7 February 2024

English only

Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
Sixty-first session
Vienna, 29 January–09 February 2024
Item 11 of the provisional agenda*
Long-term sustainability of outer space activities

Report on the technical preparatory symposium of the United Nations/Portugal Management and Sustainability of Outer Space Activities Conference (Virtual, 27–29 November 2023)

Conference room paper by Portugal

I. Introduction

1. Portugal is actively contributing to the outer space dialogue and agreed with Office for Outer Space Affairs to host an international conference on the topic of Management & Sustainability of Outer Space Activities, in May 2024. This conference will be an important moment for all United Nations Member States to actively contribute in an open forum to the discussions on the topics to be discussed in the Summit of the Future and beyond and it will address the need for the international community to come together and discuss ways to reinforce space governance and further strengthen the sustainability of human space activities in which the Secretary-General Policy Brief on Outer Space could provide a guideline for discussion.

2. To achieve this goal, two preparatory virtual symposiums were agreed to be prepared, one centred on technical challenges in November 2023, and other focused on policy in March 2024, to consult international experts form industry, academia, and Member States. The main topics for discussion are Space Traffic Management, Space Resources and Space Debris. The summary in section IV draws out insights and main themes discussed in the technical symposium, aimed to support the ongoing discussions and further work, namely by providing inputs to the policy symposium and to connect all stages of the process up to the May conference. To the extent practicable, the original language was retained to better capture the views expressed.

3. Portugal would like to thank the contribution of the moderators and rapporteurs for their excellent work and all the speakers for the interesting point of views and live

* A/AC.105/C.1/L.412.

debate provided. The schedule, speakers, moderators, and rapporteurs can be found in annex to this document.

II. Programme

4. The first day of the virtual symposium was dedicated to Space debris with two sessions, the second day to Space Resources with one session and the third and last day to Space Traffic Management with three different sessions. Each of the sessions had a moderator and a rapporteur.

SPACE TRAFFIC MANAGEMENT

5. The goal of this topic was to discuss and gather perspectives on the recommendation on space traffic management within the "For All Humanity – the Future of Outer Space Governance" Our Common Agenda Policy Brief: "Develop an effective framework for the coordination of space situational awareness, space object manoeuvres and events."

Space Surveillance and Tracking

6. Within SST it was discussed ways to enhance space surveillance and tracking capabilities to improve situational awareness and data sharing for STM as well as improvements to current orbital debris measurement coverage for the safe operations of space missions.

Objectives:

- Highlight the importance of space surveillance and tracking capabilities for effective STM.
- Identify key measurement gaps and explore ways to collect data on small, untracked debris which are important to mission safety and protection.
- Discuss strategies to enhance data collection, analysis, and sharing to improve space situational awareness and provide accurate information about space objects.
- Discuss different methods to collect measurement data (radar, optical, in-situ, laboratory) on orbital debris large and small.

Orbital Data and Catalogues

7. Under this subtopic, it was discussed the different approaches to cataloguing SSA data, including federated and centralized approaches, to improve the accuracy and accessibility of information about space objects.

Objectives:

- Emphasize the significance of regularly updated database(s) containing comprehensive information about space objects.
- Discuss the technical aspects of maintaining an accurate and accessible catalogue that includes orbital parameters, ownership details, and other relevant data.

Collision Avoidance

8. Regarding collision it was outlined how to explore collision prediction and avoidance techniques to mitigate the risk of space collisions.

Objectives:

- Focus on the critical aspect of collision prediction and avoidance in space.
- Explore, for example, advanced algorithms, models, and protocols that enable accurate orbit determination, conjunction analysis, and coordination of manoeuvre planning. Highlight best practices and coordination mechanisms to minimize the risk of collisions.

Interoperability of Space Operations

9. This subtopic addressed the challenges of space traffic coordination, identifying methods to promote the adoption of international standards and best practices for safe and efficient space operations in the context of interrelated international space cooperation.

Objectives:

- Highlight the importance of interoperability and standardized operations in the STM regime.
- Discuss international standards and best practices for spacecraft design, deployment procedures, rendezvous and docking protocols, and on-orbit operations.
- Explore opportunities for alignment of international cooperation on space traffic coordination with the goal of ensuring equitable and efficient usage of radio spectrum.
- Examine opportunities for leveraging international mechanisms for space weather coordination.

