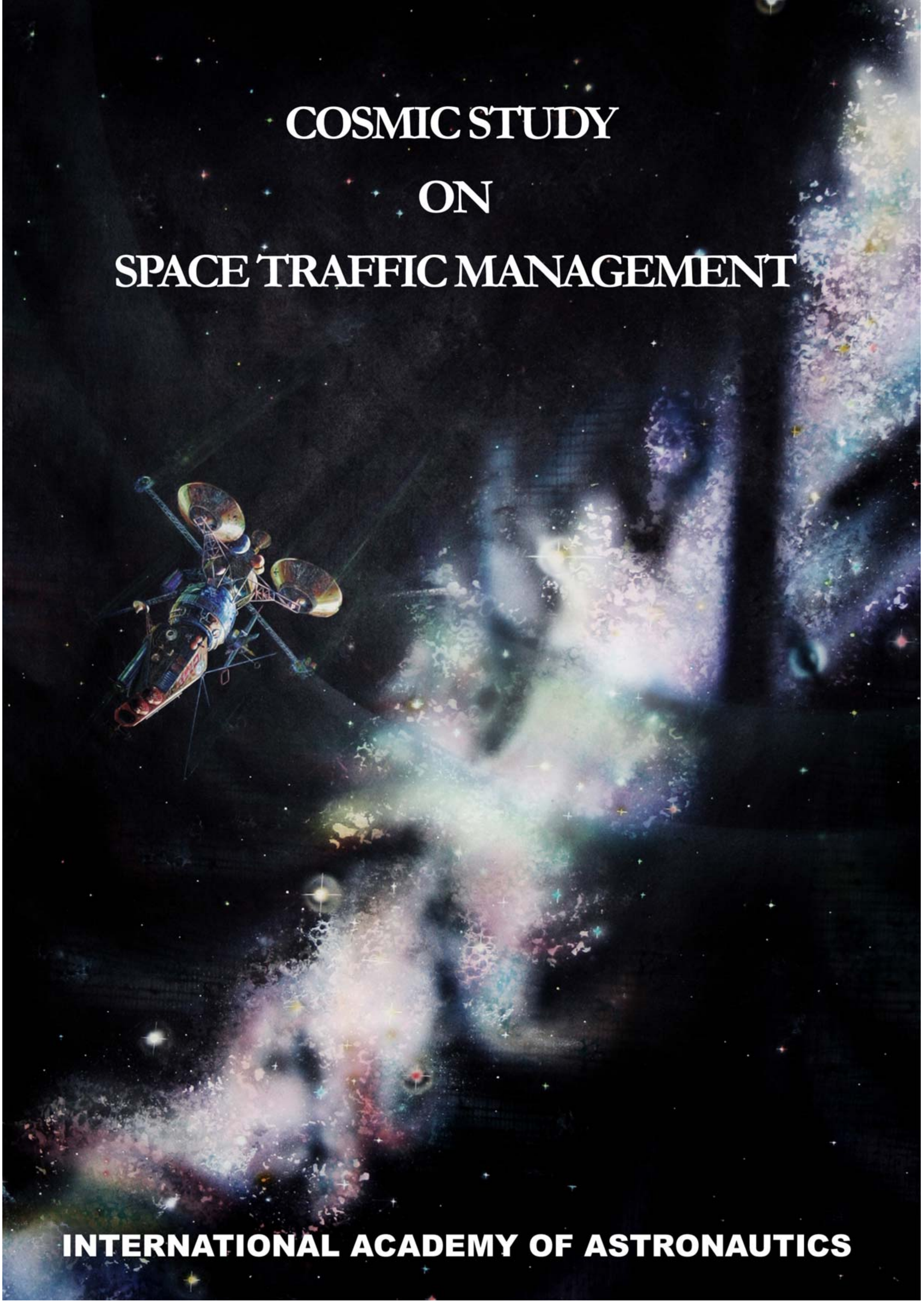
COSMIC STUDY ON SPACE TRAFFIC MANAGEMENT



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The International Academy of Astronautics (IAA) a non governmental organization recognized by the United Nations was founded in 1960. Since that time, IAA has brought together the world's foremost experts (1216) in the disciplines of astronautics on a regular basis to recognize the accomplishments of their peers, to explore and discuss cutting-edge issues in space research and technology, and to provide direction and guidance in the non-military uses of space and the ongoing exploration of the solar system. The purposes of the IAA, as stated in the Academy's statutes are to foster the development of astronautics for peaceful purposes, to recognize individuals who have distinguished themselves in a branch of science or technology related to astronautics, to provide a program through which the membership can contribute to international endeavors and cooperation in the advancement of aerospace science, in cooperation with national science or engineering academies. Prof. Ed. Stone is president of the International Academy of Astronautics.

International Academy of Astronautics (IAA)

Cosmic Study on Space Traffic Management

Space Traffic Management
Edited by: Corinne Contant-Jorgenson, Petr Lála, Kai-Uwe Schrogl

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Contributors

Ailor, William H., USA
Bravman, Joe, USA
Coleman, Kelvin, USA
Gerhard, Michael, Germany
Hedman, Niklas, Sweden
Hodgkins, Ken, USA
Johnson, Nicholas, USA
Kerrest, Armel, France
Laffaiteur, Michel, France
Ospina, Sylvia, Colombia
Perek, Lubos, Czech Republic
Reif, Susanne, Germany
Salin, Patrick, Canada
Shawcross, Paul, USA
van Fenema, Peter, The Netherlands
von der Dunk, Frans, The Netherlands

Rapporteur

Contant-Jorgenson, Corinne, USA

Coordinators

Lála, Petr, Czech Republic
Schrogl, Kai-Uwe, Germany

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LIST OF ABBREVIATIONS

AAS	American Astronautical Society
AIAA	American Institute of Aeronautics and Astronautics
ARRA	Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space
ATM	Air Traffic Management
CEV	Crew Exploration Vehicle
CD	Conference on Disarmament
COSPAR	Committee on Space Research
CTV	Crew Transport Vehicle
ECSL	European Centre for Space Law
EEZ	Exclusive Economic Zone
ELV	Expendable Launch Vehicle
ESA	European Space Agency
FAA	Federal Aviation Commission
GATS	General Agreement on Trade in Services
GEO	Geostationary Satellite Orbit
GMPCS	Global Mobile Personal Communication System
GPS	Global Positioning Systems
HCOC	Hague Code of Conduct against Ballistic Missile Proliferation
HEO	High Earth Orbit
IAA	International Academy of Astronautics
IAC	International Astronautical Congress
IAF	International Astronautical Federation
IADC	Inter-Agency Space Debris Coordination Committee
ICAO	International Civil Aviation Organization
IISL	International Institute of Space Law
IMO	International Maritime Organization
ISS	International Space Station
ITU	International Telecommunication Union
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MTCR	Missile Technology Control Regime
NPS	Nuclear Power Source
OST	Outer Space Treaty
RLV	Reusable Launch Vehicle
RFS	Radio Frequency Spectrum
RR	Radio Regulations
SARPS	Standards and Recommended Practices
SSN	Space Surveillance Network (USA)
SSS	Space Surveillance System (Russia)
SUIRG	Satellite Users Interference Reduction Group
TLE	Two-Line Elements
UNCOPUOS	United Nations Committee of the Peaceful Uses of Outer Space
UNGA	United Nations General Assembly
UNIDROIT	International Institute for the Unification of Private Law
UNOOSA	United Nations Office for Outer Space Affairs
WTO	World Trade Organization

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EXECUTIVE SUMMARY

I. Scope and Target Users of the Study

There is already a great deal of space traffic. It seems, however, minuscule with regard to the dimension of near-Earth outer space. Around 9.000 man-made objects larger than about 10 cm are currently catalogued, out of which only 650 are operational spacecraft. At first glance, the management of space traffic does not appear to be a pressing problem. On closer examination, this judgement has to be challenged. A high level and ever growing number of launches from more and more launch sites and spaceports, the participation of non-governmental entities, the positioning of satellite constellations, an increase in space debris and the advent of reusable launch vehicles support this view.

Considering this scenario, conceptualizing space traffic management will turn out to become a relevant task during the next two decades. Space traffic management however, will limit the freedom of use of outer space. Therefore an international consensus on internationally binding regulations will only be achieved, if States identify certain urgency and expect a specific as well as collective benefit – including an economic benefit - from this.

Due to its long-term approach, the study does not provide a specific plan of action to any single target user. In sketching out first steps, however, it addresses or directs decision makers in UNCOPUOS, ITU and ICAO to approach specific problems, organizations which are building blocks for a future space traffic management regime. In addition to that, further questions to be studied have been identified, which might be tasks for the respective Committees of IAA and IISL.

II. Definition of Space Traffic Management

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 means the 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.

Since an authoritative definition of space traffic management does not yet exist, this definition has been created for the purpose of this study. Through this definition, the purpose of space traffic management becomes clear: it is to provide appropriate means for conducting space activities without harmful interference. 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 the purpose of achieving a common good, actors have to follow specific rules, which are also in their self-interest.

III. Dimensions and Phases of Space Traffic

Two dimensions of space traffic are analyzed in this study: the scientific and technical area, and the regulatory field. Then, those two dimensions of space traffic are applied to analyzing the three phases of space traffic: the launch phase, the in-orbit operation phase, and the re-entry phase. Below are the findings.

IV. Findings

Space Traffic: Current Status and Prospects for 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 with high accuracy.
- The large majority of active satellites have no manoeuvring capability and most others have only a limited capacity to change their trajectory.
- There has been a slow but steady decline of launch activities since 1980, but there is a rise in the number of launch vehicles available (currently 18). There is also a growing number of launch centers (currently 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 accounted for 13% of launches during the past 20 years. It might increase with the emergence of new actors in this field, but is likely to increase dramatically only after 2020.
- Following the successful flight of SpaceShipOne, there might be – if safety is guaranteed - a growing number of suborbital manned flights, including space tourists as passengers.
- Technologies like tethers, stratospheric platforms or space elevators, which might be introduced in the future, will have to be taken into account in particular when rules for the launch and re-entry phase are developed. New concepts for satellites (like e.g. "autonomous nanotechnology swarms") will raise requirements for in-orbit operations.
- Space debris is continuously growing in quantity (currently there are about 100.000 objects larger than 1 cm, most of them not catalogued).
- The number of catalogued objects is steadily rising (currently there are about 9.000 catalogued objects larger than approximately 10 cm).
- The number of active satellites remains at 6-7% of the total catalogued objects.
- The US's space surveillance capabilities dominate, followed by Russia and 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 or to provide for orbital avoidance service for all space assets.
- There are two major catalogues of space objects, which is far from the comprehensive system of space traffic monitoring that is required.
- Information on space weather is still limited but is important for the operation of space objects as well as for the prediction of the debris environment.
- The constant monitoring and information of space weather would be a useful tool in implementing a space traffic management system.

The Current Legal and Regulatory Framework

- The general principles of space law provide a basis and rationale to establish a space traffic management regime.
- Some unique rules exist in international space law as well as in international telecommunication law, which can be considered as basic elements of a space traffic management system (especially for use of the GEO by means of the ITU Radio Regulations). These rules however are neither complete nor 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 (not legally binding agreement) encompass elements of space traffic management (use of disposal orbits, notification in case of controlled re-entry) but so far they do not include provisions on the environment, i.e. avoidance of pollution of the atmosphere/troposphere.
- Space law, however, lacks numerous provisions which are essential for a comprehensive traffic management regime (i.e. pre-launch notification). Of particular importance is a legal recognition of a difference between space objects considered as valuable assets by their owners, and space debris that have no value.
- A space traffic management regime has to consider the question of harmonizing national space legislation (much of which has yet to be established), and national licensing standards and procedures, since they may provide the building blocks for assuring technical safety.
- In regard to arms control/disarmament negotiations, notification practices (prior to launch) have been developed through the Hague Code of Conduct against Ballistic Missile Proliferation (HCOC), thus superseding 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 about and the execution of space missions), which could be perceived as limiting the freedom of use of outer space guaranteed by the Space Treaty. In order to achieve a consensus, States have to perceive 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 national military and security policies and practices, which might hinder the establishment and operational effectiveness of a space traffic management regime.

<u>Comparable Traffic Regimes (maritime traffic and air traffic)</u>

In international common spaces, such as the high seas - 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 seas, the exclusivity of the flag State is likely to be overruled by an extension of the territorial jurisdiction of one or several 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, since at present a satellite does not fly back to Earth. The extension of "coastal" jurisdiction is also an impossible solution for obvious technical reasons. These difficulties should be taken into consideration if and when a Space Traffic Management regime enters into force. Nevertheless, there are many interesting elements from the Law of the Sea which could be studied further, in particular as the development of international law for ocean space and outer space do have the common basic elements of extra territorial applications.

Air traffic management (ATM) in sovereign national air space is in the hands of the national authorities concerned. These authorities apply, as much as possible, the uniform "standards and recommended practices" developed by ICAO, the 188-member UN specialized agency that is responsible for international aviation safety. Aircraft commanders are accustomed to being transferred from one national ATM agency to another, either on the basis of horizontal border crossing or because their aircraft has reached a certain altitude, and they routinely receive instructions from the ground as to recommended speed, altitude, routing and right of way. The ATM agencies' responsibility for aviation safety also requires coordination with the military and with space agencies. These national responsibilities may be delegated to another state or to an international agency. All above ICAO rules also apply to aircraft in air space over the high seas, a *res communis omnium* like outer space. A national ATM agency may agree with ICAO to take responsibility for a specific portion of the air space over the high seas. The ICAO ATM system is highly sophisticated and effective and may serve as an example of rule-making for space traffic management purposes.

The Launch Phase

- 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 "launching State" has to be clarified.
- A pre-launch notification system is necessary, although the HCOC includes non-legally binding provisions for such notifications of Space Launch Vehicle launches.
- Obligatory information in cases of damage is relevant.
- An international level playing field for transport services should be aimed for, with a balance between public and private/economic interest.

The In-Orbit Operation Phase

- Manoeuvring 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.
- Manoeuvring in the GEO is utilised but with little consideration of possible collisions.
- Reliable collision probabilities can be estimated only when reliable information exists, which currently is not guaranteed.
- There is already one-way traffic in GEO, as all satellites in GEO are orbiting eastward in the equatorial plane.
- No systematic zoning (restriction of certain activities in certain regions) of outer space is applied.
- The ITU system of nominal orbital positions is applicable only to satellites in the GEO.
- Private/commercial actors have started (i.e. through SUIRG and ITU) coordinating to prevent radio-frequency interference.
- Matching spacecraft with space radio stations on board could make the problem of "paper satellites" transparent and better understood.

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.
- Responsibility and liability for damages caused by space objects or their components ensue not only from international space law but also from the general provisions in national legislation.
- The generally shared aspiration to reduce space debris raises the question, whether regulation should also set a standard, clarifying under which conditions a re-entry activity is considered 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 resolve the open issue of passage of space objects through airspace (the Chicago Convention does not apply to space objects in air space).
- The question arises, whether to introduce certain internationally recognized descent corridors and possibly even impact areas which are not frequently used by other traffic, and which could be dedicated to space traffic.

V. Conclusions

Framework

In this section, a model is provided for what a comprehensive space traffic management regime for 2020 could look like. An international inter-governmental agreement on the status and use of outer space could be drafted, building on but not replacing the principles incorporated in the existing space treaties. It would also include provisions for liability and the basic principle that while States are the primary actors, provisions of the agreement are applicable to private activities as well through national licensing regimes.

This international inter-governmental agreement would comprise a legal text, which cannot be changed easily and technical annexes, which can be adapted more easily (modelled on the legal texts of the ITU, ICAO or IMO and WTO). The international inter-governmental agreement envisioned would 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

- Provides traffic management rules based on the use of the database for the purpose of collision avoidance, including:
  - Safety provisions for launches
  - Safety provisions for human spaceflight (including space tourism)
  - Zoning (selection of orbits)
  - Right of way rules for in-orbit phase(s)
  - Prioritization with regard to maneuver
  - Specific provisions for GEO (harmonized with ITU rules)
  - Specific rules for LEO satellite constellations
  - Debris mitigation mechanisms
  - Safety provisions for re-entries
  - Environmental provisions (pollution of the atmosphere/troposphere, etc.).
- Clarifies "space objects", including legal distinction between valuable objects and valueless space debris.
- Clarifies "fault" or liability in case of damage caused in outer space with regard to the implications of traffic rules.
- Sets delimitation for the launch phase and clarifies the concept of "launching State".
- Provides a framework and main features for national licensing regimes (including insurance provisions), which implement the provisions of the agreement.
- Sets forth an enforcement mechanism (e.g. renouncement of access to information) and dispute settlement.
- Clarifies institutionalized interlinks with ICAO, ITU and other relevant organizations.

4. Organization

- The provisions of the three agreements initially could be monitored by UNCOPUOS and handled by UNOOSA.
- Subsequently, post 2020:
  - The new agreement, together with the existing space treaties, could be superseded by a comprehensive Outer Space Convention.
  - The operative oversight, i.e. the task of space traffic management, could be taken up by an already existing forum or organization (such as UNCOPUOS/UNOOSA or ICAO), which would evolve into a body shaped for that purpose. Looking 20 years ahead, it could also be handled by a non-governmental entity tasked by the State parties to an Outer Space Convention.
  - Space activities by private actors will develop into the same legal status as in air traffic.

Possible First Steps for Improving the Situation in Space Traffic

Space Debris Guidelines

Current guidelines for mitigating space debris developed by the Inter-Agency Space Debris Coordinating Committee (IADC) are an important, positive step toward space traffic management. They should be endorsed by UNCOPUOS as a UN legal document with a view to making their acceptance and implementation universal.

Space Surveillance and Collision Avoidance

Cataloguing activities (US Strategic Command, European Space Agency, Russian Space Agency, and private companies) should be improved and coordinated with the aim of establishing a common data policy and infrastructure. Steps could comprise developing and deploying new sensors, improving analytical techniques, and incorporating data from sensors not primarily intended for tracking orbiting space objects. Improvements to the GSO catalogue could be considered a priority and could be treated as such by the IADC Subgroup on Measurement.

Enforcement and Checking Mechanisms

Neither the UN nor ITU has any enforcement or inspection mechanisms. These are within the jurisdictional powers of sovereign states. The ITU’s list of radio space stations as well as the UN Register of objects launched into outer space, reflect governmental announcements only. This situation should be changed, resulting in obligatory notofication/registration and the provision of unified sets of relevant data.

Distinction between Valuable Spacecraft and Worthless Space Debris

UNCOPUOS should start discussing whether or not space debris are space objects in the sense used in space law treaties. If it is decided that space debris are space objects, an additional protocol should be elaborated stating what provisions of the treaties apply to valuable spacecraft and which provisions apply to space debris. If it is decided that space debris are not space objects, the protocol should determine under what conditions space debris may be removed or re-orbited in order to prevent collisions or close encounters with valuable spacecraft.

Further Research

Analysis of space activities in the framework of this study have led to numerous insights, but also reached some conclusions, where it is clear that further research is needed. Thus, it could be compared with the manner in which the space debris issue was identified more than two decades ago, and then was studied further with a growing clearness of what is really important and where concrete action has to be taken. As it has been and to some extent still is the case there, space traffic management will require further research in both the technical as well as in the regulatory fields. These tasks could be taken up by the respective Commissions of the IAA and the IISL:

Technical issues to be studied further

- Sufficiency of the current observation capacity.
- Technical set-up of a database.
- Cost efficiency.
- Technical feasibility of real-time collision warning.
- Mission costs related to collision avoidance.

