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THE CASE OF SPACE ROBOTIC APPLICATIONS IN THE EVOLUTION OF INTERNATIONAL SPACE LAW

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ABSTRACT

This paper analyzes the legal aspects involved in space robotic applications and how international space law could develop to regulate these new scenarios. The analysis of space robotics is divided into two areas of study: (1) space robotics focused on Earth-oriented activities that help to solve problems on Earth and on-orbit and (2) space robotics for space exploration activities. The paper concludes by presenting a proposal for regulating space robotics, emphasizing that international cooperation in space robotics is the key element for a faster, better and cheaper space robotics revolution.

1. ROBOTS, FROM EARTH TO SPACE

For many years humans dreamed to have devices under their control to carry out difficult, hazardous or boring tasks. The proposals to find sources of animation for these devices included electricity and "positronic brains". However, the right solution emerged during the second half of the 20th century: the source of a robot's animation is a computer. The computer has been a crucial element in the continuous revolution of robotics.[1]

Asimov summarized the idea of a robot as a *computerized* machine in the following formula: "robot= machine + computer".[2] Computers enable robots to work under different modes from tele-operation to full autonomy. In addition, another important element in the definition of robots is the fact that robots perform "tasks" and the selection of the tasks determines the design of robots in terms of manipulation and locomotion.

Robots' tasks help industry and scientists in different activities. For example robots perform hazardous tasks on behalf of humans, in the deep sea or radioactive environments related to nuclear research.[3] In this context, hazardous activities also include space activities, and thanks to the development of computers and space radiocommunication robots have been taken from Earth to space with the aim to support and help humans in space activities. Space robots can act and go beyond human limitations.

Primary limitations in the outer space environment are extreme temperatures, radiation, lighting, microgravity, the space vacuum,[4] and remote tele-operation that can cause time delay between the operator and the robot.[5]

Considering the particular features related to robots and the outer space environment previously mentioned, the following definition of space robotics is suggested for this paper: Space robotics is the science of designing, implementing and operating robots that perform tasks in outer space. Robots' tasks in space activities can be divided into two areas of study: (1) space robotics focused on Earth-oriented activities that help to solve problems on Earth and on-orbit; and (2) space robotics for space exploration activities.

1.1 Earth-oriented activities

Space robotic applications for Earth-oriented activities are led by the concept of robot satellites, providing on-orbit servicing (OOS). OOS is done by a robot satellite capable of performing remote manipulation, orbital manoeuvres and monitoring of other satellites on-orbit.

Remote manipulation can provide the necessary maintenance for satellites to extend their lifetime; this comprises tasks such as repairing or changing on-orbit replaceable units (ORUs) and refuelling of satellites with operational payloads. Orbital manoeuvring embraces tasks to de-orbit and re-orbit satellites from the geostationary orbit (GEO) and non-geostationary orbits (non-GEO). Monitoring will allow a remote inspection of satellites when a failure appears.

An accessory application in monitoring tasks is to watch and check space objects on-orbit to confirm information provided by States on functional satellites and frequency assignments.

OOS is part of space robotics for Earth-oriented activities due to the impact of OOS in solving global problems on Earth, such as space debris and the risky access to outer space. OOS could be employed in solving these problems with the implementation of active and passive measures.

An active measure is, for instance, de-orbiting and re-orbiting of non-functional satellites to control and mitigate space debris, and helping to improve the safe access to space. Besides, the maintenance of on-orbit satellites implies an active measure to mitigate and control the growth of space debris, because less new satellites will need to be launched and less non-functional satellites will be on-orbit. Another important consequence of maintenance on-orbit is related to the more efficient use of orbit positions and frequency assignments to guarantee the continuous use of space resources without interruptions from unexpected and expected events, such as a failure in orbital manoeuvring or lack of fuel.

Space agencies and satellite operators can benefit from OOS. Satellite operators that contract OOS will have a back-up opportunity to face troubles on-orbit, because a robot satellite could help to recover and maintain satellites on-orbit. In the case of space insurance companies, OOS can be reflected in a reduction of risk on-orbit.

