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Long-term sustainability of outer space activities

Implementation of the Guidelines for the Long-term Sustainability of Outer Space Activities in Germany

The present conference room paper was prepared by the Secretariat on the basis of information received from Germany. The information was reproduced in the form it was received. A shorter related text is available in all the official languages of the United Nations in document A/AC.105/C.1/L.409/Add.4.

* A/AC.105/C.1/L.405.

Implementation of the LTS guidelines in Germany

Germany welcomes the adoption of a preamble and 21 Guidelines for the Long-Term Sustainability of Outer Space Activities (LTS Guidelines) by the UN Committee on the Peaceful Uses of Outer Space (COPUOS) in 2019 as well as the decision to establish a new Working Group on the Long-Term Sustainability of Outer Space Activities. The Working Group was able to reach consensus on its terms of reference, methods of work and workplan at the fifty-ninth session of the Scientific and Technical Subcommittee (STSC) of COPUOS, allowing it to begin its substantive work in 2023. To prepare the work of the Working Group and in accordance with its multi-year workplan, the Chair invited State members of the Committee to provide information and views on the topics in paragraph 4 and 6 of the Working Group's terms of reference, methods of work and workplan, in a format deemed appropriate.

Germany attaches great importance to the long-term sustainability of outer space activities. The orientation toward the principle of sustainability is one of the overarching guidelines of the Federal Government´s space strategy. It identifies "ensuring the sustainability of space activities" as a major space policy area. The Federal Government also committed to develop a new space strategy in the current legislative period with specific consideration to the mitigation and remediation of space debris.

Achieving long-term sustainability in space requires international cooperation and internationally implemented guidelines. For Germany, international cooperation in space forms the technical and financial foundation for every major space project and is therefore indispensable. This is why Germany has worked through COPUOS to forward the goal of maintaining the long-term sustainability of outer space activities. German experts have participated in all of the four expert groups of the original LTS Working Group. Following the publication of the expert groups' reports, Germany contributed actively and constructively to the further development of the 21 LTS Guidelines, including through Conference Room Papers[1] (CRPs) and engagement in the Working Group.

The present CRP is intended to provide an overview of German measures that contribute to the implementation of the LTS Guidelines. While not necessarily a comprehensive list of all measures, it aims to give a general understanding of Germany's approach to space sustainability and to provide specific examples that contribute to sharing experiences, practices and lessons learned from voluntary national implementation of the adopted Guidelines.

This CRP focuses mainly on national measures and activities. German space activities are deeply embedded in European and international collaborations, in particular within the European Space Agency (ESA) and the European Union (EU). We therefore welcome that ESA and the EU also submitted reports on their implementation of the LTS Guidelines.

[1] Cf. Document A/AC.105/C.1/2015/CRP.11 on "Comments on and proposed amendments to the Updated set of draft guidelines for the long-term sustainability of outer space activities. Submission by Germany."

Germany looks forward to the ongoing exchange and hopes that this report will contribute to the goals and objectives of the new Working Group.

PART A – POLICY AND REGULATORY FRAMEWORK FOR SPACE ACTIVITIES

A.1: Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities and A.2: Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities

Germany attaches great importance to the issue of space law. Against this background, Germany is currently working on a national space law.

A.3: Supervise national space activities

Within the framework of the award of grants and contracts in the National Programme for Space and Innovation, the German Space Agency at the German Aerospace Center (*Deutsches Zentrum für Luft- und Raumfahrt, DLR*) places specific project requirements and monitors their fulfilment. Space mission projects involving the launch of objects into outer space are provided with specific requirements for mitigation of space debris. They are part of the Product Assurance, Safety & Sustainability Requirements for DLR Space Projects of the German Space Agency and are in line with the Space Debris Mitigation Guidelines of COPUOS and the Inter-Agency Space Debris Coordination Committee (IADC). This also applies to small satellite projects at public universities and universities of applied sciences that receive funding support from the German Space Agency and which constitute a large part of German satellite missions.

