. It is applicable to all ESA procured or operated Space Systems, e.g. launchers, spacecraft, inhabited vehicles, robotic vehicles. All ESA missions have to demonstrate compliance with Space Debris Mitigation (SDM) technical requirements in the international technical standard "ECSS-U-AS-10C – Adoption Notice of ISO 24113: Space Systems – Space debris mitigation requirements". A handbook (ESSB-ST-U-002) has been issued (ESA Space Debris Mitigation Compliance Verification Guidelines – 19/02/2015), to support all ESA Projects for the space debris mitigation compliance implementation and verification. ESA has decided to make this document public.

Guideline A.3: "Supervise national space activities"

As explained above, ESA is not a regulator and, as such, does not authorise or supervise national space activities of its member states, or any other. However, it supervises its own space missions and provides technical support to some member states in the supervision of their national, non-governmental missions under their respective domestic legal frameworks. ESA has established an independent Technical Authority in its Product Assurance and Safety Department to maintain up to date, efficient and consistent the ESA policies for Space Debris Mitigation, Re-entry Safety and Nuclear Safety for Outer Space activities (currently ESA/ADMIN/IPOL(2014)2) and supervise, assess, and certify the compliance status of all ESA Projects with the ESA relevant policies; As a result, all on-going ESA projects are compliant with the ESA Space Debris Mitigation technical requirements.

Guideline A.4: "Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites"

The frequency selection and assignment for ESA’s assets is coordinated by the Frequency Management Office. All ESA's assets are filed with the ITU. ESA’s frequency management process is in accordance with the articles of ITU Constitution and with the ITU Radio Regulations. ESA has bilateral cooperation agreements with operators of Earth orbiting satellites, including constellations, overlapping ESA's assets frequencies to exchange data for the avoidance of harmful interference. The same is true with NASA, JAXA, ROSCOSMOS and other major space fairing nations agencies for assets in Lagrange and interplanetary orbits. In following the ISO-24113 space debris mitigation requirements, ESA missions ensure protected LEO and GEO orbital regions clearance by the definition of a disposal plan and by implementing adequate space system design. ESA implements transmitter switch-off as part of their passivation sequence as well as for daily operations of Low Earth orbiting satellites outside cooperating station visibility.

Guideline A.5: “Enhance the practice of registering space objects”

Shortly after its establishment, ESA has declared its acceptance of the rights and obligations provided for in the Registration Convention, and has been registering its space objects accordingly ever since. In 2014, ESA enacted, through an internal binding instruction of the Director General, its exemplary Space Object Registration Policy and established a legal space object database closely linked to its technical DISCOS database. Those steps were reported to COPUOS in 2015 (see A/AC.105/C.2/2015/CRP.18).

Through its Space Object Registration Policy, the Agency has actively enhanced its practice of registering space objects, and notifying information to the UN Secretary General accordingly. The ESA Space Object Register presents the authoritative list of all ESA space objects that currently are or ever have been in Earth orbit or beyond.

3. Mapping to Guidelines related to Safety of Space Operations (Part B)

Guideline B.1: “Provide updated contact information and share information on space objects and orbital events”

ESA’s provides several information services to share relevant information on space objects and related events relevant for operations, among them a re-entry prediction service (https://reentry.esoc.esa.int), a fragmentation database (https://fragmentation.esoc.esa.int/), and a frontend to the central DISCOS (Database and Information System Characterising Objects in Space). DISCOS serves as a single-source reference for launch information, object registration details, launch vehicle descriptions, as well as spacecraft information (e.g. size, mass, shape, mission objectives, owner) for all trackable, unclassified objects which sum up to more than 40,000 objects today. All these services are accessible through a user portal managing the registrations and information hub (https://sdup.esoc.esa.int/) that has more than 2,000 registered users today. Access to DISCOS is provided for worldwide users.

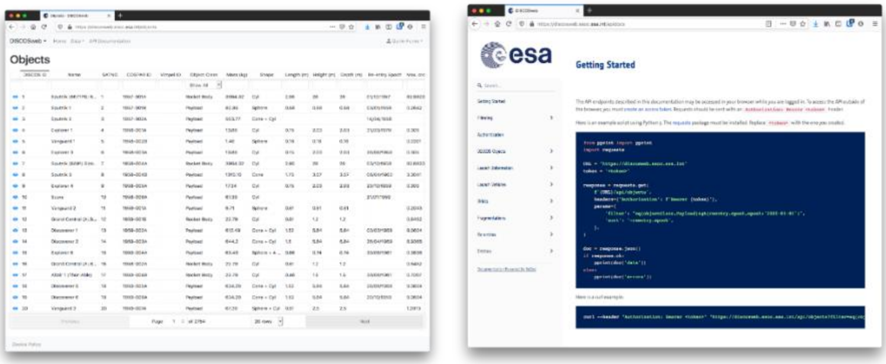

Fig.1 : DISCOS web-based and machine frontends.