Feasibility studies for OOS projects have attracted space agencies and space companies for over a decade. Some examples of OOS projects are:

- Geostationary Service Vehicle (GSV), a robotized service vehicle that provides on-orbit inspection, mechanical assistance, end-of-life checks, re-orbiting of uncontrolled satellites into a graveyard orbit and other intervention tasks for GEO satellites.[6]
- Technology Satellite for Demonstration and Verification of Space System (TECSAS), a mission that was planned to demonstrate the availability and advanced maturity of the technologies necessary for inspection if a target satellite, *i.e.* flying around, capturing and manipulating it as well as helping with flight manoeuvres.[7]
- Orbital Life Extension Vehicle (OLEV) for Telecommunication Satellites is a spacecraft that provides OOS. This satellite service includes rendezvous and docking capabilities for GEO satellites equipped with an apogee nozzle. The tasks that OLEV can perform are attitude and orbit control manoeuvres, maintenance and emergency services.[8]
- Orbital Maintenance System (OMS) and the SmartSat-1 project are a satellite-servicing system for telecommunication satellites. OMS tasks include rescue and removal of telecommunication satellites.[9]

1.2 <u>Space exploration activities</u>

Space robotics has two areas in space exploration activities: (1) Intra-Vehicular Robotics (IVR) to help and support astronauts inside research facilities on-orbit and spacecrafts; (2) Extra-Vehicular Robotics (EVR) to help and support astronauts outside research facilities on-orbit and on the surface of celestial bodies.

The plans to return to the Moon and to go to Mars and beyond are strongly supported by robotic missions. Robotic missions collect information and samples of celestial bodies; search for geological and chemical characteristics and natural resources; and identify the best locations for the proposed permanent Moon base. In addition, space robots help to test technologies, materials, interfaces, and protocols. Once robotic missions have paved the way for astronauts to establish the Moon base, the next step is to introduce human-robot missions.

In a human-robot mission, a robotic astronaut's assistant would be able to perform tasks for example in geological exploration, setting up communication networks, inspection and maintenance of surface facilities, or monitoring the astronaut's safety.[10] This last task is probably one of the priority tasks for robots participating in a human-robot mission.

Finally, recalling an idea by Clarke: "there would be no obstacle to patient, immortal machines which could sleep for centuries and then awake to carry out instructions of the long-dead builders".[11] One day robots could be astronauts: "envoys of humankind" in outer space, because robots will be the only ones who can survive over millions of light years of distance carrying in their memory the civilization of humankind. When there are no more humans to tell their own stories, robots will be enable to inform about our civilization on behalf of humankind to other "space-minded beings".

2. LEGAL ASPECTS OF SPACE ROBOTICS

The development of space robotic applications for peaceful purposes entails a positive impact on space activities and the efficient use of space resources. This section aims to identify how this positive impact is reflected in present and future space activities and deals with the legal aspects of space activities assisted by space robotics.

2.1 Towards the implementation of space robotic applications: the case of OOS

OOS is a new space service that requires the review of technical and legal aspects for its implementation and operation.

2.1.1 Satellite design

The satellites subject to OOS need to be designed and constructed to be served. At present, satellites on-orbit face two problems to receive maintenance service or manoeuvring for re-orbiting or de-orbiting: (1) large GEO satellites do not have ORUs; and (2) satellites do not have docking modules. The absence of these elements limits OOS; particularly the capture of a satellite implies high risk for both the OOS satellite and the target satellite.[12]

The implementation of OOS requires that new generations of satellites would include in their design ORUs and docking modules to receive OOS. For this reason, the provider of OOS needs to be involved already during the initial stages of a satellite's design, because the client's satellite has to meet specific technical requirements to receive future OOS. For instance, the maintenance task to re-fuel on orbit the client's satellite requires meeting specifications in the propellant fuel, docking module, and accessibility for manipulation and refuelling of the satellite.[13]

The limited number of OOS providers and ORUs manufacturers will impact industrial policies. This adjustment of rules in industrial policies can be an opportunity to encourage competition, research and development through Public Private Partnerships (PPP) between space agencies and the industry. In this context, the design of satellites to be served on-orbit can be a watershed concerning the promotion of new inventions and patents in space.

2.1.2 Servicing contract

Brisibe defines a servicing contract as a commercial arrangement for regulating the relationship between the satellite operator (customer) in need of servicing and the provider of OOS. In this respect, he suggests that the parties should limit and insure against civil liability in respect of failure and negligence in the service, and also for third-party liability to cover possible damage to other satellites.[14]

An interesting job in the elaboration of OOS will be the identification of mandatory rules to be observed in the international OOS contracts.

In addition, we can consider including a new actor in space law: the "capturing State". Prof. Christol mentions this new term within the discussion of space debris.[15] "Capturing State" could be a useful term in servicing contracts to define a new actor with its related duties and rights, in order to distinguish in international law the capturing State from the launching State.

Nevertheless, as to date the United Nations treaties on outer space support the interpretation that a capturing State is also launching State. Perhaps the practice of OOS will promote the introduction of categories within the term of "launching State" to limit clearly rights and duties at international level concerning specific services on-orbit.