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

Germany is a Member State of the International Telecommunication Union (ITU) and awards frequency rights according to their requirements. These are implemented in national law by the Telecommunications Act (*Telekommunikationsgesetz, TKG)*. According to Section 55(1) *TKG*, each frequency use requires a previous frequency assignment. Details are regulated in the Spectrum Plan (*Frequenzplan)*, the Spectrum Ordinance (*Frequenzverordnung)* and the administrative regulation for the registration, coordination and notification of satellite systems in the German name and for the assignment of the orbit and frequency usage rights. The operators apply for the assignment from the Federal Network Agency (*Bundesnetzagentur, BNetzA)*, which then forwards the application to the ITU and initiates the coordination process. After conclusion of the coordination and notification process, the BNetzA transfers the certificate of frequency assignment to the operator. The transfer is usually limited in time in accordance with Section 55(9) TKG. The expiry of the application after the expiry of a time-limit and the assignment over time ensures that unused frequencies will not remain reserved for unnecessarily long periods.

The measurement centre of the BNetzA for space radio services in Leeheim not only monitors space radio traffic, but is also responsible for locating and eliminating radio interference. In addition, the SALSAT mission of the Technical University Berlin was supported, which collects and analyses scientific data on the global use of the frequency spectrum as well as is to develop algorithms for mission analysis and detection of interferences.

A.5: Enhance the practice of registering space objects

In 1979, Germany acceded to the Convention on Registration of Objects Launched into Outer Space of 1974. A national register for space objects is maintained by the Federal Aviation Office (*Luftfahrtbundesamt, LBA)* in Braunschweig as an annex to the aircraft role.

Registration cases are prepared by the German Space Agency. These preparatory activities include the systematic collection, documentation and transmission of the relevant data of a space object to be registered to the LBA. Within the scope of these activities, contact is established with the respective operators and, if necessary, assistance is provided in the preparation of the registration documents. Experience shows that the need to coordinate with other involved nations increases and such cooperation and coordination are conducive to an effective registration process. In the recent past, for example, issues with New Zealand or the United States could be clarified jointly.

Once a space object has been entered in the national register by the LBA, the relevant registration information is forwarded via the Federal Foreign Office (*Auswärtiges Amt*) to the United Nations Office for Outer Space Affairs (UNOOSA).

By August 2022, 91 space objects were registered in the national register.[2] Germany transmits all mandatory minimum information in a uniform format to the United Nations. In line with UN General Assembly Resolution 62/101 containing "Recommendations on enhancing the practice of States and international intergovernmental organizations in registering space objects", additional voluntary information is increasingly being transmitted, which the German Space Agency queries with the operators in the interest of a transparent registration practice (e.g. type of launch vehicle or indication of the operator / owner of the space object).

Increasingly, the UN is also being informed of changes in the operational status of space objects that are listed in the German registry and are no longer operational. It is planned to make this a permanent practice and also to check all previously registered space objects and to report information if necessary.

In addition to the registration process for new space objects, it is intended to notify the Secretary-General about the re-entry of already registered space objects in order to contribute to complete documentation in the international register. Current developments in space activities (e.g. trend towards small satellites, multi-cluster launches, etc.) are monitored to ensure a meaningful and coherent German registration practice.

[2] Germany notified the Secretary-General of an additional three German space objects (Helios A, Symphonie No. I and Symphonie No. II) in accordance with General Assembly resolution 1721 B (XVI).

PART B – SAFETY OF SPACE ACTIVITIES

B.1. Provide updated contact information and share information on space objects and orbital events

The German Space Situational Awareness Centre (GSSAC), which is operated by the Federal Ministry of Defence and the Federal Ministry for Economic Affairs and Climate Action in an interagency approach, is tasked with the creation of operational space situational awareness (SSA) information. It provides SSA information as well as operational services (e.g. collision avoidance, re-entry and fragmentation analysis) for governmental recipients.

SSA data is exchanged with the United States and France via bilateral SSA sharing agreements. In the European Space Surveillance and Tracking (EU SST) programme, Germany and other Member States share national sensor data with each other, which is used to provide operational services to European users. In the context of EU SST, there is also a regular dialogue with public authorities in the United States. Discussions will be held with other states on data exchange for research and development (R&D) purposes. Under the EU Space Regulation, services of EU SST are also to be made available to non-European users.

As a major player in satellite operations in Germany, the German Space Operations Centre (GSOC) in Oberpfaffenhofen actively shares contact information and satellite ephemeris data with conjunction service providers (e.g. EU SST, the Space Data Association, United States entities) and actively contacts other satellite operators in order to harmonize collision avoidance (COLA) measures. On the R&D side, GSOC is supported by an SSA group providing data based on optical and laser ranging ground stations for low-Earth orbit (LEO) to geostationary orbit (GEO).

