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BASIC PROBLEMS IN SPACE TRAFFIC

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ABSTRACT

Some of the tasks of the Management of Space Traffic can be addressed at present. When successfully accomplished, a necessary foundation for further discussions will be formed.

In the first place, the **meaning of technical terms** may depend on the context and on the field under consideration. Since Space Traffic covers many fields, a general understanding of technical terms has to be established in order to avoid confusion. Explanations, presented in the paper, could remove some of the frequent misunderstandings.

In the second place, the **existence of all classes of orbiting objects** has to be recognized by legal instruments because each class of objects participates in Space Traffic in its own way. The present situation, when the term *space debris* does not appear in instruments of space law, can hardly be defended. There is a basic difference, not recognized by space law, between valuable active spacecraft and valueless space debris. The fact is that over 90% of all trackable objects in space belong to the class of space debris and that fact cannot be ignored. The adoption of a legal definition of space debris would contribute to a good management of space traffic.

In the third place, an official up-to-date and complete **knowledge of the functional status** of spacecraft is essential for dealing with Space Traffic. At present, there may be doubts whether a particular spacecraft is active or not, or whether it is a valuable asset or a burdensome junk. The governmental announcements of objects launched into outer space made in compliance with the Registration Convention are incomplete, use different formats, are mostly published months or years after launch, and do not establish a link with ITU assignments of radio frequencies for telecommunications. An international agreement on completeness and a on a detailed content and format of the registration announcements of launchings would serve the purpose. In principle, the agreement could be voluntary but an obligatory arrangement would be more reliable and more durable when the number of launching entities increases in the future.

INTRODUCTION

Good management of Space Traffic is everything that improves safety, efficiency and economy of space activities for our own and future generations. It consists of several tasks or problems which have to be solved one after the other, starting with basic problems, laying thus the foundation for advancing to more complicated questions[1]. Among the basic stepping stones are:

- **the common understanding of important technical terms**
- **the legal recognition of the difference between active spacecraft and space debris,** and
- **a complete, timely and updated registration of the largest objects participating in space traffic.**

THE FIRST PROBLEM: TERMINOLOGY

Space Traffic requires a richer dictionary than we find in the instruments of space law. Existing space treaties do not contain terms, such as space debris, avoidance maneuvers, space station and many others. The geostationary orbit appears only in documents of the International Telecommunication Union, ITU, not in space treaties.

Technical terms are as a rule taken over from scientific and technical publications coming from numerous and different sources. The problem is that various sources use different terms for the same object, or the same term for different objects. An example of the first group is the *geostationary-satellite orbit*, used by the ITU, the *geostationary Earth orbit*, used by the Inter Agency Space Debris Coordinating Committee, IADC, and the simple term, *geostationary orbit,* used in the UN General Assembly Resolutions. An example of the second group is *space station*, used by the ITU for a radio receiver or transmitter carried on a satellite while for anybody else it is the biggest artificial object in the sky.

Most of the terms have been in use for a long time and a large number of authors and readers have become accustomed to them. To change the usage into a standard and logical terminology is a task for the future. At present we shall have to live with the prevailing multitude of terms. **The important thing is to understand which important concepts are meant by what terms in what context.**

Space objects

Space object is a term used in the treaties on space law. Consequently, it carries a connotation of a legal term. In case such a connotation is undesirable, the term "**object in space**" can be used.

Space system has been defined by the ITU (ITU Radio Regulations, term S1.110) as *any group of cooperating earth radio stations and/or space radio stations employing space radio communication for specific purposes*. The same term has been defined in the IADC Debris Mitigation Guidelines[2] as *spacecraft and orbital stages*.

Without any color is the term **spacecraft**, an analogy to aircraft. It has been defined by the ITU (term S1.178) as a *man-made vehicle that is intended to go beyond the major portion of the Earth's atmosphere*. The IADC guidelines define it in different wording, but in the same sense, as an *orbiting object designed to perform a specific function or mission.*

Active spacecraft and spacecraft in reserve or standby mode are considered **functional**, while spacecraft that can no longer fulfill their intended missions are considered **non-functional**. Possibly the concept of an **active** or **functional** object should be understood in a wide sense. Some spacecraft are valuable assets to their owners for other reasons than just activity.

