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Exploring space technologies for sustainable development and the benefits of international research collaboration in this context

Report of the Secretary-General

Summary

This report explores the role of space technologies in accelerating sustainable development and the benefits of international research collaboration in this context. It presents applications of space science and technology for achieving the Sustainable Development Goals, including in ensuring food security, reducing the risk of disasters, preventing humanitarian crises, monitoring natural resources and reducing poverty, as well as telecommunications and health. It analyses how new technological developments that reduce the costs of using space-based applications and collaborations among local, national, regional and international stakeholders can potentially increase the uptake of Goals-relevant applications, particularly in developing countries.

The report also takes note of persisting capacity constraints and bottlenecks, including the lack of awareness of the benefits of space technologies, limited financial resources and technology and skills gaps in developing, using and adapting space technologies. The report identifies effective forms and areas of international scientific research in space technologies by highlighting case studies of various collaborative research and development-focused initiatives. Finally, the report highlights successful policies and strategies at the national, regional and international levels that can promote the harnessing of space technologies for achieving the Goals. It concludes with suggestions for Member States and the international community.

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Introduction

1. At its twenty-second session in May 2019, the Commission on Science and Technology for Development selected "Exploring space technologies for sustainable development and the benefits of international research collaboration in this context" as one of its priority themes for the 2019–2020 intersessional period.

2. The secretariat of the Commission convened an intersessional panel on 7 and 8 November 2019 to contribute to a better understanding of this theme and assist the Commission in its deliberations at its twenty-third session. This report is based on the issues paper prepared by the secretariat, the findings of the panel, country case studies contributed by Commission members, relevant literature and other sources.[1]

3. The report is structured as follows. Chapter I reviews the different applications of space technologies for sustainable development, including in ensuring food security, reducing the risk of disasters, preventing humanitarian crises, monitoring natural resources and reducing poverty, as well as telecommunications and health. Chapter II highlights recent developments in space technologies and examines bottlenecks in the use of space technologies for sustainable development in developing countries and an international context. Chapter III identifies effective forms and areas of international scientific research in space technologies by highlighting case studies of various collaborative research and development-focused initiatives. Chapter IV highlights successful policies and strategies at the national, regional and international levels that can promote the harnessing of space technologies for achieving the Goals. Finally, chapter V presents suggestions for consideration by the Commission and the international community.

I. Space technologies for the Sustainable Development Goals

4. Space science, technologies and data have the potential to contribute in direct or indirect ways to achieving all of the Goals. Space science incorporates scientific disciplines involving space exploration and the study of natural phenomena and physical bodies in outer space and often includes disciplines such as astronomy, aerospace engineering, space medicine and astrobiology.

5. Space technologies often refer to satellite Earth observation, satellite communications and satellite positioning. Technologies such as for weather forecasting, and involving remote sensing, global positioning systems and satellite television and communications systems, as well as scientific fields such as astronomy and Earth sciences, all rely on space science and technologies.[2]

A. Food security and agriculture

6. Space technologies can be vital in agricultural innovation, modern agriculture and precision agriculture. The use of space technologies for farming and natural resources management used to be limited largely to developed countries, due in part to the high costs involved. In recent years, open access to geospatial data, data products and services and the

[1] Contributions from the Governments of Austria, Belgium, Botswana, Brazil, Canada, Egypt, Japan, Madagascar, Mexico, the Russian Federation, Saudi Arabia, South Africa, Thailand, Turkey, the United Kingdom of Great Britain and Northern Ireland and the United States of America, as well as the Economic and Social Commission for Asia and the Pacific (ESCAP), the Food and Agriculture Organization of the United Nations (FAO), the International Telecommunication Union (ITU), the United Nations Office for Disaster Risk Reduction and the World Food Programme are gratefully acknowledged. For all documentation from the intersessional panel, see https://unctad.org/en/pages/MeetingDetails.aspx?meetingid=2232.
Note: All websites referred to in this report were accessed on 23 September 2019.

[2] United Nations Office for Outer Space Affairs, 2019, *Annual Report 2018* (Vienna).

lower costs of geospatial information technology facilities have stimulated the adoption of space technologies worldwide, particularly in developing countries, through initiatives such as Open Data Cube.[3]

7. Space-enabled agricultural products and services can support national agricultural ministries and departments, international organizations and farmers. For example, the World Meteorological Organization (WMO), through its agricultural meteorology programme, provides weather and drought forecasting services to farmers, herders and fishers, to promote sustainable agricultural development, increase agricultural productivity and contribute to food security.[4] In addition, the Hassas-2 precision farming initiative in Turkey produces fertilization maps and applications and disseminates satellite images and analysis data to farmers over the Internet.[5]

8. At the national level, applications can support the monitoring of crops from space using publicly available sources of satellite data and algorithms for land use and land cover.[6] For example, in 2016, Statistics Canada became the first national statistical office to replace a farm survey with a remote sensing model-based approach for crop yield estimates.[7] In addition, Crop Watch Cloud is a cloud-based crop monitoring platform that allows countries to conduct independent crop monitoring and early warning related to food security without investment in establishment and operational costs. The platform consists of four subcomponents, namely, Process, Explore, Analysis and Bulletin.[8]

9. Earth observation data can support regional and international efforts to target those with the greatest risk of food insecurity. The use of remotely sensed data is a key component in the effective monitoring of agricultural production through the global agroecological zones data portal and the integrated land resources information management system of FAO. Several countries support international assessments and forecasts based on space applications, either directly through national efforts or in partnership with international efforts. For example, the monthly report of the United States Department of Agriculture on world agriculture supply and demand estimates includes United States and world forecasts for wheat, rice, coarse grains, oilseeds and cotton.

