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FIRST DRAFT OF THE IAA STUDY ON SPACE TRAFFIC MANAGEMENT

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ABSTRACT

The investigation of space traffic and its management has only recently become a point of wider discussion. In particular the series of workshops organized by the American Institute of Aeronautics and Astronautics (AIAA) and other international organizations on international cooperation highlighted the issue. It was discussed thoroughly at the workshops, which took place in 1999 and 2001 respectively. It was at the 2001 workshop, when the suggestion was made that an International Academy of Astronautics (IAA) Study on the subject of space traffic management should be prepared. This suggestion was taken up and a proposal was presented to the Board of Trustees of IAA, which, in late 2001, accepted this proposal.

This paper presents the status of work of the study group, in particular the approach and the scope of the study as well as its preliminary findings. The study group intends to finalize its work in late 2004, in order to be able to put the study before IAA and launch its review process after the 2004 International Astronautical Congress. Following this review, the study will be published and may be expected to make an impact in fora like the UNCOPUOS.

The authors of this paper act as the coordinators/the rapporteur to this study. The paper will be presented in the IAA- and has also been presented at the IISL-session dealing with space traffic, by that bridging the two areas and seeking input from various sources.

I. SCOPE OF THE STUDY

Space traffic already takes place. It seems, however, minuscule with regard to the dimension of near-Earth outer space. Around 10.000 man-made objects larger than about 10 cm are currently tracked out of which only 650 are operational spacecraft. On the surface, the management of space traffic does not appear to be a pressing problem. Investigated further, this judgement has to be challenged. A high level or even growing number of launches from more and more launch sites and space ports, the entering of non-governmental entities, the positioning of satellite constellations, an increase in space debris and the advent of reusable launch vehicles supports this judgement. Considering this scenario, conceptualizing space traffic management will turn out to become a relevant task during the next two decades. Space traffic management will, however, limit the freedom of use of outer space. Therefore an international consensus on internationally binding regulations will only be achieved, if States identify a certain urgency and expect a specific as well as collective benefit from this.

The dimension of this task can be assessed, when the following definition of space traffic management is taken as a starting point:

> Space traffic management comprises 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.

Since an authoritative definition of space traffic management does not yet exist, this definition has been set up for the purpose of this study. Through this definition, the purpose of space traffic management becomes clear: it is to provide appropriate means so that space activities can be conducted without harmful interference. By that it supports the universal freedom to use outer space as laid down in the Outer Space Treaty of 1967. It should also be clear that for this purpose of achieving a common good, actors have to follow specific rules, which is also in their self-interest.

The investigation of space traffic and its management has only recently become a point of wider discussion. In particular the series of workshops organized by the American Institute of Aeronautics and Astronautics (AIAA) and other international organizations on international cooperation highlighted the issue. It was discussed at its 5th and its 6th workshop, which took place in 1999 and 2001 respectively. The results of these deliberations including recommendations have been laid down in the proceedings of these two events.[1] But so far, these activities have not considerably advanced the subject than Lubos Perek's startling far-sightedness analysis done in the early 80s[2] – a pioneering work, which has not been followed-up for more than a decade.

It was, however, at the 2001 workshop of AIAA, when the suggestion was made that an International Academy of Astronautics (IAA) Study on the subject of space traffic management should be prepared. This suggestion was taken up and a proposal was presented to the Board of Trustees of IAA, which, in late 2001, accepted the proposal. Following this, the study group was composed, which prepared the present study. One early milestone in the process of work was the conduct of an International Institute of Space Law (IISL)/European Center of Space Law (ECSL) Symposium alongside the 2002 session of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) Legal Subcommittee. This symposium consisted of presentations of members of the IAA study group.[3] Also, close coordination with other study projects of IAA, in particular with the one on space debris, has been sought. At the International Astronautical Congress in Bremen in 2003, intermediary results of this study have been presented to a dedicated session for discussion.[4] At the International Astronautical Congress in Vancouver in 2004, another dedicated session dealt with a first draft of the study.[5]

The approach and scope of the present study are as follows. The approach of the study can be characterized as interdisciplinary. The study group consisted of experts from the technical as

1 AIAA Workshop Proceedings "International Cooperation: Solving Global Problems" 1999, p.35-39 and "International Cooperation: Addressing Challenges of the New Millennium," 2001, p.7-14.