Regulatory issues to be studied further

- Conduct a study on whether priorisation of space activities makes sense, and whether certain space activities or specific use of outer space should be banned (e.g. funerals, advertising).
- Ways of linking/merging the ITU information/notification system with an improved UN registration system, the outcome of which would be one notification/information system.
- Relationship between international space law and Hague Code of Conduct against Ballistic Missile Proliferation (HCOC) regarding the concept of notification of launches.
- Dual use aspects of data utilization.
- Further inquiry into the interests and expectations of private actors and the economic benefit to commercial activities through space traffic management.
- Linking the issue of space traffic management to discussions in conjunction with the Conference on Disarmament on the prevention of an arms race in outer space.
- Identification of the expectations of military users of outer space with regard to space traffic management.
- Latest trends in technical international organizations like ITU, ICAO or IMO regarding the adoption of technical regulations/standards and making them binding thus providing more flexibility than the traditional system of negotiation and ratification currently provides; analysing these trends with regard to their relevance to a space traffic management regime.
- Maintaining a level-playing field and avoiding “flags of convenience” through space traffic management.

CHAPTER 1

INTRODUCTION

1.1. Scope of the Study

There is already a great deal of space traffic. It seems, however, minuscule with regard to the dimension of near-Earth outer space. Around 9.000 man-made objects larger than about 10 cm are currently catalogued, out of which only 650 are operational spacecraft. At first glance, the management of space traffic does not appear to be a pressing problem. On closer examination, this judgement has to be challenged. A high level and ever growing number of launches from more and more launch sites and spaceports, the participation of non-governmental entities, the positioning of satellite constellations, an increase in space debris and the advent of reusable launch vehicles support 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 however, will limit the freedom of use of outer space. Therefore an international consensus on internationally binding regulations will only be achieved, if States identify certain urgency and expect a specific as well as collective benefit – including an economic benefit – from this.

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

> Space traffic management means the 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.

Since an authoritative definition of space traffic management does not yet exist, this definition has been created 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 has 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 included in the proceedings of these two events.[1] But so far, these activities have not advanced considerably since they were analyzed with startling far-sightedness by Lubos Perek in the early 1980s[2] – in a pioneering work, which has not been followed-up for more than a decade.

At the AIAA's 2001 workshop, the suggestion was made that an **International Academy of Astronautics (IAA) Study** on the subject of space traffic management should be undertaken. This suggestion was accepted and a proposal was presented to the Board of Trustees of the IAA, which accepted the proposal in late 2001. Following this, the study group was composed, which prepared the present study. One early milestone in the process of work was the convening of a Symposium by the Interna-

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

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

tional Institute of Space Law (IISL)/European Center of Space Law (ECSL) simultaneously with the 2002 session of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). This symposium consisted of presentations by members of the IAA study group.[3] Also, close coordination with other study projects of the IAA, in particular with the one on space debris, has been sought. At the International Astronautical Congress in Bremen in 2003, interim results of this study were presented at a session dedicated to its discussion.[4] At the International Astronautical Congress in Vancouver in 2004, another dedicated session dealt with a first draft of the study.[5] The study was finally accepted by the Academy – following the regular review process[6] – during the International Astronautical Congress in Fukuoka in 2005. The results were presented in a Scientific-Legal Round Table there.[7]

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 well as from the legal/regulatory fields. It was comprised by a core team composed primarily by members of IAA and IISL, 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 to 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 entire first complete draft of the study. 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 provided in the definition set forth above, and the study team's interdisciplinary framework. 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 of 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, needs for technology development and application as well as regulatory provisions are investigated. The result is a set of recommendations regarding traffic management rules, as to what they should look like about a decade from now.

In 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 touch various other fields such as air traffic management, 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 elements for space traffic management are already included, e.g. means to avoid 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.

Space is used for civilian as well as military purposes. International law limits the military use of outer space only for very few specific purposes. Space traffic therefore comprises a variety of actors, which are all rather different in nature. The naturally secretive character of military activities makes it difficult to see how they can fit in a system, which has to be based on transparency. On the other hand, this

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.

6 The reviewers, selected by the relevant IAA Commission, have been Ivan Almar (Hungarian Space Office, Hungary), Henry Hertzfeld (George Washington University, Washington), Xavier Pasco (Foundation for Strategic Research, Paris) and Constantinos Stavrindis (ESA ESTEC, Noordwijk). The study group thanks them for their advice.

7 Scientific-Legal Round Table on Space Traffic Management, IAA.5.13/IISL.

transparency can currently only be achieved, if the resources of the military (in particular its observation capacities) contribute to space traffic management. Another challenge arises from military doctrines, which can contradict traffic rules or even basic principles of current space law (like the free use of outer space). This study does not delve into the possible concrete ways and means for shaping traffic management rules, which might be acceptable also to the military users of outer space under the current circumstances. It adopts the assumption that in 2020 space traffic management will not only benefit public as well as private space activities, but that it will also benefit military space activities. A model could be the ITU, where the regulation of the frequency spectrum includes civilian as well as military uses, and rules applied safeguard the interests of both types of actors.

The study does not 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 any regulation which may limit their freedom. This situation, however, could change at any time if major collisions were to occur in orbit, thereby affecting 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 regulations could look like in 2020, in order to raise the common benefit for the use of space in the future.

1.2. Dimensions and Phases of Space Traffic

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

Space traffic comprises **two dimensions**. These are the **scientific and technical area** and the **regulatory field**. In chapter 2, the status of 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 similar traffic regimes for air traffic and maritime traffic completes this chapter. Thus, this chapter will lay the groundwork for judging the prospects of space traffic, to identify existing and lacking or missing 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 fifteen years. 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 summarized 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 sectors. 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, and to a scantily 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 the use of the GEO so far can be considered to be basically managed. Specifically movements of satellites on specific orbital planes or in altitude have to be covered by rules. This leads to the need for a comprehensive collision-warning system. The existence and access to on-time information about the status of space operations will be essential for a functioning space traffic management system, as it is in the case of 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 arises, whether certain space activities should have priority over others (e.g. manned over unmanned, scientific over commercial applications, "useless" and/or dangerous activities, like advertising or funerals in orbit over more "useful" activities).

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 of shaping distinct blocks of regulatory provisions. In the following section, 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.

1.3. Use of Terms

This study does not introduce technical terms or definitions "just for the purpose of this study," with the exception of the definition of "space traffic management" given above. It recognizes the fact that various organizations or groups of experts use different terminologies, sometimes using different terms for the same concept, in other cases using the same term for different concepts. Also, an important problem of terminology in languages other than English (see: IAA Multilingual Space Directory) is not considered here. Rather, an attempt has been made to understand which important concepts are meant by which terms, in what context.

The three main sources of terms are:

- General usage in technical literature and periodicals.
- Space law treaties, UN Documents, UNGA Resolutions, UNCOPUOS documents.
- Radio Regulations (RR) and other documents of the International Telecommunication Union (ITU).

The first source uses the "common language;" the second source uses terms and phrases appearing in the space law treaties. The third source regards space affairs quite naturally from the point of view of radio telecommunications, without spelling out the fact explicitly in every frequently used term.

The present study uses quotations and/or citations from all three sources. Whenever confusion might arise, the technical term is given at its first appearance in a version as long as required for understanding the respective context. A few examples of differences in terminology are provided below.

- **Space Traffic Management** comprises technical and regulatory provisions for guaranteeing safe and interference-free access into outer space, operations in outer space, and return from outer space to Earth.
- **Space Object** is a term used in space law treaties, carrying a connotation of a legal term. If such connotation is not desired, **Object in Space** can be used.
- **Space Station** in common usage designates a very large spacecraft designed to have a human crew. In the ITU terminology (term S1.64) it designates *a station located on an object which is beyond, is intended to go beyond, or has been beyond, the major portion of the Earth's atmosphere.* And a **Station** (term S1.61) is *one or more* (radio) *transmitters or receivers or a combination of transmitters and receivers, including the necessary equipment, necessary at one location for carrying on a radiocommunication service, or the radio astronomy service.* What a difference between the ISS and a radio receiver, both covered by the same term!
- **Space System** has been defined by the ITU Radio Regulations[8] (term S1.110) as *any group of co-operating earth* (radio) *stations and/or space* (radio) *stations employing space radio communications for specific purposes.* The IADC Space Debris Mitigation Guidelines[9] define it as *spacecraft and orbital stages,* in agreement with common usage. The ITU sense can be specified as **Space System of Radio Stations.**
- **Satellite System** has been defined by ITU (term S1.111) as a *space system using satellites.* It can be specified as **Satellite System of Radio Stations.** In common usage, Satellite System is, of course, a system of satellites having radio stations among its many components.
- **Spacecraft** is 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 a different wording but in the same sense, as *an orbiting object designed to perform a specific function or mission.*
- **Space Debris** are, according to the IAA Orbital Debris Position Paper[10] and the UN Technical Report on Space Debris (Rex Report)[11], *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 an other functions for which they are or can be authorized.* Space Debris may escape orbit around the Earth, re-enter Earth's atmosphere, or remain in Earth orbit. In the last case it is also called **Orbital Debris**. [12]
- **Satellite Orbits** are trajectories, mostly periodical, of satellites around the primary body, in our case the Earth, under the influence of natural forces. The following terms are widely used:
- **Low Earth Orbit (LEO)** is used for orbits below about 2.000 km above Earth's surface, with periods of 127 minutes or less. Orbits at altitudes below 500 km are frequently used for crewed space activities. Launch vehicles are able to place large payloads, often used in human space flight, into these orbits. The low altitude also greatly simplifies the return of crews to Earth. Low orbits are also used by launch vehicle stages, which are often left in low orbits when upper stages carry payloads into higher altitudes. High Earth Orbit (HEO), is also used in this study for all orbits above LEO except GEO.
- **Medium Earth Orbit (MEO)** is an orbit between LEO and GSO. In particular, the two existing constellations of navigation satellites, GPS and GLONASS, use inclined orbits with periods of 12 hours and 11 hours 15 minutes respectively. Their orbital regime ensures that multiple satellites of the constellation are visible to users on the ground at all times.

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8 ITU Radio Regulations, Article S1 Terms and Definitions and www.itu.int/terminology/index.html.

9 Inter-Agency Space Debris Coordination Committee space debris mitigation guidelines, UN Doc. A/AC.105/C.1/L.260 of 20 November 2002.

10 Position Paper on Orbital Debris, International Academy of Astronautics, Updated edition, September 2001. First edition published in 1995.

11 Technical Report on Space Debris (Rex Report), UN Doc. A/AC.105/720, New York, 1999.

12 E.g., Orbiting Debris, A Space Environmental Problem, Background Paper, Congress of the United States, Office of Technology Assessment, OTA-BP-ISC-72, Washington, D.C., September 1990.

- **Earth Orbit,** without an attribute, is used in astronomy[13]. It refers to the orbit of the Earth around the Sun. But in astrodynamics, "Earth orbit" means "orbit around the Earth". There should not be any confusion because the astronomical definition is not relevant to this study.
- **Sun-synchronous Orbits** are those that use one of the natural perturbations to synchronize the satellite with the Sun in such a way that the satellite passes over the equator, or any specific latitude, at the same time each day. Such orbits are practically perpendicular to the equator (inclination slightly greater than 90°) and therefore spacecraft in Sun-synchronous orbits can monitor all geographical latitudes. These orbits are used for remote sensing because the ground can be viewed under the same illumination in subsequent passes. Sun-synchronous orbits are at various altitudes, mostly at 700-900 km, sharing these altitudes with spacecraft and debris in other than sun-synchronous orbits.
- **Geosynchronous Orbit (GSO)** is an orbit with a period equal to the period of rotation of the Earth (23h 56m 04s) about its axis.
- **Geostationary Orbit (GEO)** is a special case of GSO when the inclination is zero. According to the IADC Space Debris Mitigation Guidelines, it 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.* It is understood that *the sense of orbiting is the same as the sense of rotation of the Earth, i.e., anticlockwise if viewed from the North.* According to the ITU Radio Regulations (term S1.190) the same concept is called the **geostationary-satellite orbit**, and defined as *the orbit of a geosynchronous satellite whose circular and direct orbit lies in the plane of the Earth's equator.* The UN General Assembly resolutions and other documents[14] call the same orbit simply the **geostationary orbit**. The advantage and popularity of that orbit is due to the fact that a satellite moves very slowly around its nominal orbital position. It can be kept within the lobe of high sensitivity of a stationary antenna on the ground with a relatively small amount of fuel (see Orbital Position). A perfect geostationary orbit is a mathematical abstraction valid only for a symmetrical Earth and in the presence of the attraction of the Earth only. In fact, the Earth deviates from a sphere. Small forces caused by the asymmetry and by the attraction of the Sun and the Moon, called perturbations, will change the originally circular orbit into a slightly elliptical one and will push the satellite of the plane of the Earth's equator. Even a small eccentricity will cause an oscillation of the satellite around its nominal orbital position as seen from the rotating Earth.
- **Nominal Orbital Position in the GEO** has been defined by the ITU as *the longitude of a position in the geostationary satellite orbit with a frequency assignment to a space station in a space radiocommunication service. The position is given in degrees from the Greenwich meridian.*

The listing by ITU in its Master International Frequency Register constitutes a statement that a radio station operating at the assigned location, complying with stated parameters and with the permitted tolerance, will neither generate, nor suffer from, harmful interference with other communication systems. The ITU rules require that the deviation of the actual position of the object from its nominal orbital position 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, at the geostationary distance, is equal to 74 km. Thus a spacecraft carrying the radio station has to remain within a square in the sky of 148x148 km. When the perturbations move the spacecraft close to the border of the ideal "parking box", it has to be acted upon by a small correction rocket. This process is called **station keeping**. For space radio stations in orbits other than the GEO, the orbital position is not a convenient parameter because it changes rapidly with time. One spacecraft may operate one or more space radio stations. Vice versa, one space radio station may be operated by radio transmitters on one or more spacecraft.

13 E.g., McGraw-Hill, Dictionary of Scientific and Technical Terms.

14 E.g., UN Doc. A/57/20, Report of the COPUOS, New York, 2002.

CHAPTER 2

STATUS

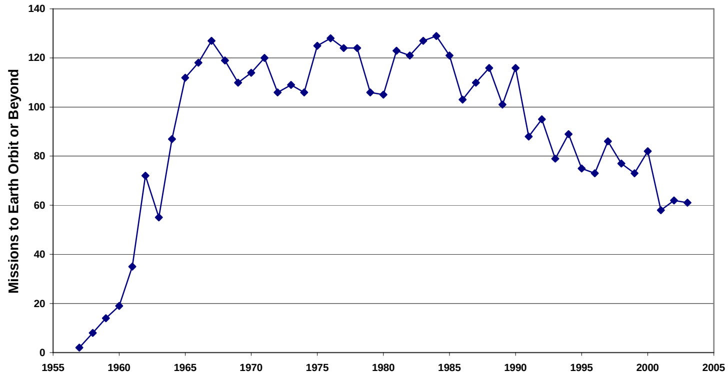
2.1. Space Traffic: Current Status and Prospects for 2020

2.1.1. Launch Activities

In the more than 46 years since the launch of Sputnik 1, the international investment in space activity for both human space flight and robotic endeavours has been considerable. In 2003 a new milestone was achieved with the 4300th space mission to reach Earth orbit or beyond. Although the number of functional spacecraft in Earth orbit is near an all-time high, the rate at which satellite launches occur is at the lowest levels since the early 1960's, in large part due to the increased longevity of spacecraft.

During the 1970's and 1980's, the average number of annual missions to Earth orbit and beyond was 116, but this fell to only 85 in the 1990's (Figure 2-1). The difference is almost entirely attributable to the sharp reduction of space missions undertaken by the Russian Federation. In 1990 the Soviet Union was responsible for 75 of 116 space missions conducted worldwide. By comparison, the countries of the former Soviet Union accounted for only 24 of 61 missions in 2003, including three international Sea Launch missions that employ Russian and Ukrainian stages.

Figure 2-1 History of Space Missions to Earth Orbit or Beyond



The reduced number of missions in the early 21st century also reflects two other factors. The initial deployments of the first major commercial LEO communications systems in the 1997-1999 period (Iridium, Orbcomm, and Globalstar) accounted for an average dozen missions for each of those three years. However, the financial difficulties experienced by all three systems greatly influenced other plans to deploy similar communications networks, leading to a slowdown in such endeavours. Secondly, the increasing longevity of GEO spacecraft, global financial pressures, and technical problems encountered with the development of new generations of spacecraft have led to a slight decline in GEO missions from an average of 30 per year for the period of 1998-2000 to an average of 25 per year for the period of 2001-2003.[15]

15 For statistics on space launches and registration see UN Doc. A/AC.105/C.2/2005/CRP.10 of 14 April 2005.

Launch failures continue to play a relatively minor role in overall space launch traffic. Such failures typically occur 2 to 3 times per year. In 2004, only one launch attempt failed to reach Earth orbit, and two others failed to deploy their payloads into the desired orbits.

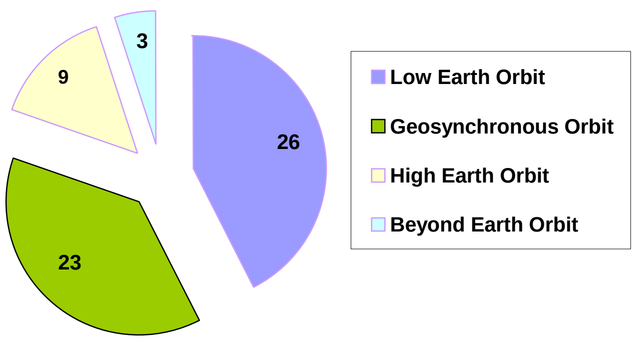
As has been the case since the beginning of the Space Age, the United States and the Russian Federation remain responsible for the greatest number of launches each year. Together, they conducted 41 of the 53 (77%) missions to reach Earth orbit or beyond in 2004. The only other entities to successfully launch more than one mission during the year were China with eight and the European Space Agency with three.

LEO remains the region of greatest interest, accounting for approximately 43% of all missions to reach Earth orbit in 2003 (Figure 2-2). GEO missions ran a close second with 38%, followed by other high Earth orbit missions (15%) and flights beyond Earth orbit (5%). As in past years, the vast majority of LEO missions were concentrated in the lower LEO regime (below 1000 km).

Overall, the space launch infrastructure throughout the world remains strong and underutilized. The 62 confirmed missions attempted in 2003 originated from 12 launch centers in North and South America, Europe, Asia, and the Pacific Ocean. Of these, seven launch centers supported only three or fewer launches during the year. Four other launch centers remained idle, as did submarine platforms, which can launch from various locations in the world.

The variety of launch vehicles available to deploy both small and large satellites to low or high altitudes is extensive. In 2003 a total of 26 launch vehicle classes were flown, not counting the variants of vehicles, such as in the Delta 2 and Soyuz families. Mirroring the situation with launch centers, numerous launch vehicle types were flown only a few times during the year and others were not used at all.

Figure 2-2 Space Missions of 2003



Forecasts for space launch activity in the years between 2010 and 2020 depend strongly upon both economic and technological assumptions. As suggested above, the capacity of the current space launch services sector far exceeds annual utilizations. Therefore, the sharp decline in launch activity during the 1990's was driven by other factors, largely economic in nature. In fact, advances in spacecraft technology, which have led to dramatic reductions in the size of spacecraft for a given mission capability, and the introduction of new, smaller, less expensive launch vehicles have often been cited as the rationale for projecting an increase in launch activity.