B. Health applications

10. In recent years, space-based technologies have played a growing role in furthering global health objectives. In the public and global health domains, "space science, technology and applications, including Earth observation and remote sensing; telecommunication, positioning and tracking; and space-based research play a crucial role in supporting decision-making, improved care, education and early warning measures".[9]

11. Information from remote-sensing technologies is used to monitor disease patterns, understand environmental triggers for the spread of diseases, predict risk areas and define regions that require disease-control planning.[10] For example, a malaria early warning system based on geospatial data is responsible for 500,000 fewer new cases in 28 countries.[11] In 2018, data from National Aeronautics and Space Administration (NASA) satellites were used for cholera forecasting in Yemen, with a 92 per cent accuracy rate.[12]

[3] Contribution from FAO.

[4] A/AC.105/1179.

[5] Contribution from the Government of Turkey.

[6] Examples from Bangladesh and Cambodia were shared at a Commission on Science and Technology for Development regional consultation at ESCAP in August 2019.

[7] Contribution from the Government of Canada (see https://marketplace.officialstatistics.org/earth-observations-for-official-statistics).

[8] Contribution from the Institute of Remote Sensing and Digital Earth, Academy of Sciences, China.

[9] A/AC.105/1179.

[10] Contribution from the Government of South Africa.

[11] Juma C, Harris WL and Waswa PB, 2017, Space technology and Africa's development: The strategic role of small satellites, Faculty Research Working Paper Series No. 43, Harvard Kennedy School.

[12] Contribution from the Government of the United States.

In addition, the World Health Organization uses digital elevation models provided by the Japan Aerospace Exploration Agency (JAXA) to map difficult-to-access areas, to implement efficient measures for infectious diseases, such as for polio in the Niger.[13]

12. Public health is an example of a sector in which the use of satellite communications and remote sensing is vital. Satellite communications are an integral part of overall health information infrastructure. Key applications of satellite technology in this field include telemedicine, telehealth, disease surveillance systems and health mapping.[14] Beyond monitoring infectious diseases or supporting access to medical care in remote locations, space technologies can enable medical research that would otherwise be difficult to conduct in a terrestrial environment.[15] For example, high quality protein crystals grown in a microgravity environment can support new drug designs for cancers, infectious diseases and lifestyle-related diseases.[16]

C. Disaster risk reduction and humanitarian crisis prevention

13. In 1998–2017, globally, 1.3 million people were killed by climate-related and geophysical disasters and a further 4.4 billion people were displaced, injured or left homeless or in need of emergency assistance.[17] Space-enabled technology applications have become an important element of local, regional and national disaster risk reduction strategies. Globally, the Sendai Framework for Disaster Risk Reduction 2015–2030 notes the importance of promoting access to reliable data and making use of space and in situ information through geospatial and space-based technologies, as well as Earth and climate observations enabled by remote sensing, to enhance measurement tools and the collection, analysis and dissemination of data.

14. Earth observation, involving remotely sensed satellite images and increasingly high-technology in situ instruments (such as on floating buoys, to monitor ocean currents, temperature and salinity; land stations, to record air quality and rainwater trends; seismic stations, to monitor earthquakes; environmental satellites, to scan the Earth from space; and the use of sonar and radar to observe fish and bird populations), helps to detect and monitor disaster risks, particularly for natural hazards, and exposure to vulnerability. For example, accurate weather forecasts and improved communications helped manage evacuations and save lives during the 2017 Atlantic hurricane season.[18] In addition, countries vulnerable to cyclone risks, such as Bangladesh and India, have been investing in modern meteorological services, to improve early warning systems and cyclone shelters and embankments.[19] In May 2019, Tropical Cyclone Fani killed at least 89 people and caused over $1.8 billion in damage; India evacuated 1 million people and Bangladesh a further 1.6 million people.[20]

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[13] Contribution from the Government of Japan. Elevation data is widely used in mapping infectious diseases in part because of the influence of elevation on rainfall, temperature and humidity (Hay SI, Tatem AJ, Graham AJ, Goetz SJ and Rogers DJ, 2006, Global environmental data for mapping infectious disease distribution, Advances in Parasitology, 62:37–77).

[14] A/AC.105/1115.

[15] Advances in telemedicine, disease models, psychological stress response systems, nutrition, cell behaviour and environmental health are some of the benefits gained from the International Space Station microgravity environment (see https://www.nasa.gov/mission_pages/station/research/benefits/human_health.html).

[16] Contribution from the Government of Japan.

[17] United Nations Office for Disaster Risk Reduction and Centre for Research on the Epidemiology of Disasters, 2018, *Economic Losses, Poverty and Disasters: 1998–2017*.

[18] See https://public.wmo.int/en/media/news/extremely-active-2017-atlantic-hurricane-season-finally-ends.

[19] See https://blogs.worldbank.org/voices/modernizing-weather-forecasts-and-disaster-planning-save-lives.

[20] Reliefweb, 2019, Tropical Cyclone Fani, available at https://reliefweb.int/disaster/tc-2019-000041-ind.

D. Natural resources and environment management

15. Earth observation is an essential tool for managing natural resources and the environment. It is highly relevant for both achieving the Goals and monitoring progress.[21] It provides information to support agricultural production, fisheries and freshwater and forestry management, and can also help monitor activities harmful to the environment, such as fires and illegal logging, mining and poaching.