2 Perek, Lubos, Traffic Rules for Outer Space, 82-IISL-09.

3 Proceedings of the IISL/ECSL Symposium on Prospects for Space Traffic Management, 2 April 2002, Vienna, UN Doc. A/AC.105/C.2/2002/CRP.7 of 4 April 2002.

4 Session on Space Traffic Management, IAA.5.5.a, in the Space Debris and Space Traffic Management Symposium.

5 Session on Space Traffic Management, IAA.5.12.4, in the Space Debris and Space Traffic Management Symposium.

well as from the legal/regulatory fields. It was composed of a core team, which prepared the text. While these members initially drafted sections in their particular field of expertise, the work was further done on the text as a whole so that no reference is made on contributors of specific sections but the study as a whole is to be regarded as a joint product of this core team. In addition to that, an independent team of advisors contributed ideas and suggestions to the first complete draft of the study as a whole. This team also consisted of experts with different backgrounds broadening the input even further.

The scope of the study reflects the understanding of space traffic management as given through the definition laid out above and the interdisciplinary set-up by the study team. The study encompasses detailed analyses of the technical background for space traffic management and the regulatory spectrum. It starts with a report of the current status. This comprises the status of space activities as well as the status of the legal and regulatory environment and also comparable traffic regimes. This will provide the basis for identifying the needs for traffic management provisions in the two spheres of technology and regulation. The main part of the study lays out elements for a space traffic management regime for the year 2020. Subdivided into the three phases of space traffic, the launch phase, the in-orbit operation phase and the re-entry phase, the needs for technology development and application as well as regulatory provisions are investigated. The result is a set of recommendations regarding how traffic management rules should look like about a decade from now.

Through investigating these issues, the study does not only apply an interdisciplinary approach inside the realm of space. It also has to take into account and touches various other fields as air traffic management and telecommunications regulation and the work conducted by the relevant institutions, in particular the International Civil Aviation Organization (ICAO) and the International Telecommunication Union (ITU). It has to do so, since in these two areas there have already been prepared elements for space traffic management, i.e. for the avoidance of radio-frequency interference or the use of the geostationary orbit. The present study brings these developments together and merges them into a coherent, encompassing approach.

The study does not, however, endorse a rush to regulation, since the authors believe that more research on space traffic is needed and that many States do not yet perceive the need to accept a limitation in their freedom through regulation. This situation, however, could change at any time if a major collision occurred that affected high–value spacecraft or even astronauts. In this respect, a comparison could be drawn with the problem of space debris, which has been put on the international inter-governmental agenda only after many years of careful scientific and conceptual study. Following this example, the present study on space traffic management presents a model of what space traffic management could look like and lays out a roadmap for a research program, identifying areas where further research is necessary and what regulation could look like in around 2020 in order to raise the common benefit for the use of space in the future

With this claim, the study is presented to IAA for the formal review process. Following this, it is intended to present the study at a dedicated Scientific-Legal Roundtable at the International Astronautical Congress in Fukuoka in 2005.

II. DIMENSIONS AND PHASES OF SPACE TRAFFIC

(as a concept used in the study)

Space traffic encompasses almost all space activities from their start to their end. Only planetary probes leaving the near-Earth environment fall under it for a shorter part of their lifetime. For the purpose of this study, activities on the surfaces of the Moon and other celestial bodies are excluded.

Space traffic touches two dimensions. These are the scientific and technical area and the regulatory field. In chapter 2, the status in these two dimensions will be analyzed. The relevant technical data for the use of outer space will be presented together with prospects for various space activities including the development of the space debris environment. On the other hand, the current legal and regulatory framework is analyzed alongside the respective areas of space law, air law, telecommunications law as well as national space law, air law and licensing provisions. A comparison with comparable traffic regimes for air traffic and maritime traffic completes this chapter. So, this chapter will lay the groundwork for judging the prospects of space traffic identify existing and lacking provisions for regulation and through this lead to the drafting of elements for a future space traffic regime.