DISCOS is also the backbone for several analysis activities, such as compliance monitoring for the annual space debris environment report (https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf).

As part of the operational collision avoidance for ESA-operated missions, as well as for contracted third party missions, ESA shares contact information in conjunction data messages (CDMs), e.g. through using the owner and operator contact data base in space-track.org. ESA regularly updates own satellites' information and share orbits and manoeuvre plans.

Guideline B.2: "Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects"

ESA has an operational collision avoidance service in place that covers ESA-operated and some contracted third-party missions. As part of this process, ESA shares operational orbit information of its spacecraft with other operators and in particular during a conjunction event also directly.

Through the Space Safety Programme, ESA develops further the technology for the refinement of orbit information, with specific focus on laser ranging to non-cooperative targets and networking aspects.

Guideline B.3: "Promote the collection, sharing and dissemination of space debris monitoring information"

Some ESA assets, such as the 1-m telescope at the Optical Ground Station in Tenerife, Spain, or the test-bed Telescopes in Cebreros, Spain, and the La Silla, Chile, site of ESO are used for testing observation techniques and for limited ad-hoc observation campaigns. Further, ESA developed two bread-board radar systems, a monostatic and a bistatic system, for technology testing. Through ESA's Space Safety Programme, also European assets are developed and tested that contribute to the collection of monitoring information.

ESA supports the development and related procurement of sensor facilities for member states under 3rd party agreements, for example the Spanish Space Surveillance and Tracking (S3T) system.

Fig. 2: ESA's Optical Ground Station (OGS) and the Monostatic Space Surveillance Radar (MSSR) close-monostatic L-band radar.

Guideline B.4: "Perform conjunction assessment during all orbital phases of controlled flight"

ESA's collision avoidance process is operational since 2002 and has been evolving continuously, since. Today, a backbone system pools chaser orbits and covariance information and checks also for conjunctions that are not reported via CDMs from the data sources, and computes for all known close conjunctions the collision risk. A modern web-based front-end allows authorised users to access up-to-date information easily.

ESA is addressing the need to develop technologies for automating decision processes, late decisions and coordination with other operators and constellations through the "Collision Risk Estimation and Automated Mitigation" (CREAM) under the Space Safety Programme.

Hosting the Second Conjunction Summary Message (CSM) Workshop in October 2010 at ESOC, where the fundamental structure and basic content of the CDMs had been agreed in the operator community, ESA has a track record in bringing together the technical communities in operational collision avoidance. ESA has entered into a direct data sharing with the largest operator today, SpaceX in 2021 in order to ensure efficient and fast information exchange.

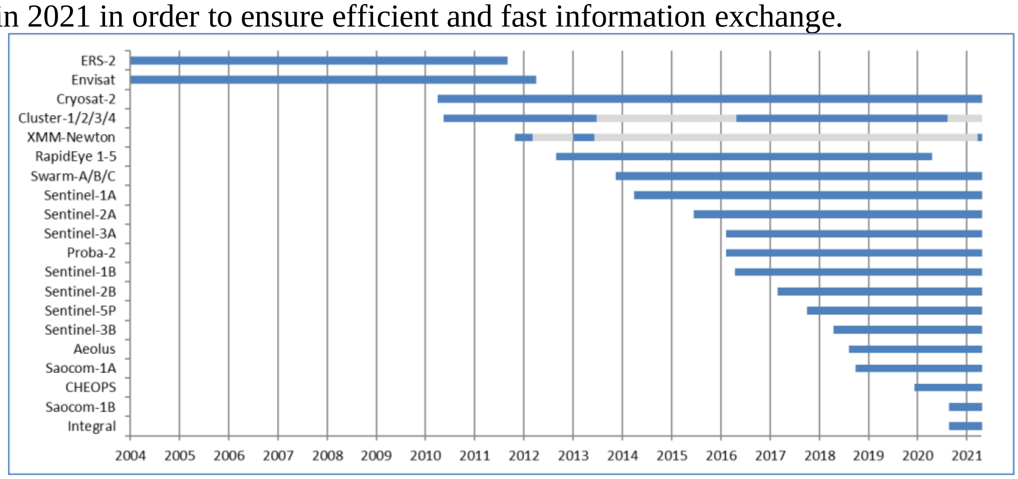

Fig. 3: Missions of ESA and third parties covered by ESA's collision avoidance process. More missions covered during limited time periods (such as early orbit phases) are not shown.