Figure 2-2 Space Missions of 2003

One important factor in the difficulties encountered by the LEO commercial communications systems of the 1990's was the arrival of other technologies, which benefited competitive terrestrial networks and also led to alternative communications solutions in high orbits. The high cost of developing complete space communications systems with numerous satellites and ground support and distribution facilities became less attractive from a commercial perspective. This in turn led to the cancellation or postponement of many proposed space systems.

The availability of relatively inexpensive small satellite launchers, beginning in 1990 with the Pegasus launch vehicle, also has not precipitated a rush to orbit as anticipated by many. Although markets for commercial space services from LEO, including communications and Earth observation, continue to grow, they do so at a slow pace. Even further reductions in the cost of placing satellites in orbit may not quickly result in a significant increase in space launch traffic.

The most promising, though not near-term, technology is that of reusable launch vehicles (RLVs). However, the first RLVs are unlikely to be fully operational before 2010. Even by 2020 their impact on the number or mass of satellites being deployed may not be great. Although they may replace some ELVs, RLVs may not lead to a marked increase in satellite usage, just as small launch vehicles have failed to do so. Even through 2020, the use of RLVs is likely to be restricted to supporting missions below 1000 km with emphasis on human space flight, such as to the International Space Station and for "space tourism".

Perhaps the most important lesson of the past 30 years is that, notwithstanding the revolutionary changes of the 1960's, mature space programs evolve slowly.

2.1.2. Active Satellites

The number of active satellites in orbit has increased at a steady but modest rate for more than a decade. Assessments of the total number of spacecraft currently operational or in a stand-by mode normally conclude that 700 is a reasonable estimate with the distribution of active satellites between LEO and HEO roughly equal. The precise number of active spacecraft is difficult to determine due to both national security and commercial constraints.

A total of 73 new spacecraft were placed into orbit in 2004, although seven had completed their missions by the end of the year or were unable to meet objectives due to orbital insertion problems. Consequently, only 66 spacecraft – less than 10% of the total on-orbit assets - were still operational at the start of 2005. Since the average spacecraft lifetime is less than 10 years, the 2004 launch rate is insufficient to maintain the existing level of active satellites.

Interestingly, for more than a decade the number of active satellites has increased at a roughly linear rate, remaining at about 6-7% of the total catalogued satellite population. The significant increase in the number of active satellites in the second half of the 1990's, following the deployment of the Iridium, Orbcomm, and Globalstar constellations, was largely offset by the number of operational Russian spacecraft, which fell from approximately 180 in the early 1990's to about than 100 in 2003. In recent years, lower launch rates and the failing of older spacecraft have mitigated the growth rate of active satellites.

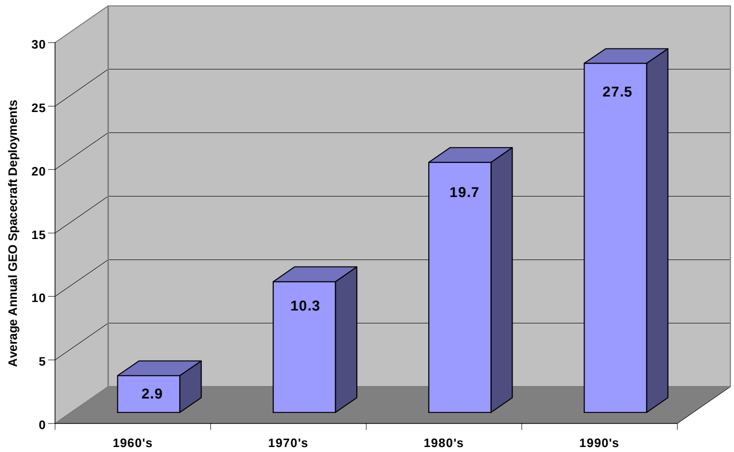
The geosynchronous orbital regime represents the greatest concentration of active satellites. For the past several years the number of functional spacecraft in GEO has been on the order of 275-300. Figure 2-3 indicates the annual rate of GEO satellite deployment in each of the past four decades. The GEO population is clearly the most diverse in terms of ownership with more than 35 countries and organizations owning assets there.

The demand for additional communications services from GEO has been met not only with an increase in the number of active spacecraft but also with a substantial increase in the capacity of individual spacecraft, which in turn has led to larger vehicles. In 1988 the PAS 1 spacecraft with a beginning-of-life mass of about 700 kg was launched by an Ariane 4 launch vehicle. Twelve years later, an Ariane 5 launch vehicle was needed to loft its replacement, PAS 1R, with a beginning-of-life mass of more than 3.000 kg. Although a few small GEO spacecraft are now being offered, the trend remains toward more massive satellites.

One of the noteworthy changes in satellite operations in the 1990's has been the increase in the exploitation of LEO by countries and commercial organizations alike. With the exception of the aforementioned commercial communications constellations, most of the new LEO satellite operators have deployed only a few, modest satellites. Earth observation has become one of the principal missions for these spacecraft, which prefer sun-synchronous orbits, usually between 450 and 1.000 km.

A renewed interest in very small satellites may foreshadow an increase in the number of active LEO satellites, although such spacecraft are normally short-lived. At least 10 satellites with a mass of less than 100 kg were deployed each year during 1999-2003. Some experimental satellites called picosats have a mass of less than 1 kg.

Figure 2-3 Deployment Rate of GEO Spacecraft



Operational space systems between LEO and GEO remain few in number. The US and Russian navigation satellite networks (GPS and GLONASS, respectively) operate in the regime near 19.000-20.000 km. The newly approved European Galileo navigation satellite system will have orbits near 24.000 km. The ICO constellation of communications satellites began deployment near 10.000 km in 2001, following an initial launch vehicle failure in 2000. On the other hand, the large communications and national defense systems of the former Soviet Union in highly elliptical, highly inclined orbits (so-called Molniya orbits) appear to be on the decline.

During the next two decades the number of operational spacecraft is likely to continue to increase at all altitudes with possibly the greatest increase in LEO. The rate of growth is difficult to predict, but during the next ten years the rate is unlikely to change significantly from the recent past. Even if the number of very small satellites launched annually were to increase, the relatively short lifetimes of these satellites would mitigate the overall effect on the number of operational vehicles.

2.1.3. Human Space Activities and Space Tourism

During the 20 year period of 1982-2001, human space flight activities accounted for 13% of all space traffic. On average, 7 piloted missions were flown each year along with 5 robotic logistics flights. In 2001 the percentage of space traffic devoted to human space programs reached 26%, primarily due to a reduction in Earth applications and science missions. The tragic loss of the Columbia Space Shuttle in early 2003 had a dramatic effect by dropping human-related space flights to only 10% of the world's space missions.

The centerpiece of human space flight for the next 10-15 years is likely to remain the International Space Station (ISS). With major modules provided by the United States, the Russian Federation, Japan, and the European Space Agency and with other significant contributions by Canada, Brazil, and others, ISS will continue to be the largest and most frequented assembly in orbit through at least 2014. On average, ten or more flights can be expected to dock with ISS each year.

The People's Republic of China began testing its Shen Zhou spacecraft in 1999, achieving its first human space flight mission in October 2003. China has expressed a desire to undertake a comprehensive human space flight program, with the establishment of LEO orbital platform and flights beyond Earth orbit.

The 2004 initiative of the United States to return humans to the Moon, Mars, and other destinations (the "Space Exploration Initiative"[16]) will lead to the development of a new Crew Exploration Vehicle (CEV), which is scheduled to replace the Space Shuttle after 2010. Variants of the CEV may operate in LEO as well as to support deep space missions. However, the number of annual CEV missions at least through 2020 is not expected to exceed the number of yearly missions previously undertaken by the Space Shuttle.

During the 1980's and 1990's ESA and Japan embarked upon programs to develop independent human space flight capabilities. Both programs would have directly supported the ISS. ESA's Crew Transport Vehicle (CTV) concept envisioned a vehicle of 10 metric tons launched by an Ariane 5 launch vehicle and capable of carrying a crew four. Although an Atmospheric Re-entry Demonstrator (ARD) was flown in 1998, the CTV project is no longer active. An unmanned logistics vehicle for ISS, called the Automated Transfer Vehicle (ATV), has continued under development, and its inaugural flight is expected in 2006.

Japan's initial entry into the arena of human space flight was to have been based upon the H-II Orbiting Plane (HOPE), a logistics vehicle under development for the ISS. The HOPE project was later replaced by the more conventional H-II Transfer Vehicle (HTV), which might fly as early as 2005 but does not possess the potential for human occupancy. No formal Japanese plans for the development of spacecraft to support human space flight now exist, although such a program was again under consideration in early 2004.

The establishment of a commercial space tourism industry has long been an unfulfilled goal. Only recently have fledgling endeavours to allow non-aerospace professionals opportunities to venture into space been seriously undertaken. In 2001, 2002 and 2005 paying private citizens from the United States and South Africa briefly visited the ISS via Russian Soyuz TM spacecraft. Similar flights at a frequency of 1-2 per year are possible.

In part to jump-start a true space tourism industry, the X Prize Foundation in 1996 offered a prize of $10 million to the first organization that *"privately finances, builds & launches a spaceship, able to carry 3 people to 100 km; returns safety to Earth; and repeats the launch with the same ship within 2 weeks"*.

16 http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf

Some of the other objectives of the X Prize Foundation have been to focus public attention and investment capital on space activities, to inspire and educate students, and to create a new generation of heroes. 20 teams from five countries have entered the competition. With the flight of SpaceShipOne in 2004, a new era began, where – if safety can be guaranteed – a certain amount of traffic in suborbital human flights can develop during the next two decades. The US FAA is working on guidelines for space tourism and presented a first draft regulation in early 2005.[17] Awarding the $10.000.000 ANSARI XPRIZE was not the end, but the beginning of an annual event called the X PRIZE CUP[18].

During the next two decades, human space flight activities will likely pose few serious challenges from a space traffic management perspective. Such missions will almost certainly be restricted, due to space technology and biomedical constraints, to the very lowest regions of LEO. Operational conflicts with the growing numbers of active satellites and space debris should be minor for now. The development in suborbital around 100 km high flights (involving systems, which still have to e regarded on a legal basis not as “space objects” but as “aircraft”) might however affect the use of the “grey zone” between air traffic and clear space activities thus becoming a serious concern for space traffic management.

2.1.4. Other Activities

2.1.4.1. Physical Basics of Orbital Motion and Possible Interference with other Human Activities

Space traffic has some fundamental characteristics, which distinguishes it from other human activities on land, sea and air environments. In those traditional environments, the motion of most objects can be speeded up or slowed down and its direction changed. In outer space, the ability to change velocity is the exception, rather than the rule. Even more important, objects on Earth can be at rest for indefinite time spans, but an object can last in outer space only if it is in orbital motion which is usually very fast compared to our everyday experience.

There are laws of physics which govern the motion of any object in space and must be taken into account in all efforts to regulate space traffic. To make matters simple, one can consider the Earth to be exactly spherical and influencing the motion of space object according to the Newtonian law of gravitation (neglecting the friction of its upper atmosphere). In this case the orbit would be elliptical and its focus would be in the centre of the Earth. The closest point of this elliptical orbit to the Earth (usually measured from the Earth surface) is called perigee, the farthest apogee. For lunar or interplanetary probes the orbit would be hyperbolic, the apogee being „in infinity“.

According to the one of the laws of planetary motions (formulated in the 17th century by Johannes Kepler), the orbital period would depend only on the mean distance of the satellite from the Earth, called semi-major axis, and not on the eccentricity of the orbit. This has an interesting consequence – for example a satellite at circular orbit (eccentricity equal to zero) 800 kilometres above the Earth needs exactly the same time to orbit the Earth (100.9 minutes) as a satellite at elliptical orbit of 400 to 1200 kilometres.

Another important characteristic of the motion of objects in elliptical orbit is a consequence of the conservation of energy law. The sum of potential and kinetic energy of the object remains constant. Therefore, the speed of the object is maximal at the lowest point (where the potential energy is lower) and minimal at apogee. A satellite moving at elliptical orbit between 400 and 1.200 kilometres changes its velocity from 7.88 to 7.05 kilometres per second.

The last basic characteristics that should be mentioned here is that the ideal satellite motion is taking place in the plane which is passing through the centre of the Earth and its position is described by two

17 http://ast.faa.gov/rep_study/license_safe_report.htm

18 http://www.xprizefoundation.com/index.asp

parameters (orbital elements): inclination to the equator, and position of its crossing with the equator (longitude of the ascending node). The velocity vector lies in this plane and it is therefore extremely propellant consuming to change the position of orbital plane in space. This is why all transport and re-supply missions to orbital stations should take place only when station's orbital plane is passing near to the launching place.
In the ideal world, the orbital elements described above would not change with time and prediction of the space object motion would be a matter of relatively simple computation. However, as will be described in part 2.1.7, the situation is much more complicated. In any case, these main characteristics of orbital motion lead to the following observations:

- The orbit of any space object is in principle determined by conditions at the end of the launching phase and by the gravity field of the Earth. Any substantial change of such orbit requires additional energy.
- Even with propulsion systems on board the space object, it would be costly (in terms of propellant consumption) to change the orbital plane and this fact should be taken into account in planning the new missions or correcting the orbit of existing systems.
- For elliptical orbits, it is most efficient to make their corrections at higher altitudes (near apogee), where orbital velocity is minimal. This is commonly used for transfer of satellites from preliminary highly elliptical transfer orbit into circular geostationary orbit.

2.1.4.2. Sounding Rockets and Balloons, Prospects for Hypersonic Travel, Tethers, Space Elevators, Autonomous Robotic Missions and High Altitude Platforms

It is often the case that at the border of different regions, specific activities could take place. This is true also for space traffic. To orbit a satellite, one should reach not only adequate altitude, but also necessary velocity – sometimes called the circular or first cosmic velocity. Because of the density of the upper atmosphere, satellites can typically orbit the Earth only at altitudes over about 100 kilometres. The velocity of an object in circular orbit at 100 kilometres would be 7.84 kilometres per second and it would take 86 minutes to orbit the Earth. This is the shortest possible orbit duration–all higher orbits will require longer times. Objects that are not able to make at least one complete orbit (with exception of objects leaving the Earth gravity field for good) are considered to follow a suborbital (or ballistic) trajectory. Such objects are not given the international designation by the World Data Center-A for Rockets and Satellites, located at the Goddard Space Flight Center in Greenbelt (Maryland), on behalf of COSPAR (Committee on Space Research). They also are not entered in the United States Satellite Catalog (where each space object has unique identification number) and consequently no State has announced these launches under the terms of the United Nations Registration Convention.

Before the launch of the first Sputnik in 1957, only sounding rockets and balloons explored the upper atmosphere. This allowed for short-time samples of the physical conditions in limited areas. Nowadays, such means are used mostly in combination with satellite devices to make detailed measurements during interesting periods (e.g. of increased geophysical activity) at specific locations (like polar regions or equator). Sounding rockets can reach altitudes over 100 kilometres, but because they are usually launched vertically, they potentially intrude into space traffic only in a limited area near the launching base. Military tests of ballistic missiles are more problematic for space traffic because they can reach high altitudes while covering a distance of several thousand kilometres. Therefore, careful coordination will be required in the future to avoid interference of suborbital objects with space traffic. It could be organized in a similar way as already existing arrangements, which ensure that during the launch, the space shuttle does not collide with any tracked space object.
Suborbital traffic may increase substantially in the near future. The reason is the growing interest in "space tourism". It is much cheaper and technically less demanding to send a special capsule with crew on board on ballistic trajectory than to orbit the whole Earth. Such a flight could last only tens of minutes, but space tourist will still experience weightlessness and panoramic view of our planet. After initial simple and infrequent missions, technology may evolve into more regular activities. The X Prize competition (see 2.1.3) is already stimulating developments in this direction. Of course, the de-

finitive breakthrough would be the development of aerospace plane, which would allow for commercial intercontinental transport through lower parts of outer space. The use of suborbital trajectories would lead to substantial shortening of flights – e.g. from New York to Tokyo in less than 3 hours.

The conventional delimitation of outer space and suborbital activities will be even more vague with introduction of the so-called tethered satellites. Recent simple experiments proved the feasibility of connecting two or more satellites by thin but strong tethers, which could be hundreds of meters long. As it was shown above, satellites at different altitudes have corresponding orbital periods. In tethered systems, the two satellites travelling in different orbits are forced to move around the Earth in the same time period. Thus, the lower satellite, which would normally have a shorter orbital period, is slowed down, while the upper one is dragged by the tether to a higher orbital speed. This produces a tension force in the tether that maintains the system in a stable configuration in which the tether is aligned with a radius from the Earth centre. There are many expected advantages of such systems – starting with scientific geophysical research and leading even to the possibility of producing energy through interaction with atmospheric particles and magnetic fields. By attaching a tether to large spacecraft, a scientific payload could be lowered deeper into atmosphere, where regular satellites cannot survive. On the other hand, long tethered systems would have substantial cross-section and would pose much greater collision danger to other satellites.

Looking into very distant future, it is theoretically feasible to develop such a long tether system that it could at one end reach beyond the geostationary orbit and at the other end be anchored to a suitable point of the Earth surface at the equator. This is a principle of a space elevator.[19] Realization of such a delicate system would require substantial improvement of technology, in particular the progress in the use of strong but light composite materials. Once such a system (or several systems at different points of the equator, connected through the geostationary arc) is constructed, it would change the very basics of the space traffic. Payloads could be moved along the elevator to outer space (to geostationary orbit and even into interplanetary space) without the use of rocket propulsion. Of course, such a large structure would interact with all objects orbiting below the geostationary orbit. A sophisticated system of small active movements of the structure to avoid collision with catalogued space objects was already proposed. The ultimate solution would be the elimination (sweeping-off) of all such obstructing objects and complete transfer of human space activities to this revolutionary system, as proposed by Sir Arthur C. Clarke.

Space traffic will also grow with the advent of autonomous robotic missions, e.g. servicing satellites.[20] This field will grow, if commercial applications, in particular for satellites on the GSO become feasible. Such missions will pose challenges to space traffic management, since they will be manoeuvring extensively in outer space.

High altitude or stratospheric platforms for purposes in the field of communications or remote sensing might be located at altitudes of 20 to 50 km. This is not yet outer space, but they have to be taken into account when transfers from and into outer space are regarded and when the grey zones between air law and space law are investigated.[21]

2.1.5. Debris Environment

The space debris environment has been steadily growing since the launch of the first artificial Earth satellite. Within three weeks of the launch of Sputnik 1, the Earth satellite population consisted of only

19 Space elevators have become a highly visible topic in the programmes of the International Astronautical Congresses. See also e.g. www.spaceelevator.com with many references. On legal aspects see Nase, Vernon, The Questionable Legality of the US Space Elevator Concept, in: German Journal of Air and Space Law ZLW(55,1) 2006, forthcoming.

20 See e.g. on the US mission DART (Demonstration of Autonomous Rendezvous Technology) www.msfc.nasa.gov/news/dart. Another mission in the past has been the Japanese ETS-VII satellite with German participation.

21 See Haanappel, P.C.C. High Altitude Platforms and International Space Law, IAC-04-IISL.5.07.

space debris: the inoperative Sputnik 1 and the derelict rocket stage which placed it into orbit. Since then the amount of space debris, both in numbers and mass, has risen dramatically. Today, approximately 95% of all orbiting objects tracked by the US Space Surveillance Network (SSN), 13.000 in all, is debris.