SPACE DEBRIS

The goal of this topic was to discuss from the technical perspective recommendations on space debris within the “For All Humanity – the Future of Outer Space Governance” Our Common Agenda Policy Brief: “Develop norms and principles for space debris removal that take into account the legal and scientific aspects.”

The sessions addressed main topics such as models and techniques for space debris, active debris removal, in-orbit servicing, and orbital debris mitigation. The main objectives were to:

- Discuss different models and techniques used for space debris characterization.
- Explore ways and methods for improving space debris evolution modelling.
- Explore types of capture and removal techniques and removal prioritization.
- Propose methods for mission concepts to achieve debris removal.
- Discuss the technical challenges and benefits of the in-orbit servicing missions such as life extension, recycling, in-orbit assembly and manufacturing and others.
- Identify technical issues to be consider when developing frameworks for the new circular space economy arising from in-orbit servicing.
- Address effective ways of debris mitigation in all stages of a spacecraft life cycle.
- Examine the existing Life Cycle Assessment methodologies and propose the establishment of an accurate methodology.
- Methods for end-of-life management, deorbiting and re-entry.

SPACE RESOURCES ACTIVITIES

The goal of this session was to discuss from the technical perspective recommendations on space resources within the “For All Humanity – the Future of Outer Space Governance” Our Common Agenda Policy Brief:

> “Develop an effective framework for sustainable exploration, exploitation and utilization of the Moon and other celestial bodies. This framework could include binding and non-binding aspects and should build up upon the five UN treaties on outer space and other instruments for international cooperation in the peaceful uses of outer space.”

It addressed space mining, extracting resources in-situ/in space use and transportation to Earth, especially with the aim to discuss:

- In space resources identification and evaluation, containment and packaging, sustainable transportation systems, re-entry and recovery and planetary protection and contamination control techniques.
- Resource potential, in-space processing, mining in low-gravity or microgravity environments handling the unique properties of extraterrestrial resources, developing mining equipment capable of withstanding harsh conditions, safe extraction, and potential environmental considerations.
- Resource extraction and utilization, recycling and reusability, close-loop systems, energy efficiency, life cycle assessment.
- The concept of a circular space economy and how resource activities can enhance sustainability, efficiency, and long-term viability.

III. Attendance

10. This symposium was sketched to allow participation from all the world in different time zones and bringing together more than 10 countries with moderators and rapporteurs from Member States that fully supported the symposium. The conference was followed live by more than 700 attendees and posteriorly the different sessions were visualized more than 500 times on YouTube, which clearly shows the importance of the discussions and the relevance of the topics.

IV. Summary of the Forum exchanges

SPACE TRAFFIC MANAGEMENT

In the first session of Space Traffic Management the panellists discussed all the STM subtopics.

11. The number of satellites being launched continues to increase, generating more data and services, but also creating more debris. For every launched satellite there are created 10 to 100 times more objects in space, accounting with secondary objects associated with the launch. It was emphasized that a critical point in the utilization of space was already surpassed and, that even if all space activities were ceased the number of objects in orbit has already built a capacity where the traffic can sustain itself and the number of debris would continue to increase despite the cease of activities. It was expressed that the biggest challenge relates with the fact that once a satellite gets into to space it does not always come back and that the first objects launched by humankind are still in space, causing operators to have reached a critical point were conjunction warnings or collisions are periodic. With this challenge in mind, the next step will involve orbital manoeuvres as something normal and frequent to be done at a weekly or monthly basis.

12. As part of the solution for this complex problem, the first step is to gather space objects tracking data.

13. One possibility already being used by space industry and institutions is the development of satellites able to track space objects (with optical and radar payloads), combining it with a ground-based network, and creating the capability to associate these tracking data from different platforms into the generation of a space catalogue which will be transformed into a single operational picture and as an outcome provide actionable insights. The different platforms identified during the session are optical telescopes/cameras, lidar, radar and passive RF sensors.

14. Conjunction assessment is an activity that is required 24/7. It is important to have tools that provide several functionalities with data from multiple sources, for the Collision Avoidance Maneuver Planning. Using the speaker’s example, with regards

to the 2022 statistics, the organization performed 279 course assessments, 156 fine assessments and 1 collision avoidance manoeuvre procedure. Since space environment is changing dramatically the tools need to increase their automation capability and capacity growth since constellation missions imply increasing of capacity. SSA & STM research is also of importance.