16. Earth observation data from satellites can also be used to overcome various challenges related to air pollution and in areas such as water management and forest preservation. For example, the observation of precipitation is useful in addressing water-related disasters such as floods, typhoons and landslides. JAXA has developed a precipitation monitoring system that offers global rainfall maps using satellite data, such as the global precipitation measurement mission and the global change observation mission. In addition, Brazil monitors forests using satellite images collected by the National Institute of Space Research, although the size of the area to be observed represents a challenge. The Biomesat project is an initiative for monitoring forest health in the Amazon using nanosatellite technologies.[22]

17. Earth observation is also a tool for monitoring illegal mining activities. Remote sensing can be used to monitor natural variations in sand flux in rivers and, thereby, illegal sand mining. For example, satellite data from the NASA gravity recovery and climate experiment can reveal sediment discharge rates at river outlets, and the raw materials Copernicus programme of the European Union uses satellite images to help monitor and manage natural resources and the raw materials sector.

18. Finally, Earth observation can be used to monitor country-specific environmental conditions and challenges, such as with regard to snow, ice and glaciers. For example, with financial support from the horizon 2020 programme of the European Union, a company in Austria led efforts to develop and implement a standard European service for snow and land ice monitoring as a downstream service for the Copernicus Earth observation programmes programme.[23]

E. Connecting the unconnected

19. Access to terrestrial networks is limited or non-existent in many parts of the world, particularly in sparsely populated remote or mountainous areas. Satellite technologies are well-placed for the delivery of broadband services in such areas either on their own or in combination with other technologies and existing infrastructure. Instead of the traditional network infrastructure used for broadband connectivity (i.e. blanket coverage with many adjacent cells each supported by a base station), a new set of network technologies can often reduce infrastructure requirements and offer more cost-effective service delivery options. For example, Bangladesh has recently launched a telecommunications satellite that is also broadcasting television and radio programmes and will soon provide Internet, telemedicine and distance-learning facilities for people in remote areas.

20. New and emerging technologies may shape the evolution of telecommunications access, including low and medium-altitude satellites, other aerial devices and the innovative use of unused portions of the radio frequency spectrum.[24] For example, the development and future deployment of non-geostationary orbit satellite fixed-satellite service systems has the potential to increase access to broadband infrastructure and bridge the digital divide,

[21] Anderson K, Ryan B, Sonntag W, Kavvada A and Friedl L, 2017, Earth observation in service of the 2030 Agenda for Sustainable Development, *Geospatial Information Science*, 20(2):77–96; Wood D and Stober KJ, 2018, Small satellites contribute to the United Nations Sustainable Development Goals, available at https://digitalcommons.usu.edu/smallsat/2018/all2018/437/.

[22] Contribution from the Government of Brazil.

[23] See http://www.enveo.at/euprojects/89-cryoland.

[24] Contribution from the Government of South Africa; contribution from the Chief Executive Officer, Institute for Transformative Technologies.

particularly for populations in rural areas. In addition, private sector companies can provide global Internet access through nanosatellite constellations and high-altitude balloons.

F. Other applications

21. Beyond satellite Earth observation and satellite communications, other space technologies such as satellite positioning can support transport and fleet management, as well as scientific applications such as measuring the impacts of space weather on the Earth, of earthquakes and of climate change. More broadly, space science and technologies can support applications in poverty mapping, education, urban planning and many other Goals-relevant areas.

22. Recent studies have demonstrated the potential of satellite imagery and machine learning to predict poverty rates, using publicly available and non-proprietary data.[25] For example, the World Bank conducted a study to predict poverty rates using convolutional neural networks along with high-resolution satellite imagery.[26] Such methods can also help developing countries estimate measures of urban poverty, including the proportion of the urban population living in slums and informal settlements and the rate of access to basic services and infrastructure. The use of machine learning to detect informal settlements is an emerging area of research.[27] However, it remains to be seen whether such big data-derived indicators will be as accurate as research and pilot projects indicate. There are opportunities for big data to augment the evidence base in developing countries, in which traditional statistics are not always available, yet some algorithms may increasingly develop out of synchronicity with the underlying socioeconomic reality over time.[28]

23. Space applications can also support education. For example, electronic education initiatives can benefit from satellite telecommunications; the United Nations Children’s Fund supports the mapping of schools using satellite imagery and machine learning.[29] Scientific, technological and innovative research and development for space applications may also yield practical Goals-relevant applications. For example, battery storage capabilities have become more robust due to research for space applications funded by the United States.

II. Rapid technological change and capacity constraints

24. New technological developments can lower the costs of using, adopting and adapting space science and technologies. Machine learning, big data and cloud computing make it possible to derive automated insights from satellite imagery for poverty rate monitoring and agricultural applications. Emerging satellite functionalities can enable new Goals-relevant applications. Aerial platforms such as drones may have a complementary role to satellite-based Earth observation. Crowdsourcing is expanding collaboration opportunities between citizens and space agencies and programmes and initiatives in both developed countries and the least developed countries, to fill data gaps for a range of

[25] Jean N, Burke M, Xie M, Davis WM, Lobell DB and Ermon S, 2016, Combining satellite imagery and machine learning to predict poverty, *Science*, 353(6301):790–794.

[26] Engstrom R, Hersh JS and Newhouse DL, 2017, Poverty from space: Using high-resolution satellite imagery for estimating economic well-being, Policy research working paper No. 8284, World Bank.