A spacecraft may contain technical innovations which have to be protected, or it may carry classified information. In both cases the spacecraft are of value to their owners. Keeping information from undesired publication is a **function** of its kind.

Space debris.

According to the IAA Orbital Debris Position Paper[3] and the UN Technical Report on Space Debris (Rex Report)[4], **space debris** are *all man-made objects, including their fragments and parts, whether their owners can be identified or not, in Earth orbit or re-entering the dense layers of the atmosphere that are non-functional with no reasonable expectation of their being able to assume or resume their intended functions or any other functions for which they are or can be authorized.* Space debris may escape orbit around the Earth, reenter Earth's atmosphere or remain in Earth orbit. In the last case it is called also **orbital debris**.

Satellite Orbits

Sun Synchronous Orbits are synchronized with the Sun in such a way that they pass over the equator the same time each day. They are used for remote sensing because the ground is viewed under the same illumination in subsequent passes.

Widely used[5] are terms **Low Earth Orbit** (LEO) for orbits below about 2000 km above Earth's surface, with a period of 127 minutes or less, **Medium Earth Orbit** (MEO) for orbits between LEO and GSO, **Geosynchronous Orbit** (GSO) for orbits of a period equal to the period of rotation of the Earth (23h 56m 04s) about its axis. Geostationary Orbit (GEO), a special case of the GSO, is discussed in the following section.

According to usual practice and some encyclopedias[6], the simple **Earth orbit** refers to the orbit of the Earth around the Sun.

Geostationary orbit.

According to the IADC Debris Mitigation Guidelines **Geostationary Earth Orbit** (GEO) is an *Earth orbit having zero inclination and zero eccentricity, whose orbital period is equal to the Earth's sidereal period.* The altitude of this unique orbit is close to 35,786 km. According to the ITU Radio Regulations[7], the same concept is called the **geostationary-satellite orbit**. It is the *orbit of a geosynchronous satellite whose circular and* ***direct*** *orbit lies in the plane of the Earth's equator.* **Direct** means that the sense of orbiting is the same as the sense of rotation of the Earth, that is anticlockwise if viewed from the North.

The UN General Assembly resolutions and other documents[8] call the same orbit simply the **geostationary orbit.**

Orbital position.

A perfect geostationary orbit is a mathematical abstraction valid only for a spherically symmetrical Earth and in the presence of the gravitational attraction of the Earth only. In reality, the Earth deviates from a sphere. Moreover, spacecraft are also under the gravitational attraction of the Sun and of the Moon. These additional facts generate small forces called **perturbations.** These perturbations change the originally circular orbit into a slightly elliptical one. They also push the orbital plane out of the plane of the equator. Even a small eccentricity will cause an oscillation of the satellite around its nominal orbital position as seen from the rotating Earth.

The orbital position has to be maintained within a certain tolerance, as a rule 0.1° to the East or West and the same amount to the North or South. One tenth of a degree is, at the geostationary distance, equal to 74 km. Thus a spacecraft has to be kept within a square on the sky of 148x148 km extent. When the perturbations push the spacecraft close to the border of the ideal "parking box", an orbit maneuver has to be performed by activating thrusters on board the spacecraft. The process is called **station keeping**.

Orbital positions and radio communication frequencies are listed by the ITU in its Master International Frequency Register. An entry in the Register constitutes a statement that a radio station operated at the assigned location within the permitted tolerance and complying with other stated parameters, will neither generate, nor suffer from, harmful interference with other systems. The location of a radio station on a geostationary satellite is specified by projecting it from the geostationary orbit to the sub-satellite point on the equator of the Earth. The geographical longitude of the sub-satellite point determines the location unequivocally.

It has to be stressed that **the ITU registers space radio stations, not satellites.** One satellite may operate one or more space radio stations. Vice versa, one space radio station may be operated by radio transmitters on one or more satellite.

For obvious reasons, orbital positions in the above sense do not find application outside the geostationary orbit.