2.1.3 Space insurance

International responsibility and liability to cover the damage occurred by space objects are crucial themes in this section. States are internationally responsible for space activities in accordance with Article VI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.[16] Likewise, Article VI establishes that international liability for damage is allocated in the launching State, but in practice liability can be shared with the private entities that are authorized to carry on space activities. Furthermore Article VII refers to the State of Register, which is one of the launching States or the only launching State. Therefore, when determining international liability for damage caused by space objects, we have to consider these three categories of State actors related to international responsibility, liability and registration.

A complex scenario for insurers is a satellite transfer on-orbit to a foreigner satellite operator, because the launching State status does not change even with the transfer on-orbit. Sometimes launching States are not practically involved with a satellite on-orbit anymore; however, they will always be jointly liable for the launched satellite.

Considering in concrete terms the case of OOS, the insurance policies should include the coverage on-orbit of two particular aspects: (1) the possibility of damage to a defective satellite on-orbit (service interruption, degradation or lack of fuel), necessitating the determination of whether a defective satellite should be considered a partial or total loss and the cover of revenues during the interruption of the service; (2) the liability conditions to protect the owner of the defective satellite and the provider of the OOS against third-party claims on-orbit under the possibility of accident during orbital manoeuvring. In addition, further analysis will be required to determine liability in OOS taking into account direct and indirect damages, and nominal and punitive damages.

A final remark on insurance companies is that they can particularly benefit from the implementation of OOS, because the loss of satellites on-orbit can decrease considerably with rescue and maintenance servicing. Besides, insurance companies can introduce incentives for promoting OOS with cheaper insurance policies than those for satellite operators without OOS.

2.2 Space robotics for solving global problems

Experts have noted the need for active or corrective measures to deal with global problems, such as space debris and maintaining safe access to outer space. However, the technological means to implement them were not clear. Robot satellites are the response to implement these tasks.

2.2.1 The need to improve the efficient use of space resources

Space resources are composed of frequency assignments and orbit positions; both are considered limited natural resources. The international authority in charge of the management of space resources is the International Telecommunication Union (ITU).

According to Article 44 of the ITU Constitution, the use of space frequencies and orbits shall be rational, equitable, efficient and cost-effective.

At present, the access to space resources is complicated for new satellite operators due to congested orbits. In particular, the congestion in GEO draws our attention to the need of improving the efficient use of space resources and the duties of information that Member administrations of the ITU should observe: (1) there are old assignments that have not been suspended and are not in use anymore; and (2) the overfilling, better known as "paper satellites", which are blocking the use of space resources with speculative satellites.

How can space robotics help to improve the efficient use of space resources? For the first problem, OOS enables satellites to maintain in use frequency assignments and orbital positions for longer time. At present, there are frequency assignments and orbital positions recorded in the ITU's Master International Frequency Register (MIFR) that are unused, and the ITU has not received the suspension notice to inform the end of the satellite operation.

The use of robot satellites to provide OOS to GEO satellites will be a measure to prevent the interruption of the service, and an opportunity for new-coming operators to participate in the provision of space services. This opportunity will be reflected in the consolidation of "the second-hand satellite market", when satellite operators transfer on-orbit the property of the satellite. The transaction of second-hand satellites will include the associated frequency assignments and orbit positions. In such a way, the buyers will have access to congested orbits and save the time required to start the procedure with the ITU for frequency assignments and orbital positions.

It is important to mention that there have been already cases of on-orbit transfer ownership of satellites;[17] this practice came from the need to meet the deadline to bring into use the frequency assignments of a satellite network and the orbital positions recorded in the MIFR. This rule on due diligence was introduced by Resolution 49, in order to reduce the problem of "paper satellites" that jeopardize the efficient use of space resources with unused frequency assignments and orbital positions.

In practice the mission design, construction, launch, deployment and initial operation of large GEO satellites take sometimes more than the regulatory time limit of seven years.

Therefore, satellite operators, who are behind their schedule in bringing into use frequency assignments, have the option to buy and transfer a satellite on-orbit from another satellite operator to a new orbit that needs to be brought into use. There are some doubts about the efficient use of space resources with this practice because despite the fact that new frequency assignments and orbital positions are brought into use, it remains unclear what happens with the frequencies and orbit that were in use by the satellite which is transferred to a new location. These space resources left by the transferred satellite would be unused.