[27] Kuffer M, Pfeffer K and Sliuzas R, 2016, Slums from space: 15 years of slum mapping using remote sensing, *Remote Sensing*, 8(6):455–483; Schmitt A, Sieg T; Wurm M, Taubenböck H, 2018, Investigation on the separability of slums by multi-aspect Terra SAR[synthetic aperture radar]-X dual co-polarized high-resolution spotlight images based on the multi-scale evaluation of local distributions, *International Journal of Applied Earth Observations and Geoinformation*, 64:181–198; Stark T, 2018, Using deep convolutional neural networks for the identification of informal settlements to improve a sustainable development in urban environments, Master of Science thesis, Technical University of Munich, Germany.

[28] Lazer D, Kennedy R, King G and Vespignani A, 2014, The parable of Google flu: Traps in big data analysis, *Science*, 343(6176): 1203–1205.

[29] See https://www.unicef.org/innovation/school-mapping.

applications related to, among others, weather, climate change, air quality monitoring and vector-borne disease monitoring.

25. However, while the costs of some space technologies are decreasing and the availability of open source data is increasing, some bottlenecks hinder their application in certain fields and use in some regions, including the following: lack of awareness of the benefits of space technologies; high costs and lack of financial resources to develop space programmes, particularly in developing countries; technology and skills gaps in developing, using and adapting space technologies; challenges with regard to user needs and access to and compatibility of available data sets; geographical constraints to developing space launch facilities and conducting astronomical research; emerging issues concerning regulations and the international governance of space commons; and some of the risks in using space technologies. Regional and international cooperation is needed to address such capacity constraints and application bottlenecks.

A. Recent technological developments

26. Artificial intelligence and machine learning can enable users to analyse vast amounts of Earth observation data in a faster and more efficient manner. With appropriate in situ observations, convolutional neural networks may be used to automate image recognition and classification tasks based on remotely sensed imagery. As a result, Earth observation data may be analysed in real time, minimizing the time and effort required of human analysts.

27. There are several global developments to more effectively harness machine learning for achieving the Goals. For example, the platform for big data in agriculture of the Consultative Group on International Agricultural Research coordinates efforts to apply machine learning, precision agriculture and other novel techniques to solve agricultural challenges worldwide.[30] However, machine learning models are only as good as the data they are trained on, and the quality of the data can determine the suitability of the model for accurate and robust prediction.[31]

28. Increasingly, the application of artificial intelligence and machine learning to Earth observation data is occurring on cloud computing platforms. The cloud computing model is becoming the prevailing mode of work for most medium and large-scale global data sets, including Earth observation applications. This is due to the ability of cloud services to archive large satellite-generated data sets and provide the computing facilities to process them. Examples of cloud platforms include Copernicus Data and Information Access Services, the Earth Observation Data and Processing Platform of the Joint Research Centre, Earth on Amazon Web Services, Google Earth Engine, NASA Earth Exchange, Open Data Cube and the climate data store of the European Centre for Medium-Range Weather Forecasts.

29. There are some examples of possible future satellite positioning technology applications. First, data from continuous recording global positioning system reference stations can be used to extract information on atmospheric and tropospheric water content that can be fed into operational weather forecasts and improve forecasts in areas with heavy rainstorms. Second, experiments are underway to use data from continuously recording stations to monitor the passage of tsunamis across ocean basins, based on the impact on the ionosphere; if a tsunami is detected, its source, likely passage across ocean basins and potential impact can be predicted 24 hours in advance. In addition, satellite Earth observation platforms are increasingly capable of monitoring global wireless spectrums.[32]

30. Drones can serve as an alternative source of Earth observation data that is relatively affordable compared with satellites, and they are increasingly being used in crop prediction

[30] Contribution from the Government of the United States.
[31] Contribution from ITU.
[32] See, for example, https://www.he360.com.

and food security applications.[33] Drones can be built for several thousands of dollars and travel over 100 km on one battery, yet their use presents some concerns that need to be addressed through regulation and, until these are fully resolved, the cost advantage of drones cannot be fully realized.

31. Crowdsourcing, enabled through digital, mobile and social networking tools, can support efforts to more effectively harness space technologies for sustainable development. Crowdsourced image labelling is used by several aid-related non-governmental organizations to manually identify patterns of areas affected by a natural disaster and can be automated with machine learning.[34] Data Collaboratives for Local Impact, a partnership between the United States President's Emergency Plan for AIDS Relief and the Millennium Challenge Corporation, is working in Africa to build an enabling environment for data-driven decision-making to end the AIDS epidemic, improve health outcomes, reduce gender inequality and support economic opportunities for vulnerable youth.[35]

32. The emergence of private sector actors in space technologies is a key driver of rapid technological change in the sector. In particular, the cost of sending a satellite into orbit has declined significantly because private firms have developed innovative approaches to design and operation. This trend will significantly change the role of public agencies in the development of space technologies and of private low-cost space operators, and open possible new configurations of public–private partnerships and collaboration.

B. Capacity constraints in the use of space technologies

33. Space-related technologies are changing at a pace that makes it difficult for non-specialists to keep up to date with the technologies and their implications. Lack of awareness concerning the benefits of space technologies for sustainable development can prevent countries from harnessing such technologies. For example, in the experience of the European Space Agency, there may be a lack of understanding among the development aid community and recipient States about the information that satellite technology can deliver, a lack of understanding of the costs and benefits and a lack of experience in how satellite information can be used in development activities.[36]

34. The use of space-related technologies and data does not necessarily require the creation of space programmes or agencies. In some developing countries that have made more intensive investments in space programmes, such initiatives could draw criticism that highlights other priorities and concerns that should be addressed before investment in space technologies. Raising awareness about the benefits of space technologies for sustainable development, the different levels of investment that a country can make and how benefits can be more equally distributed among the population, is key.