Phases of the lifetime of a spacecraft

The IADC Debris Mitigation Guidelines (see Note 2) introduced a very useful concept of operational phases of a spacecraft:

Launch phase*. the launch phase begins when the launch vehicle is no longer in physical contact with equipment and ground installations that made its preparation and ignition possible (or when the launch vehicle is dropped from the carrier aircraft, if any) and continues up to the end of the mission assigned to the launch vehicle.*

Mission phase*. The mission phase is the phase when the spacecraft fulfils its mission. It begins at the end of the launch phase and ends at the beginning of the disposal phase.*

Disposal phase*. The disposal phase begins at the end of the mission and ends when the spacecraft has performed actions to reduce the hazards it poses to other spacecraft or systems.*

It has to be noted that a spacecraft enters the disposal phase only if is capable to perform actions to reduce the hazards. In any case, after the operational phases have been terminated, the spacecraft, or its parts and fragments, continue orbiting and participating in space traffic as non-functional objects, i.e. space debris. Many space debris stay in orbit for a considerable time, from a few days at about 200 km altitude to millions of years at the GEO. From the point of view of space traffic, a post-operational phase should be added:

Space debris phase. The space debris phase begins when the spacecraft becomes non-functional and its operator lost any possibility to control it. That may happen at the end of either the mission phase or at the end of the disposal phase. The object may break up into smaller pieces, eventually decaying by evaporating in the atmosphere or impacting on the surface of the Earth

THE SECOND PROBLEM: SPACE DEBRIS

Each class of orbiting objects participates in Space Traffic in its own way. Active spacecraft is subject to other constraints than space debris. Consequently, all classes of objects have to be recognized in instruments regulating space traffic. Even natural objects, meteoroids, will have to find their place in space traffic regulation, possibly in automated warning practices of close encounters. Here we are concerned with artificial objects, i.e. with **space debris**. This term does not appear in any of treaties or agreements dealing with space law.

Definition

Over 90% of all trackable objects in space, and almost 100% of objects that are too small to be tracked, are space debris. This fact will have to be recognized by any future legal instrument dealing with space traffic.

Thanks to the IAA Position Paper (see Note 3), space debris is understood to mean all artificial objects in space that are non-functional, from burnt up rockets and stages, to satellites which have permanently terminated their activities, and down to fragments of various sizes and to flakes of paint. The lower limit of size of space debris has not been fixed. Dust particles or molecules of gases seem to be too small to be called space debris.

The question is when and by whom an object can be designated as space debris.

The Outer Space Treaty, in its Article VIII stated that *"A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object. Ownership of objects launched into outer space ... is not affected by their presence in outer space or on a celestial body or by their return to the Earth"*. Consequently, **only the launching state or a possible new owner can make a statement as to the functional status of its object with any authority**. This principle will most probably be preserved in the future at least for active satellites.

Participants in space traffic have to know the functional status of an object in particular in case of a close encounter. If they are likely to encounter an active object, communication with its owner may be of importance to decide which of the two objects can or should initiate an avoidance maneuver. In an encounter with a piece of space debris, the burden of an avoidance maneuver lies with the owner of the active satellite.

The necessity of providing information about a change of functional status from an active spacecraft to non-functional space debris has been felt by some owners of spacecraft. Indeed, some launching states or agencies provide information on the functional status of their objects but the practice is not uniform. Well known is the phrase *"Spent boosters, spent menoeuvring stages, shrouds and other non-functional objects"* used in the USA governmental announcements made in compliance with the Registration Convention[9]. That phrase is used when the object is non-functional at the time of detection or registration. When an object terminates its functions at a later time, no change of its functional status is, as a rule, announced. The decay of an object is announced as *no longer in orbit.* Contrary to the present practice of the USA, some states do not announce their non-functional objects at all.

As regards the termination of activities, we found announcements by Sweden concerning satellites Freja, Tele-X, and Astrid 2[10], and announcements by Italy concerning satellite BeppoSAX[11]. The Italian Space Agency announced in the UN document as well as in a diplomatic note verbale that "*the satellite is now space debris without attitude control and is only subject to the law of orbital* decay".

These examples show that a possibility of announcing changes of active objects into space debris exists but that it is used in some cases and not used in others. Space traffic law will have to make it an obligation to announce such changes in the interest of traffic safety.

Conclusion: space debris should be defined as permanently non-functional objects in space. The definition should call for announcements of changes of the functional status of spacecraft into space debris. The announcements should be obligatory for launching states or for those who became subsequently owners of the spacecraft.

The legal definition will have to be the result of an international agreement. Therefore we refrain from proposing a specific wording of the definition.

Regulation

Restricting the generation of new debris. The IADC Guidelines (see Note 2) should be adopted in their entirety.