In addition to government and DLR missions, there are a number of German academic and commercial satellites whose operators usually use their own infrastructure to operate their satellites. Some of these operators already use the services of the EU SST programme. GSSAC also provides SSA data for EU SST, where the Operation Centres responsible for the Collision Avoidance service (here: France and Spain in redundance) communicate proximity warnings to the registered owner or operator.

Within EU SST, the participating member states exchange SSA data in standardised formats (e.g. tracking data messages, TDM). This enables validation and merging of data from multiple sources and the generation of products from them, such as autonomous European collision warnings. The data exchanged is merged into a central database operated at the GSSAC and will be further developed into a European orbital data catalogue. At GSOC, all relevant international standards for data exchange (i.e. conjunction data message, CDM; orbit data message, ODM; reentry data message RDM) are operationally implemented in order to fully support data exchange among operators and conjunction service providers.

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

The German Experimental Space Surveillance and Tracking Radar (GESTRA) represents an essential element in the area of SSA. In Germany, GESTRA allows monitoring the LEO independently and generating orbital data of space objects in this orbital area at the GSSAC. Developments of advanced technologies for increased performance of GESTRA have already been started. Information obtained with GESTRA will also be made available to German universities and research institutions for research activities. The provision of orbital data in the context of bi- and multilateral cooperation is intended. GESTRA will be integrated into EU SST and will expand its sensor architecture. In addition, the Tracking and Imaging Radar (TIRA) of the Fraunhofer Society is an important instrument for tracking and characterising individual objects with high precision.

For improving the accuracy and precision of orbital data, GSOC is operating two telescope stations located in South Africa and Eastern Australia within the Small Aperture Robotic Telescope Network (SMARTnet). With these stations, measurements of resident space objects are gathered. They proved to be a significant improvement of the accuracy of derived orbit information in GEO. A third station is planned to be deployed in South America in 2023. Together with the Astronomical Institute of the University of Bern (AIUB), GSOC is operating SMARTnet since 2017, where AIUB is operating a telescope station in Switzerland with four telescopes. SMARTnet is an international and open platform to exchange Level 1b measurements of resident space objects using the international standard TDM, and currently two additional partners are contributing with data of telescope stations located in Spain and Slovakia. The data allow for deriving highly accurate ephemeris data which is used in the context of satellite safety. Scientific research of GEO will also be pursued.

In addition to these operational capacities, several scientific institutions are conducting research on improved capacity to collect orbital data from space objects. These projects include the development of laser-based precision-tracking techniques to better determine the path of debris objects and to better plan evasive manoeuvres. In addition, a research observatory as well as a satellite laser station contribute to the position and orbit determination of space debris. Commercial companies are also developing capacities to collect SST data.

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

With the aid of newly acquired measurement data, a national object and orbit data catalogue is to be set up at the GSSAC, into which the detected objects are to be inserted and regularly updated. This catalogue is intended to serve as a basis for products and services for the GSSAC in order to protect national space systems, for example, from collisions with other space objects. GESTRA measurement data will also be made available to German universities and research institutions for scientific purposes. The provision of orbital data in the context of bilateral / multilateral cooperation is intended.

Within EU SST, Germany will build and maintain the EU SST object and orbital data catalogue under the leadership of the German Space Agency. For this purpose, data of the sensors

contributed by the Member States are processed centrally and the EU SST object and the orbit data catalogue generated in this way is made available to the Member States.

At the DLR Institute of Software Technology in close cooperation with the GSOC, the software Backbone Catalogue of Relational Debris Information (BACARDI) is being developed. It is intended to calculate and display orbital data for up to 100,000 objects in space in real time. The software currently receives measurement data primarily from the SMARTnet network, but also from sensors of the DLR Institute of Technical Physics and external databases. BACARDI is primarily intended to support the GSOC in mission operations, to find new resident space objects, to process data to higher accuracy and to predict close approaches between any objects within the database. However, data products can also be exported and can therefore be used in other software programs, e. g. for sensor tasking. Additionally, these data can also be made available for other entities.

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

Germany is participating in the EU SST programme, which, among other things, carries out conjunction analyses for EU Member States, EU organisations and European satellite operators. Germany contributes sensor data to the collision avoidance (CA) service of EU SST and operates the EU SST database at GSSAC for the exchange of data within the EU SST partnership. Users must register themselves and their space objects for the CA service and define the desired products together with the relevant operations centre. In March 2022, there were over 140 registered users (i.e. satellite operators, EU organisations or civil protection authorities) from 22 EU Member States that have registered 270 satellites for the CA service. The service is freely available to all European operators and in the future also to non-European users under the new EU Space Regulation. German academic and commercial small satellite operators are interested in cooperating more closely with bodies such as GSSAC in the field of conjunction analyses. For this purpose, the German Space Agency and GSSAC have recently held discussions to improve cooperation with small satellite operators.