35. The lack of domestic and international financial resources is another obstacle to investing in space programmes in developing countries. Official development assistance directed to space-related projects is relatively modest, amounting to $607 million in 2000–2016. By comparison, total official development assistance commitments in 2016 alone amounted to $188 billion. Leading donor countries include those with well-established space programmes (such as Japan, the United States and the European Union) and those with special programmes to use space technologies for development aid (such as the United Kingdom). The priority areas of official development assistance flows

[33] See https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Pages/Events/2018/Drones-in-agriculture/asptraining.aspx.

[34] International Environmental Policy Consultancy, 2018, *Artificial Intelligence for the United Nations 2030 Agenda* (Wageningen University and Research, Netherlands).

[35] Contribution from the Government of the United States.

[36] Caribou Space, 2018, *Satellite Environmental Information and Development Aid: An Analysis of Longer-Term Prospects* (Farnham, United Kingdom).

to space-related projects in this period were environmental management, forestry management and telecommunications.[37]

36. In many developing countries, the lack of capability and expertise to produce satellite information with local resources and to provide user support can be a barrier to expanding the use of satellite technologies.[38] There is also an absence of a critical number of personnel with the capacity to generate downstream applications of space technologies. In developing countries, losing even a single expert can jeopardize efforts in government agencies. This absence of critical mass applies not only to institutions developing space applications but also to government agencies and private sector firms that could be the potential users of such technologies.[39]

37. Obstacles to the wider use of satellite technologies include restrictive data access, lack of standardization, data that are not fit for purpose, lack of analysis-ready data and insufficient frequency of observations.[40] Other challenges include geographical constraints in some countries in developing space launch facilities and conducting astronomical research, the regulation and governance of space commons and the risks and trade-offs of using space technologies.

III. International scientific research in space for achieving the Goals

A. International Space Station

38. The world's largest international cooperation programme in science and technology is the International Space Station, which has been operating continuously since 1998. It is a collaboration between the space agencies of Canada, Japan, the Russian Federation, the United States and Europe, which developed and now jointly operate and use the station. It has three laboratory modules furnished with research equipment (Destiny (United States, 2001), Kibo (Japan, 2008) and Columbus (Europe, 2008)) and external platforms that support experiments and applications in space science, Earth observation and technology. Scientific and research activities include experiments on micro-organisms, cells, tissue cultures and small plants and insects; research on ageing and the effects of long-duration spaceflight on the human body; physics experiments with different materials, such as on the behaviour of liquids in microgravity; and high-technology experiments on remote operations, energy efficiency and maritime surveillance.

39. Research and discoveries on the station are supported by thousands of researchers, engineers and technical personnel on Earth. They also feed into the work of scientists and of universities and private companies, which benefit from state-of-the-art space technologies. As space agencies seek cost-effective solutions, the International Space Station stimulates industrial activities and private sector research and development in space technologies (such as commercial spaceflight, commercial capsules, commercial robotics services and commercial services for collecting, processing and analysing data on space debris). Agencies such as JAXA, NASA and the European Space Agency are considering new types of public–private partnerships.[41]

[37] Organization for Economic Cooperation and Development, 2019, *The Space Economy in Figures: How Space Contributes to the Global Economy* (Paris).

[38] Caribou Space, 2018.

[39] Contribution during the Commission on Science and Technology for Development side event at the twenty-third session of the Intergovernmental Consultative Committee on the Regional Space Applications Programme for Sustainable Development, Bangkok, 28 August 2019.

[40] Glaude V (2019). ITU AI[Artificial Intelligence] for Good Global Summit, track 3: The eye in the sky – space, AI[artificial intelligence] and satellite, presented at the fifty-sixth session of the Scientific and Technical Subcommittee, 11–22 February, available at https://www.unoosa.org/documents/pdf/copuos/stsc/2019/tech-62E.pdf.

[41] Organization for Economic Cooperation and Development, 2019.

B. Regional cooperation on scientific research in space

40. An effective form of long-term international research cooperation in space is provided by the European Space Agency. Its mission is to shape the development of the space capability of Europe and ensure that space research benefits the citizens of Europe and the world. The organization has 22 member States, is funded by financial contributions from members and is international, with headquarters in Paris and different sites across Europe.[42]

41. The Earth-orbiting space science missions of the European Space Agency, several of which are part of international collaborations, are dedicated to observing the universe, the solar system and fundamental physics.[43] Current missions observing the universe include the Hubble Space Telescope, a joint project of the European Space Agency and NASA launched in 1990. Another notable mission is Gaia, which has produced the richest star catalogue to date, contributing to understanding of the history of the Milky Way galaxy. In addition, the European Space Agency, with the Canadian Space Agency and NASA, is collaborating to launch the James Webb Space Telescope in 2021.

42. The European Space Agency is the main technical partner of the two flagship space projects of the European Union, namely, the European Global Navigation Satellite System (known as Galileo) and the Copernicus Earth observation programme.

C. Regional cooperation for drought monitoring from space

43. Given the increased frequency of droughts in Southeast Asia, building resilience has become a pressing need.[44] Asia and the Pacific regional cooperation platforms and networks related to space technology applications and disaster risk management, including the Regional Space Applications Programme for Sustainable Development, have extended their spheres to address global sustainable development challenges beyond disaster risk reduction, such as drought monitoring.