OOS is one active measure to improve the efficient use of space resources, but it is also necessary to review the ITU's Radio Regulations. For example, dealing with the problem of mismatch in the MIFR in which "[a] satellite with the associated frequencies has been deployed at this orbital location but has not been there anymore",[18] while the frequency assignments and orbit are still recorded in the MIFR. To solve this problem, Member administrations have been invited to collaborate, informing the ITU on voluntary basis about the real status of their satellite networks and satellites on-orbit. On the other hand, there have been cases in which the ITU has found a mismatch in the MIFR with the collaboration of other Member administrations.

In the regulatory field, the modification of the ITU's Radio Regulations can be proposed during the next Word Radiocommunication Conference 2012 (WRC-12). In order to introduce that Member administrations shall confirm the date of bringing into use of the satellite in addition to the information of due diligence in Resolution 49 and with a clear indication of whether it concerns a new launch or the satellite's being drifted from another orbital location to which it had previously been launched.[19] It is worth mentioning that this last measure coincides with a recommendation of the UN Resolution on the Application of the concept of the "launching State".[20]

2.2.2 Space debris

The Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation guidelines define space debris as "all man made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non functional".[21]

In this field, space robotics with OOS applications can contribute to the control and mitigation of space debris with passive and active measures.

Passive or preventive measures are actions that seek to control and reduce the generation of space debris. Prof. Kopal has mentioned an example of a passive measure, consisting of introducing changes in the design of space objects.[22] In this respect, as we have mentioned before, the next generation of satellites should be designed to be served on-orbit, a requisite to receive future OOS. These changes in the satellite design for maintenance and recovery will enable the life extension of satellites.

Active or corrective measures include the capture of non-functional and abandoned satellites for de-orbiting or re-orbiting. With a new generation of satellites having docking modules, this task will be easier for robot satellites providing OOS. Finally, the main role of the corrective measures will be to clean GEO and non-GEO from non-functional satellites.

2.2.3 Risky access to outer space

The International Academy of Astronautics (IAA) Cosmic Study on Space Traffic Management suggests the following definition of Space Traffic Management (STM): "[a] set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference".[23]

Safe access into outer space is jeopardized by the increased number of space debris and the risk of collision with functional space assets. In this context, OSS can assist with active measures in maintaining the safe access into space, such as tasks of de-orbiting and re-orbiting non-functional satellites that have the docking module. Nevertheless, for current non-functional satellites on-orbit, it is not possible to perform OOS due to the difficulties in approaching and pulling them.

One of the findings in the IAA Cosmic Study on Space Traffic Management mentions the possibility to introduce a certain "internationally recognized descent corridors" dedicated to space traffic.[24] To implement this proposal, in my opinion the first necessary measure should be to avoid locating new satellites on those corridors. A second measure could be to have the OOS satellites near the corridors for moving non-functional satellites.

2.3 Space robotics for space exploration

The legal aspects related to space robotic applications for the different tasks in space exploration are mentioned in this section. In this theme we will see that the development of artificial intelligence in space robots will bring into play more legal concerns with respect to human-robot missions.

2.3.1 Frequency management for space exploration

Future decisions on frequency assignments for space exploration on the Moon or Mars will need to be endorsed by the ITU. Decisions on the management of space resources of other celestial bodies will be made with an eye on avoiding harmful interference of frequencies. This problem can appear when a growing number of robotic missions and satellites will be orbiting the Moon or Mars.

The ITU's Working Group Party 7B on Space Radio Systems has been analysing a document on the definition of frequency bands for human and robotic exploration of the Moon compatible with deep space missions.[25]

Another promising forum to find consensus on this theme is the Space Frequency Coordination Group (SFCG),[26]which has already started a discussion on spectrum coordination and interoperability for planned missions to the Moon and Mars. In this respect, the SFCG adopted Resolution A26-1R1, titled "Lunar and Martian Interoperability and Spectrum Coordination".[27] In this resolution the Annex elaborated by the Lunar/Martian Spectrum Coordination Group determined the terms of reference for future discussions on the theme.

The importance of frequency assignments in space robotics lies in the support of tele-operations, interfaces, and communications in deep space missions. Harmful interference in deep space missions can cause the loss of a robot or a dangerous situation for an astronaut.

Therefore, the coordination of frequencies on the Moon before the establishment of the lunar base should be within the ITU list of pending issues.

2.3.2 Astronauts' safety and space robotics

Legal aspects in space robotic missions include suitable insurance policies for robots, and its software and hardware. Experts have also to observe the robot safety regulations adopted by space agencies at national or regional level.

Another aspect to consider in space robotic missions is the Planetary Protection Policy of the Committee on Space Research (COSPAR).[28] This document establishes the Principles and Guidelines for Human Missions to Mars, which apply equally to missions conducted robotically or with human explorers.