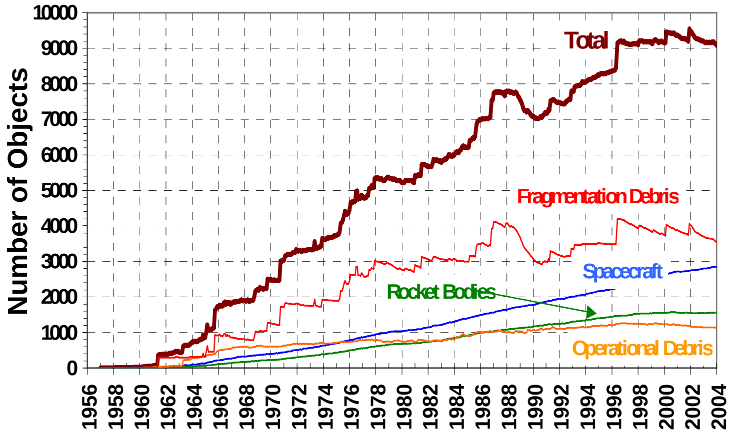
The working definition of space debris (part 1.3) encompasses non-functional spacecraft, launch vehicle stages and components, mission-related debris such as released lens covers or straps, debris created by surface degradation, and fragments from satellite explosions or collisions. Unfortunately, these debris are distributed through all operational satellite altitudes, from 200 km to more than 40.000 km.

Knowledge of the large (approximately 10 cm) debris environment primarily comes from the US SSN and the Russian Space Surveillance System (SSS), which both operate numerous, high-power radars around the world to monitor near-Earth space. Debris less than 10 cm in diameter but larger than about 2 mm can be detected by special radar observation techniques, but most cannot be tracked on a routine basis as are their larger cousins. To estimate the number of debris less than 1 mm in diameter *in situ* sensors are employed, and detailed examinations of impact craters on spacecraft surfaces which have been returned to Earth are performed. From these data statistical models can be developed to characterize the total numbers of debris smaller than 10 cm.

Some of the space debris have large masses. The 200 most massive rocket bodies have masses between 2 and 10 metric tons. The 200 most massive payloads cover approximately the same range. Most of them have no means to regulate their decay and avoid possible collisional break-ups into very large numbers of small debris.

By 2002, the number of non-functional spacecraft had grown to more than 2.000, while the number of rocket bodies and mission-related debris had reached 1.500 and 1.000, respectively. However, by far the largest contributor to the debris environment is satellite break-up debris, numbering approximately 3500-catalogued objects (Figure 2-4). More importantly, the number of break-up debris larger than 1 cm in diameter is probably greater than 100.000. A collision between debris of one cm in diameter and an operational spacecraft could well cause the latter to cease functioning.

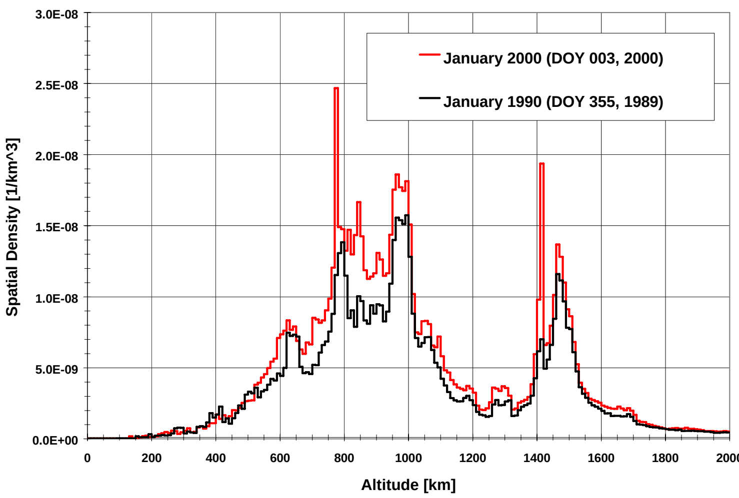
Figure 2-4 Growth of Earth Satellite Population



From 1960 to 1980, the catalogued satellite population (primarily debris) increased at an approximately linear rate of 240 satellites per year. By contrast, the net annual increase from 1980 to 2000 was only 180 satellites per year, due in part to the implementation of debris mitigation practices. The lower launch rates of the 1990's played virtually no role, since most of the "missing" missions were short-lived, very low altitude flights, which did not contribute to the long-term growth of the debris environment. During the second half of the 1980's and in 1996, sharp increases in the number of objects occurred due to satellite break-ups, although high solar activity in the following years helped to offset these increases by speeding up re-entry.

One of the principal measures of the amount of debris at any given altitude is spatial density, i.e., the average number of objects in a specified volume, usually measured in cubic kilometres. Figure 2-5 indicates the spatial densities of all objects in LEO in 1990 and 2000. Clearly the greatest concentrations of objects are near an altitude of 800, 1.000, 1.400, and 1.500 km. The sharp increases in spatial density between 1990 and 2000 at 780, 830, and 1.415 km altitude due to the deployment of the Iridium, Orbcomm, and Globalstar constellations, respectively.

Figure 2-5 Spatial Density in Low Earth Orbit, 1990 and 2000



Below 500 km, the spatial density changed little during the 10-year period, due to strong atmospheric drag, which limits the lifetime of satellites in orbit. However, for all altitudes above 500 km there is a distinct increase in spatial density. This reflects a steady growth in the debris population. For example, the 58 space missions of 2001 resulted in the cataloguing by year's end of 186 new objects. Of these, more than half (56%) were debris: 65 rocket bodies and 39 mission-related debris. On the other hand, just over a third (36%) of all 2001 mission objects (spacecraft and debris) had decayed by the start of 2002.

The primary source of debris in orbit, now accounting for more than 40% of all catalogued objects, is the break-up of spacecraft and launch vehicle orbital stages. More than 185 satellite break-ups had been identified by 2004. Although progress in curtailing the break-up of satellites, particularly orbital stages, has been achieved, much remains to be done. In 2001 alone, five orbital stages or their components exploded, creating hundreds of new debris. In all cases, the vehicles had performed their spacecraft delivery missions successfully, but residual propellants had been left on board. Four of the five stages had been in space for 10 years or more, and the design and operation of their launch vehicles have since been changed to prevent such occurrences. The launch vehicle associated with the fifth orbital stage to break-up in 2001 was redesigned before it flew again. In 2002 and 2003, the number of launch vehicle stages and components involved in break-ups not associated with re-entry were 2 and 3, respectively.

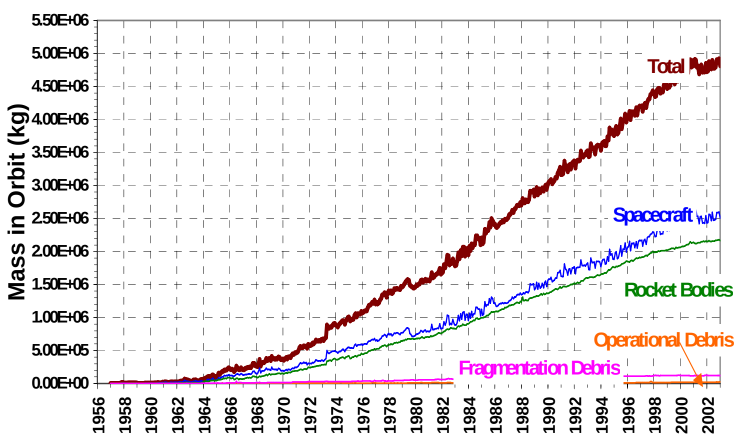
Curtailing the growth of the debris environment is essential to limiting the potential of future satellite collisions, which might disable an operational satellite but would certainly create large numbers of new debris. To date only one accidental collision between two catalogued objects - one an operational spacecraft and one a fragment from an exploded rocket body - has been identified. Such collisions over the next two decades should remain rare, but later in this century the rate will increase noticeably if debris mitigation measures are not adopted.

2.1.6. End of Service

Derelict spacecraft and orbital stages now outnumber active spacecraft by more than 5 to 1. This has led to a steady increase in the mass of satellites in orbit (Figure 2-6). From 1970-1980, the annual rate of satellite mass increase was about 110 metric tons. Since 1980, the rate has been very stable near 170 metric tons, and the total mass in orbit is now approximately 5.000 metric tons.

Disposal of spacecraft and orbital stages at the end of their useful lives is now recognized as an important aspect of mission design and planning. The two principal objectives are to avoid risks to operational spacecraft and to mitigate the accumulation of debris in orbit.

Figure 2-6 Growth of Satellite Mass in Orbit



The techniques of satellite disposal in LEO and GEO are different. In the former, spacecraft normally should be de-orbited directly into the atmosphere over a broad ocean area or should be transferred into a lower orbit with a natural decay time of less than 25 years. Orbital transfers may first lower apogee slightly below the operational altitude of the satellite network to eliminate potential collision hazards and then lower perigee sufficiently to ensure decay within 25 years. Several national space agencies and the IADC support this so-called 25-year rule.

To shorten the orbital lifetimes of launch vehicle stages, the spacecraft can be initially released at a low altitude from which they boost themselves to their operational altitudes (as done by the Iridium and Globalstar spacecraft). Alternatively, the launch vehicles can insert their payloads directly into operational altitudes and then perform perigee-lowering manoeuvres, as described above.

In the GEO, spacecraft should be moved to a higher orbit to prevent collisions or close encounters with active satellites. Since 1993, the International Telecommunication Union (ITU) and several other organizations have recommended that the minimum disposal altitude should be 300 km above GEO. In 1997, the IADC offered a more sophisticated recommendation, which calculates a minimum disposal altitude, based upon the characteristics of the spacecraft and generally results in minimum disposal altitudes of 235 to 450 km above GEO. This is to ensure that, in the long term, the solar radiation pressure and luni-solar perturbations (see 2.1.7) will never bring the spacecraft within 200 km of GEO. Any propulsion system used to insert spacecraft into GEO and later released should also subsequently manoeuvre it to a higher disposal orbit. Another option is to insert the spacecraft and propulsion system directly into the disposal orbit, followed by a manoeuvre of the spacecraft down into GEO. The ITU has now accepted the IADC GEO spacecraft disposal recommendation.

The retrieval of non-operational spacecraft and orbital stages now in orbit will likely remain a considerable challenge, both technically and economically, during the next decade or two. Several concepts have been proposed, but thus far, none have met feasibility and cost-benefit criteria.

In addition to the removal of spacecraft and orbital stages from congested regions, the vehicles should be "passivated" to prevent future explosions. Passivation includes the removal of all residual propellants and pressurized fluids by burning or venting, the discharge of all batteries, the deactivation of range safety devices, and the elimination of all forms of rotational energy, e.g., in momentum wheels. The implementation of launch vehicle passivation measures has been widely adopted by the aerospace community and has proven to be very effective.

2.1.7. Monitoring of Artificial Space Objects

Basic characteristics of orbital motion were described in 2.1.4.1. According to the Newtonian physics, position of space object could be computed at any instant if one knows the initial conditions of its motion and precise description of the acting force. Instead of six initial conditions (three components of position and three components of velocity), six orbital elements provide the same information, but describe the motion more transparently. As already mentioned, orbital elements would be constant in case of motion in the gravity field of the spherical Earth. Any other forces will cause *perturbations* of such an ideal orbit.

The most pronounced feature of the real Earth is its flattening (polar radius is shorter than the equatorial one by 21,4 kilometers). This causes slow rotation of the satellite's orbital plane, but does not change the inclination. This effect is zero for polar orbits. Also, the position of the perigee inside the orbital plane is changing with time. This motion is zero for inclination of 63.4 degrees and this fact is used for so called "Molniya orbits" (apogee of highly elliptical orbit stays over northern latitudes, which is useful for communications in those areas). Additional irregularities of the Earth gravity field cause more complex (usually periodic) changes of orbital elements, but do not change the total orbital energy. Therefore they do not substantially influence the lifetime of space objects.

The gravity fields of other celestial bodies also cause periodic perturbations of orbits of artificial satellites, particularly those on high elliptical orbits. The most important *luni-solar perturbations* influence mostly the eccentricity and inclination of orbits. This has found practical use in shortening the lifetime of last stages of launchers left in geostationary transfer orbits. In favourable oriented orbit, the perigee of several hundred kilometres could rapidly decrease by this effect, leading to the decay of useless rocket stage in several months time.

In contrast to previously described gravitational perturbations, the *non-gravitational perturbations* have the main effect to change the energy of space objects. The most important is the atmospheric drag, which systematically decreases the energy and for satellites in low and medium orbits is therefore the main factor determining their orbital lifetime. Even more important difference is that while gravitational perturbations can be computed with necessary accuracy, non-gravitational forces (atmospheric density, solar radiation pressure, thermal radiation of the Earth, etc.) are functions of time and it is very difficult to develop models which describe their influence adequately. This is the main reason why long-term predictions of space object's motion and time and location of their natural decay are usually very uncertain.
The atmospheric air density mainly depends on altitude, following an exponential decrease. The slope of this decrease and its day/night, seasonal, and latitudinal variations are strongly affected by solar activity, which follows an 11-year cycle, and by geomagnetic activity due to the interference of solar winds with the magnetosphere. Methods of predicting the space weather (changes in physical parameters of interplanetary space) are still at an early stage.

- Methods of tracking satellite

Orbits are uniquely described by 6 parameters, e.g. the six Kepler elements, or the 6 components of the combined velocity and position vector at a given time. These parameters can be determined from fits to observation data. Such data are received from radar, telemetry, optical observations or Global Positioning Systems (GPS). Radar and telemetry data consists of range, azimuth, elevation, and possibly the rates of change of one or more of these quantities, relative to a site attached to the rotating Earth. GPS provides the range and range-rate relative to a set of navigational satellites with precisely known orbits. Optical data consists of positions relative to celestial sphere or range to the station from laser observations. In any case, there is a complex mathematical apparatus involved in transforming such observational data into inertial position and velocity and consequently determining the orbital elements with their time variations. Because radar and optical systems collect data passively, they require no additional payload on the space object and can be used also for tracking space debris. At the same time they are the least accurate methods of orbit determination. Conversely, GPS data are more accurate but they require additional instrumentation on board. GPS can also be used for semi-autonomous orbit determination because it requires no ground support. So far, GPS instrumentation is used only on a minority of operational satellites and cannot be used for tracking space debris.

Therefore, in order to systematically monitor space traffic, a global network of observational points and considerable computational capacity must be available. At present, there are only two global networks that stand up to this task - the US Space Surveillance Network (SSN) and the Russian Space Surveillance System (SSS), both of which operate numerous, high-power radars and several sophisticated optical systems around the world to monitor near-Earth space. This involves detecting, tracking and cataloguing orbiting space objects. Other countries maintain tracking and telemetry stations for control of their space assets, but lack the capability to monitor space traffic as a whole. Experimental instrumentation to observe space debris by radio-electronic means is currently located in USA, Germany, France and Japan, and experimental optical systems are located in the US, Russia, ESA, Japan, France, the United Kingdom and Italy.[22]

22 ESA has already recognized that a comprehensive space observation capability of its own would be necessary and of strategic relevance (see the Resolution for a European Policy on the Protection of the Space Environment from Debris, adopted on 20 December 2000, ESA/C/CXLIX/Res.6) but is still in the course of shaping a respective strategy.

At the time of preparation of this study, there existed two practically independent catalogues (records of the characteristics of the orbital population, mostly collection of orbital elements), frequently updated by observations: the United States Satellite Catalog, and the space object catalog of the Russian Federation. Data are also archived in the Database and Information System Characterizing Objects in Space (DISCOS) of ESA. A catalog record can be stored on a number of media. An electronic format is most suited to the recording of such information, modification and updating of characteristics, manipulation of data for purposes of comparison, input to models of space environment and also access via networks by users for the purposes of querying and contribution. The well-known Two-Line Elements (TLEs) of unclassified space objects, produced by the SSN, have been available to the general public along with the NASA Satellite Situation Reports by the NASA Goddard Space Flight Center in Greenbelt, Maryland.

Current catalogs contain information on space objects as small as 10-30 centimetres in diameter. Some recent activities in the United States are aimed at tracking of 5 cm objects at altitudes below 600 km. Improvements to provide cataloguing of objects as small as 1 cm would be very difficult. Therefore, only statistical measurements can be used for modelling the space environment for objects of smaller sizes.

The capacity and accuracy of the current monitoring system are not sufficient to provide collision avoidance for all operational systems. Therefore, only crewed spacecraft are warned if an object is projected to come within a few kilometres. For example, if an object is predicted to pass through a box measuring 5 km x 25 km x 5 km oriented along the flight path of the space shuttle, the SNN intensifies its tracking of the potential risk object. If the improved fly-by prediction indicates a conjunction within a box measuring 2 km x 5 km x 2 km, an avoidance manoeuvre may be performed.

2.1.8. Findings

- 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 with high accuracy.
- The large majority of active satellites have no maneuvring capability and most others have only a limited capacity to change their trajectory.
- There has been a slow but steady decline of launch activities since 1980, but there is a rise in the number of launch vehicles available (currently 18). There is also a growing number of launch centers (currently 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 accounted for 13% of launches during the past 20 years. It might increase with the emergence of new actors in this field, but is likely to increase dramatically only after 2020.
- Following the successful flight of SpaceShipOne, there might be – if safety is guaranteed - a growing number of suborbital manned flights, including space tourists as passengers.
- Technologies like tethers, stratospheric platforms or space elevators, which might be introduced in the future, will have to be taken into account, in particular when rules for the launch and re-entry phase are developed. New concepts for satellites (like e.g. “autonomous nanotechnology swarms”) will raise requirements for in-orbit operations.
- Space debris is continuously growing in quantity (currently there are about 100.000 objects larger than 1 cm in low-Earth orbits, most of them not catalogued).
- The number of catalogued objects is steadily rising (currently there are about 9.000 catalogued objects larger than approximately 10 cm).
- The number of active satellites remains at 6-7% of the total catalogued objects.
- The US’s space surveillance capabilities dominate, followed by Russia and Europe. The US pro vides data and processed information on a voluntary basis.

- The capacity and accuracy of current space monitoring systems is not sufficient to cover small objects or to provide for orbital avoidance service for all space assets.
- There are two major catalogues of space objects, which is far from the comprehensive system of space traffic monitoring that is required.
- Information on space weather is still limited but is important for the operation of space objects as well as for the prediction of the debris environment.
- The constant monitoring and information of space weather would be a useful tool in implementing a space traffic management system.

2.2. The Current Legal and Regulatory Framework

The current legal and regulatory framework for space activities is characterized by a growing diversification. Its centrepiece is "international space law" in its narrower sense. This comprises the five space law treaties and the five United Nations General Assembly (UNGA) Resolutions as compiled in the UN brochure "United Nations Treaties and Principles on Outer Space".[23] These texts have been negotiated in the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), which therefore can be regarded as the primary forum for the development of space law. During the past decade, however, international regulations relevant to space activities have been elaborated increasingly in other international fora as well.[24] In a first instance, is the International Telecommunication Union (ITU), which deals with the allocation of radio frequencies; the World Trade Organisation (WTO) that deals with market issues. In addition, there are fora dealing with disarmament and private law. Parallel to these, the development of "soft law" provisions (without the binding force of treaties) has become an increasingly important factor in the regulation of space activities. Further, air law provisions have to be taken into account, when discussing certain aspects of space traffic. Thus, today's space law in the broader sense comprises much more than the small booklet with the UN texts.[25] Nothing proves this more than the encompassing approach to space traffic management.

2.2.1. Provisions of International Space Law

Space Law in the narrower sense, however, is the starting point for the reflection on the current legal and regulatory framework.[26] In particular the 1967 Outer Space Treaty lays out a set of principles, a number of which are of direct relevance to space traffic.