44. The ESCAP regional cooperative mechanism for drought monitoring and early warning brings together developed countries and countries with economies in transition with advanced experience in using innovative space applications with countries with a high level of disaster risk that could use the information and tools but lack the capacity to do so. Through its technical service nodes in China, India and Thailand, the mechanism has provided technical support in Cambodia and Myanmar through training, validation and the installation of drought monitoring systems. The operationalization of the drought monitoring system in Myanmar with technical support from India has significantly improved monitoring capability in Myanmar. The system provides agricultural drought information in terms of prevalence, severity and persistence using moderate resolution data, multiple indices for drought assessments and the augmentation of ground data bases. The mechanism has provided continued support in capacity-building to Member States through various thematic training sessions, as well as policymakers with information that will enable them to make evidence-based decisions on how and when to prepare for drought. In addition, the mechanism provides support to drought-prone countries in forging strong institutional partnerships between ministries through capacity-building, knowledge and information sharing and integrating drought risk reduction into policy, planning and implementation.

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42 The member States are Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland and the United Kingdom; Slovenia is an associate member; and Bulgaria, Croatia, Cyprus, Malta, Latvia, Lithuania and Slovakia, as well as Canada, have cooperation agreements with the Agency.

43 See https://www.esa.int/ESA/Our_Missions/(sort)/date.

44 This section is based on A/AC.105/1179; United Nations Office for South–South Cooperation, 2018, *Good Practices in South–South and Triangular Cooperation for Sustainable Development, Volume 2* (New York); and contributions from ESCAP.

D. Space-enabled cooperation for disaster response and humanitarian relief

45. Space technologies facilitate data collection and transmission, smooth and expedient communications and tracking and tracing efforts during and after natural disasters and in complex humanitarian emergencies.

46. The United Nations Platform for Space-based Information for Disaster Management and Emergency Response promotes the use of space-based information in disaster management, disaster risk reduction and emergency response operations by raising awareness of the benefits of space technologies for disaster management and building the capacities of Member States to use those benefits effectively. Combining regional and global approaches, the United Nations Platform organizes technical advisory missions, conferences, workshops, discovery days and thematic expert meetings.

47. Some countries with requisite space capabilities, technologies and data contribute to international efforts for disaster reduction and humanitarian relief. For example, the Landsat series of satellites, developed by NASA and operated by the United States Geological Survey, provide data used by the Servir network, a development initiative of NASA and the United States Agency for International Development that creates maps used in disaster relief and to support sustainable land use planning in developing countries. The network provides data, information, methods combining Earth observation and geospatial data for decision-making and visualizations to address environmental problems, including deforestation, pollution, floods, droughts and biodiversity loss. Currently, there are nodes in Africa (Kenya and the Niger), America (Panama and Peru) and Asia (Nepal and Thailand). In addition, United Kingdom-based Inmarsat has donated satellite telecommunications and connectivity equipment to the Philippines Department of Social Welfare and Development for use during natural disasters and emergencies.[45]

E. International scientific cooperation to enhance access to space

48. Several international efforts are promoting access to space, particularly for developing countries and countries with economies in transition. The United Nations Office for Outer Space Affairs and JAXA cooperation programme known as Kibo Cube offers developing countries the opportunity to deploy cube sats from the Kibo laboratory on the International Space Station.[46] The first such satellite was developed by a team from the University of Nairobi and successfully deployed in 2018. This is the first satellite of Kenya and is a good example of how international collaboration contributes to access to space.

49. Similarly, the Asia-Pacific Space Cooperation Organization supports satellite development by training students and academics, supporting the development of the radiometric calibration capabilities of member countries of the organization and developing small satellites through its Joint Small Multi-Mission Satellite Constellation programme. In addition, under a United Kingdom-funded global partnership to improve fire detection rates in South Africa, capacity-building will be provided by Strathclyde University to students at Cape Peninsula University of Technology for the development of a cube sat platform.

50. Bilateral agreements can support science and technology partnerships involving both public and private sector actors through donations of equipment, capacity-building and the provision of access to satellite capacity. For example, two companies from the United Kingdom provide services, either commercial or in-kind, to support the achievement of the

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[45] *Business Mirror*, 2019, UK[United Kingdom] firm, DOST[Department of Science and Technology] forging £11 million contract for radar satellite to monitor PHL[Philippines] waters, 21 July.

[46] Cube sats are a class of nanosatellites that use a standard size and form factor. They provide a cost-effective platform for scientific investigations, new technology demonstrations and advanced mission concepts (see https://www.nasa.gov/content/what-are-smallsats-and-cubesats).

Goals in the Philippines. The bilateral agreement includes capacity-building activities not only to build and use space technologies but also to establish a new space agency.[47]

IV. Policies and strategies to harness space-based applications for achieving the Goals

51. Harnessing space technologies for achieving the Goals does not necessarily require experts in space science but rather geospatial technologists and engineers who can transform satellite-generated data into Goals-related applications. A space agency or talent for space science and engineering is not as important as scientists, engineers, technologists and geospatial experts who can develop applications in pursuit of the Goals. Such experts in downstream applications can transform Earth observation and other space-derived data into insights for the environment, economy and society.