The implementation guidelines for human missions should develop a planetary protection protocol with human and robotic aspects such as subsurface exploration and sample handling. "Neither robotic systems nor human activities should contaminate 'Special Regions' on Mars".[29]

In human-robot missions particular attention is given to the astronauts' safety. To define this concept, we can refer to the International Space University (ISU) Students Report 2008. This report defines crew safety "as the freedom from injury, danger, or loss of an astronaut's health and physical well-being".[30]

The interaction between humans and robots has been discussed under the scope of ethics. Some of the documents adopted by experts on this theme are the following:

- the World Robot Declaration adopted in 2004 in Fukuoka, Japan.[31] Experts call for a next-generation robots that could be partners, coexisting with and assisting human beings physically and psychologically. The peaceful purpose of next-generation robots is emphasized in the sentence: "Next-generation robots will contribute to the realization of a safe and peaceful society";[32]
- the Japanese guidelines. The roboethics[33] approach establishes that robots shall observe measures of safety and this is an ethical concern in the increasing autonomy of robots. In this context, Japan compiled a "set of guidelines to ensure a safe deployment of robots in nonstructured environments". These guidelines include that "all robots would be required to report back to a central

database any and all injuries they cause to the people [...]";[34]

- the Roboethics Roadmap elaborated by the European Robotics Research Network (EURON) in 2006. Section 7.5.4 refers to outdoor robotics in space: space robots in space exploration (deep space vehicles, landing modules, rovers), space stations (autonomous laboratories, control & communication facilities), and remote operation (autonomous or supervised manipulators). The benefit of using robots in space is to expand Earth and space knowledge;[35]
- the Korean Roboethics Charter in 2007 was an initiative by the Republic of Korea.[36] In general terms, the objective of this Charter is to establish ethical guidelines for human interaction with robots without danger. This will be done with the definition of standards for manufacturers and users. Likewise, the Charter stipulates the formulation of ethical standards to be programmed into robots. The legal issues that the Charter reviews are related to the protection of data acquired by robots and establishing identification and traceability means of machines.[37]

Autonomous robots and artificial intelligence will bring into play new elements in the allocation of liability and the limited responsibility of scientists. Otherwise, robo-ethics is a good starting point for a future regulation on space robotics.

Later, it will be necessary to review whether specific rules for space robotics as applied in human-robot missions are needed.

3. Alternatives for the evolution of international space law in the case of space robotics

One of the functions of international space law is to provide legal certainty when new space technology impacts space activities. This section aims to find out an efficient way to deal with space technology advancements and the adaptation of space law to regulate new scenarios, services and actors. In other words, it aims to identify an efficient and practical approach towards the evolution of international space law with the case analysis of space robotics. For this purpose, three alternatives are analysed: 3.1 the need for a new international space treaty; 3.2 the amendment of current UN treaties on outer space; and 3.3 the interpretation of UN space treaties under international law.

3.1 A new international space treaty

The Legal Subcommittee of the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) is in charge of elaborating international treaties on outer space. However, it seems that at present international space law is in a dormant mode because there has not been a new treaty since the 1980s. Over ten years ago Prof. Kopal wrote his diagnosis of the slowdown in the development of international space law:

"[O]ne of the important factors against further development of international space law has been the weakening of the political will on the part of the international community, and of its readiness to be bound by further and more specific obligations. We can even speak about certain fear of law, as if the legal norms should impose only needless burdens without much practical value".[38]

Political will is essential in space law due to the strong relationship between legal and political aspects in this field. In the practice the interplay of States' interests prevail over the legal aspects.[39] Therefore, considering the lack of political will it would be very difficult to reach consensus on a new worthy document. The trade-off in the preceding negotiations is likely to result in a document that all Members accept, but with a general language open to application in any given situation, with limited advantages in practical terms. In addition, a new regulation will probably pass through an "extremely slow decision-making process".[40]

In addition to the lack of political will and a time-consuming procedure to create a new treaty on outer space, we also have to consider the difficult task to negotiate and reach the consensus among the sixty-nine Member States of UNCOPUOS.[41]

However, should the creation of a new treaty be decided it would be recommendable to formulate legal rules of conduct in it for future enforcement, and avoid general statements.[42]

There have been different proposals to elaborate new international instruments. For instance, the IAA Cosmic Study on Space Traffic Management has suggested a new comprehensive regulation of space activities, integrating existing regimes for specific areas. Likewise, in the case of space debris the proposal is that the IADC Space Debris Mitigation guidelines should have the level of international treaty. However, precedent experiences in the promotion of new space treaties where experts have called for treaties on themes such as remote sensing of the Earth and nuclear power sources in outer space, there has not been enough support among the Members of UNCOPUOS.