The CA service of EU SST comprises clearly defined methods and processes for categorising approaches and dealing with high-risk events. Registered users receive further information in such cases. Individual cases also receive advice on possible actions (e.g. evasive manoeuvres). These services may also be provided to German operators who are not users of EU SST services.

GSSAC maintains a database with satellite and mission-specific contact information from German satellite operators. Dedicated contact persons are known for various satellite missions.

GSOC started to develop and operate a software system for conjunction assessment in 2009 and, ever since, is continuously developing, maintaining and operating the system. Besides conjunction assessment, the GSOC CA system also features CA maneuver planning and generation of CA products. GSOC supports other entities in conjunction assessment and collision avoidance. GSOC shares satellite ephemeris data with conjunction service providers and actively contacts other satellite operators in order to harmonize CA measures where needed.

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

In Germany there is no governmental development or production of national space launch vehicles. Germany also does not possess any launch sites for launch vehicles. Germany participates in launch vehicle programmes of ESA.

The federal government is currently supporting the commercial development of small launch vehicles ("microlaunchers"). Developments related to the implementation of this guideline can be reported on further in the LTS Working Group.

The GSOC is currently developing a software system for the assessment on the safety of launch trajectories in terms of probability of collision with resident objects in space. The system will support future launch segment operators in the assessment of safe launch windows and decision making (i.e. launch go / no-go).

B.6. Share operational space weather data and forecasts

In Germany, a prominently scientific effort is made to advance fundamental knowledge, modelling of phenomena and transfer towards operational forecasting of space weather. There is a diverse group of experts at universities and research institutions, among others, which conduct basic and applied research on space weather. The entire path is covered from the Sun and heliosphere, via magnetosphere, plasma sphere, ionosphere and thermosphere, to effects on space and terrestrial infrastructure, including among other things, air traffic. The expert community is involved in collaborations with each other, nationally and internationally and is very well connected.

Some institutions already offer pre-operational services. The DLR Institute for Solar-Terrestrial Physics operates the Ionospheric Monitoring and Prediction Center (IMPC). It provides a range of services including space weather data and products. In addition to data products, the IMPC provides tools such as scintillation indices to the ESA Space Weather Service Network and EU-funded projects. As part of the Pan-European Consortium for Aviation Space Weather User Services (PECASUS), the Institute delivers IMPC products to the International Civil Aviation Organization (ICAO) to generate advisories for aviation in case of space weather events.

On the governmental side, there is interest in and awareness of the topic. Accordingly, various services and capacities are under development. Since 2021, a Space Weather Advisory Centre has been operated at the GSSAC. The German Weather Service (*Deutscher Wetterdienst*, DWD) distributes the above-mentioned space weather advisories on behalf of ICAO. Germany could participate in a European space weather service through a national space weather service and assist in the development of data policies and networking at international level in the future.

In order to enable such services and the observation of space weather in general, the protection of the necessary frequency spectrum for monitoring space weather is being actively pursued, including through governmental entities.

Various facilities in Germany operate ground-based space weather sensors such as the Geodetic Observatory Wettzell of the Federal Agency for Cartography and Geodesy (*Bundesamt für Kartographie und Geodäsie*, BKG) and the international Low-Frequency Array (LOFAR) for radar interferometry. In addition, Germany obtains data from space-based sensors, including those of the United States' National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA).

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

On behalf of the German Federal Ministry for Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz, BMWK*), the German Space Agency has drafted a concept for the establishment of a national space weather service In close cooperation, several federal ministries are involved in this effort by pooling existing capacities in Germany. For example, for this purpose, existing infrastructure of the GSSAC and the DWD are taken into account. In addition to further national cooperation, it will be examined whether European as well as international scientific links can be additionally integrated to make use of synergies. A study on national space weather demand analysis is in preparation and will provide information on potential users of space weather services (e.g. warnings) and specific national needs.

In the area of developing standards and procedures with regard to space weather measures in satellite construction, DLR is cooperating internally in the Working Group on Radiation Effects on Electronic Systems.