In chapter 3, the two dimensions of space traffic will be applied to analyzing the three phases of space traffic:

- The launch phase
- The in-orbit operation phase
- The re-entry phase

They provide the structure for the in-depth analysis for elements of a space traffic regime for the next one and a half decade. Each phase is subdivided into an analysis of the status and trends in technology developments on the one hand and the regulatory aspects on the other hand. A brief characterization of the three phases and the related problems could be summed up in the following way.

The launch phase has to take into account expendable as well as reusable launch vehicles, comprising operators from the governmental as well as the non-governmental field. Particular stress has to be put on aspects of debris mitigation. The regulatory aspects have to respond to a current lack of pre-launch notifications, a little harmonized system of national licensing provisions. In addition a close link has to be made with air law.

The in-orbit operation phase has to investigate the rules for the use of various orbits. Only GEO so far can be seen as basically managed. Specifically movements of satellites on specific orbital planes or in altitude have to be covered by rules (who will have to give way, if this is possible?). This leads to the need of a comprehensive collision-warning system. It will turn out that the existence and access to on-time information about the status of space operations is essential for a functioning space traffic management system, as it is the case with the air traffic management. Another area of regulation in this context will be the mitigation of space debris including the use of disposal orbits. Additionally the question does arise, whether certain space activities should have priority before others (e.g. manned before unmanned?, science before applications?, “useless” and/or dangerous activities like advertising or funerals in orbit before “useful”?).

The re-entry phase is relevant for the operation of reusable transportation systems as well as the intentional or un-intentional de-orbiting of other space objects including space debris. Again the link with air law provisions has to be drawn. New requirements for notification will be necessary in this context.

The division into these three phases seems useful with regard to their different technological characteristics and to the possibility to shape distinct blocks of regulatory provisions. In the following, the three phases will be analyzed in-depth and a synthesis of the findings and recommendations will be given as a model for space traffic management in the year 2020.

III. PRELIMINARY FINDINGS

As pointed out, the study aims at an outline of a Comprehensive Space Traffic Management Regime. The preliminary findings can be summed up as follows:

Space Traffic: Current Status and Prospects for 2010 and 2020

- The motion of space objects is influenced by different forces, which cannot be accounted for precisely. Errors in predictions of space object motion are primarily caused by variations of atmospheric density, and the error in predicted position in orbit increases with the square of elapsed time. For this reason, positions of all objects should be monitored systematically and pecisely.
- The large majority of active satellites have no manoeuver capability and most others have only a limited capacity to change their trajectory.
- There is a slow but steady decline of launch activities since 1980.
- There is a rise in the number of launch vehicles (today 18). There is also a rise in the number of launch centers (today 11).
- The prospects for the introduction of full/partly RLV are still open. In any case, by 2020 they would probably still be limited to supporting missions below 1000 km.
- Human spaceflight has been accounting for 13% of launches during the past 20 years. It might rise with the emergence of new actors in this field but dramatically only beyond 2020.
- Technologies like tethers, stratospheric platforms or space elevators, which might be introduced in the future will have to be taken into account, when rules in particular for the launch and re-entry phase are developed.
- The population of space debris is continuously growing in number (today around 100,000 objects larger than 1 cm, most of them not catalogued).
- The number of catalogued objects is steadily rising (today 10,000 objects larger than approximately 10 cm).
- The number of active satellites remains at 6-7% of total catalogued objects.
- Capabilities for space surveillance rest with the US (and to a smaller extent to Russia and some singular capabilities in Europe); the US provides data and processed information on a voluntary basis.
- The capacity and accuracy of current space monitoring systems is not sufficient to cover small objects and provide for orbital avoidance service for all space assets.
- There are two major partly overlapping catalogues of space population, which is a far cry from the needed unified and complete system of monitoring space traffic.
- Information on space weather is still limited but important for the operation of space objects as well as the prediction of the debris environment.
- The constant monitoring and information of space weather would be a useful tool for implementing a space traffic management system.