Guideline B.5: "Develop practical approaches for pre-launch conjunction assessment"

At ESA the process for the screening the launch trajectory for any close approaches is left up to the launch operator. ESA takes care that the spacecraft orbit after separation is pre-screened before launch as well, and for that follows the best practice interfacing with the US 18th space control squadron so that relevant forms are filled and agree before launch.

Guideline B.6: "Share operational space weather data and forecasts"

In the framework of the Space Situational Awareness (SSA) and Space Safety Programme (S2P) ESA has developed the European Space Weather System consisting of ground and space-based measurement systems, and the Space Weather Service Network which supports the collection, archiving, sharing and dissemination of space weather data, model outputs and forecasts in a timely manner among both service providers and service users. Over 50 institutes/organisations from across the European region contribute to the overall data and service provision activities.

Space weather service end users, data users and the research community are free to access ESA's pre-operational space weather services through the Service Portal (https://swe.ssa.esa.int/). The portal provides access to 29 pre-operational services based on over 200 data products.

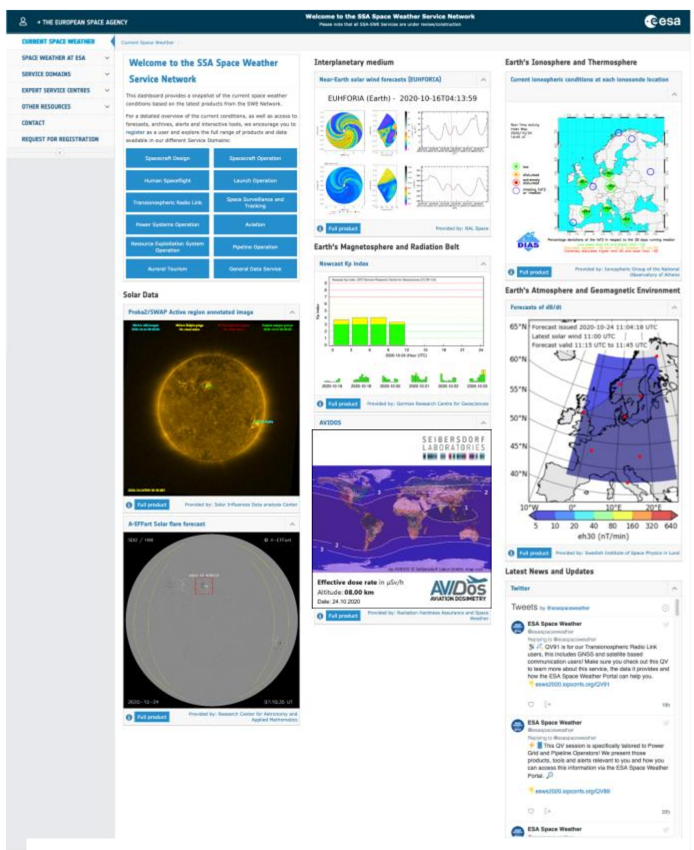

Fig. 4. Space Weather Service Portal front page

ESA is building European capability for space weather observations for operational applications. In the SSA programme ESA has implemented two hosted payload missions, Service Oriented Spacecraft Magnetometer (SOSMAG) onboard GK2A satellite and Next Generation Radiation Monitor (NGRM) onboard EDRS-C for monitoring the Earth's magnetic field and the radiation environment in GEO, respectively. Further hosted payload missions are being implemented during S2P Period 1. ESA is also implementing the Lagrange mission to the 5th Lagrangian point (L5) for new space weather monitoring capability away from the Sun-Earth line. The Lagrange mission is implemented in cooperation with NOAA and NASA, who will provide some payload instruments for the mission.

Guideline B.7: "Develop space weather models and tools and collect established practices on the mitigation of space weather effects"

The European Space Weather System development activities carried out in the framework of the Space Safety Programme (S2P) form a coordinated approach towards the establishment of new space weather models, tools and applications, which together are actively advancing European space weather capability. In the S2P programme activities, scientific prototypes are evaluated, tested and validated as preparation for the transition to operational service provision.