The impacts of space weather effects on technological systems have already been investigated in relevant studies at national and international level. The Federal Government has carried out an analysis of the effects of solar wind events on terrestrial electricity transmission networks. In addition, the Federal Armed Forces have also investigated similar space weather issues. An analysis on risks and the specific effects of solar storms on critical electrotechnical infrastructure in Germany as a whole has not yet been commenced.

There are also a number of European studies on space weather effects. In general, however, the studies mostly relate to effects on infrastructure on the Earth or in the atmosphere. For satellites in orbit, studies on the influences of radiation effects are already known.

Germany is currently participating in further developing scientific models and services for the prediction of space weather, as well as developing payload instruments for the measurement of space weather phenomena in orbit, primarily via the ESA Space Safety Programme. German scientists contribute with both their expertise and competence to the development and manufacture of measuring instruments and to the further development of prediction models. Further national capacities are currently under development. The small satellites sector provides an exchange on the possibilities of German operational, satellite-based space weather observations.

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

All major active and planned governmental German satellites have global navigation satellite system (GNSS) receivers on board to enable precise position determination in orbit. This data is available to operators via the telemetry of the satellites as long as the satellite is in operation and telemetry is actively received on the ground. Some small satellites also carry GNSS receivers (e.g. BEESAT-9 from TU Berlin or Flying Laptop from IRS Stuttgart) on board. In general, most German small satellites are larger than the standard size 1U and can therefore be tracked with modern SST capacities.

In addition, manufacturers and operators of space objects are encouraged or required to limit the long-term presence of their space objects in the protected orbit regions LEO and GEO. The Product Assurance, Safety & Sustainability Requirements for DLR Space Projects set requirements for the disposal of objects in LEO and GEO in accordance with the Space Debris Mitigation Guidelines of COPUOS and the IADC (e.g. maximum stay of 25 years in LEO). These requirements are also applicable to the small satellite promotion programme of the German Space Agency.

Researchers and operators in Germany are also working on satellite technologies to limit the residence time of objects in protected orbital regions. For example, the satellite Flying Laptop intends to increase its resistance area by deploying a drag sail at the end of the mission and thus accelerate its re-entry. Such braking mechanisms are also investigated at other facilities and in German industry. The five RapidEye satellites have lowered their orbital altitudes via engines to such an extent that they will re-enter within 25 years. Airbus Defence and Space and DLR are also cooperating in the consortium of the RemoveDEBRIS project, which is testing methods for the active return of objects. Another example is the company Bayern-Chemie, which is currently developing special solid-propellant rocket motors that can be used for autonomous de-orbiting manoeuvres. Germany has also signed the ADRIOS programme of ESA, which aims at actively removing space debris.

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

In the case of the ROSAT re-entry on 23 October 2011, DLR informed the public about the re-entry ahead of time. The most important partner agencies were informed about the re-entry through the IADC in advance. DLR also coordinated closely with individual international partners, such as the United States.

At the IADC, a “Re-Entry Test Campaign” takes place once a year. These campaigns aim to exchange orbit data, re-entry analyses and other information in the event of the uncontrolled re-entry of a space object within the framework of the IADC. Germany regularly participates in these re-entry test campaigns. The test objects are usually selected taking into account scientifically interesting parameters (e.g. orbit type, visibility for sensors, or spacecraft class).

Germany participates with sensor data in the re-entry analysis service of EU SST. The service provides predictions for the uncontrolled re-entry (i.e. nominal time of re-entry and ground tracks within the time re-entry window) of objects with a mass of more than 2,000 kg or a radar cross-

section of over one meter. Registered users can access a list which contains all objects that are expected to re-enter within the next 30 days. EU SST services are open to European users, in January 2021 more than 70 users were registered for the re-entry service.

Concerning construction solutions, the concept *Design for Demise* (D4D) is currently being studied internationally with an increased focus, which is intended to promote the most complete annealing of all component parts of space objects when they re-enter the Earth's atmosphere. To this end, research is also being carried out in Germany, including through involvement in activities of the *CleanSpace* programme of ESA. The Product Assurance, Safety & Sustainability Requirements for DLR Space Projects also suggest applying D4D measures. Overall, however, D4D is still in an early stage.