The Current Legal and Regulatory Framework

- The general principles of space law provide for a basis and rationale to establish a space traffic management regime.
- There exist some singular rules in international space law as well as in

international telecommunication law, which constitute elements for a space traffic management system (especially for the GEO through the ITU). They are, however neither complete nor are they harmonized. ITU rules, aiming at the avoidance of radio-frequency interference are far more advanced than rules, aiming at the avoidance of physical interference.

- In this context, the IADC space debris mitigation guidelines of 2002 (non-binding soft law) encompass elements of space traffic management (use of disposal orbits, notification in case of controlled re-entry; but so far no provisions on the environment, i.e. avoidance of polluting the atmosphere/troposphere).
- Space law is, however, lacking numerous provisions, which are essential for a comprehensive traffic management regime (i.a. pre-launch notification).
- A space traffic management regime has to touch also the question of harmonizing national space legislation (mostly to be established) and its consequential licensing standards and procedures, since they provide the building blocks for assuring technical safety.
- In the context of arms control/disarmament negotiations notification practices (prior to launch) are currently discussed, thus surpassing the status of civilian space law and negotiations in UNCOPUOS.
- The implementation of a comprehensive space traffic management regime would require additional regulation (with regard to information and the execution of space missions), which would further limit the freedom of use of outer space; in order to achieve a consensus on this, States have to perceive a certain urgency and have to expect a specific as well as collective benefit (as they receive from existing regulation).
- There are interfering factors, in particular military doctrines, which might hinder the establishment and working of a space traffic management regime.

Comparable Traffic Regimes

In international spaces such as high sea—and outer space—no territorial jurisdiction applies. Only personal jurisdiction does. When rules such as traffic management are concerned, this system is far from being efficient. It is the reason why in the high sea, the exclusivity of the flag State is due to be overruled by an extension of the territorial jurisdiction of one or some States. This solution is not acceptable for space activities as there is no territorial jurisdiction involved. The solution of the port State is not usable as, for the time being a satellite does not fly back to Earth, the solution of extension of "coastal" jurisdiction is also impossible for obvious technical reasons. These difficulties should be taken into consideration if and when Space Traffic Management will be set in force.

The Launch Phase

- There is a rise in the number of launch vehicles (today 18).
- There is also a rise in the number of launch centres (today 11).
- The prospects for the inauguration of full/partly RLV are still open. In any case, by 2020 they would still be limited to supporting missions below 1000 km.
- Human space flight might only change dramatically beyond 2020.
- Safety certifications should be introduced.
- A clarification of the term "space object" is needed.
- The question of delimitation of air space and outer space should be revisited.
- The concept of the "launching State" has to be clarified.

- A pre-launch notification is necessary.
- Obligatory information in cases of damage is relevant.
- An international level playing field for transport services should be aimed for with a balance of public and private/economic interest.

The In-Orbit Operation Phase

- Maneuvring and in-orbit collision avoidance (with regard to other operational space objects as well as with regard to space debris) is growing in number and importance.
- Maneuvring in the GEO is intensely applied but with little consideration of possible collision.
- Reliable collision probabilities can be estimated only when reliable information exists, which currently is not guaranteed.
- There is no prioritization with regard to maneuvers.
- There is no prioritization of certain space activities, no "right-of-way-rules", nor is any kind of utilization of space ruled out (except it is against the peaceful uses).
- There are no communication rules (advance notification and communication if orbits of other operators are passed).
- The ITU system of nominal orbital positions finds application only to satellites in the GEO.
- Private/commercial actors have started (i.a. through SUIRG and ITU) coordinating against radio-frequency interference.