A. National policies and strategies

52. The promotion of national policies on space and geospatial applications is highly dependent on the socioeconomic and political context in a country. Governments in developing countries may have different motivations to engage at different levels in space-related activities and face different limitations. For example, in Botswana, satellite services are used for different applications to support the Government by enabling informed regional planning and enhancing infrastructure.[48] In addition, Madagascar has established a national observatory of radio astronomy.[49] South Africa has a national interest in making greater investments in space technologies. Operating a satellite programme has several benefits in South Africa, including decreasing dependence on foreign partners, increasing customized satellite services and data and providing local human resources with opportunities to understand satellite operations.[50]

53. Some countries link their space programmes and initiatives with broader economic, development and science and technology initiatives. For example, within the framework of a Russian Federation project on the digital economy, one target is to create a domestic digital platform for collecting, processing, storing and disseminating remotely sensed data on the Earth from space under a digital Earth project by 2022.[51] In addition, in Saudi Arabia, the National Centre for Remote Sensing Technology is a scientific government institution that supports and aims to enhance applied scientific research and adopt essential trends in scientific research and technical development in line with the national scientific technology policy.[52]

54. Some countries are investing in infrastructure and capacity-building programmes to support research and development, education and entrepreneurship in space-related fields. For example, Thailand is developing infrastructure to facilitate space-related research and entrepreneurship at the Space Krenovation Park, to promote the development of the upstream space value chain.[53] In addition, in Belgium, the Federal Science Policy Office manages the national Support to Exploitation and Research in Earth Observation programme, which offers universities, public scientific institutions and non-profit research institutions with opportunities and tools for the development of expertise in Earth observation and maximized scientific use of satellite and airborne data.[54]

[47] Contribution from the Government of the United Kingdom.
[48] Contribution from the Government of Botswana.
[49] Contribution from the Government of Madagascar.
[50] Contribution from the Government of South Africa.
[51] Contribution from the Government of the Russian Federation.
[52] Contribution from the Government of Saudi Arabia.
[53] Contribution from the Government of Thailand.
[54] Contribution from the Government of Belgium.

55. The socioeconomic and political context in a country shapes the development of national policies. In many cases, experts in downstream applications organizing in informal groups ultimately convince Governments of the need for a national geospatial data infrastructure and geo-information and other space-related policies. In other cases, for example in the United Kingdom, a grand challenge approach motivates solutions to well-defined problems, with collaboration across the Government, academia and the private sector.

56. National Governments and their respective space agencies or geospatial departments can proactively share data with bilateral and multilateral organizations to support the achievement of the Goals. For example, the Spot Vegetation programme, part of a European Earth monitoring system developed jointly by Belgium, France, Italy, Sweden and the European Commission, delivered free-of-charge data sets to the user community from 2001 on, and was the precursor to the Copernicus programme.[55] Similarly, all Earth science data from satellites of NASA, the National Oceanic and Atmospheric Administration and the United States Geological Survey are made available under a policy of free, full and open access, under a non-discriminatory principle whereby all users should be treated equally, allowing countries that may not have satellite operation capability to benefit from globally relevant data sets.[56]

B. Regional cooperation

57. Regional cooperation mechanisms can support the development of regional space-related policies, spatial data infrastructure and political consensus-building for space-focused development initiatives.

58. In Africa, the African Union Heads of State and Government adopted the African Space Policy and Strategy in 2016 as the first step towards realizing an African space programme, one of the flagship programmes under Agenda 2063 of the African Union.[57]

59. In Asia and the Pacific, the third Ministerial Conference on Space Applications for Sustainable Development in Asia and the Pacific adopted the Asia-Pacific Plan of Action on Space Applications for Sustainable Development 2018–2030, representing a collective commitment to scale up the use of space technologies and geospatial information applications in the region. The plan of action will guide participating countries and organizations on policy actions and interventions to support the delivery of the ESCAP Regional Road Map for Implementing the 2030 Agenda.[58]

60. Several regions feature extensive collaboration on technical and capacity-building initiatives to support space science, technology and data for the achievement of the Goals. For example, a dual-satellite Earth observation mission by Argentina and Brazil aim to support research on ocean ecosystems, marine habitats and seashores, and help map water-related hazards. Such collaborations and partnerships contribute to knowledge transfer and the building of technological capabilities in aerospace and science, technology and innovation in the region. In Asia and the Pacific, ESCAP shared, in 2017–2018, more than 400 satellite images and products on droughts, cyclones, earthquakes and floods to disaster-affected countries as a continuously operational service, with free data and support from member countries of the Regional Space Applications Programme for Sustainable

[55] Contribution from the Government of Belgium.

[56] Contribution from the Government of the United States.

[57] The two policy goals are to "create a well-coordinated and integrated African space programme that is responsive to the social, economic, political and environmental needs of the continent, as well as being globally competitive" and to "develop a regulatory framework that supports an African space programme and ensures that Africa is a responsible and peaceful user of outer space" (see https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-african_space_policy_-_st20444_e_original.pdf).

[58] Contribution from ESCAP.

Development.[59] Finally, the African Development Satellite initiative aims to help countries in Africa develop and launch a remote-sensing mini-satellite equipped with hyperspectral sensors for detecting and monitoring carbon dioxide and climate change and quality.[60]

C. Multi-stakeholder initiatives

61. As space science and technology is increasingly transformed by cloud computing, artificial intelligence and crowdsourcing, private sector firms and non-profit organizations will continue to play a role in sharing Earth observation data, models and other relevant digital resources. In addition to the efforts of national Governments, private satellite data providers release proprietary Earth observation data for humanitarian and development purposes. Such initiatives need to be encouraged, to share digital public goods related to Earth observation.