- The principle of utilisation of outer space for the benefit of, and in the interests of all countries.
- The principle of outer space being the "province of mankind".
- The principle of freedom of exploration and use of outer space.
- The principle of freedom of scientific investigation.
- The principle that the State retains jurisdiction and control over its space object, whether it is in outer space or on Earth for as long as it is registered with/by the State.
- The principle of non-appropriation of outer space, including the Moon and other celestial bodies.
- The principle of respect of international law, including the UN charter.
- The principle of use of outer space for peaceful purposes, and the interdiction of weapons of mass destruction.
- The recognition of astronauts as "envoys of mankind".

23 UN Doc. A/AC.105/572. The treaties are: Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty, OST) of 1967, Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (Astronauts Agreement) of 1968, Convention on International Liability for Damage Caused by Space Objects (Liability Convention) of 1972, Convention on Registration of Objects Launched into Outer Space (Registration Convention) of 1975, Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement) of 1979; the UNGA Resolutions are: Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space of 13 December 1963 (UNGA Res. 1962(XVIII)), Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting of 10 December 1982 (UNGA Res. 37/92), Principles Related to Remote Sensing of the Earth from Outer Space of 3 December 1986 (UNGA Res. 41/65), Principles Relevant to the Use of Nuclear Power Sources in Outer Space of 14 December 1992 (UNGA Res. 47/68), Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries of 13 December 1996 (UNGA Res. 51/122).They can also be found at http://www.oosa.unvienna.org/spacelaw/treaties.html.

24 See United Nations, proceedings of the Workshop on Space Law in the Twenty-First Century, 1999 (UN Doc. A/CONF.184/7) and Liebig, Volker/Schrogl, Kai-Uwe, Space Applications and Policies for the New Century, Frankfurt 2000, 187-202.

25 See the four folders of Böckstiegel, Karl-Heinz/Benkö, Marietta/Hobe Stephan (eds.), Space Law Basic Legal Documents, 1999 ff with far more than 100 relevant texts amounting to many hundred pages.

26 See Jasentuliyana, Nandasiri, International Space Law and the United Nations, Den Haag 1999.

These principles are complemented by regimes on liability and the registration of space objects. These regimes are contained in the respective Conventions of 1972 and 1975. Thus, it can be stated that the existing legal framework provides the foundation for the establishment of a space traffic management regime has been laid. There is no real traffic management scheme so far – as will be shown in the following section (2.2.2) – but it contains all principles, which are relevant to establishing such a regime. The duty to cooperate in outer space, the freedom of use and the other principles mentioned above, seem to call for a more precise regulation to ensure safety and proper implementation.

For this purpose, the principles enshrined in the Outer Space Treaty were further elaborated in subsequent treaties and UNGA Resolutions have been worked out. The most recent, UNGA Resolution, the Space Benefits Declaration of 1996, is exactly the interpretation of a principle, laid down in Article 1 of the Outer Space Treaty. The principle of freedom of exploration and use of outer space, in the same Article, might become the anchor for the elaboration of a space traffic management regime. Freedom of use can be guaranteed only when all users respect this principle. This can only work, if rules of the road–limiting complete freedom but assuring the basic freedom of use and the safe execution of this right–are established.

2.2.2. Missing Provisions in International Space Law

International space law is far from complete in the sense that it provides answers to all possible questions. So far, it has provided a slim but robust framework for space activities. But in particular the emergence of space activities by private actors leads to a number of problems of interpretation and application of the treaties and sets of principles, which still have not been answered in all their aspects. This is in general true for space activities by private actors, which have to be conducted with authorization and continuing supervision by an appropriate State. But with only 100 States being party to the OST and only a few having established national authorization mechanisms, private actors might escape being governed by international space law provisions.[27]

Of particular relevance to space traffic management is the lack of a legal delimitation of air space from outer space. So far, the delimitation, although on the agenda of the UNCOPUOS Legal Subcommittee for decades, has not been settled.[28] This, however, has not had any effect on space activities, since the application of space law has not been questioned in any specific case. The missing delimitation on the other hand can become a problem, when the re-entry of reusable space vehicles is concerned. While the US Space Shuttle descends over international commons its own national territory, the Soviet Shuttle Buran descended the last 8.000 km of its flight at an altitude of below 100 km over the national territories of numerous African States and Turkey.[29] A space traffic system has to answer the question of where the "innocent passage" of reusable vehicles starts.

Space law is also missing some other features, which are relevant to space traffic[30]:

- The Registration Convention does not require pre-launch notification but only requires registration following the launching. Provisions for pre-launch notifications only exist on a multilateral basis in the non-legally binding Hague Code of Conduct against Ballistic Missile Proliferation (HCOC).
- 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).[31]

27 E.g. the problems arising from the application of the legal principle of the "launching State" and the threats of "flags of convenience" in outer space, see Schrogl, Kai-Uwe/Davies, Charles, A New Look at the Concept of the "Launching State". The Results of the UNCOPUOS Legal Subcommittee Working Group 2000-2002, in: German Journal of Air and Space Law ZLW, (51,3) 2002, 359-381.

28 See Goedhard, Robert, The Never-Ending Dispute: Delimitation of Air Space and Outer Space, Gif-sur-Yvette 1996.

29 See Benkö, Marietta/Gebhard, Jürgen, The Definition/Delimitation of Outer Space and Outer Space Activities including Problems relating to the Free ("Innocent") Passage of Spacecraft Through Foreign Airspace for the Purpose of Reaching Orbit and Returning to Earth, in: Benkö, Marietta/Schrogl, Kai-Uwe (eds.) International Space Law in the Making, Gif-sur-Yvette 1993, 111-149,

30 Cf. AIAA 2001 and Perek 1982.

- There is no prioritization of manoeuvres, no traffic separation ("one-way-traffic").
- There are no "zoning" rules (restriction of certain activities in certain areas).
- There are no communication rules (advance notification and communication if orbits of other operators are passed).
- There is no legal distinction made between valuable active spacecraft and valueless space debris.
- There are no legally binding rules with regard to the mitigation of space debris and the disposal of spent space objects as well as the prevention of pollution of the atmosphere/troposphere.
- Space law lacks enforcement mechanisms. There is no "police" in outer space and there is no elaborate dispute settlement system, although the Liability Convention includes a system for settlement of claims.
- Private space activities can in some cases may escape (i.e., not be subject to) space law, which is still State centred,
- and, as already pointed out, the legal delimitation of air space and outer space is missing.

A space traffic management regime has to fulfil these shortcomings of international space law.

2.2.3. Provisions of National Space Legislation

Space Activities by private entities are possible under existing space law. There is, however, a provision in Article 6 of the Outer Space Treaty requiring appropriate States to authorize and continuously supervise such activities, since States bear international responsibility for all national activities in outer space. Building on this provision, a rather small number of States has enacted national space laws in order to create regulation for this purpose of authorizing private activities.[32] So far, only about a dozen States have adopted such laws, varying in scope and content. At least ten others are working on such legal projects. While there are some initial attempts in UNCOPUOS to harmonize these activities and their outputs, no mechanism has yet been found to fulfil that promise. Harmonization is necessary in view of various consequences for a comprehensive space traffic management regime:

- National space legislation should establish technical and safety standards for space objects.
- If every State sets its own standards, this lack of harmonization could lead to different safety standards ("flags of convenience") and distorted competition.
- A space traffic management regime therefore has to consider the issue of harmonizing national space legislation, its licensing standards and procedures.

Rules intending to achieve safe access to outer space, safe operations of space activities, collision avoidance as well as the prevention of pollution (as intended by this study) can be found within national space acts and other national regulations (e.g. licensing regimes). But one has to take into account that these rules originally were not meant for dealing with traffic management. One may differentiate between rules applicable to all space operations and those applicable only to a certain phase of space operations (launch / in-orbit / re-entry).

31 There is no legal basis in international space law, which would clearly make it imperative e.g. to ban funerals in space, a practice, which is already applied and which simply produces space debris. International space law does not contribute it another status than e.g. satellite telecommunications. On the other hand, there has already been at least one step taken by a government to forbid a particular use of outer space: the US House of Representatives reacted to complaints by the scientific community (in particular astronomers) about light pollution and passed an act (H:R.1654, §70109a. Space Advertising) in 2001, which would prohibit obtrusive advertising in space.

32 See von der Dunk, Frans, Private Enterprise and Public Interest in the European Spacescape – Towards Harmonized National Space Legislation for Private Space Activities in Europe, Leiden 1998 and Gerhard, Michael/Schrogl, Kai-Uwe, Report of the 'Project 2001' Working Group on National Space Legislation, in: Böckstiegel, Karl-Heinz (ed.): 'Project 2001' – Legal Framework for the Commercial Use of Outer Space, Cologne 2002, 529-564.

- General Rules

National rules do not enter into the question of an equitable access to space. But there are rules dealing with the safety of space activities. These rules intend to prevent damages, and also deal with the potential risk of the legislating State's liability as a Launching State (Art. VII LIAB). While these provisions typically are established with regard to long-term prevention, some provisions intend to avoid impending collisions to the same end. For these purposes regulations are necessary to provide the appropriate authority with the necessary information, including the observation of a space object / activity during all its phases of space operation. Finally one might identify general rules with regard to the prevention of pollution of the near-Earth space.

For each of these rules the following paragraphs aim to identify the sphere of application as well as its content in order to determine whether or not they are also applicable to space operations that are examined in the present study.

Safe Operations

Ensuring safe space operations is one of the intents of all of the National Space Acts regulating the authorisation of a space activity with regard to Art. VI OST. Therefore the authorising State typically requires that the applicant demonstrates that the activity will not create public health or safety of persons or property problems. The method of such a demonstration varies from one State to another. In the UK a very elaborate document-based safety check is undertaken. In Russia the applicant only has to confirm the safety of the space operation including its reliability by presenting adequate documents (Sec. 5 Licensing Statute). In Australia, the Minister requires a technology security plan (Sec. 2.13 Space Activities Regulations) and in the US a safety approval is necessary (CFR 14 / III / 415.31 et. seq.; Regulations of the Communications Act).

In order to stop dangerous space activities, all States have (according to national law) the right to suspend or revoke a licence once granted.

Collision Avoidance

Collision avoidance (and warning) may also be subject to all three phases of space operation, as interference may emerge while a space operation is targeted on (i) launching a space object and inserting it into an orbit while crossing other orbits, (ii) operating a space object in its orbit while other objects may transfer that orbit and on (iii) transferring through other orbits while re- or de-orbiting a space object in finalising a space operation.

The primary instrument established by national law to avoid any collision emerged from the necessity to build up a national registry for space objects according to Art. II (1) REG. Here all States require the operator of a space object to furnish the basic orbital parameters (e.g. in the US CFR 14 / III / 415.81, in Australia Sec. 76 (2) of the Space Activities Bill, in Argentina Art. 5 of the Regulations to the Register of objects launched into outer space, in the UK Sec. 7, 5 (2)(b) of the Outer Space Act, and indirectly in Sweden Sec. 4 of the Decree on Space Activities, in Ukraine Art. 13 of the Law on Space Activities). In practice, the information is of little effectiveness because it is concerned with only the basic parameters and because there is no real obligation to furnish such information within an adequate timeframe. Furthermore, most of all debris / inactive parts are not considered as being a space object by the legislating State. Finally there is no additional step (by these laws) in making use of these data in order to provide a (national or international) collision warning / avoidance system – except what is examined within the license-granting and supervision process in order to ensure the safe operation of that very space activity).

In the US, a new NASA mission may decide to utilize a certain orbit at any inclination without coordinating with any other domestic (governmental or private) or foreign mission already at that altitude.

Even US regulatory agencies, such as the FCC and the Department of Transportation grant commercial licenses with little or no regard to the presence of existing operational spacecraft or debris near the proposed orbit.[33] In the UK an advance approval is necessary for any intended deviation of the given parameters. If the deviation is unintended, the operator only has to inform the Secretary of State. In Sec. 5 of the Outer Space Act the legislators require the applicant for a licence not to interfere with other activities in outer space.

Information on space operations

Information on the objects being part of the space operations might be given by a notification / certification process as established in Russia and the Ukraine.

General information is given to all States which have implemented Art. II (1) of the Registration Convention with regard to the name of all Launching States, an appropriate designator of the space object or its registration number, the date and territory or location of launch, the basic orbital parameters and the general functions of the space objects. Some States (e.g., Argentina) require further information. Here, inter alia, the mass of the object has to be given to the registrar. Other general information is given while applying for the licence to perform a space activity as mentioned above.

Some States (e.g. Australia and the UK) also require information that has changed during a space mission. Most of the States are legally entitled to enter launch sites and other facilities in order to obtain the necessary information (typically with regard to their obligation to supervise a space activity). In Australia, a Launch Safety Officer may be nominated.

Observation of space operations

The monitoring of a space activity (in space – not on the facility) is not regulated at all.

Prevention of Pollution

The obligation to prevent contamination of outer space or adverse changes in the Earth environment is explicitly regulated in the UK Outer Space Act for those activities subject to these licensing requirements (Sec. 5). This is similar to the Russian Space Legislation. Here, Art. 5 of the Licensing Statute requiring (within the licensing procedure) a confirmation by the applicant of the ecological safety of the relevant space operation. In the Ukraine the protection of the environment is a general purpose of the Law on Space Activities (Art. 8). In the US (National Environmental Policy Act) and in Australia (Sec. 2.17 Space Activities Regulations) the launching of a space object is subject to an ecological check. The subject is treated differently in Argentina. Despite a regulation concerning the licensing of space activities, precautions vis-à-vis an adverse effect on outer space have to be included in the national register of space objects (Art. 5).

- Rules applicable to certain phases of space operations

Besides these rules applicable to all phases of space operation one might identify other rules, especially applicable to the launch phase, the in-orbit phase or the re-entry phase.

The launch phase

According to the structure of the Australian Space Activities Bill, the Space Activities Regulations extensively deal with requirements concerning the licensing of a launch facility and launch vehicles. Especially the program management plan (2.11.) and the technology security plan (2.13.) specify the above treated requirements on a safe operation. For the launching itself, these are specified by the standard launch permit conditions (3.02.).

33 Johnson, Nicholas L., Space management concepts and practices, IAC-03-IAA.5.5.a.01, 4.

Special rules concerning the launch phase might be envisaged because of the involvement of reusable launch vehicles / aerospace objects. Those vehicles only exist to a certain extent in the US (the Space Shuttle System) but not in other States. Nevertheless such rules cannot be found within space law provisions of the US Some regulations deal with the transit of a space object through national air space.

The in-orbit phase

Explicit norms regulating the in-orbit-phase of a space operation do not exist anywhere in national space laws. There are no norms dealing with “right of way – rules”. As far as some States have incorporated the ITU obligations regarding notification, coordination and registration of satellites into national law, the access to and use of those orbital slots is predominantly governed by the ITU-RR.

Specific uses of space (“zoning rules”) are indirectly implemented in national space laws, namely - as one may argue - those restricting space activities by requiring licences for performing such an activity. Insofar, the crucial point is the form of the sphere of application of the licensing procedure. In most legislation this applies to the “performance of space activities”. As far as specific uses (e.g. advertising or funerals) are part of that notion, these activities may be restricted by the licensing requirements. As far as they are not (or as far as States do not have a national licensing system according to Art. VI Outer Space Treaty), there do not exist any restrictions by national law (as according to a basic principle of the rule of law, everyone is free to perform an activity, which is not restricted). Hence, the notion of “space activities” as well as its legal definitions have to be interpreted on a case by case study, whether or not a specific use is part of the notion of “space activities” and therefore may be restricted. A generous interpretation of that notion does not seem possible where “space activity” has to be interpreted as operating a space object (UK, Sweden, South Africa), where the activity has to be performed in orbit (Sweden) or where only the launching and re-entry is regulated (Australia). The Russian Law on Space Activities extends its sphere of application to all activities performed in order to explore and use outer space and any other activity performed by using space technology. According to that law specific uses as introduced above may be restricted e.g. for safety reasons.

Most recently, the US has established a collision avoidance policy (which does not have the legal status of national space legislation): the 2003 revision of NASA’s policy on limiting space debris generation, NASA Policy Directive 8710.3A, includes for the first time a responsibility of the program or project manager to coordinate with the Department of Defense before any manoeuvre which changes the altitude of the orbit by 1 km.[34] It is, however, stated that this is primarily driven by liability considerations since the daily collision risk would be much greater than that associated with a manoeuvre.

34 Johnson, Nicholas L., Space management concepts and practices, IAC-03-IAA.5.5.a.01, 7.

The re-entry phase

The termination of a space operation is regulated only in the UK Outer Space Act. According to Sec. 5 the original licence (to perform a space activity) may be granted under the condition that the licensee notifies any final disposal of the payload and that the Secretary of State may issue guidelines on how the disposal may take place. Here one might tie up at least some regulations concerning the intentional de-orbiting and the co-ordination of its re-entry. As these conditions may be varied (according to the requirements of Sec. 6) by the Secretary of State during every single moment of the space operation, such a condition may be added also by the end of a space operation.

The involvement of reusable launch vehicles and aerospace objects is only taken into account in some US (policy) regulations. Nevertheless, other national air space might be concerned with the (launch or) re-entry of such an object. That might cause problems and interference, which can be subject to national legislation. Two year ago, in the US, the FAA/AST developed a concept of operation for commercial space transportation in the national airspace system. Against the background of the increasing number of launch activities as well as the upcoming use of reusable launch vehicles and aerospace objects using the same air space as aviation traffic, the integration of space and aviation operations is essential. Suggesting amongst other a single infrastructure for those, a specific process of review and approval for the relevant space operations or special transition corridors and flexible space ways, the concept gives a very detailed impression on what has to be done on that part.

- Conclusions

- To a certain extent national space laws and other national regulations provide an adequate starting point to deal with traffic management. But considering that these norms are drafted with the object of implementing Art. VI OST and of reducing the risk of liability, they are not in every case appropriate to meet all targets.
- An additional problem arises if the intended sphere of application for the traffic management rules varies from that of the national space legislation (which is mostly applicable to space activities or space objects).
- Finally, not all purposes of traffic management are dealt with in national laws, these have to be drafted, taking into account international agreements. Nevertheless, the above examined norms may provide a basic approach to the implementation of traffic management, either in addition to, or within these national space laws.

2.2.4. Other Provisions of International Law (Telecommunications, Trade, Disarmament, Private Law)

- Telecommunications Law

International telecommunications law deals basically with space radio stations, i.e. with radio stations installed on spacecraft. It does not deal with spacecraft as such. Yet, to a certain measure, telecommunications law contains certain features of a space traffic management regime, primarily with the purpose of avoiding radio-frequency interference but also in some cases with the purpose of avoiding physical interference. Through the allocation of frequencies and associated orbital positions in the GEO, the International Telecommunication Union (ITU)[35], on the legal basis of its Constitution and its Convention as well as its Radio Regulations, regulates this segment of outer space by providing a basis for a comprehensive traffic management regime in this specific instance. Allocating positions in the GEO (regardless of the different approaches called "first come, first served" and "a priori planning", which also represent different political concepts for the utilization of outer space and the distribution of resources) the ITU comprises some features of space traffic management as mentioned above (2.2.2):

35 On ITU’s structure and working mechansims see www.itu.int.

- i.a. a pre-launch notification system, the separation/spacing of satellites (to avoiding radio-frequency as well as physical interference) through allocating these positions, and elements of dispute settlement.
- The ITU, however, does not deal with launch activities, nor does it comprise specific rules for movement in outer space; it only deals with the static question of positioning satellites in this specific orbit.