15. It is needed to innovate technologies and advance the economies that support space sustainability, assuring the support to formulate policies that foster sustainability.

16. With regards to the technology for life extension on Geostationary Earth Orbit (GEO) or Low Earth Orbit (LEO) it is crucial to provide station keeping, manoeuvrability or salvage of the orbit position and in this way reducing the number of launches and waste. In-space situational awareness/inspection provides visual data on the object allowing to assess its behaviour and develop an action plan to remediate the object or to implement other preferred solution. Orbital transfer services can lead to Active Debris Removal in this way remediating the environment.

17. It should be taken into consideration services such as refuelling, maintenance, repair, and recycling, all contributing to the circular economy.

18. As an example, missions like ELSA-d, launched in 2021 as a technology demonstration (and composed by two spacecrafts connected – the client and the servicer – that were separated after launch with the goal of performing rendezvous tests with the client and then capture it) was concluded with success. This showed the possibility for Active Debris Removal or In-Orbit Servicing.

19. As a long-term solution it is needed a broader adoption of the preparation adaptation, investing in preparing the satellites for In-Orbit Service. Sustainability should consider the full life cycle of a satellite with End of Life being the most responsible way to dispose a satellite. Furthermore, when designing satellites is necessary to think about the future, if things go wrong how can it be remediated?

The second session of Space Traffic Management was dedicated to Space Surveillance and Tracking & Orbital Data and Catalogues.

20. It was highlighted the opportunities and challenges by the rapid growth of in space utilization, and by the tremendous growth of activity in Low Earth Orbit, which underpins the crucial need for space traffic coordination as a service. In the space domain, ‘data is the new oil’ and nowhere is this truer than with the number of new actors developing space situational awareness capabilities. This innovative technology, combined with its diversity, and a multiplicity of actors means that the global community needs to tackle how to better coordinate and cooperate given the growing number of ways to analyse and fuse SSA data together, which is leading to different catalogues and potential collision risks.

21. The panellists expanded on these themes in their remarks. It was stressed three possible rules for improving space traffic coordination:

- Methodology (show your work);
- Propagate ephemeris to notify other operators (share your work); and,
- Understand the big picture (as there are different degrees of congestion across LEO corridors).

22. One key message was that scientific and operational traceability (or transparency) is required to ensure space safety for the over 8,000 operational satellites providing critical services globally.

23. During the discussion phase it was mentioned more specifically about the common errors in calculating ephemeris and potential collision risks depending on the formula used to determine the location of a satellite. In some cases, the risk of collision is outsized due to ‘uncertainty’ being stated as randomness, rather than a lack of knowledge. Similarly, there are numerous factors that contribute to

uncertainty. An important point raised was that there is a paradox that exists when people speak of ‘space sustainability’ given that it is understood differently by different groups of experts and that advancing sustainability on Earth may in fact lead the space environment to be less sustainable.

24. It is needed to ensure that the international community is focused on the ‘right’ problem when addressing SSA. Close approaches are increasing dramatically in certain orbits, and while debris as small as 1 cm can be mission terminating, existing sensors can’t track this in LEO and the gap is close to basketball-size in GEO. The international community shouldn’t be misled by focusing on cleaning up small debris when in fact the bigger SSA challenge is to protect actively manoeuvring spacecraft given the challenge of unmodeled or mismodeled manoeuvres. Addressing these challenges requires a holistic approach that incorporates procedures and mitigation strategies across operators (government and commercial). It was highlighted that one of the ways to address this challenge is through the development of standards for SSA and STM and there is work that ISO is undertaking in this area.

The third session of Space Traffic Management was dedicated to Collision Avoidance and Interoperability of Space Operations.

25. The panellists in this session addressed the Net Zero Space Initiative and as an example, industry such as Planet which has launched more than 500 satellites had successfully disposed 200 satellites already. The orbits of its satellites launched at low altitudes, allows faster reentries and disposals. Planet also advocates for establishing collision avoidance best practices such as data transparency and data sharing. Working towards transparent and standardized data sharing – should include sharing contact information and ephemerides, and working towards standard data formats

26. Continuous improvement of SSA data quality should be achieved by improving ground and space-based tracking assets.

27. It was also mentioned (like in the first session) that faster and more reliable data exchange and coordination is needed and that relying on emails for data sharing is not optimal. It is needed to automate the data sharing as well as to increase the capability to coordinate interactions between operators quickly and accurately to actively coordinate and share manoeuvre plans. Automated alerting workflows to notify of conjunctions is critical.