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

Laser beams are used in Light Detection and Ranging (LIDAR) missions. Together with France, Germany is currently developing the MERLIN satellite, which is to measure the methane concentration in the Earth's atmosphere using a LIDAR instrument. During the development process, the project partners analyzed the probability of accidental illumination of on-ground astronomical sites and passing space objects by the laser instrument in order to minimize the mission's risk of personal hazards and the risk to other space objects and to contribute to the safe and sustainable use of outer space.

Several observatories in Germany engage in satellite laser ranging (SLR) activities to enable the precise tracking of specific satellites. The energy emitted by SLR systems, such as for example the BKG's Geodetic Observatory Wettzell, is limited in order to prevent the accidental damaging or fragmentation of the targeted objects. SLR activities are only conducted on satellites which have been approved upon request by the International Laser Ranging Service.

The DLR Institute of Technical Physics is developing technologies and sensors for the safe emission of laser beams from laser optical ground stations, taking into account eye-safety issues. The Institute further develops laser ranging technologies to track cooperative objects, i.e. objects equipped with retroreflectors, and conducts research to detect debris objects via SLR.

PART C – INTERNATIONAL COOPERATION, CAPACITY-BUILDING AND AWARENESS

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

The orientation towards the principle of sustainability and the intensification of international cooperation are central guidelines of the space strategy of the Federal Government. This guideline therefore touches upon core elements of German space policy. Germany will continue to promote ecologically, economically and socially sustainable activities, innovations and business models in its space activities that serve the people and our planet at national, European and international level, in particular within the framework of the United Nations. A large part of German space activities is embedded in international organisations, such as ESA, the EU and EUMETSAT. In addition, German experts are involved in a variety of international forums and bodies dealing with various space issues, including the mitigation of space debris, standardisation, Earth observation and disaster management.

Germany also cooperates with numerous international partners on the basis of bilateral government and agency agreements in the field of the peaceful use of space.

Germany is actively participating in COPUOS in order to advance the agenda for the sustainable use of space and international cooperation. UNOOSA is supported by Germany financially with a focus on the UN-SPIDER programme. Germany also contributes to the UN programme for space applications and participates in capacity building activities.

Germany is therefore actively committed to international cooperation in space activities and to the sustainable use of space within the meaning of this guideline. It advocates a multilateral approach to the implementation of space activities as well as capacity-building for the long-term sustainable use of space.

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

Germany has many years of experience in exchanging expertise and information on the long-term sustainability of space activities.

Germany is represented by the German Space Agency in the IADC, which it chaired from April 2020 to October 2021. During this period, key IADC documents, including the Space Debris Mitigation Guidelines, were updated and adopted. These serve as a basis for national and international guidelines and standards on space debris mitigation. German experts are involved in the IADC working groups and exchange experiences and expertise.

Within the framework of the EU SST, there are exercises and workshops as well as special topics (orbit determination, cataloguing, CA services) which various operation centres of the Member States are focusing on. Knowledge and experience are also exchanged in working groups.

In standardisation bodies such as the International Organisation for Standardisation (ISO), the European Cooperation for Space Standardisation (ECSS), the Consultative Committee for Space Data Systems (CCSDS), the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC), German representatives are involved in the development of international standards that are relevant for the long-term sustainability of space activities, in particular in the area of the mitigation of space debris, or standardisation of data formats and procedures for the exchange of data and information.

Germany also participates in exchanging know-how on specific aspects of long-term sustainability. In the field of near-Earth objects (NEO) this includes the International Asteroid Warning Network (IAWN) and the Space Mission Planning Advisory Group (SMPAG). German experts contribute scientific expertise to both bodies, engage in specialist groups and manage action items.

In addition to these established bodies, there are numerous international specialist conferences in which German experts participate and share their expertise. These include general events such as the International Astronautical Congress (IAC), the International Aerospace Exhibition (*Internationale Luft- und Raumfahrtausstellung*, ILA) or the annual German Aerospace Congress (*Deutscher Luft- und Raumfahrtkongress, DLRK)* as well as specialist events such as the series of European Space Debris Conferences.

An exchange on the topic of sustainability with non-state actors takes place through contracts and grants as well as the Working Group on Product and Quality Assurance of the German Space Agency. In view of the increasing number of university small satellites, the German Space Agency initiated a dialogue with German public universities and universities of applied sciences in 2021 on the topic of sustainability where it presented the DLR requirements for space debris mitigation. In addition, a survey on satellite operations among public universities and universities of applied sciences was carried out. This dialogue is to be continued and will serve as a general exchange of knowledge and experience on space debris mitigation between universities and the German Space Agency.