The present wording of the recommendation determines only a wide interval of values of the solar radiation pressure coefficient, namely between 1 and 2, possibly leading to insufficient perigee distances of disposal orbits. Therefore, a specific recommended value of the solar radiation pressure coefficient should be stated in section 5.3.1 of the guidelines, in order to make the determination of the minimum perigee distance of the disposal orbit beyond the geostationary orbit unequivocal.

Small space debris. Shielding is a sufficient protection against impacts of debris up to about 1 cm. Such objects are as a rule fragments not requiring individual listing or tracking. They should neither be under the protection of the existing space treaties, nor carry the obligation of return to owner if found.

Larger debris requiring protection by evasive maneuvers of active spacecraft. If possible, these objects should be tracked, and warnings of close encounters with manned spacecraft should be issued. For this reason existing **space agencies should widely cooperate or agree on establishing a special international agency, as recommended by the AIAA Workshop in 1999**[12].

The obligation of return to owner if found should be limited to cases when the return is requested by the owner. The reason is that objects found have rarely any value at all.

Very large space debris. There are hundreds of space debris of one ton or more posing lethal danger to manned spacecraft in case of collision or close encounter. **International support should be given to scientific and technical efforts to devise methods for their de-orbiting before collisional breakups produce very large numbers of space debris**. These objects deserve individual tracking, listing and warning mechanisms.

Space Debris in the United Nations

A proposal of a Work Plan on Space Debris was put forward by France, supported by member and cooperating States of the ESA, at the 2003 session of the Legal Subcommittee[13]. The proposal, planned for the years 2005 – 2008, called for technical briefing on space debris and review of the existing legal regime applicable to space debris, for a review of the IADC mitigation guidelines and legal matters arising therefrom, and for the identification of the most appropriate legal instrument. No consensus, however, has been reached. Consequently, discussions on legal aspects of space debris, including its legal definition, will remain – for the time being – in the academic community.

THE THIRD PROBLEM: REGISTRATION OF SPACE OBJECTS

The Registration Convention is a legal instrument with a great potential. It could play an important role in the era of space traffic regulation. Unfortunately the launching registrations made in compliance with the Registration Convention are incomplete, there is no fixed deadline for submission of announcements, and the UN Register is an impenetrable jungle of hundreds of announcements, with widely differing formats and notations. Following a discussion in the UN Scientific and Technical Subcommittee, the UN Office of Outer Space Affairs prepared an Online Index of space objects listed in the governmental announcements. The index lists objects in the time sequence of launchings. It is frequently updated and supplemented by published data from other sources. It is accessible on the Internet[14]. It provides an easy access to all information contained in the UN Register.

Quite recently, the Legal Subcommittee of COPUOS recognized that the practice of States and international organizations in registering space objects on the register is widely divergent[15]. It reached consensus on adopting a four-year working plan (2004-2007) to examine the practice of registering with a view to identifying common elements[16].

In our opinion, the practice of registering space objects should go beyond identification of common elements. It should provide a compilation of authoritative information on space objects and establish links between

- **the registration of space objects in compliance with the Registration Convention,**
- **the ITU registration of space radio stations, and**
- **National Registers of space objects.**

To attain that aim, the registration should be guided by the following principles:

Completeness of registrations

The present UN Register, i.e. the set of governmental launching announcements, is rather incomplete[17]. There are many omissions to register by several launching entities. The problem could be removed by making the registration obligatory for all launching entities. Moreover, the **OOSA should be put in charge of following the completeness of registrations,** as part of their work on keeping the UN Register and on updating the Online Index. In case of a possible omission, the OOSA should be obliged to draw the attention of the respective launching entity to the obligation of registering.

Another problem is in the small number of States being parties to the Registration Convention. The yearly exhortation by the General Assembly to accede to the Registration Convention have not yet produced a massive response.

Some international organizations, such as Intelsat, do not register **by intention**. The reasons why prestigious organizations avoid registering their spacecraft should be examined and possible obstacles removed.

Any legal instrument dealing with the Management of Space Traffic would make sense only if all, or at least an overwhelming majority, of space users participated.

Fixed deadline for submitting registrations

Registrations have to be effected at a **fixed time** related to launch. The present wording in the Registration Convention, namely *registering as soon as practicable*, means that no deadline for registration has been set. Indeed, States have the information on a successful launch within hours, yet they submit their announcements within weeks, months or years after launch, as the case may be.