The Re-Entry Phase

- Intentional (RLVs as well as active debris mitigation) and un-intentional de-orbiting (natural debris mitigation through decay) is now more frequent, but care should be taken that large debris structures will be de-orbited in fragments.
- Responsibilities and liabilities for damages caused by space objects or its components ensue not only from international space law but also from the general provisions of national (tort) civil and administrative law.
- The generally shared wish to reduce space debris raises the question, whether regulation should also set a standard under which conditions a re-entry activity is in general legitimate and under which conditions it is not.
- Notification of, and coordination with, local and downrange air traffic, maritime authorities, and local government officials are already considered a best practice in coordinating launch activities.
- Space Law and Air Law have to solve the open issue of passage of space objects through airspace (the Chicago Convention does not apply to space objects in air space).
- The question is posed to introduce certain internationally recognized descent corridors and possibly even impact areas which are not frequently used by other traffic and which might be dedicated to space traffic.

CONCLUSION

As it has been pointed out in introduction, this study clearly recognizes that time for immediate actions to implement a comprehensive space traffic management regime is not yet near. The aim of the study is more focused on providing a conceptual view on space traffic management and to identify the areas where further research is necessary. In addition to that, it intends to make recommendations, on where and how regulatory mechanisms could or should be set up and also points to single issues, which might be taken up at an earlier stage.

In conclusion, a research plan is laid out, pointing at issues, which have been identified as not being studied extensively

enough so far. Following this, the findings of the study comprising also recommendations are summarized in a model for space traffic management. In this context building blocks are identified, which might also be tackled on a short-term basis.

Framework

In the following, a model is provided on how a comprehensive space traffic management regime for 2020 could look like.

There could be drafting of an international inter-governmental agreement building on and not replacing the existing treaties. It would include provisions for liability and the basic principle that States are the primary actors but that provisions of the agreement are applicable for private activities as well through national licensing regimes (certain issues will be clarified in the agreement).

This international inter-governmental agreement would:
- Comprise a legal text, which cannot be changed easily and technical annexes which can be adapted more easily (modeled from ICAO or IMO)
- Contain three parts:

1. Securing the Information Needs

- Defines necessary data (on trajectories as well as radio frequencies)
- Sets provision for the data (sources, governmental as well as private, including financing)
- Establishes a database and distribution mechanisms for data (format of the database, access to data on request, collision warning as a service)
- Establishes an information service on space weather

2. Notification System

- Sets pre-launch notification with better parameters than Registration Convention as well as other provisions (e.g. ITU and proposed UNIDROIT Protocol)
- Provides information on the end of active/operational lifetime of space objects
- Provides pre-notification of orbital maneuvers and active de-orbiting (communication rules and cooperation provisions)

3. Traffic Management

- Clarifies "space objects", including legal distinction between valuable objects and valueless space debris
- Clarifies "fault" in case of damage caused in outer space
- Sets delimitation for the launch phase and clarifying the concept of the "launching State"
- Provides traffic management rules based on the use of the database for the purpose of collision avoidance, including:
  - Safety provisions for launches
  - Zoning (selection of orbits)
  - Right of way rules for in-orbit phase
  - Prioritization with regard to maneuver
  - Specific provisions for GEO (in harmonization with ITU rules)
  - Specific rules for LEO satellite constellations
  - Debris mitigation mechanisms
  - Safety provisions for re-entries
  - Environment provisions (pollution of the atmosphere/troposphere, etc.)
- Clarifies "space objects", including legal distinction between valuable objects and valueless space debris
- Gives a framework and main features for national licensing regimes, which implement the provisions of the agreement

- Sets out an enforcement mechanism (e.g. renouncement of access to information) and dispute settlement
- Clarifies institutionalized interlinks with ICAO and ITU

4. Organization

- The provisions of the three agreements are in a first step monitored by UNCOPUOS and handled by UNOOSA
- In a second step, post 2020:
  - The new agreement may be (together with the existing space treaties) replaced by a comprehensive Outer Space Convention;
  - ICAO's mandate may be enlarged to cover both the aviation and space traffic management legal frameworks;
  - UNCOPUOS as well as UNOOSA functions could be integrated into new ICAO;
  - Space activities by private actors will develop into the same legal status as in air traffic.

It is planned that the study will also contain draft legal texts for these areas.