28. Works towards transparent and standardized data sharing (including uncertainty and contact information) need to be achieved as well as continuous improvement of SSA data quality.

29. Forcing data transparency should not be the only option and operators should instead be incentivized to share information. For example, there are benefits of “federated learning” and this also encourages everyone to be involved.

30. As a global endeavour it is needed to move towards faster and more reliable data exchange and coordination.

31. It was also stressed the need for responsible coexistence with other operators and that operational excellence should be achieved based in three pillars.

32. Maintain quality predicated ephemerides and spacecraft manoeuvrability status information for the organization’s vehicles and regularly update the information with the chosen collision avoidance screening authority.

33. Perform rapid and reliable CA risk assessment to identify high-risk conjunctions that require proactive mitigation.

34. Pursue adequate mitigation actions to avoid high-risk conjunctions and ensure that these are properly and transparently coordinated.

35. Another important aspect is the space safety improvements that are needed and the lack of meaningful pre-launch conjunction screenings in the industry. With more launches, there’s a growing risk in pre-launch incidents.

36. It was also identified a lack of an international and neutral platform where STM and manoeuvre coordination can reliably take place with actors from every country feeling encouraged to participate as well as a lack of harmonized regulation in the context of collision risk management and the associated acceptable and unacceptable practices.

37. There are key technologies and methods like, data fusion, AI powered collision prediction, and automation that are critical to STM.

38. During the various sessions regulation was identified as missing. This is one of the reasons why industry issued the “Satellite Orbital Safety and Best Practices” a document that was released by Iridium, OneWeb, and SpaceX in 2022. This shows the willingness of the involvement of the private sector as a joint effort and commitment with several initiatives, including the space sustainability rating.

39. To achieve a responsible space sector there are key ingredients to be considered. It is needed economic viability since it cannot be possible to fund space sustainability just on public sector funding, and therefore it is required to have private investment. Space sustainability is a market. To sustain this position, it is referred to the space economy in 2022 where if 1% of the market went to space sustainability this sector alone would be worth 5 billion U.S. dollars.

40. It is also needed a public sector commitment and consistent behaviour. This commitment comes with the need to develop space sustainability as a commercial sector and that the public sector responsibility is not in conflict with the commercial success of space sustainability.

41. The public sector does not need to solve space sustainability alone, and the private sector must invest in this mission as well.

42. There is a difference between industrialization and commercialization. Industrialization should be seen as a support from public sector by doing project procurement and asking industry to develop building blocks. Commercialization is about selling services on a commercial market and commercial services should be built on top of public sector services.

43. One very important point emphasized was that space traffic is not the same as air traffic and therefore they should not be regulated in the same manner.

44. With regards to collision avoidance two perspectives were shared on why this is so important.

- Local perspective: collisions with objects larger than 1 cm have the potential of prematurely ending a mission.
- Global perspective: collisions can significantly contribute to the evolution of the debris environment.

45. Recently there has been noted a big change which is the massive increase in the number of objects in LEO. This includes objects in large constellations and are primarily in lower LEO altitudes. In higher LEO altitudes, it is more payload-related debris.

46. The new emerging trends go towards more automated systems. This means partially automated screening process and communication mechanisms, although this creates a lot of overhead and is not particularly efficient. It is needed to examine how it can be implemented in the systems to take automated decisions that are also trusted and how can we design manoeuvres that are efficient and make sure all our neighbours are informed.

47. Other emerging trends on small satellites and trackability is that there is a shift from a small number of very heavy satellites to a large number of smaller, lighter

satellites. This has affected the ability to track, and particularly quickly track/identify objects.

48. Collision avoidance is an operational reality for actors in space and convergence of self-interest and long-term sustainability of operations is captured in the UN LTS guidelines.

49. Lastly there are other points of view that should be considered. STM is multifaceted and it also concerns to spectrum resources. It is important to be able to attend the necessary spectrum to ensure the use of the services and have them be free from interference. Not all services have the same level of risk from interference. Control, for instance, is very important to be free from interference.

50. It is suggested to use the mechanisms of the ITU to ensure the needs and future needs of STM are protected within the radio regulations. And STM actors should be encouraged to approach spectrum managers and actively follow the work of the WRC if new protections are needed.