The rationale to prefer the elaboration of international treaties rather than principles or declarations is due to the role of international treaties as a source of international law in accordance with Article 38 (1) of the Statute of the International Court of Justice. There is no doubt about the legal weight of a treaty, thus it is the ideal scenario to establish international commitments. However, the lack of political will and the fear of legal commitments diminish the potential of this alternative.

Although an ideal scenario in space robotics would be to adopt a treaty for international cooperation in space robotics, the adoption of a new international treaty could be not the right strategy for developing international space law within the current conditions.

3.2 Amendment of current UN treaties on outer space

The five UN treaties on outer space include an article, which enables State Parties to consider the introduction of amendments, provided they are accepted by a majority of States. In particular, the Convention on Registration of Objects Launched into Outer Space[43] stipulates in article X that ten years after entry into force, the review of the Registration Convention shall be included in the provisional agenda of the UN General Assembly (UNGA). However, when one third of the States Parties require a review of this convention a conference shall be convened. The Registration Convention is one of the UN treaties that need to be updated, in order that the State Members submit information about manoeuvres and orbital changes, two of the tasks that OOS will be providing.

This international instrument should update the information parameters concerning the registration of space objects, and also needs to include clearly the obligation of States to update the information at any time a change occurs. Furthermore, the UN Office for Outer Space Affairs (UNOOSA) and ITU should find the ways of coordination and collaboration for monitoring the information within their registers. The information that should be required in the UNOOSA register concerns: pre-launch, launch, operation, interruption or end-of-life, transfer on-orbit, change of property of satellites on-orbit, and orbit position in GEO.

An amendment in the Registration Convention to update the information parameters will provide space agencies and satellite operators with more reliable information to plan their activities. In addition, it will help to improve the efficient use of space resources, as well as knowledge about non-functional satellites on-orbit.

ITU also needs to update the information parameters in the MIFR, to require the Member administrations to provide confirmation of the launch, the commercial name of the satellite networks, service interruption, end-of-life, and the detailed information regarding transfer-on orbit, and purchase of second-hand satellites on-orbit.

Furthermore, ITU experts should review the possibility for OOS of a new classification within the radiocommunication services and if the OOS needs particular frequency assignments for its operation.

The modifications in the ITU's Radio Regulations could be introduced during the next WRC-12 if the necessary support among the Member administrations is reached.

3.3 Interpretation of space law under international law

The need for adapting UN treaties on outer space to the changes in space activities can be done through an "evolutionary dynamic interpretation".[44] An example of this is the interpretation of UN treaties by UNGA Resolutions. However, we must remember that UNGA resolutions have a limited impact due to the diplomatic nature of these documents and the fact that UNGA does not have legislative attributions.

Besides UNGA resolutions, experts have the option of using international law for the interpretation of space law. In this context, it seems that the general formulation of the UN treaties on space law was a manner to introduce flexibility in the space regulations. Flexibility makes it easier to adapt space regulations to new developments in space technology. Thus, flexibility could be an advantage rather than a weakness to face the fast evolution of space technology.

Space law was not mean to be a complete set of detailed rules but the general framework with principles that are necessary for certainty and development of international cooperation in space activities. And when new scenarios can not find the needed answers in space law it is time to return to expert interpretation of international law to solve case by case the new developments of space activities related to space robotic applications.

4. Proposal

In December 2008, the Council of the European Union (EU) approved the conclusions concerning the draft Code of Conduct for outer space activities (EU Code of Conduct). This document includes themes related to the implementation of OOS, for instance on-orbit manoeuvres to repair space objects, mitigate space debris and reposition of space objects.[45] In addition, there is one section about notification of outer space activities. Regarding notification, the information that subscribing countries commit to notify include scheduled manoeuvres, orbital changes and re-entries, collision or accidents which have taken place, and malfunction of orbiting space objects.[46] Regarding satellite information, it is important to mention also that the establishment of an Outer Space Activities Database is suggested.

The EU Code of Conduct is a comprehensive document with conduct guidelines to perform different and some new space activities, considering scientific and technological development. This approach for improving the use of outer space resources is in my opinion a good starting point towards future legal obligations under an international treaty. It follows a historical practice, in which recognized values of the society that have been in practice develop over time into custom that could incorporate these values in a legal system.