End users are involved during both development planning stages and also frequently as part of user test campaigns, such that a close link to the user communities is maintained and the added value of the developed products and/or toolkit to the end user is clear. Examples of successful product developments with results made available to the users through the Space Weather Service Portal include for example the A-EFFort solar flare forecasting product group, the SaRIF product group geared towards satellite risk prediction and radiation forecasts, and many others.

A Virtual Space Weather Modelling Centre (VSWMC) is under development which provides a unique modelling facility through coupling many European space weather assets. This tool, accessible through the Space Weather Service Portal, brings together space weather models and data repositories and is being developed to provide an end-to-end modelling framework without the need for the user to spend time in establishing an environment for the model execution and colleting the required input data from a variety of sources.

Guideline B.8: "Design and operation of space objects regardless of their physical and operational characteristics"

ESA develops a set of technologies to ensure that the physical design and envisaged operational characteristics do not constitute a risk for trackability and derived orbit determination. Furthermore, its applicable space debris mitigation requirements (i.e. the ECSS adoption of ISO 24113) does not introduce a relation on size. Technologies targeting add-ons for small spacecraft to improve the capability of ground surveillance systems to track them ("design to track") and to provide identification means are respectively being develop under the Space Safety programme and the Advanced Research in Telecommunications Systems programme. To ensure the compliance with space debris mitigation guidelines, and in particular the clearance of the protected regions, the CleanSat technologies, under ESA's CleanSpace initiative, include work on drag augmentation devices which scale well to smaller systems.

Spacecraft developed through ESA's "fly your satellite" programme require full adherence to space debris mitigation requirements and dedicated sessions are organised to ensure awareness in terms of mitigation options and operations related to trackability issues for small satellites. Further outreach to the world-wide community is organised based on this experience. The launch of satellites on the said programme take place via service providers who adhere to space debris mitigation guidelines themselves.

Guideline B.9: "Take measures to address risks associated with the uncontrolled re-entry of space objects"

ESA provides a re-entry prediction service covering all uncontrolled re-entries from Earth orbit primarily targeted at its own missions and towards national risk coordination centres in its Member states, but covering all other orbital objects as well. Methodologies are kept-up to date via dedicated research activities and coordination within the IADC, and data exchange mechanisms are tested and exercised in bi-lateral formats. Outreach on some of these event in the public interest, e.g. Tiangong-1, is covered under this service as well.

ESA has exercised and internalised its rights and obligations under Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, in the past when dealing with uncontrolled re-entries, and provided support to some of its Member states in doing so as well.

Software models to estimate the risk posed by an uncontrolled re-entry are made available publically, with regular training opportunities, via ESA's DRAMA (https://sdup.esoc.esa.int) software. Advances re-entry break-up simulation software and test facilitates are being established and harmonised under various agency programmes.

The acceptable risk to people, property, public health and environment associated with uncontrolled re-entry is covered by the technical requirements in ESSB-ST-U-004 – ESA re-entry safety requirements. When the assess risk is too high, controlled re-entries are implemented such as for Metop-SG and other new platforms. In additions, "design for demise" is a new approach being implemented in a more consistent way in order to make sure that objects will demise during re-entry. A careful mapping of the space subsystems generating a higher has been carried out with the support of the large space integrators. Several demisable building blocks are being developed (e.g. demisable tanks, demisable SADM, demisable magnotorquers, demisable joints) which will have a recurring costs in line with non demisable equipment. Furthermore, studies are on-going to deepen the understanding of the scientific know-how of demisability including possible in flight verification to validate the models. Studies of containment of pieces are being as well carried out. Lessons learned are being disseminated publically via ESA ESTIMATE database and practical recommendations are being put together in a Design for Demise handbook.

Guideline B.10: "Observe measures of precaution when using sources of laser beams passing through outer space

As of today ESA is not yet operating own laser ranging facilities. Through the development of an Expert Centre such data acquisition is possible via third parties. These stations operate under their own safety regulations, among them considering go/no-go flags and procedures for restricted laser tracking of satellites under the International Laser Ranging Service (ILRS). ESA is in the process of deploying its own Laser Ranging test-bed station to Tenerife. The hosting site requirements (IAC) require a clearing process.