SPACE DEBRIS

51. The first session was dedicated to models, techniques for space debris and orbital debris mitigation while the second session was dedicated to active debris removal and in-orbit servicing.

52. It was stated that clearly satellites play a vital role in today's society, through applications, helping us understand climate change, answering scientific questions.

53. The problems that arise from a heavy use of space infrastructure is that some orbits are increasingly cluttered with debris, which threatens our future in space. The 2023 report on Interconnected Disaster Risks by the United Nations University – Institute for Environment and Human Security (UNU-EHS) names space debris as one of six areas at risk of reaching a tipping point – a certain threshold of instability that, when reached, causes a system to collapse or fundamentally change. This shows that space sustainability is a very serious subject, and so it is paramount to discuss it, starting with models and techniques for orbital debris mitigation. Observing debris and the orbital environment is foundational for the safe and sustainable use of outer space. There are 35.000 objects > 10 cm tracked on regular basis, but also 60.000 objects > 5 cm and 900.000 objects > 1 cm, which are still lethal. Even the 10 cm population is not completely tracked, especially in GEO, and for the 1 cm population there are no observations, so there is no knowledge in this segment.

54. The current focus of space programs lies on LEO/MEO, and partly on GEO, and soon it will also have to take into account the cislunar orbits, for when Humankind wants to return to the Moon. It is extremely important to increase our knowledge of the space debris environment to ensure that we are prepared from a safety point of view. The basic safety and sustainability information comes from surveillance and tracking. It is not just about knowing where objects are, but also what they are (characterization especially of lethal non-trackable population) to develop reliable risk assessments for our missions.

55. During the session it was identified that today it is needed more investment in civil/commercial systems for traffic control and it is required to have more operators and more data for SSA. It is necessary to take responsibility of SSA as a civil mission to make it effective for space sustainability. There is growth in commercial SSA which is more agile and quicker than government funded structures, so it is important not to ignore commercial solutions.

56. In GEO, some objects are already being tracked by commercial solutions. Those commercial SSA suppliers have supported governmental and UN entities over the past years.

57. Commercial SSA coverage in LEO is in development. It is required the development and deployment of new radars that can track new objects, but a problem remains, persistence of observations and correlating them as those commercial

entities have not as robust catalogues as public entities. More objects in LEO also makes tracking more expensive.

58. During the session several techniques for space debris detection were identified.

- Space Debris Laser Ranging, which requires powerful lasers. These systems can track satellites up to GEO, but space debris only up to 1.500 km orbital altitude.
- Multistatic laser ranging is a method in which one station aims a laser at a space object, which then reflects the light diffusely. Several stations pick up the signal from their point of view and share that data which increases the orbit prediction quality.
- Combination of SDLR observations with single photon light curves (temporal variation of reflected sunlight). This allows to measure the rotation of an object.
- Radar as a method to track objects in space.
- Using optical camera networks and observe objects based on existing catalogue data.

59. It is needed to have different mindsets and rethink the processes from processes of the past. Cameras can give a broad overview of the object population while radars can focus on smaller objects. It is also needed an ecosystem that provides and uses more data rather than relying on modelling and simulations.

60. One recommendation could be to increase the number of SDLR stations to improve orbit predictions; MHz laser ranging (one laser + detector setup for SLR and SDLR); data fusion (using different techniques to observe the same objects); input from amateur astronomers and machine learning.

61. It is required to combine observations from multiple sources to get a better picture.

62. A crucial question to ask is, what are the most important measures to mitigate/reduce space debris?

63. The main priority should be preventing the creation of space debris.

64. Other important method to reduce space debris is the End of life-activities that can have different solutions depending on the orbit the satellite is. It can include raising or lowering an orbit by ~200 km (“graveyard orbit”) and keeping the satellite outside of station keeping box of other satellites in case of GEO satellites; or bring them back to Earth in case of LEO satellites.

65. The success of EoL operations is of paramount importance for success of the long-term sustainable use of outer space and lifetime should have limits in LEO (less than 25 year or 5 years as accordingly to FAA rules) and GEO.

66. The management of the space environment needs observations, but also statistical population and evolution models. In addition, it is required rules and regulations on debris mitigation, post-mission disposal, collision avoidance, active debris removal and the protection of dark and quiet skies. The long-term debris environment evolution driven by collisions of non-manoeuvrable objects, so we need to come up with techniques to prevent that. Scientific research and observations provide foundations for sustainability, this is what current and new guidelines and regulations need to be rated against.