C.3. Promote and support capacity-building

Germany supports a wide range of capacity-building measures, in particular with UNOOSA. As part of the Programme on Space Applications of UNOOSA, the Center of Applied Space Technology and Microgravity (*Zentrum für Angewandte Raumfahrttechnologie und Mikrogravitation*, ZARM) and DLR are organising the Drop Tower Experiment Series (DropTES), which enables research teams from developing countries to carry out microgravity experiments at the drop tower in Bremen. DropTES has recently concluded its seventh cycle by hosting a team from the *Universidad Católica Boliviana "San Pablo"* at the drop tower. Another cycle will begin later this year. In addition to this long-standing programme, UNOOSA and DLR also held a workshop for teachers from several African countries at DLR_School_Labs in 2019 in order to convey methods with which interest in space activities and the associated school subjects can be aroused in the classroom. This network has stayed in contact through regular exchanges ever since the event in 2019.

Germany supports the UN-SPIDER programme of UNOOSA, which promotes the worldwide use of satellite services and data for disaster management. Since 2007, UN-SPIDER maintains an office in Bonn with German funding. After initial start-up funding, the support for the office was renewed in 2018 and changed to project-based funding in cooperation with the University of Bonn. UN-SPIDER implements a number of capacity-building activities in the area of disaster management in developing countries and facilitates access to space-based data.

Germany also supports the International Charter 'Space and Major Disasters'. Since 2010, when DLR became a member of this group of Space Agencies, DLR has provided many images of the German radar satellite missions TerraSAR-X and TanDEM-X to activations of the Charter. This data has assisted worldwide users of the Charter in responding to a wide range of natural disasters, including floods, earthquakes and forest fires.

The learning platform "EO College", operated by the Friedrich Schiller University Jena in cooperation with DLR and ESA, offers free online tutorials and massive open online courses on Earth observation, remote sensing and related topics. In consideration of an increasing need for Earth observation education and training activities with a focus on hyperspectral imagery, "EO College" is now supplemented by "HYPERedu", which was developed as part of the German EnMAP mission.

Germany is also involved in capacity-building measures in the area of space law. The guidance document on the legal framework for space activities developed by the Working Group on the Status and Application of the Five United Nations Treaties on Outer Space under a German chair is aimed in particular at new space actors and aims to familiarise and facilitate their obligations under space law and their implementation. The Cologne Commentary on Space Law (CoCoSL) was set up in cooperation between DLR and the University of Cologne. It has been translated into several languages, including four UN languages, and represents a contribution to the uniform interpretation and application of space law. Germany also welcomes the project *Space Law for New Space Actors* of UNOOSA and participates in related outreach activities.

Germany also supports the capacity-building efforts of ESA and the European Centre for Space Law (ECSL). For some time now, these have been hosting a number of events and activities, including in the field of sustainable space activities. DLR experts actively contribute to events organised by ECSL. An example of this are the contributions to the IISL / ECSL Space Law Symposium during the session of the Legal Subcommittee in 2021.

In the area of SSA, the cooperation focuses on the EU SST as well as individual partners with whom bilateral agreements have been concluded. Data exchange with developing countries can take place on a case-by-case basis.

Germany is already supporting a wide range of capacity-building measures and is endeavouring to further develop this support.

C.4. Raise awareness of space activities

The potential applications of space-based activities are diverse. German space actors such as DLR and the German space industry are naturally interested in bringing the benefits of German and international space activities into the focus of the public. The DLR strategy 2030 describes how DLR intends to develop future-oriented solutions for digitisation, mobility and safety over the next ten years and focuses on the key role space plays in achieving these goals. With publications and declarations of intent like this, DLR aims to raise awareness of the benefits of space applications for the Earth.

The German Space Agency regularly publishes the journal *Countdown*, which is available free of charge in printed form and online. It contains contributions on current topics and space activities. On the platform *space2school,* the German Space Agency presents learning content for research in and about space in different subjects and for different learning levels. The exhibition *INNOspaceEXPO "ALL.TÄGLICH!"* informs about the importance of space technologies in everyday life and is also accessible virtually.