Considering the EU Code of Conduct, my proposal is in a similar sense. Space robotics can be implemented in a Code of Conduct to start creating awareness on the need to reconfigure the commitment to the sustainability of space activities. Nevertheless, although the EU Code of Conduct includes most of the new developments in space activities, I would include two more aspects in the draft of the EU Code of Conduct: (1) the establishment of the principles of space activities in a hierarchical order; and (2) the elaboration of a section on space robotics for space exploration and Earth-oriented activities and a list with conduct guidelines to enhance cooperation in space robotics among the international community.

The approval of various countries of the Code of Conduct on space activities could be the way to seek for a new treaty on outer space in the near future, if the subscribing countries agree to support the creation of a new treaty based on this Code of Conduct.

I consider that the field of international cooperation in space robotics is an area that needs to be promoted more among space agencies because it is a key element for a faster, better and cheaper space robotics revolution.

CONCLUSIONS

Space robotic applications for Earth-oriented activities are led by the concept of robot satellites, providing on-orbit servicing (OOS). OOS can help to solve problems on Earth, such as space debris, risky access to space and the need to improve the efficient use of space resources. For instance, second-hand satellite market could be a measure to give access to new operators to the congested GEO orbit.

ITU (MIFR) and UNOOSA registers are crucial tools towards the efficient use of space resources. UNOOSA and ITU can enhance coordination and collaboration in the field of information on outer space activities. UNOOSA and ITU registers can both share information to solve cases of unclear information. However, the merge of both registers is not recommended due to their different nature and objectives.

Furthermore, in order to improve the reliability of ITU and UNOOSA registers and avoid satellite information mismatch between the information in the registers and the real status on-orbit. The ITU and UNOOSA should update the list of information that is required for the registration of satellite networks and the launching and operation of space objects.

In this context, ITU should also review the possibility to include the OOS in the ITU Radio Regulations as a new radiocommunication service, and the question of how to deal with the special characteristics of OOS for frequency assignment and orbital positions.

In the field of robotics for space exploration, robo-ethics is a good starting point for a future regulation on space robotics for human-robot missions. Besides, frequency coordination for human and robotic exploration of the Moon and Mars is an important issue to be decided.

Concerning regulation of space activities involving space robotics, the best manner to include legal aspects of space robotics is a two-phase plan: (1) to elaborate a comprehensive Code of Conduct for outer space activities that includes new space activities such as OOS and international cooperation in space robotics; and promote the acceptance of this Code by the greatest number of countries; and (2) seek for agreement to adopt an international binding document.

Finally, it is important to mention that international cooperation in space robotics is a key element for a faster, better and cheaper space robotics revolution.

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[2] *Id,* at 162.

[3] *See generally*, P. E. Mort &A. W. Webster, *Robotics in the Nuclear Industry*, in J. Gray &D. Caldwell (Eds.), Advanced Robotics & Intelligent Machines 133 (1996).

[4] N. Tolyarenko, *Introduction to Space Robotics*, lecture at the MSS/MSM Academic Year 2005/2006, International Space University, Strasbourg, October 2005.

[5] *See generally*, A. Allery, An Introduction to Space Robotics 22 (2000).

[6] G. Visentin & D. L. Brown, *Robotics for Geostationary Satellite Servicing*, 23 Robotics and Autonomous Systems 45 (1998).

[7] B. Summer, *Unmanned On-orbit Servicing (OSS), ROKVISS and the TECSAS Mission*, Advanced Space Technologies for Robotics and Automation (ASTRA), Noordwijk (2004).

[8] C. Kaiser, *et. al*, *OLEV- An On-orbit Servicing Program for Commercial Spacecrafts in GEO*, 10th European Space Agency (ESA) Workshop on ASTRA, Noordwijk (2008).

[9] S. Kimura, *et. al.*, *Rendezvous Experiments on SmartSat-1*, 2nd IEEE International Conference on Space Mission Challenges for Information Technology (SMC-IT'06), 374 (2006). Available at: smc-it.jpl.nasa.gov/docs/Abstracts/M58.pdf (last visited 15 August 2009).

[10] S. Heikkilä, *et. al.*, *Centaur-type Service Robot Technology Assessment for Astronaut Assistant Development*, 10th ESA Workshop on ASTRA, Noordwijk (2008).

[11] A. C. Clarke, Voices from the Sky: Previews of the Coming Space Age 75 (1966).

[12] Nevertheless, a future development seems feasible in the method to capture non-functional satellites or space objects with the use of tether satellites.

[13] *See generally* C. Heemskerk, *et.al.*, *Ground Test For On-Orbit Servicing of a GEO Satellite Fleet*, 10th ESA Workshop on ASTRA, Noordwijk (2008).