The preferable solution would be to submit announcements at a fixed time **before launch**. Launching into space has become a routine activity, in spite of highly complex technology. It should be known what is in space and what will go into space in the near future, whether from the ground, or from the middle of the ocean, or from an aircraft. The information is of particular importance to all operators of spacecraft.

Launching announcements are submitted in accordance with diplomatic protocol, of necessity requiring some delays. The possibility should be considered to make use of electronic submission of the basic information for insertion into the UN/OOSA Online Index, preceding the diplomatic note.

Obligatory content of announcements of registrations.

The following data and information should be obligatory:

International system of designations. Spacecraft can best be identified by the International System of Designations introduced by COSPAR in 1958. It is being systematically used by the scientific community and by some states in the launching announcements. It assigns a unique symbol to each man-made object in space. Its value would be increased if used by all launching entities.

National name or designation of spacecraft corresponding to the entries in National Registers.

Date and location of launch, as already required by the Registration Convention.

Shape, size and mass are not obligatory under the Registration Convention but should be included because they provide useful information on spacecraft, in particular for computation of lifetime.

Specific function. The "general function" required by the Registration Convention is sometimes given in very general terms, not providing any idea of the function of the spacecraft. The information should be at least as specific as it appears in the Aeronautics and Space Report of the President[18], e.g., GPS satellite, military satellite, solar science satellite, etc.

Approximate operational orbital data. Approximate **operational** altitudes of perigee and apogee, period and inclination, and nominal orbital position in case of geostationary satellites, would be more informative than the present practice of announcing initial orbital elements which are obsolete at the time of publication.

ITU names of space radio stations on board of the spacecraft and used frequency bands should appear in the announcements in order to provide a link between the ITU Master International Frequency Register and the UN Register or the OOSA Online Index. It would also provide information on active entries in the ITU Space Network List, thus partly alleviating the problem of the so called "paper satellites".

Manned spacecraft. Information should be provided on the crew, their functions, envisaged length of the mission and other relevant data.

Updating of information

All data should be **updated** after important changes, such as a change of function, a change of orbital position if the object is in the GEO, a change from an active satellite to space debris, and finally the decay.

National Registers

The Registration Convention requires in its Article II the establishment of **National Registers**. It would be helpful if National Registers were accessible on the Internet to provide an independent confirmation of data published in the UN Register and in the UN/OOSA Online Index.

The above steps would contribute to an orderly conduct of launchings and what is quite important, would make the governmental announcements of objects launched into outer space the most **authoritative** and **reliable** sources of information, as they deserve to be.

CONCLUSION

Traffic is regulated in detail on the road, on the sea, and in the air for obvious reasons of safety and efficiency. Outer space is an exception because of its wide expansion and a relatively small number of orbiting spacecraft. Things have changed with time, but regulation of traffic has not. It is still at the level of the 1960's. The only attempt at regulation was adopted in the GEO, not because of density of traffic but in order to avoid harmful interference of radio communications.

Time has come, however, to protect the valuable assets of some 500 to 600 active satellites from thousands of fast moving large debris and uncounted numbers of small but still dangerous fragments.

The task is enormous. Any meaningful regulation will require the use of extensive observations, and of instantaneous communications and computations.

Space debris should be legally defined as permanently non-functional objects in space and the role of owners to announce changes in functional status should be spelled out.

Registration of space objects should be complete and should be published at a fixed time. It should contain international designation, shape, size and mass of the object, specific function, approximate operational orbital data, ITU names and designations of space radio stations on board, and relevant data from National Registers.

Selected information has to be disseminated without delay to operators of spacecraft and to a certain degree to users of space applications.

Spacecraft will have to be designed with proper arrangements for disposal after termination of services.

A very difficult problem is posed by very large space debris already in orbit with no provision to shorten their lifetimes. Hopefully, methods for their removal will be found in the future. At present, **no legal barriers to the removal of unwanted objects should be created and those existing should be removed. Scientific studies of removal should be supported.**

The present paper has a modest aim to show that some traffic problems can be approached already now and that their solution will facilitate the systematic application of the principle of separation of traffic, of timely warning of close encounters and, in general, in keeping space fit for future uses.

NOTES

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