At the DLR_School_Labs at various locations in Germany as well as online, researchers at DLR pass on their knowledge of experiments under space conditions or of technical phenomena in space activities to school groups. The student labs are interactive and convey knowledge about space applications and their significance for modern life on Earth. DLR_School_Labs regularly organise competitions and participatory actions to inspire students for space activities. DLR_next is responsible for the learning content, a platform on which, in addition, further information regarding space activities is prepared for a young audience

Non-state actors in German space activities are also committed to making the areas of application and advantages of space-based projects more tangible and better known. The German Aerospace Industries Association (*Bundesverband der Deutschen Luft- und Raumfahrtindustrie*, BDLI) has launched the campaign Space is #all-embracing (Raumfahrt ist #allumfassend*)* to show how space applications help shape and simplify our daily lives. The website provides insights into how German space companies are involved in many European space projects and raises awareness of the various missions and activities.

PART D – SCIENTIFIC AND TECHNICAL RESEARCH AND DEVELOPMENT

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

Germany aims to support the implementation of this guideline through national programmes, European projects at ESA and EU as well as internationally.

Through DLR, Germany is involved in the activities of the Committee on Space Research (COSPAR), which develops guidelines for protecting the Earth and space from harmful contamination. The Product Assurance, Safety & Sustainability Requirements for DLR Space Projects contain requirements based on the COSPAR guidelines.

In addition, Germany contributes to the promotion and development of sustainable space technologies through numerous initiatives. With five European companies in the RETro Propulsion Assisted Landing Technologies (REALT) project, DLR is involved in the research and development of key technologies for backward-landing rockets. In addition, the SALSAT mission of the TU Berlin was launched in 2020, which contributes to the efficient and sustainable use of the radio spectrum for the future of satellite communication. The German Space Agency is also paying special attention to sustainability in the context of the INNOspace Masters competition. The 2021-2022 competition was governed by the overarching theme of Sustainable and Efficient Innovations for Space and Earth.

The DLR Institute of Robotics and Mechatronics is developing a space robotic system which is able to assemble, maintain, update, and repair space infrastructure in Earth and moon orbits. This technology is contributing to lifetime extensions of current satellites and aims to contribute to a more efficient use of launch capacities. The robotic system is developed as a general-purpose tool, which could be used for applications not known or specified yet.

With a strong focus on sustainability in the new national space strategy, Germany plans to become even more intensively involved in the matter.

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

At German universities and institutes, numerous research projects are underway on novel technological approaches to dealing with space debris. These projects explore novel engines, mechanisms for enabling space objects' disposal, methods for the active removal of space debris and much more.

In order to better comply with the space debris mitigation guidelines of COPUOS, the German Space Agency dynamically adapts the Product Assurance, Safety & Sustainability Requirements for DLR Space Projects to swiftly integrate new scientific findings into the requirements. New developments, such as design for demise approaches or specific measures applicable to satellite constellations are also taken into consideration. In addition, the importance of IT, cyber and data security in relation to space sustainability is growing. Attacks on the integrity of data systems necessary for the operation of satellite systems can have catastrophic effects. For this reason,

space cyber security is considered in the Product Assurance, Safety & Sustainability Requirements for DLR Space Projects.

At ESA level, Germany supports this guideline by funding programmes to promote the responsible and sustainable use of space, such as the first space debris removal mission (ClearSpace-1) to remove an ESA-owned space debris object from LEO. This is a first attempt in the preparation of future ADR missions as well as for commercial services for maintenance in orbit including end-of-life management of future constellations.

Germany is a partner of the Plan European Roadmap and Activities for SPace Exploitation of Robotics and Autonomy (PERASPERA) project, which is coordinated by ESA and aimed at providing the most important tools to increase the technological maturity of robotic technologies for satellite maintenance and exploration in the period 2020-2030. These actions will be carried out in line with current and future developments at both national and ESA level. In order to establish such framework conditions, the PERASPERA project introduced the European Operations Framework (EOF) as part of its work on SRC Space Robotics Technologies, which contains a proposal for technical standards to be applied for the different on-orbit servicing activities and for support further regulation, licensing and standardisation activities by competent authorities and organisations.

Several DLR institutes are studying and developing technologies to help manage the space debris population. At the DLR Institute of Technical Physics, laser optical technologies are being studied which enable precise orbit determination down to 10 cm size. A new telescope with 1,75 m diameter, i.e. the Johannes Kepler Observatory located in Empfingen, Germany, enables the passive optical characterization of objects in LEO. The Institute of Robotics and Mechatronics is developing a space robotic system which is able to capture large space debris objects in intensively used orbits. The GSOC is developing systems for rendezvous, inspection, capturing (space segment), operations, telepresence (ground segment) and for test, verification and simulation.