62. Multi-stakeholder entities can forge global and public–private partnerships to more effectively harness space science, technology and data for the achievement of the Goals. The United States, through the United States President's Emergency Plan for AIDS Relief, is a founding member of the Global Partnership for Sustainable Development Data, which works to convene, connect and catalyse partnerships to build demand, political will and capacity for data-driven decision-making to advance sustainable development solutions. The Global Partnership partnered with the Committee on Earth Observation Satellites, the Group on Earth Observations, NASA and others to launch the Africa Regional Data Cube, which is building capacity in Ghana, Kenya, Senegal, Sierra Leone and the United Republic of Tanzania to use time-series satellite images and other geospatial data to improve environmental management, adaptation to climate change and agricultural productivity. The Data Cube, which will feature regional Landsat data, will serve as a platform for the scale-up of a continent-wide geospatial capability.[61]

63. Public–private partnerships, whether national or global, can support space science, technology and data for achieving the Goals. For example, the Partnership for Resilience and Preparedness Initiative, a public–private alliance hosted by the World Resources Institute, seeks to improve access to data, including space-based Earth observation, to empower communities and businesses to better plan for and build climate resilience.[62]

D. International cooperation and collaboration

64. Countries can continue to invest in multilateral mechanisms for the effective sharing of Earth observation data, digital assets (such as machine learning models) and derived geospatial products. Such mechanisms can be supported by international charters or agencies, regional platforms and national Governments and their respective space agencies.

65. An example of worldwide collaboration through which satellite data are made available for the benefit of disaster management is the international charter on space and major disasters. By combining Earth observation assets from different space agencies, the charter allows for resources and expertise to be coordinated for rapid responses to major disaster situations, thereby helping civil protection authorities and the international humanitarian community.[63]

66. Throughout the United Nations system, there are efforts to share data or derive data products and services with Member States. Among United Nations Office for Outer Space Affairs efforts to share Earth observation data, its Open Universe Initiative in partnership with Italy is aimed at enhancing the online availability and visibility of astronomical and

[59] These data and services were worth over $1 million (United Nations Office for South–South Cooperation, 2018).

[60] Contribution from the Government of Egypt.

[61] Contribution from the Government of the United States.

[62] Ibid.

[63] Ibid.

space science data following internationally agreed standards. In addition, WMO, through its space programme, "conducts a wide range of activities and acts as a bridge between satellite operators and users with the overall objective of promoting the wide availability and utilization of satellite data and products for weather, climate, water and related applications by WMO members".[64]

67. The international community can continue to invest in multilateral cooperation in scientific research and the development of space technologies and to collaborate in global education and capacity-building. Examples include the International Space Station and other collaborative international research efforts, the International Student Education Board, and the Virtual Laboratory for Training and Education in Satellite Meteorology established by WMO and the Coordination Group for Meteorological Satellites. Finally, the University Space Engineering Consortium supports practical space-related development activities, mainly at the university level, such as designing, developing, manufacturing, launching and operating micro, nano and/or picosatellites and rockets.

68. Among other initiatives in the international community, the Committee on Earth Observation Satellites, the Group on Earth Observations and the United Nations Committee of Experts on Global Geospatial Information Management foster collaborative efforts towards harnessing space technologies for achieving the Goals.

V. Suggestions for consideration

69. Space science, technology and data hold the potential to help achieve the 2030 Agenda and the Sustainable Development Goals. Costs are being driven down by new technological developments and collaborations between local, national, regional and international stakeholders. Yet development is challenged by persisting bottlenecks, including the lack of awareness of the benefits of space technologies, limited financial resources and technology and skills gaps in developing, using and adapting space technologies. National and regional policies and strategies to support space science, technology and data for achieving the Goals could include efforts to build upstream and/or downstream capabilities; improve infrastructure and increase public awareness; develop policies for open data and open science for geospatial data; and leverage public–private cooperation on common goals for space science, technology and data for achieving the Goals. The international community is encouraged to develop collaborative agreements that take advantage of the individual competitive advantages of countries, encourage regions to develop their own space facilities and develop space-related capacity by training space technology experts, to be included in policy processes.

70. Member States may wish to consider the following suggestions:

(a) Develop national policies and strategies with a grand challenges approach to space science, technology and data for the achievement of the Goals that bring together Governments, academia, the private sector and civil society to take part in such activities, from basic research to implementation;

(b) Work with the private sector to deliver products to end users;

(c) Increase national support not only for building upstream capabilities (such as launch facilities and satellite engineering) but also for critical downstream capabilities (such as processing and analysing Earth observation data) that support the achievement of the Goals;

(d) Develop open data, cloud computing and science policies that incorporate the sharing of Earth observation data;

(e) Encourage educational collaboration through networks of universities to build space-related capabilities, such as through the University Space Engineering Consortium and the Space Generation Advisory Council.

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[64] A/AC.105/1179.

71. The international community may wish to consider the following suggestions:

(a) Develop cooperative bilateral agreements that leverage competitive advantages;

(b) Develop space science, technology and data capacities through train-the-trainer and/or massive open online courses;

(c) Continue to build and support intergovernmental platforms that strengthen the capacities of end users of geospatial data in developing countries.

72. The Commission is encouraged to take the following steps:

(a) Support multi-stakeholder collaboration in policy learning, capacity-building and technology development;

(b) Improve coordination among stakeholders and enable partnerships with regard to rapid technological changes that harness the specific expertise and interest of stakeholders;

(c) Share best practices and lessons learned on the formulation of space-related policies and strategies, the development of space programmes and the utilization of space science, technology and data for Goals-related applications.