ESA has established a laser roadmap in in the Space Safety Programme that foresees a gradual increase of the capabilities from laser tracking of cooperative and non-cooperative objects, under daylight conditions towards a laser-based catalogue of orbital elements that shall then lead to demonstration of momentum transfer through photons ("nudging") to induce very small velocity changes to space debris objects. A system architecture study has just been completed that also addressed the legal, regulatory, and safety aspects of such more powerful laser ranging. To address some of the needs, ESA will develop, under the technology development programmes, a robust laser safety sub system based on real-time video data. Such a component may in the future be added to a laser station.

4. Mapping to Guidelines related to International Cooperation (Part C)

Guideline C.1: "Promote and facilitate international cooperation in support of the long-term sustainability of outer space activities"

The promotion and facilitation of international cooperation in the space domain is at the heart of ESA's programmes and activities. Apart of the wider programmatic and cooperation context, ESA engages in many activities that promote and facilitate international cooperation in support of LTS, some of those are highlighted in the following. As an example, since 1993 ESA hosts every 4 years the European Conference on Space Debris, the largest dedicated gatherings on the subject. The eighth edition in 2021 saw 570 registered participants that could attend 143 oral talks and 119 poster presentations during four days of the conference. Furthermore, ESA is a founding member of the IADC and has chaired the forum several times as well as has been hosting the annual meetings. ESA delegates act as working group chairs regularly.

In its role as a permanent observer in COPUOS, ESA regularly contributes to the sessions of the STSC and the LSC; including with a regular technical presentation under agenda item 7 "Space Debris" of the STSC, following a long tradition and receiving recognition. ESA staff is also contributing expertise to UNCOPUOS working groups, such as the working group on the long-term sustainability of outer space, author of these guidelines. ESA is also regularly contributing CRPs to the LSC and analyses space law developments as part of the support to delegations in preparation of the sessions.

In 2019, the UN Office for Outer Space Affairs (UNOOSA) and the European Space Agency (ESA) signed a joint statement on their intention to cooperate on the challenge of space debris. They agreed to work together to increase global understanding and the consolidation of knowledge on space debris; to disseminate information on the latest research on space debris; to support the implementation of existing space debris mitigation guidelines; and to strengthen international cooperation and global awareness on space debris mitigation.

Guideline C.2: "Share experience related to the long-term sustainability of outer space activities and develop new procedures, as appropriate, for information exchange"

ESA makes available to registered users worldwide it's risk assessment tools and methodologies to analyse the collision risk and reduction strategies during the design of a mission. The registration is free of charge and gives access to MASTER and DRAMA via sdup.esoc.esa.int (space debris user portal).

Regularly, ESA staff provide lectures at various universities on space debris topics. Further, a five day training courses on space debris is provided through the ESA Academy annually. The course is certified and gives access the ECTS points. The series of ESA space debris conferences every four years makes its mandatory papers available publicly via conference.sdo.esoc.esa.int.

Clean space and space debris training courses are organised yearly with the ESA education office.

Guideline C.3: "Promote and support capacity-building

ESA continues to provide tailored training courses to support capacity building to governments and space agencies in the last few years. In many cases, these training course follow by topic support or technical assistance agreements.

In general, ESA maintains a free-of-charge service (via the space debris user portal https://sdup.esoc.esa.int) to support researchers, mission designers, and operators when its simulation software such as DRAMA and MASTER is used in assessing or implementing space debris requirements.

More generally on capacity-building in fields of relevance for sustainability of space activities, ESA and the ECSL offer a large variety of courses, events and activities to an ever growing space law network across Europe and beyond. The activities of the ECSL are regularly summarised in the preparatory paper for the LSC session, distributed to IRC, and to the COPUOS during the LSC session.

Guideline C.4: "Raise awareness of space activities"

Raising awareness of space activities is very important for ESA. The most prominent events are broadcasts via TV or webstreaming on ESA launch or other critical mission events. Regularly ESA host outreach events to the general public and provides tours to ESA facilities. ESA maintains a broad archive of material showcasing space-related topics, often tailored for specific age-groups or background and expertise.

In order to share best practices on space debris mitigation ESA made publicly available its released handbook ESSB-HB-U-002 in 2015. That handbook presents guidelines for the verification of compliance with space debris mitigation guidelines.

The annual ESA environment report (https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf) has been developed explicitly in support of the guidelines for the long-term sustainability of outer space activities and aims to provide a transparent overview of global space activities, to estimate the impact of these activities on the space environment, and to quantify the effect of internationally endorsed mitigation measures aimed at sustainability of the environment. With the annual release cycle of the report positive and negative changes in the environment become visible. The report is publicly available.