67. Other ways to achieve space debris mitigation/reduction could be through active debris removal or/and in-orbit servicing. Nevertheless, there are several challenges with these technologies. One is the technology since the development takes time and verification is fundamental. There is a need to demonstrate these capabilities in orbit. Another challenge is the guidelines development and best practices. It is important to capture lessons learned and best practices and it is needed to perform end-to-end demonstration in-orbit to guarantee safe operations of IOS.

68. One possible way to address it is the Zero Debris approach as a stepping-stone to achieve a circular economy in space.

69. Starting to work towards a circular economy with the life extension of satellites in orbit by refuelling, refurbishing, assembling, manufacturing, and recycling in a safe way. It is a change of mindset of the way we operate.

70. In-orbit servicing and active debris removal are extremely complex and space objects are not cooperative, which can lead to a high risk to create more debris.

SPACE RESOURCES ACTIVITIES

71. As a framework for In Situ Resource Utilization (ISRU) it can be stated that there are four steps on the way to ISRU: development, prospecting, in-situ test, and validation as well as implementation. ISRU can provide the basis for activities on celestial bodies (e.g., life support and reduction of logistic costs and extension of mission duration). One aspect that needs to be considered is that the mass of products supplied by ISRU and the mass of the ISRU system brought from Earth should always be balanced. Currently, the focus seems to be more on the processing side, while prospecting and transportation are often undervalued.

72. The speakers mentioned reasons to explore the Moon which, when seen from some perspectives, could be a difficult case due to energy intensive processes and difficult access points. Nevertheless, it is possible to extract oxygen from rocks since some of them contain around 40% of oxygen. The process for oxygen extraction is rather complex as it foresees to melt salt and then drop in a rock, followed by electrolysis. There are several challenges: regolith cohesiveness (‘stickiness’), electrostatics, gravity, vacuum, high temperature/salt/gases, lunar surface temperatures, radiation, vibration, shocks, and unknown unknowns. One of the most important reasons to do ISRU could be being able to produce oxygen on the Moon to use it either on the Moon or beyond. Oxygen could be used for astronauts to breathe but also as oxidizer for fuel. Each region of the Moon has its own characteristics that are relevant for exploration. For example, the Earth facing side (nearside), is a basalt region, all very well explored. The far side is totally different when compared to nearside, and only just now has been opened for exploration it has interesting and large craters (e.g. Shackelton crater), that when are located near the poles can have permanently shadowed areas as well as areas where there is almost permanent sun light. Extreme temperatures and temperature variations make Moon exploration very challenging for current technologies. At the South Pole there are possibilities to extract water ice but there is also immense scientific interest in that region. Scientists assume there could be molecules in the South Pole region which could be there since billions of years and be signs for life.

73. Space resource activities are also very important from the science perspective and scientists are worried that the scientific use of the South Pole could be diminished by extensive exploration activities.

74. There are several missions that have already been completed (success or attempt) or that are planned which shows a growing interest in the Moon.

75. With regards to Mars, it was underlined the importance of science as a component of space exploration, also influencing our life on Earth.

76. With respect to Mars, today it can be said that there is already an ISRU system operating in Mars with the current missions in operations on Mars. The question is now how to scale it up. Mars has characteristics that make it simpler for resource utilization since its thin atmosphere already contains oxygen, which is interesting for ISRU activities. The first step on Mars exploration should be water extraction, followed then by hydrogen and oxygen production. There seems to be ice resources available broadly on the surface of Mars, but the bottleneck will be assessing how difficult it is to reach that ice on Mars surface, while the prospection should not be very complicated. The speakers presented the idea of using plasma conversion of CO2 from the Martian atmosphere as a ISRU method on Mars and it can also be used as a

twin process to use CO2 neutral fuels on Earth through a power to liquid scheme. Carbon and Nitrogen are also interesting minerals, which can among others be used as fertilizers.

77. The requirements for transportation of crew to the Moon and Mars are very different, ISRU on Mars would be far more feasible and with much greater mission impact considering the characteristics of the planet but also the long travel distances from Earth.