[14] T. C. Brisibe, *Satellite Servicing On Orbit by Automation Robotics: Legal and Regulatory Considerations*, 29 Journal of Space Law 25 (2003).

[15] *See* C. Q. Christol, *Scientific and Legal Aspects of Space Debris*, 34 Acta Astronautica 372 (1994). When Christol refers to the need to clarify the roles of capturing State and a capturing international intergovernmental organization, he refers to the capture of non-functional space objects. However, in OOS the capture of functional satellites for maintenance and refuel is also included.

[16] UN Doc. GA/RES/2222(XXI). *See also* the Convention on International Liability for Damage Caused by Space Objects UN. Doc. GA/RES/2777 (XXVI).

[17] *See* A/RES/59/115 (2005). The Resolution on the application of the concept of the "launching State" recognizes this practice in paragraph 3, and recommends that the States should share this information on voluntary basis.

[18] J. Albuquerque, *Efficient Use of Orbit Spectrum Resources: Possible Action Within and Outside the ITU Radio Regulations*, Radiocommunication Bureau (BR) Workshop on the efficient use of the spectrum/orbit resource, Geneva (2009).

[19] *Id.*

[20] A/RES/59/115, *see supra* note 17.

[21] IADC Space Debris Mitigation Guidelines, Doc.IADC-02-01, para. 3.1 (2007). *See also* Committee on the Peaceful Uses of Outer Space, Report of the Scientific and Technical

Subcommittee on its forty-fourth session, UN Doc. A/AC.105/890, Annex IV (2007).
[22] *See supra* note 15 at 371.
[23] IAA, Cosmic Study on Space Traffic Management 10 (2006).
[24] C. Contant-Jogenson, *et.al.*, *Report the IAA Cosmic Study on Space Traffic Management*, 22 Space Policy 286 (2006). *See also, supra* note 23 at 89.
[25] ITU, Study Group Working Document 222/7 (2005). This working document is confidential for a period of 30 years, limiting its availability only to the members of the study group.
[26] SFCG is a group of space agencies and related national and international organizations, providing a flexible environment for the solution of frequency management problems.
[27] SFCG, Handbook of the Space Frequency Coordination Group (2009).
[28] COSPAR, Planetary Protection Policy (2002).
[29] *Id.* at A-4.
[30] International Space University: Masters Program 2008, *ALERTS: Analysis of Lunar Exploratory Robotic Tasks for Safety* 7 (2008).
[31] World Robot Declaration, Japan (2004).
[32] *Id.* at I(3).
[33] Roboethics is the human ethics of robots' designers, manufacturers, and users. G. Veruggio, *Roboethics: Social and Ethical Implications of robotics*, *in* B. Siciliano & O. Khatib (Eds.), Springer Handbook of Robotics 1504 (2008).
[34] *Id.* at 1506.
[35] EURON Roboethics Atelier Genoa, EURON Roboethics Roadmap 33 (2006).
[36] Veruggio, *supra* note 33 at 1507.
[37] S. Lovgren, *Robot Code of Ethics to Prevent Android Abuse: Protect Humans*, in National Geographic News, 16 March 2007 (last visited 10 September 2009) http://news.nationalgeographic.com/news/2007/03/070316-robot-ethics.html
[38] V. Kopal, *International Law in Outer Space: A Useful Tool of International Cooperation in Space Activities*, in N. Jasentuliyana & K. Karnik (Eds.), Space Futures and Human Security 215 (1997).
[39] *See* K. Zemanek, *The Basic Principle of UN Charter Law*, in R. St. J. Macdonald & D.M. Johnston (Eds), Towards World Constitutionalism 405(2005). Zemanek's explanation on the relationship between politics and law regarding the UN Principles established in the UN Charter, and in my opinion this same applies to space law.
[40] K-U Schrogl, *Space Traffic Management: The new comprehensive approach for regulating the use of outer space- Results for the 2006 IAA Cosmic Study*, 62 Acta Astronautica 273 (2008).
[41] At present, there are 69 Member States. UN Doc. GA/RES/62/217.
[42] Kopal, *supra* note 38 at 217. Coinciding with this last point, Prof. Kopal has expressed that the UN space treaties and principles need to be elaborated as rules of conduct, and he identifies two main areas to work on: international cooperation in space, and the protection of the space environment.
[43] UN Doc. GA/RES/3235 (XXIX).
[44] *See* The Charter of the United Nations a Commentary 16, 2nd ed. (2002). The concept of "evolutionary dynamic interpretation" was introduced for interpreting the UN Charter.
[45] Council of the European Union, Doc No. 16560/08, para. 4.3 (2008).
[46] *Id.* para. 6.1.