The ITU rules are applicable only to the use of the GEO and not to other orbits or space activities. Its basic legal foundation is the principle that the GEO is a limited natural resource. This became part of international law (not in the OST but in the International Telecommunication Constitution) in the early 1970s. Most recently the status of limited natural resource has been enlarged to include all satellite orbits.[36] This could be a door-opener for further actions by ITU to establish elements of space traffic for other orbits (especially LEOs populated by satellite constellations, the Global Mobile Personal Communication Systems, GMPCS), since they have to be used as it is part of the relevant provision in the ITU Constitution, which constitutes international law:

- rationally, efficiently and economically
- so that countries or groups of countries may have equitable access to those orbits.

The establishment of these legal principles and the perspectives for ITU's regulatory powers have also led to the idea of making the ITU the overall institution for the management of outer space resources (possibly by imposing usage fees) and consequently for space traffic management.[37]

- Trade Law

With the establishment of the World Trade Organization (WTO) in 1997, satellite communications have lost their purely technical definition and have become an object of global trade in the legal sense.[38] The Annex on Telecommunications[39] comprises two aspects with relevance to space traffic management. These are the opening of the markets for satellite telecommunication services and the establishment of dispute settlement procedures within the WTO for this sector, thereby filling a gap in space law, at least for this limited purpose.

- Disarmament and arms control

International agreements in the area of disarmament and arms control can indirectly influence space traffic. International law only prohibits the stationing of weapons of mass destruction in orbit (OST) and the testing of nuclear weapons in the atmosphere (NTBT). The use for military purposes and the stationing of other weapons in space is not prohibited. Their stationing or eventual use might hinder the use of outer space by other actors. Arms limitation and non-proliferation measures like the Missile Technology Control Regime (MTCR) do eventually have an influence on the number of launch providers.
Already in 2000, the US and Russia had agreed on prior notification with regard to launch activities, but information had only to be shared amongst the two partners.[40] A few years later the International Code of Conduct against Ballistic Missile Proliferation was adopted at an international conference in the Hague on 25-26 November 2002. The Code had been developed within the MTCR. The Code was

36 Article 44,2 of the ITU Constitution.

37 See Lyall, Francis, On the Reform of the ITU and Commercial Use of Outer Space, in: Böckstiegel, Karl-Heinz (ed.): 'Project 2001' – Legal Framework for the Commercial Use of Outer Space, Cologne 2002, 259-281.

38 See in detail Salin, Patrick A., Satellite Communications Regulation in the Early 21st Century – Changes for a New Era, Den Haag 2000.

39 General Agreement on Trade in Services (GATS), Annex 1B to the Agreement establishing the WTO, WTO Agreement on Basic Telecommunications; see the texts at http://www.wto.org/english/docs_e/legal_e/final_htm#services.

40 Memorandum of Understanding on Notification of Missile Launches of 16 December 2000. The text is posted on the webpage of the US State Department http://www.state.gov/www/global/arms/treaties/mou_msllaunch.html.

later renamed “the Hague Code of Conduct against Ballistic Missile Proliferation (HCOC)”.[41] The Code is a non-legally binding instrument, but its political impact is of considerable nature. With 117 subscribing States by the end of 2004[42] and with a structure of a secretariat function through the Immediate Central Contact (ICC) and with inter-session meetings and regular meetings of subscribing States on a yearly basis, it has become an important multilateral instrument. The Code sets out provisions for transparency measures in the form of annual declarations to be submitted by the subscribing States on national Ballistic Missile and Space Launch Vehicle programmes. According to HCOC Article 4 iii) the Code provides for the exchange of pre-launch notifications on national Ballistic Missile and Space Launch Vehicle launches and test flights, which should include such information as the generic class of the Ballistic Missile or Space Launch Vehicle, the planned launch notification window, the launch area and the planned direction.

Discussions in the Conference on Disarmament (CD) recently brought up again issues of openness and confidence building in the use of space. The Russian Federation made an initiative in June 2003 announcing their willingness to provide advance notification of forthcoming spacecraft launches and of their purpose and main parameters.[43] Thus, the shortcomings of the Registration Convention, which requires no prior notification, is – at least politically – supplemented at the international level.

- Private Law

The International Institute for the Unification of Private Law (UNIDROIT) drafted a Convention and three Protocols on international interests in mobile equipment, one of which deals with satellites/space assets.[44] It seeks to establish a register of economic interests in space assets, which will complement the registration mechanisms of the Registration Convention (UNOOSA), and the ITU Radio Regulations, which register space radio stations.

2.2.5. Provisions of Air Law

The Chicago Convention of 1944 is the international instrument which contains the basic rights and obligations of the States parties to the Convention with respect to the use of national, foreign and international air space. It provides the fundamental legal foundation for the regulation of world civil aviation. The Convention and its Annexes deal in particular with the safety aspects of aviation and provide for detailed technical and operational requirements to which the parties have to or are advised to adhere (so-called “Standards and Recommended Practices”). But it also contains several articles, which bear on the economic regulation of international air transport.[45]

The Convention is also the constitution of ICAO, the International Civil Aviation Organization, a specialized agency of the UN with headquarters in Montreal, whose membership stands at almost 190. ICAO’s mission is to promote the safe and orderly development of international civil aviation throughout the world.

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41 International Code of Conduct against Ballistic Missile Proliferation (The Hague CoC) of November 2002, http://www.state.gov/t/np/rls/fs/27799.htm.

42 General Assembly resolution A/RES/59/91 of 17 December 2004 “The Hague Code of Conduct against Ballistic Missile Proliferation”.

43 UN Doc. CD/1710 of 26 June 2003. The Russian initiative is posted on the webpage of the Russian Foreign Ministry http://www.ln.mid.ru/ns-dvbr.nsf/engdvzaprkt.

44 See Stanford, Martin, The UNIDROIT project for the creation of a new legal regimen governing the taking of security in high-value mobile assets, in: Proceeding of the Third ECSL Colloquium: International Organisations and Space Law 1999, esa SP-442, 375-380.

45 See the Preamble, which provides i.a. “… the undersigned governments having agreed on certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically.”

Article 1 of the Chicago Convention contains the guiding principle governing international air transport, *i.e.* the State's sovereignty over its air space: "The contracting States recognize that every State has complete and exclusive sovereignty over the airspace above its territory".

This principle had already been recognized when its predecessor, the Paris Convention of 1919, was adopted and was therefore never a point of real debate. Understandably, given the time of adoption, the Convention does not provide for a definition of air space. It was said at the time that it reflected the Roman adage *Cuius est solum eius [est] usque ad coelum et ad inferos*, or 'who owns the land owns down to the center of the earth and up to the heavens'. Where the heavens end was not considered relevant at a time when space exploration was still only a dream. Note that "territory" in the above provision includes territorial waters.

Article 6 of the Convention applies this sovereignty principle in greater detail to international air transport services: "No scheduled international air service may be operated over or into the territory of a contracting State, except with the special permission or other authorization of that State, and in accordance with the terms of such permission or authorization."

In other words - and this applies in practice also to non-scheduled or charter services - national airspace is closed for foreign aircraft unless admission is specifically granted. There is no right of 'innocent passage'. And by multilaterally agreement, there is no freedom to operate air services from one country to the other. International air transport could thus only develop through a series of bilateral air transport agreements (treaties) resulting from intergovernmental negotiations between sovereign States and concluded for the benefit of the national airlines concerned.[46] There are now over 3000 of such 'bilaterals' worldwide, standardized in form but, because of differences in commercial airline interests, size of markets and negotiating strengths of the States concerned, they vary greatly in substance.

To mitigate the effects of the prohibition laid down in articles 1 and 6 of Chicago, a group of States at that Conference concluded the *International Air Services Transit Agreement* also known as the *Two Freedoms Agreement* through which they exchanged, on a multilateral basis, the right to overfly (fly through the airspace of) the territories of the parties to that agreement (1st freedom) and to land in those territories for technical/operational, *i.e.* non-commercial, reasons (2nd freedom). As of 1 April 2004 there are 121 parties to this agreement, creating a large area of freedom to transit air space across the globe for the international airlines concerned. But some countries with large and/or strategically located territories such as China, Russia and Canada have not ratified this agreement. The right to overfly these countries is thus the subject of bilateral negotiations between those countries and the countries whose airlines would like to use this right on a more permanent basis. The price tag attached to the right thus obtained may be steep!

It has become standard practice for countries to include in bilateral air transport agreements, which regulate commercial access (the right to transport passengers and cargo in both directions) of airlines to the foreign countries concerned, these 'two freedoms' irrespective of their being a party to the above multilateral agreement or not. The transit right may thus be guaranteed by two different instruments. But of course nothing prevents a country from withdrawing from or terminating both the multilateral and the respective bilateral agreement(s).

Though 'air space' was not defined, 'aircraft', the machines or devices used by the airlines to operate their air services, did get a definition, which is found in the Annexes to the Convention: "…any machine that can derive support in the atmosphere from the reactions of the air *other than the reactions of*

46 Note that the European Commission has been authorized by the EU member States to engage in such aviation negotiations on behalf of all member States (and their airlines), though initially only with the US Separately, a 2002 judgement of the European Court of Justice has outlawed the traditional 'nationality clause' in bilateral agreements concluded by individual member States with third countries as this clause allows only the national airlines of the two parties concerned to benefit from the respective rights included in the agreements concerned: also when it concerns international air transport to/from the EU, discrimination amongst European airlines on the basis of nationality is forbidden.

the air against the earth's surface".[47] The text in italics was added in 1967 to exclude hovercraft from the provisions of the Convention.

Reusable launch vehicles such as the space shuttle, while flying or 'gliding' back to earth, could be considered to fall under this definition. In practice, however, given the primary space goal, functions and features of the shuttle, the application of space law to the latter has been deemed more appropriate, and is, for all practical purposes, undisputed. The fact that the space shuttles use air space necessitated the making of ad hoc arrangements to avoid interference with other air space users. The US Department of Transportation (DOT) is in charge thereof.[48]

- Air navigation services and facilities[49]

"Each contracting State undertakes to adopt measures to insure that every aircraft flying over or manoeuvring within its territory and that every aircraft carrying its nationality mark, wherever such aircraft may be, shall comply with the rules and regulations relating to the flight and manoeuvre of aircraft there in force. Each contracting State undertakes to keep its own regulations in these respects uniform, to the greatest possible extent, with those established from time to time under this Convention…" So reads the general rule of article 12 of the Chicago Convention.

Air traffic management and related services are the subject of specific rules and regulations promulgated by ICAO, the so-called *standards and recommended practices* (SARPS)[50], which are of a 'quasi-legislative' nature. This qualification is used because the member states are not obliged to fully and completely implement and/or comply with the regulations so adopted but have the freedom to deviate as long as they immediately inform ICAO of such deviations or 'differences'. This reflects the above mentioned sovereignty principle, also - implicitly or expressly - referred to in other articles of the Convention.[51] Apart from SARPS, there is a veritable plethora of procedures, guidelines etc.

47 Annex 2, Chapter 1. Definitions and Annex 11, Chapter 1. Definitions.

48 Within DOT, the Federal Aviation Administration (FAA) and, within the FAA, the Associate Administrator for Commercial Space Transportation (AST) have been involved in a long-term project which focuses on the development and implementation of capabilities, procedures, and processes necessary to integrate new commercial space transportation operations into the National Airspace System, as well as accommodate increased activity of existing launch operations. The project began in 1997. Once fully realized, the Space and Air Traffic Management System (SATMS) will represent an environment in which space and aviation operations are fully integrated in a modernized National Airspace System, see AST Strategic Plan 2002, http://ast.faa.gov.

49 The general term 'air navigation services' covers Air Traffic Management (ATM), Communication, Navigation and Surveillance Systems (CNS) and Meteorological Services. Under ATM come the Air Traffic Services (ATS) which is basically everything a national Air Traffic Control agency does to avoid collisions, i.e. controlling arriving and departing flights, and monitoring everything that moves on or close to the airport ("aerodrome traffic") and acting as Area Control Service, i.e. monitoring aircraft, after take-off, once they have reached a certain – 'en-route'- altitude and until they have been handed over to another, adjoining, Area Control Service. Air space management and air traffic flow management, also falling under ATM, include the efficient management and utilization/allocation of airspace and airport capacity (routes, zones, flight levels, time, space) for an optimal match of supply and demand, see on this topic further, van Antwerpen, N.A., The Single European Sky, Air and Space Law (27,3) 2002.

50 Art. 37 lists a great variety of topics related to the safety of air transport which are covered by SARPS: "(a) Communications systems and air navigation aids, including ground markings, (b) Characteristics of airports and landing areas, (c) Rules of the air and air traffic control practices, (d) Licensing of operating and mechanical personnel, (e) Airworthiness of aircraft, (f) Registration and identification of aircraft, (g) Collection and exchange of meteorological information, (h) Log books, (i) Aeronautical maps and charts, (j) Customs and immigration procedures, (k) Aircraft in distress and investigation of accidents; and such other matters concerned with the safety, regularity and efficiency of air navigation as may from time to time appear appropriate."

51 Art. 28, entitled 'Air navigation facilities and standard systems', provides: "Each contracting State undertakes, so far as it may find practicable, to: (a) Provide , in its territory, airports, radio services, meteorological services and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices recommended or established from time to time, pursuant to this Convention;.." (emph. add.). Art. 38, entitled 'Departures from international standards and procedures', makes clear that states do have the right to not comply as long as they notify ICAO of the differences between their own national practice and the international standard concerned. Annex 11 to the Convention, entitled "Air Traffic Services: Air Traffic Control Service, Flight Information Services, Alerting Services"contains the detailed SARPS as referred to in the above art. 28.

which, though not of a mandatory nature, are globally adhered to and form part of the body of rules governing air navigation.

The only place where all members are bound by exactly the same ICAO rules is in air space above the high seas, where national sovereignty is absent: in the words of the above article 12: "Over the high seas, the rules in force shall be those established under this Convention."[52] (See also Law of the Sea Convention, article 87: "((…) Freedom of the high seas (...) comprises, inter alia, (…) (b) freedom of over flight...")). This freedom to over fly the high seas is thus regulated in detail through ICAO. Given the comparable legal status of outer space, the regulation of the use of air space over the high seas by ICAO may provide an interesting starting point for drafting traffic management rules pertaining to the use of outer space.

The main 'technical' organ within ICAO charged with the task to propose or amend traffic management rules is the *Air Navigation Commission.* But it is the *Council*, the permanent legislative organ of ICAO, elected by the Assembly, which adopts (and amends) the respective rules and regulations (SARPS).

The air traffic management-related SARPS can be found in two annexes to the Convention, Annex 2 ("Rules of the Air") and Annex 11 ("Air traffic Services"). Annex 11 contains international standards and recommended practices pertaining to "the establishment of airspace, units and services necessary to promote a safe, orderly and expeditious flow of air traffic. A clear distinction is made between air traffic control service, flight information service and alerting service. Its purpose, together with Annex 2, is to ensure that flying on international air routes is carried out under uniform conditions designed to improve the safety and efficiency of air operations. The Standards and Recommended Practices in Annex 11 apply in those parts of the *airspace under the jurisdiction of a Contracting State* wherein air traffic services are provided (…)."[53] (emph.add.)

"The objectives of the air traffic services shall be to:

a) prevent collisions between aircraft;
b) prevent collision between aircraft on the manoeuvring area and obstructions on that area;
c) expedite and maintain an orderly flow of air traffic;
d) provide advice and information useful for the safe and efficient conduct of flights;
e) notify appropriate organizations regarding aircraft in need of search and rescue aid, and assist such organizations as required."[54]

The following services are meant to accomplish those objectives:
"air traffic control service": objectives a, b and c,
"flight information service": objective d, and
"alerting service": objective e.[55]

Apart from a number of general provisions in chapter 2, *e.g.* on the establishment and designation (and identification) of the units providing air traffic services, on coordination between the aircraft operator and air traffic services, coordination between military authorities and air traffic services and coordination of activities potentially hazardous to civil aircraft (such as launches?), the chapters 3, 4 and 5 regulate in more detail the activities of the above three services, followed by chapters on communications and (meteorological) information requirements.

Article 2.1.1 of Annex 11 provides that "Contracting States shall determine, in accordance with the provisions of this Annex and *for the territories over which they have jurisdiction*, those portions of the

52 For an exception to this rule, i.e. in case a State has accepted responsibility to provide air traffic services over a part of the high seas, see below under "Air space over the high seas".

53 Annex 11, Foreword (Applicability).

54 "Objectives of the air traffic services", Annex 11, art. 2.2.

55 "Divisions of the air traffic services", Annex 11, art. 2.3.

air space and those aerodromes where air traffic services will be provided. They shall thereafter arrange for such services to be established and provided in accordance with the provisions of this Annex (…)"[56] (emph. add.)

Thus, theoretically, an aircraft operated on an international route, while crossing one national air space after the other, passes from one national air traffic management system to another and is in each case obliged to conform with the rules and regulations applied by the national authorities concerned.

In practice, for the sake of the safety of international air transport, an interest shared by the world aviation community, most states have harmonized their rules and regulations sufficiently to, routinely, make safe passage of aircraft possible on a global scale. Problems arise in a different area: the sheer size and magnitude of aircraft operations worldwide, the scarcity of air space and the constant transfer of air navigation responsibilities from one national authority and its facilities to the other, both increasing the risk of confusion, delay, human error and possible disaster.

Annex 2 contains the "rules of the air" which apply to "aircraft bearing the nationality and registration marks of a Contracting State *wherever they may be*, to the extent that they do not conflict with the rules published by the State having jurisdiction over the territory overflown."[57] (emph. add.).

The general rules in Chapter 3 of Annex 2 cover the following topics:
- Protection of persons and property (*e.g.* minimum heights, cruising levels, formation flights, prohibited areas and restricted areas);
- Avoidance of collisions (*e.g.* right of way, lights to be displayed, water operations);
- Flight plans (e*.g.* contents of a flight plan);
- Air traffic control service (e.g. air traffic control clearances, adherence to flight plans, position reports, communications with the ground);
- Unlawful interference, Interception and VMC (visual meteorological conditions) visibility and distance from cloud minima.

The remaining Chapters 4 and 5 deal with Visual flight rules and Instrument flight rules.
(For the application of these rules to air space over the high seas, see below under "Air space over the high seas").

As stated before, States are responsible for the provision and operation of air navigation facilities and services above their sovereign territory. This responsibility has two aspects. First, it is left to the State concerned to determine in what way it will execute its air navigation tasks, *e.g.* through a government agency (the traditional approach) or through a corporative or privatized entity (a format of increasing popularity). But whatever arrangement a State chooses it will continue to be held accountable for the way the system works in practice.

A second aspect is of a more operational nature: the fact that aircraft *en route* may cross many boundaries, involving a constant transfer of controls from one national air navigation system to another, creates an obvious need for bilateral and, as a logical consequence, also multilateral cooperation between the responsible authorities concerned, both at the level of States and at the operational level, his in order to avoid gaps, *i.e.* no controls, or overlapping, and thus potentially conflicting, multiple controls. This is particularly true in Europe, with many sovereign states of sometimes geographically small dimensions and each state responsible for its own piece of air space. There has, as a consequence, always been a great deal of bilateral and multilateral coordination under the aegis of ICAO and also of the regional organization EUROCONTROL. As certain issues of a regional nature are dealt with by both ICAO and EUROCONTROL there is extensive coordination between the two organizations.