78. One of the decisive and critical needs for human living on celestial bodies as much as is food and shelter for human survival is the access to electrical power. For that purpose, there is a need for a massive power supply of at least 1MW on the Moon. ISRU technology can be used to provide power sources for future space activities. During the panel, it was mentioned the long-term ambition of industry to produce solar panels on the Moon from local space resources.

79. Human missions on celestial bodies are exciting but must be preceded by robotic missions. Establishing a refuelling station to refuel spacecrafts on celestial bodies would be great step in the first exploration phase.

V. Observations and recommendations

SPACE TRAFFIC MANAGEMENT

80. With the emergence of more data there are challenges on taking the different kinds of data from different sources. Fusing different data sources and turning them into insights for costumers is a major challenge.

81. With regards to governments, normally every government likes to use their own object identifying number and catalogues, but every country uses its own identification method making it difficult to correlate data and as such the biggest challenge when using this data. With regards to private companies, despite also being applicable for governments, the most common data is post processed which can imply little valuation depending on its format. Overall, the primary challenge is to have a clear definition or understanding of the coordinate systems from the sensors and translating that coordinate systems to the operation picture.

82. With regards to conjunction analysis, it is needed to take into account the actions of other satellite operators, but the interaction is a major issue. It is hard to interact directly with another operator and sometimes the interactions are happening by email. Nowadays, there are indirect methods, like loading the precise orbits information into platforms, gathering the other satellite owners' precise information and then recalculate and distribute the modified CDM or modified conjunction.

83. It is necessary to improve this structure since connecting directly to other space operators is more efficient overall.

84. It is also needed to look into the satellite life cycle with a different mindset and industry creates expectation from governments in terms of facilitating it to achieve sustainability.

85. From an operator perspective, space sustainability should be seen as an investment and not an expense. Events that unfold in space take place over many years, thus it is needed to invest in the long-term sustainability and governments can foster this mindset, for example through opportunities for financial support or other mechanisms which support that mentality towards sustainability. Afterall space is a global resource, and every government plays a part in managing that resource. From a servicer point of view, it is necessary to assure that the activities are thought of and enabled through licensing regimes, since some activities such as rendezvous with a derelict satellite or capture are still not regulated.

86. Spectrum management was also addressed and at this point this new type of activities have not been well analysed by ITU and it is necessary to analyse the

requirements and needs of missions such as IOS and others. Overall, lack of harmonization, in licensing regimes, funding mechanisms, etc. is the biggest issue.

87. One major overall take away from this session is that STM must be global and that the regional approaches have to come together.

88. The discussion highlighted the importance of sharing data; all panellists agreed that sharing the result and the methodology is important in reducing uncertainty.

89. It was also understood that just having manoeuvre capability will not resolve the growing SSA-STM challenge and that transparency in how collision risk (the methodology) is calculated is important. From a technical standpoint, it was stated that the current collision avoidance process is not effective with the exception of certain corridors in LEO where there is more radar coverage and drag is less of an issue.

90. With regards to the long-term sustainability of outer space activities, mitigation and remediation needs to be coupled with space traffic coordination and this is particularly important with new actors who are not as closely abiding to debris mitigation guidelines. It was noted that the amount of mass being left in orbits that will last more than 25 years has increased significantly compared to the first decades of the space race. In particular, this underscores the importance of capacity-building through the UN as a means to share awareness of the debris challenge and bring all space actors up to speed on the importance of the long-term sustainability of outer space activities.

91. Panellists expressed the need to define what full transparency means. The goal should be to make collision avoidance more reliable maybe to achieve it operators don’t need all the information for that.

92. In lower altitudes of LEO where there are many actors and trust among the actors is crucial assuming all will act in good faith. The minimum level of transparency concerns how to interact safely with other operators involved. Forcing transparency isn’t good, since all actors like to feel involved and like to have a say. It is needed a global approach.

93. The panellists also noted that there is a need for technical informed regulation, “rules of the road.” It is needed to define how and who should behave in which way and when. For example, should a more modern satellite move instead of an older satellite? That would be a significant step towards reliable automation.

94. The industry cannot be waiting for regulation to provide rules of the road, it would not be correct and could take too long and it should be taken into account that technology is always faster than regulation. Pressure on operators today to keep their missions safe and preserve the environment around them is already calling for rules of the road. It is needed more coordination around operators.

95. The panellists addressed a scenario in which, regulation takes more time to come to life than what is expected and how the industry would adapt/regulate themselves in an unregulated scenario.