In 2021, ESA addressed sustainability and space debris aspects as focus topics in social media activities, culminating in the join preparation with UNOOSA of nine infographics and related podcasts aiming at the general public and wide distribution. The regular social media stories on debris-related events and activities (such as covering the work behind a collision avoidance manoeuvre) are among the most visible of ESA.

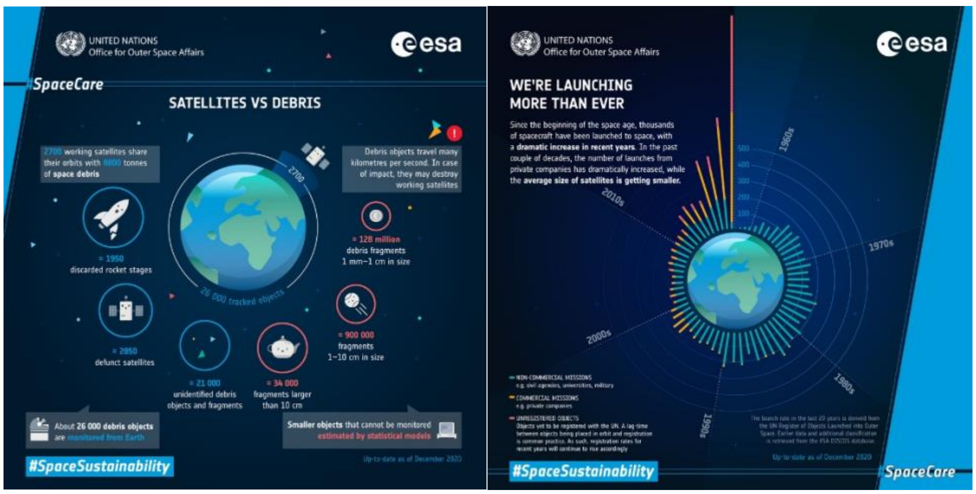

Fig. 6 Example infographics by UNOOSA and ESA

5. Mapping to Guidelines related to Scientific and Technical Research and Development (Part D)

Guideline D.1: "Promote and support research into and the development of ways to support sustainable exploration and use of outer space

ESA has led the development of numerical metrics based on the physicals design, orbital use, and operational processes to capture the impact of space missions on the space environment. These metrics and implementations are made available to researchers and product developers, including the space sustainability rating in collaboration with the World Economic Forum and MIT, to find new ways of making space sustainability an actionable goal.

In 2019, ESA hosted an open competition for researchers to test machine learning approaches. To allow for such analyses, ESA has distributed and keeps available anonymised operational CDMs to support research in conjunction evaluation.

ESA is the only agency worldwide which has developed the framework for the implementation of Life Cycle Assessment (LCA) of space mission in order to evaluate and potentially mitigate environmental impacts. This framework includes a handbook and database which are made available to European agency and industry. Furthermore, ESA has carried out initial analysis of environmental impacts of space missions including launchers and satellites. LCA requirements are part of several ESA contracts such as Ariane 6, the high priority Copernicus expansion missions and Galileo second generation.

ESA is developing several technologies to implement in a more effective way space debris mitigation requirements, namely design for demise, passivation, de-orbiting devices, both passive (e.g. sails) and active (de-orbiting kit). The high priority Copernicus expansion missions are also designed to be removed in case of failure in space by including markers, de-tumbling devices and grappling devices.

Technologies to implement in an automated cost effective way space debris remediation and in-orbit servicing. Close proximity operations guidelines are being prepared in coordination with industry in order, in the long term, to derive standards to implement safe automated, cost effective approach in space.

Guideline D.2: "Investigate and consider new measures to manage the space debris population in the long term

ESA implementing the first space debris remediation mission (Clearspace-1) through a service contract to de-orbit an ESA owned space debris. This mission will pave the way to more ADR missions as well as commercial services for in-orbit servicing including management of end of life of future constellations.

Furthermore, de-orbit kit to actively deorbit satellites at the end of life even in case of failure are being developed with the goal of reaching PDR (and TRL5) by 2022.

High priority Copernicus missions are also being prepared to be removed and this approach is being considered also for other ESA missions.

By considering orbits are natural resources, the risk of kinetic interference (due to the creation of space debris threatening further collisions) can be quantified and the natural capacity of the space environment to sustain operations established. This in turn would allow to tune technologies in such a way that they have a maximum effect on mitigating the adverse effects of space debris, proportionally to the risk taken. ESA is investigating such feedback mechanisms.