56 For an exception to this territorial jurisdiction, involving portions of the airspace over the high seas, where national air traffic services are provided, see below under "Air space over the high seas".
57 Annex 2, art. 2.1.1

The European Organisation for the Safety of Air Navigation, EUROCONTROL, an inter-governmental organisation with 33 member States, has as its primary objective to develop a seamless, pan-European air traffic management (ATM) system "that fully copes with air traffic demands, while maintaining a high level of safety, reducing costs and respecting the environment."

Air traffic control in the narrow sense of the word, *i.e. preventing collisions between aircraft, preventing collisions on manoeuvring areas between aircraft and obstructions on the ground, and expediting and maintaining the orderly flow of air traffic*, is provided in two ways: (a) by Air Traffic Controllers working at airports for the arrival and departure flight phases, and (b) in Air Traffic Control Centres for the en-route flight phase. There are 75 of these latter centres in Europe, 74 national ones (!) and one operated by EUROCONTROL.[58] As there are in Europe significant variations in procedures and equipment between ATC Centres, one of the main tasks of the Organisation is to foster harmonization with respect to the ATM systems and improve safety and overall performance of the whole system.

For the safe overall management of European air space for its civil and military users, a cooperation and coordination mechanism is in place at various levels in the Organisation. Thus, at the highest institutional level, the General Assembly[59], responsible for the Organisation's general policy, is composed of the national Ministers of Transport and of Defense and, on a day-to-day level, military operations are subject to practical coordination measures to prevent interference/collisions with civil users.

The – understandable – longer-term goal of EUROCONTROL is to develop a pan-European seamless air traffic management system. Separately, but in close consultation and cooperation with EUROCONTROL, the European Commission has launched the Single European Sky (SES) concept which will create a single Community airspace for en-route traffic in the upper airspace, through the establishment of a European Upper Flight Information Region (EUIR), composed of functional blocks of air space which would not be based on national boundaries, as is the case today, but on operational and technical requirements only. The idea is to combine the unique expertise and experience of Eurocontrol with the enforcement powers of the European Union in order to create a single European air traffic management system.[60]

ICAO, at the same time, continues to promote and prepare for global air navigation/ air traffic management in which both present (GPS, GLONASS) and future (Galileo, MTSAT) satellite navigation systems would/could play a crucial role. The 11th ICAO Air Navigation Conference, held in 2003, addressed all technical, operational and regulatory aspects of what in ICAO parlance is called the (future) CNS/ATM systems: communications, navigation and surveillance and air traffic management.[61] (The above satellite systems would fall under the N -navigation, of the above CNS).

Only recently, following the first flight of SpaceShipOne, the President of the ICAO Council suggested in January 2005 that ICAO would be the most appropriate organization to regulate the safety of suborbital flights. The debate following this statement also brought up the idea of establishing ICAO

58 EUROCONTROL's ATS Centre in Maastricht, the Netherlands, controls the upper airspace of Belgium, the Netherlands, Luxembourg and part of Germany. Its future ATS Centre in Vienna, Austria will control (parts of) the upper airspace of 8 Central-European states, i.e. Austria, Bosnia-Herzegovina, Croatia, Czech Republic, Hungary, Italy, Slovak Republic and Slovenia. Ms. Anne-Frédérique Pothier of Eurocontrol's Legal Services provided information and suggestions with respect to the text devoted to Eurocontrol.Of course, she takes no responsibility for the resulting draft or for any errors it may (still) contain.

59 Note that the General Assembly will, de iure, come into being once the revised Convention of 1997 enters into force. In view of the early implementation of certain provisions of the revised Convention, a Provisional Council was established. This Council advises the Permanent Commission, which is the decision making body of the Organization.

60 In the mean time the Council of EuropeanTransport Ministers and the European Parliament have, to that effect, adopted 4 Regulations which entered into force in April 2004 and which will form the basis for further implementing rules to be developed primarily by Eurocontrol. And the European Community will be involved in the latter process by becoming a member of Eurocontrol. For further info on SES see the Spring 2004 issue of Eurocontrol publication Skyway at www.eurocontrol.int/library/skyway/index.html.

61 See Report of the Eleventh Air Navigation Conference, Montreal, 22 September to 3 October 2003, AN-Conf/11-WP/206 – 2/10/03, www.icao.int.

as the space traffic management organization in the future.[62] However, so far, neither the topic of space traffic management nor that of the use of air space by (re-usable) space vehicles has entered the official ICAO deliberations. The Air Navigation Commission and a separate advisory committee established by the ICAO Assembly, the Committee on Joint Support of Air Navigation Services, would appear to be the most appropriate organs for this purpose.

- Air space over the high seas

Article 12 of the Chicago Convention states: "Over the high seas, the rules in force shall be those established under this Convention." The ICAO Council has determined on a number of occasions that the 'rules of the air' of Annex 2 are *standards,* i.e., they apply, without exception, to the high seas. All Contracting States are therefore obliged to comply with these rules. (In practice this responsibility, of the relevant authority of a specific State, rests with the pilot-in-command who operates the aircraft registered in that State).

There is an exception to this general rule: there are *parts* of the high seas where the SARPS as determined/interpreted by a specific Contracting State apply. According to Annex 2: "For purposes of flight over those parts of the high seas where a Contracting State has accepted, pursuant to a regional air navigation agreement, the responsibility of providing air traffic services, the "appropriate ATS authority", referred to in this Annex is the relevant authority designated by the State responsible for providing those services."[63] The phrase "regional air navigation agreement" refers to an agreement approved by the Council of ICAO, normally on the advice of Regional Air Navigation Meetings.

The above provision of Annex 2 is mirrored - and clarified - by a provision in Annex 11 reading as follows: "Those portions of the airspace over the high seas (...) where air traffic services will be provided shall be determined on the basis of regional air navigation agreements. A Contracting State having accepted the responsibility to provide air traffic services in such portions of air space shall thereafter *arrange for the services to be established and provided* in accordance with the provisions of this Annex."[64] (emph. add.)

In other words, by virtue of such a regional air navigation agreement, a Contracting State will apply to a specific portion of the high seas all SARPS of Annexes 2 and 11, which may be necessary/relevant *as if that portion of the high seas is a territory over which it has jurisdiction.* It may apply those provisions in a manner consistent with that adopted for air space under its jurisdiction*, i.e.* including any 'differences'.[65]

Although not specifically mentioned in the above texts, one could also envisage that a State which has accepted this responsibility under a regional air navigation agreement would be allowed to (sub-) delegate this task to another State or to an international organization like EUROCONTROL, see emphasized part of text to note 19 above ("*arrange*…").

62 See van Fenema, Peter, Suborbital Flights and ICAO, Air and Space Law (30,6) 2005.

63Annex 2, para. 2.1.2. "Appropriate ATS authority" is defined as: The relevant authority designated by the State responsible for providing air traffic services in the air space concerned. N.B. "Appropriate authority" is, regarding flight over the high seas: the relevant authority of the State of Registry, and, regarding flight other than over the high seas, the relevant authority of the State having sovereignty over the territory being overflown, see Annex 2, Chapter 1 "Definitions".

64 Annex 11, para. 2.1.2

65 The ICAO Council authorized this practical approach, see Annex 11, para. 2.1.2, note 2. Examples of this practice, which results in a re-alignment of Flight Information Region (FIR) boundaries to delegate ATM services pertaining to a portion of the high seas to a specific national FIR, may be found in ICAO (Air Navigation Commission) documents. The purpose is simply one of improving safety and efficiency. 'Differences', as we saw earlier, are the differences between a State's own national practice and the international standard concerned; ICAO has to be notified of such differences to enable the organization to inform all national civil aviation authorities – and through them, the national airlines - of the Member States.

2.2.6. "Soft Law" Provisions

Soft law does not possess the status and binding character of international law. It is usually developed in fora, which can not be categorized as "inter-governmental". Even so, in the area of space activities they are drafted, mainly by governmental organizations, in particular space agencies. These members of such fora, however, do not have the power to prepare binding international law. During the past two decades, they have instead established coordinated mechanisms and established technical standards. They act in the fields of science as well as space applications.[66] In the latter, the Committee on Earth Observation Satellites (CEOS) should be mentioned in particular.

Of specific relevance to space traffic management is the Inter-Agency Space Debris Coordination Committee (IADC). It has been instrumental in setting such agreed standards in the field of space debris mitigation. In 2003 this set of guidelines – agreed among the member agencies – was brought to the attention of UNCOPUOS with the aim of making them applicable on a global scale.[67] Some provisions, like the prevention of on-orbit break-ups or the limitation of objects released during normal operations, have an indirect impact on traffic management, and they help in keeping the space environment a safe place. Other provisions go to the core of space traffic management. These are in particular the provisions on removing spacecraft and orbital stages that have reached the end of their mission operations from the useful densely populated orbit regions. For these purposes, the guidelines do not only set specific standards for evacuating orbits and defining disposal orbits but also set requirements for information and notification, for example in the case of controlled re-entry.

The IADC guidelines are applicable to mission planning and the design and operation of spacecraft and orbital stages that will be injected into orbit by its member organizations. They only have the status of non-binding soft law. They nevertheless set forth a potential basis for specific elements of a space traffic management system.

2.2.7. Interfering Factors Through the Military Use of Outer Space

This study deliberately excludes military space operation rules from its scope. The establishment of a comprehensive space traffic management regime will have to cope with the reluctance of the military sector around the world to coordinate in an open manner. While a modus vivendi has been found in ITU for this purpose, space traffic is - apart from that - affected by military doctrine. For example, the "Long Range Plan" of the US Space Command, published in 1998, promotes the doctrine of "control in space", comprising the ability to assure access to space, freedom of operations there and the "ability to deny others the use of space, if required".[68] Another, more recent example is the December 2004 White House policy on satellite navigation, which states the prevention of perceived hostile use of satellite navigation systems is stated.[69] Since some policy statements could be perceived as a challenge to international space law (the freedom of use of outer space as laid down in the OST), such concepts will have to be addressed when considering the implementation of a space traffic management regime based on equitable assured access.

Any future space traffic management regime will have to satisfy the interests of both civilian and military users. Traffic management only works well when all users of the orbits abide by it. The transparency requirement of such a regime does not allow for secretive operations and manoeuvres that en-

66 See Ferrazzani, Marco, Soft Law in Space Activities, in: Lafferranderie, Gabriel/Crowther, Daphne (eds.), Outlook on Space Law over the Next 30 Years, Leiden 1997, 429-447.

67 Inter-Agency Space Debris Coordination Committee space debris mitigation guidelines, UN Doc. A/AC.105/C.1/L.260 of 29 November 2002.

68 US Space Command, Long Range Plan – Implementing USSPACECOM Vision for 2020, Washington D.C. 1998, Executive Summary, 5.

69 See the US Space –Based Positioning, Navigation, and Timing Policy of 8 December 2004, para. VI; http://www.ostp.gov/html/FactSheetSPACE-BASEDPOSITIONINGNAVIGATIONTIMING.pdf.

danger the safe operations of others. While purposes and tasks of military satellites might and will be kept secret, an orderly and transparent use of orbits will be necessary in the self-interest of the military actors as well. There might be certain features of traffic management, like “keep out zones”, which might be particularly relevant and applicable to military space operations, thus safeguarding the particular security needs of these actors. But with growing space traffic, the military will also have a growing interest in reliable regulations. This could prevent dangerous misperceptions, which on Earth have often led to aggression and pre-emptive strikes. The field of space debris has already seen positive developments, where the military had been reluctant for a long time but now is pushing for the establishment of stricter codes of conduct. And it will be the case with space traffic, where at least a basic setting will comprise both types of space users.

Another area, where the military does and will further play an important role is in the provision of data and information. Although the observation capacities of today are almost completely owned by the military (in particular the US Strategic Command but also by the military in Russia, Germany and France), a cautious openness in distributing these data has already emerged. In 2020, this situation is likely to be different with other actors (like ESA or Japan, China and India) having built up their own observation capacities, probably under civilian control, which might then be more (but certainly not completely) open for broader use.[70] This would reduce the potential of the military to hinder the establishment of a traffic management regime by restricting the necessary information.

2.2.8. Findings

- The general principles of space law provide a basis and rationale to establish a space traffic management regime.
- Some unique rules exist in international space law as well as in international telecommunication law, which can be considered as basic elements of a space traffic management system (especially for use of the GEO by means of the ITU RR). These rules however are neither complete nor 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 (not legally binding agreement) encompass elements of space traffic management (use of disposal orbits, notification in case of controlled re-entry) but so far they do not include provisions on the environment, i.e. avoidance of pollution of the atmosphere/troposphere.
- Space law, however, lacks numerous provisions, which are essential for a comprehensive traffic management regime (i.a. pre-launch notification). Of particular importance is a legal recognition of a difference between space objects considered as valuable assets by their owners, and space debris that have no value.
- A space traffic management regime has to consider the question of harmonizing national space legislation (much of which has yet to be established), and national licensing standards and procedures, since they may provide the building blocks for assuring technical safety.
- In regard to arms control/disarmament negotiations, notification practices (prior to launch) have been developed through the Hague Code of Conduct against Ballistic Missile Proliferation (HCOC), thus superseding 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 about and the execution of space missions), which could be perceived as limiting the freedom of use of outer space guaranteed by the Space Treaty. In order to achieve a consensus, States have to perceive 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 national military and security policies and practices, which might hinder the establishment and operational effectiveness of a space traffic management regime.

70 See http://www.spacesecurity.org/SSI2004.pdf, p.14.

2.3. Characteristics of Comparable Traffic Regimes

2.3.1. Air Traffic

Three phases are distinguished in this study: the launch phase, the in-orbit operation phase and the re-entry phase. Air traffic management seems highly relevant to all three, because of the unavoidable transit in air space by the space object concerned during the launch phase and the transit in air space in case of re-entry, and also as an example of how to regulate national operations in a *res communis omnium, i.e.* during the in-orbit operation phase.

The use of air space by aircraft is regulated in detail: States apply ICAO standards and recommended practices (SARPS) to the management of air traffic in air space under their jurisdiction. And above the high seas the relevant SARPS in Annex 2 primarily, the "Rules of the Air", give clear guidance to the States (and to the pilots-in-command of the aircraft registered in those States) on how to operate and behave.

If a State finds it necessary to deviate from the ICAO rules, the details of these "differences" are communicated to all ICAO members. And if a part of air space above the high seas has been 'given' to a member State to manage air traffic therein, the rules are also clear for all parties concerned. Finally, a State may delegate (part of) its national air traffic management tasks to another State or to an international agency as long as the responsible entity and the rules it applies are clear, order and safety in air space are in principle not at stake.

Aircraft commanders are accustomed to being transferred from one 'authorized agency' to another, either on the basis of horizontal border-crossing or because their aircraft reaches a certain altitude. Aircraft commanders also routinely receive instructions from the ground as to suggested speed, altitude and direction. And the aircraft commander is familiar with the concept of 'right of way', with, as a rule, the most manoeuvrable 'machine' giving priority to the less manoeuvrable one.

Finally, in areas where no national air traffic management is in place (high seas), a combination of known and recognized flight routes and altitudes, flight instruments on board, knowledge of the rules of the air and recurrent training of the crew and the jurisdiction and control of the State of registry of the aircraft, all these together are generally sufficient for the safe and orderly use of the air space concerned.

Incorporating space objects into this sophisticated air traffic management system, both in the launch phase and in the re-entry phase (including modified /expanded right-of-way rules which take account of the lack of manoeuvrability of space objects in the various flight stages), should not pose any insurmountable challenges to the operational and regulatory experts concerned. The US (FAA/AST) activities in this field on a national scale (see para. 2.2.5) warrant further study and debate. Additionally, at some point in the future, for the sake of uniformity and predictability, an adaptation of ICAO SARPS to this special use of air space may become advisable.

The in-orbit operation phase poses a different challenge: the absence of rules, and of an experienced/expert rule-making authority, requires beginning from scratch. And the question is whether the experience gained with the management of aircraft operations above the high seas could provide a useful starting point for that purpose.

Particular attention should be paid to (a) the way in which the rules of the road with respect to this *res communis omnium* are developed within ICAO and upheld/enforced by all member States, and (b) the way in which, through multilateral arrangements (see the above 'regional air navigation agreements'), the task to provide ATM services in a specific portion of the air space over the high seas is delegated to a specific State.

2.3.2. Maritime Traffic

The status of maritime traffic greatly changes according to the maritime area where it takes place. The coastal State is fully competent on internal waters including ports. The territorial waters form part of the States' territory but other States' ships enjoy the right of innocent passage. In the High Seas, in principle, a ship shall be subject to the exclusive jurisdiction of the State of the flag.[71] The Contigous Zone and the Exclusive Economic Zone (EEZ) also form part of “international waters” together with the High Seas, but have considerable elements of coastal State jurisdiction and sovereign rights. Transit passage through straits used for international navigation gives certain freedom to transiting ships.

As far as traffic management is concerned, three points should be considered:
- Who has the right to make the rules?
- Who has the right to control their implementation?
- Who has the right to punish violations?

The balance of rights and obligations with regard to maritime jurisdiction is of considerable complexity. The 1982 United Nations Convention on the Law of the Sea provides a detailed structure of jurisdiction for States under their function of coastal, flag- and port State. This balance of interests is evidenced by the detailed provisions for, *inter alia*, “innocent passage”, “archipelagic sea-lanes passage”, “transit passage”, the designation of sea-lanes, traffic separation schemes and the designation of special protection areas.

Two points will be highlighted below: the exclusive jurisdiction of the flag State for activities in the high seas, and the current trend to give a more important role to the coastal State.

- The high seas: exclusive jurisdiction of the flag State

According to Article 87 of the Law of the Sea Convention, "The high seas are open to all States". Freedom of navigation is expressly guarantied as the first freedom of the High Sea. This fundamental principle of international law is not only applicable to the maritime area of high seas. According to Article 87 and other provisions in the Convention, such as Article 56 and 58, the principle of freedom of the high seas also relates to other parts of international waters, in particular the EEZ. The rights and duties of coastal States and flag States therefore have to be considered with due regard to their respective jurisdiction as laid down in the Convention and by other rules of international law.

States enjoy this freedom. Private persons, either physical or legal, must obtain a flag and the authorisation of a State to fly this flag and to sail out at sea. Article 94 of the same convention states that the flag State must "effectively exercise its jurisdiction and control in administrative, technical and social matters over ships flying its flag". This obligation is elaborated by the same article: "Every State shall take such measures for ships flying its flag as are necessary to ensure safety at sea".

If there are international rules the flag State must apply them. In taking the measures called for in Article 94, paragraphs 3 and 4 each State is required to conform to generally accepted international regulations, procedures and practices and to take any steps which may be necessary to secure their observance. If there is a violation of such rules, other States may report the violation to the flag State but cannot act themselves. "A State which has clear grounds to believe that proper jurisdiction and control with respect to a ship have not been exercised may report the facts to the flag State. Upon receiving such a report, the flag State shall investigate the matter and, if appropriate, take any action necessary to remedy the situation." The exclusive role of the flag State and the State of nationality also applies for inquiries in the case of an accident (Article 94/7) and to penal jurisdiction in matters of collision or any other incident of navigation. (Article 97). If a ship violates any international rule, only the flag State or the State of which the offender is a national is competent to take the offender to a court.

71 http://www.oceanlaw.net/etxts/losc.htm.

These principles have drawbacks: If the rules apply according to the nationality or flag of a person or ship; in the same place many rules may apply, much control may be involved. For traffic management, it is not only dangerous, it is also very inefficient. Fortunately international treaties may be accepted by many States, but they are rarely accepted by all. In practice, the main problem is more the lack of efficient control than the lack of rule. Moreover, some States have an interest to be inefficient in their control. The problem comes from the current trend to register ships under flags of convenience. The problem in the maritime sector of flags of convenience is old and well known. Actions taken, for instance in the International Maritime Organization (IMO), leads in the direction of giving more rights to the coastal State and port State.