96. It was stated that there are costs associated with collision avoidance and regulations take longer to come than is necessary sometimes. There’s a degree of pragmatism that industry needs to adopt to address it in the meantime. The economics are a big driver to allow such accidents to happen.

97. In 1963 space services were introduced into the radio regulations for the first time for the operation of an artificial satellite in orbit. At the time, all Member States agreed that there were risks of escalating the cold war and risks in outer space. It’s a question of risk and economics. When there’s a need to move in a pressing manner, it is possible. ITU has a “well trained” mechanism to establish regulations (which doesn’t exist for STM).

98. Also, from this panel the main message was that is it needed global coordination.

SPACE DEBRIS

99. The most important from now onwards would be to ensure that what is launched into space would be brought down to Earth (post-mission disposal), a Zero Debris approach. This does not tackle heritage debris but with ongoing and increasing traffic, post-mission disposal is the most important element.

100. Post-mission disposal success rates must significantly improve. It is important to educate satellite operators about the importance of post-mission disposal for their missions as not everyone is fully aware of the existing guidelines and recommendations but would be also positive to create incentives for compliance.

101. It is also required a harmonized regulatory framework so that everyone pushes in the same direction. Liability, responsibility, export control, the need for consultation. There is also a need for standardization, guiding principles and definitions to agree on where the LTS guidelines are a great example and the UN and COPUOS have an important role to ensure this, but it is needed international coordination.

102. It is strongly needed to track objects currently not in the catalogue to fully understand the magnitude of the problem. It requires a more effective tracking and cataloguing.

103. It is required to ensure international capabilities to enable support of object tracking and predictions and standardization. It is needed to have the right information on the right objects.

104. Access to data is the crucial, but unfortunately no single information source is providing the full picture.

105. Although tracking is important it is not sufficient. It is required to increase the investment in technologies such as Active Debris Removal.

106. It is paramount to share knowledge on findings, methods, techniques, more and better data as input for the models. No one can solve this problem alone, a global effort on tracking is needed.

SPACE RESOURCES ACTIVITIES

107. During the session it was addressed that the timeframe until space resource activities on the Moon could become a reality will depend on three main constrains: Technology, Funding and Regulation. With the very ambitious missions planned worldwide, commercial, and institutional, from Europe, US, India, China and other countries, a current estimate would be between 10 to 20 years until larger scale space resource activities become a reality.

108. Considering the rate of landers going to the Moon in the near future, and the evolutions on the launch sector, the costs of such missions are likely to significantly decrease, which could reduce the time. This cost reduction is a real big shift, which will enable future mission.

109. The commercial component of Moon exploration will be very important, and a strong business case will be required where ISRU on the Moon has to prove to be cheaper than bringing the respective material from Earth to the space.

110. The amount of people thinking about the development of new technologies and using existing terrestrial technology for space to decrease costs and open new opportunities is increasing and this will promote the speed of activities around the World.

111. The financial contributions and political decisions will be critical for the future developments.

112. According to the speakers the focus should be on using resources in space rather than bringing them back to Earth. This seems to be the currently more realistic approach also from a business perspective. Looking at the examples of batteries,

cobalt is needed at the moment, but use is limited due to geopolitical reasons. So, if such materials could be extracted in outer space for the need of humanity, this could in the long-term be a good point for humanity.

113. Planetary protection was identified by speakers as a regulatory issue to be discussed in the March conference, but it could be bypassed if there are no strict regulations.

114. It was clearly stated by the speakers that regulation is needed to ensure legal certainty. It should not be too restrictive to allow economic growth but at the same time it should ensure that space is available for future generations. It was also clearly stated that regulation is a duty of the UN, that can be supported by industry. A legal framework needs to be in place the sooner the better to avoid a very difficult west situation in outer space. With some of the developments happening, activities are speeding up and are testing the boundaries of currently existing legal frameworks. It was stated that if there are no rules, industry and the first comers will make the rules and that is not the appropriate way and may create a problem for future generations.

115. As a conclusion, it can be stated that from the technical point of view we are at the verge of a big transformation with industry actively moving forward and at a speed that needs to be matched by regulation.

116. It was identified that it is important that Member States discuss within UN to find convergence to ensure that regulation is in place when industrial and institutional activities become a regular activity in the celestial bodies.