- The increasing role of other States

Two possibilities may be highlighted: one is only “moving” the problem, the other is changing the rules.

The increasing role of the port State.

What cannot be done in the high sea may be done in ports. The exclusive jurisdiction of the flag State leads to a kind of "anarchy" and, as far as safety is concerned, to too many accidents. Fortunately, for the time being sea activities are always turned toward some land. A ship sails from one harbour to another. When she sails in the high sea, she is only under the law of her flag State, but when she enters the harbour of another State, this State may exercise its territorial jurisdiction, which then overrules personal jurisdiction and may be far more efficient. Exercising territorial jurisdiction means making its rules applicable but also making its control mechanisms and judges effective.

The competence of the coastal State to legislate and to enforce such national legislation with respect to pollution from vessels should be mentioned. Certain rights are given by the convention to such coastal State jurisdiction over pollution caused by foreign ships outside the territory of the coastal State. The system of judicial and enforcement jurisdiction in this regard is complex. Certain safeguards as laid down by the convention, in particular Articles 223-233, always have to be observed.

The increasing role of port State control is interesting. In Europe, port authorities have agreed to the Paris Memorandum of Understanding (MoU) (1980). The Paris MoU consists of 19 participating maritime Administrations and covers the waters of the European coastal States and the North Atlantic basin, from North America to Europe. It aims at eliminating the operation of sub-standard ships through a harmonized system of port State control. Inspections take place on board foreign ships in the Paris MoU ports, ensuring that these ships meet international safety and environmental standards, and that crew members have adequate living and working conditions.

Black and grey lists of ships and States are established. Cooperation with other similar groups are maintained (US coast Guard, Tokyo MoU and Caribbean MoU). After each accident and pollution a little step forward is undertaken. For example, the so-called "Erika 1 Package" to ban from the region ships that fly the flag of a state on the Black List, after multiple detentions for lack of security. Nevertheless, the Paris MoU organisation report 2001[72] is far from optimistic. Safety management defects are increasing, new flags of convenience are coming into business and "these registers have managed to find their way to the top of the Black List in a single year".
The control of the port State is one way to handle the problem of “substandard shipping”, by developing international law in the direction of more protective rights for the State whose coastline and waters are threatened by foreign ships which are not to be considered up to standard of seaworthiness.

The increasing role of the coastal State

Coastal States may regulate passage in their territorial waters and in some specific cases in their EEZ, related to pollution incidents; this it is not the case in the high seas, where the coastal State has no

72 http://www.parismou.org/anrep/anrep2001.pdf.

power at all to regulate unilaterally the passage of foreign ships. A solution was found thanks to the International Maritime Organisation. (IMO). It was necessary to use Regulation V point 8 of the Safety of Life at Sea Convention, called "SOLAS Convention" of 1974, and ,article 10 of the 1972 "Convention on the International Regulations for Preventing Collisions at Sea," "COLREG Convention." Article 10 provides for traffic separation schemes adopted by the International Maritime Organisation.

When a costal State wants to implement a traffic separation scheme it makes a proposal to IMO's Sub-Committee on Safety of Navigation which will discuss the issue and put it forward to the Maritime Safety Committee (MSC), IMO's senior technical body. If accepted as a recommendation, the traffic separation scheme may be put in place by the costal State.[73] This recommendation is not compulsory, even if every shipmaster knows it is in his interest to follow these rules. Thus the coastal State has no real possibility to control the implementation of this "rule" and even less the right to punish wrongdoing. Nevertheless, most of the time, these rules are accepted and implemented by the ships, because, at the end of the voyage the ship must enter a port. Then, as a territorial State, the State of the port may control and even refuse entrance to any ship.

- Regulation

An interesting feature for a regulatory process can be found in the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM-Code) under the SOLAS convention, which entered into force in 2002. Technical regulation can become binding without formal and expressive acceptance through ratification, but through a mechanism of tacit acceptance and a respective automatism. This could be regarded as an interesting model for flexible regulation of technical parameters for space traffic.

- Findings

In international common spaces, such as the high seas - 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 seas, the exclusivity of the flag State is likely to be overruled by an extension of the territorial jurisdiction of one or several 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, since at present a satellite does not fly back to Earth. The extension of "coastal" jurisdiction is also an impossible solution for obvious technical reasons. These difficulties should be taken into consideration if and when a Space Traffic Management regime enters into force. Nevertheless, there are many interesting elements from the Law of the Sea which could be studied further, in particular as the development of international law for ocean space and outer space do have the common basic elements of extra territorial applications.

73 See IMO Resolution A.572(14), General Provision on Ship's Routeing, of 19 May 1998

CHAPTER 3

ELEMENTS FOR A SPACE TRAFFIC REGIME

3.1. The Launch Phase

3.1.1. Trends in Technology Developments

3.1.1.1. Expendable and Reusable Launch Systems, Aerospace Objects

The question of the future evolution of launchers is directly linked to the size of satellites and the launching costs. The technology-drivers for the evolution of launchers are:

- the need for a lower cost for access to space,
- the need for an easy operational implementation,
- a better respect of the environment,
- the possible reuse of launchers and, in particular, the first stages in order to reduce the costs,
- the possibility of multiple re-ignitions to reach several orbits.

In addition, to go faster and cheaper, new technologies will be required for exploration of our solar system and other systems.

The overall situation of the launching industry has changed during the last 30 years. Coming from a period with a limited number of launchers, a large number of launchers are now available with a 50 per cent overcapacity. Space agencies are focusing their efforts on developing a new generation of reusable launch vehicles over the next 15 to 20 years.

In 2010, geostationary satellite launches will still be the major part of the space transportation market. This market is shared between conventional launchers from the United States, Europe and the Russian Federation for this country, operated by joint ventures with western companies (Starsem, Sea Launch, International Launch Services and Eurockot Launch Services). Chinese and Indian launch vehicles are also present on the market.

The conventional launch service offer has improved the situation as a result of intensive streamlining of production, especially in terms of cost and performance. This industrial rationalization process is the most crucial challenge that space transportation will be facing in the years ahead. As overcapacity increases, the pressure to cut costs and enhance performance is also rising.

This situation must not lead us to underestimate the important choices now facing future-generation launch vehicle programmes. Through very ambitious technology programmes, a new generation of launch vehicles will be available. These new vehicles, probably developed by public-private partnership, will be reusable and could be ready to enter service in 2015-2020.

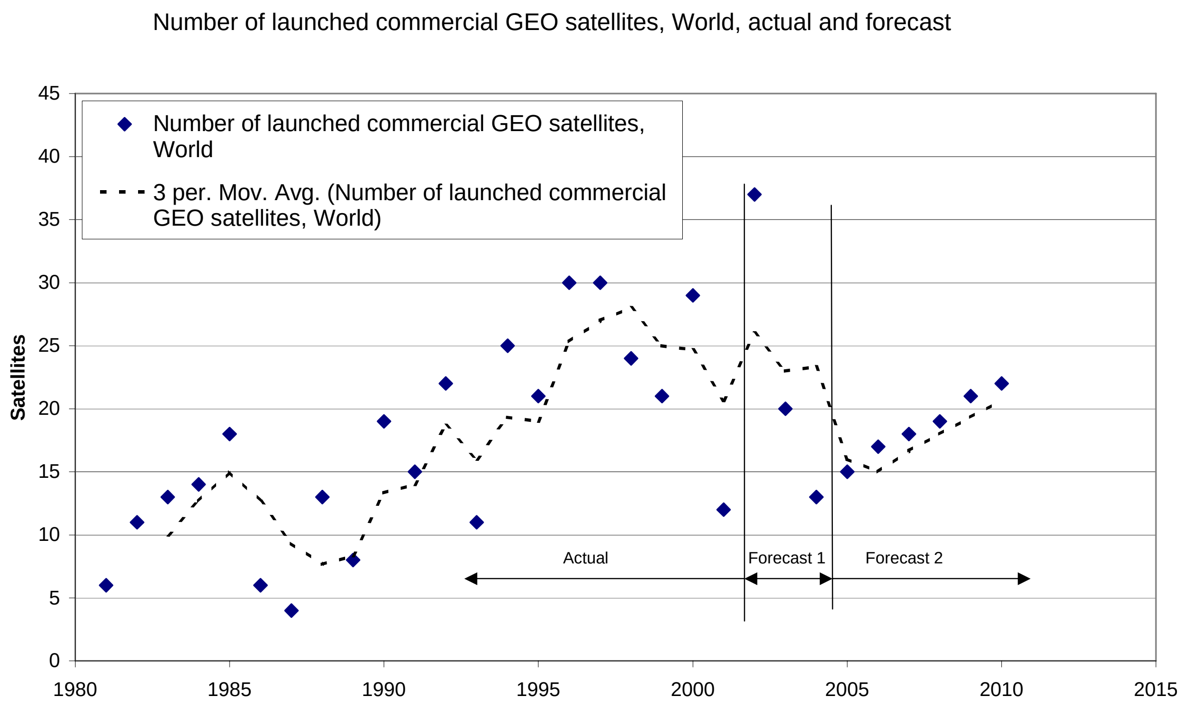
Lastly, inter-orbital transportation is gaining ground and taking advantage of significant technological advances such as electric propulsion, solar propulsion and electromagnetic tethers. These new technologies could reduce the cost of high-energy launch trajectories into geostationary orbit or towards the Moon and other planets by at least 50 per cent. And other highly sophisticated systems could shorten the time needed to reach planets by a factor of three or more. Such progress would be a major boost for planetary exploration.

In conclusion, for the time being, space powers are still relying on their own mature space transportation systems, but are working on future reusable systems.

3.1.1.2. Commercial and Private Ventures

For the next ten years, it is estimated that about 185 commercial satellites will be launched in GEO (source Euroconsult). The following graph presents the evolution of the commercially launched geostationary satellites from 1980 to 2002 and the forecast for the coming years.

Figure 3-1 Number of Launched Commercial GEO Satellites (World, Actual and Forecast)



In conclusion, commercialization will continue to be, an important factor in the next 10-15 years. Despite the short-term reduction in launch activity, this situation has to be taken into account for any policy and regulation of the launching sector. Most GEO satellites are now launched by the commercial sector.

3.1.1.3. Future of Human Spaceflight Activities

In estimating the future trends in space traffic, one should take into account governmental as well as commercial activities involving robotic spacecraft and also flights of humans into outer space. In March-April 2002, a survey was conducted by FuturaSpace LLC, which targeted space experts from 22 countries. The objective was to provide an independent and global look into the future of human spaceflight activities and to identify possible developments in the upcoming decades.

According to the executive summary of the study "Future Trends in Human Spaceflight: A Global Survey", performed by FuturaSpace LLC on the basis of 157 qualified responses received, several new developments took place recently, that are likely to shape the future of human spaceflight activities. The flight of the first space tourist, the X PRIZE initiative, construction of the International Space Station (ISS) and Chinese Shenzhou flights are only some of the developments, which clearly signal a new era in human spaceflight. An era that is significantly different from the previous bipolar Space Race, an era of increased international cooperation, with new players and new rationales. Although human spaceflight has a heritage of intense international competition and prestige-driven missions, over the years two alternative rationales have emerged: scientific exploration and commercial. These two axes are likely to play an increasingly important role in defining tomorrow's agenda for human spaceflight. Moreover, they are closely linked to another recent development, large-scale international cooperation.

Not all of the future players involved in human spaceflight will be nation-states. Both recent developments and the survey results point towards an increasing role for commercial entities in future human spaceflight initiatives, especially in space tourism. However, if space tourism is to evolve into an "adventure tourism" industry with a strong private sector involvement, overcoming the cost and safety hurdles is essential. Today, both the survey findings and the lack of a focused vision indicate that humans will not be setting foot on the Moon and Mars anytime soon. While most of the surveyed experts think humans will return to the Moon before 2020, the first mission to Mars is not expected until after 2020. When these missions are undertaken, their nature is likely to be quite different than that of the Apollo missions; this time there will be a stronger science and exploration agenda. If a stepping-stone strategy is implemented, where the ISS, the Moon, and Mars are the key stones, humanity can gain the sufficient know-how and, more importantly, a clear vision for moving beyond the Moon and Mars.

Within this decade, it seems unlikely that humans will be moving beyond LEO. Visits to the International Space Station seem to be the most likely space tourism activity. There is very little confidence, among the surveyed experts, that an alternative to the Shuttle and Soyuz will emerge in this decade for space tourists. However, in terms of national capabilities, China will most likely develop its indigenous human spaceflight capability.

By 2020, Japan is thought by the experts to emerge as the fourth nation to achieve this capability. Meanwhile, space tourism is expected to gain momentum, as alternative vehicles are developed to accommodate a growing market. Beyond the ISS, international cooperation is expected to propel humans on a return mission to the Moon, widely seen as a stepping-stone to the future human exploration of Mars.

Beyond 2020, the human spaceflight landscape is expected to change dramatically on two fronts: scientific exploration and commercial activities. It is widely believed that by 2030 humans will finally set foot on Mars, further increasing humanity's scientific knowledge of the Solar System. On the commercial front, the FuturaSpace study expects wide-scale expansion of space tourism as private human spaceflight expenditures increase significantly relative to public expenditures.

3.1.2. Regulatory Aspects

The major points of concern when attempting to define the "launch phase" for regulatory purposes or otherwise is to articulate both a starting and an end point for the phase. United States Federal Aviation Administration (FAA) regulations for commercial space transportation define "launch" as the phase which begins with the arrival of a launch vehicle at the launch site or range and ends (for purposes of ground operations) when a launch vehicle leaves the ground, or (for purposes of flight operations) after the launching agent (i.e. person, company, state government agency) completes all exercise of control over the vehicle. Thus, basically launch includes all hazardous pre-flight activities through orbital delivery of the payload.

Other options, however, exist, whether on the basis of technical or operational criteria, or even of legal considerations as such. The insurance business uses definitions to clearly limit the extent of obligations to compensate claims, which may be different – obviously a point which requires further investigation.

However, one might arrive at yet another definition, one that may seem more intuitive or obvious at initial consideration. The launch phase would commence with ignition/lift-off, which is where many might suggest that the real transportation begins, and end with payload separation. In regard to the latter, this would be where non-transportation considerations would become the most important ones from a regulatory perspective. Since the place of separation of payloads may vary considerably as between e.g. LEO and GEO satellites, a problem could arise here in that two satellites present in the same area may fall under different regimes: one GEO satellite merely transiting to its proper orbit would be in its launch phase still, whereas a LEO satellite already orbiting would by definition be in its in-orbit phase.

One might also consider that the end of a launch phase would occur at the point or altitude at which the object bound for space crosses the boundary that separates air (atmospheric) from space (exo-atmospheric). This definition would of course require some internationally accepted definition of where space begins, a delimitation/definition which does not exist.

In view of the envisaged practical orientation of the IAA Study, the United States FAA definition should be taken as a starting point and examined. As a comparison it would still be valid to acknowledge definitions used in other sectors, and to show why one definition is most appropriate when speaking of the launch phase in the context of space traffic control.

- The role of Article VI of the Outer Space Treaty

If the above point of departure for analysis is to be taken, the question immediately arises as to the role of Article VI of the Outer Space Treaty in this respect. It provides for responsibility for national activities in outer space, whether conducted by governmental agencies or by non-governmental entities. Given that there is no formal, internationally agreed upon definition as to where space begins, it may not be helpful for defining the launch phase as such. However, international responsibility of a state under Article VI, Outer Space Treaty, hinges on the 'presence' of a national activity (N.B.: not a space object as such) in outer space.

By contrast, a state's responsibility arises under more general norms of international law for activities occurring in areas other than "outer space". In view of the full equation of private activities in outer space to public activities in outer space under Article VI, Outer Space Treaty, as contrasting with the general concept of state responsibility where states can not as such be held responsible for private space activities (as a consequence e.g. the US assumes liability for damage to third parties above a statutorily imposed amount up to a statutorily imposed ceiling), the proper definition of what constitutes 'outer space activities' may have a considerable impact as far as regulating the launch phase is concerned - even if it is perhaps challenging to attempt to define it.

- The role of Article VII of the Outer Space Treaty, and of the Liability Convention

Similar considerations pertain to the role of Article VII of the Outer Space Treaty, as well as of the Liability Convention that elaborates this Article. Both link the liability for damage caused by space activities – as caused more or less directly by a space object – to the state(s) involved in the *launch (i.e. the "launching state(s)")* of that space object. The Liability Convention itself only partly (tries to) define(s) the notion of launch by including attempted launches within the scope of that notion as it is relevant for liability, which may be interpreted as meaning that 'launch' does not automatically start at lift-off as such, since an attempted launch would include cases where actual lift-off has not been realized.

Yet, it will be clear that there might be some impact on the regulatory issue where a launch phase is supposed to end: prior to such point, involvement of a particular state would very likely satisfy the criteria for becoming a launching state, whereas after such a point this might on the contrary be very hard to argue.

3.1.2.1. Information Needs (Information/Notification)

There are already several rules and principles in space law that are relevant to the need for information and notification. Thus, under the Registration Convention obligations already exist to nationally register and internationally notify such registration - an obligation resting upon the "launching state(s)". It may be noted that currently efforts are underway in the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) to widen the scope of parameters to be internationally notified. Also, there are the more general obligations of Article IX (3rd & 4th sentences) of the Outer Space Treaty resting upon any state, to inform and consult on potentially harmful interference of its own space activities with other states' space activities.

The major question thus would be: to what extent and for which purposes is there a desire or even a need for more information than is currently available, and to what extent can such a desire or need be accommodated through regulatory measures? This question becomes particularly relevant in light of increasing private participation in launch activities. It is doubtful whether the current, rather state-oriented and largely optional system would still suffice. A mechanism might need to be created whereby private parties are informed appropriately, and held responsible to inform appropriately on relevant space activities.

A related question then arises as to the scope of such an information gathering mechanism. The answer to this question might depend largely on what constitutes the space traffic management environment and what is meant or intended by the term "management" in this context. Is space traffic management envisioned as an extension of air traffic management, or is it something entirely, or at least to a considerable degree, different? Before this question can be answered, it will be necessary to define and identify all the components that constitute the concept of 'space traffic' - service providers that provide separation like air traffic controllers, users of the 'system', authorities with monitoring and enforcement capacities, etc. In the case of space traffic, the last category mentioned both constitutes a matter for the future, and requires a different approach from air law in view of the absence of territorial sovereignty over any stretch of outer space. This also may again raise the issue of the need to demarcate air space from outer space.

3.1.2.2. Regulatory Needs at the International and National Levels

From a *safety perspective*, for example, concepts such as rules of the road or safety certification (for relevant hardware) would become more feasible once the conclusion is reached that existing state responsibilities to provide information do not suffice to ensure safety of space transport in a satisfactory manner. Here, analogies with the field of international civil aviation come into play. These analogies are relevant despite the dominant presence of the concept of sovereignty in this area. Through the workings of the Chicago Convention and its Annexes, and the role of the International Civil Aviation Organization (ICAO), a remarkable level of international harmonization of applicable standards and certification regimes has been made possible.

From a *liability perspective* different issues would arise. In order to establish liability in cases where damage has occurred, provisions on obligatory information are relevant. Reference has already been made to the Registration Convention in this regard, which could be seen as providing for an (embryonic) international system of information specifically with a view towards establishing liability. From the discussions on the issue of space debris it is clear that there are still major improvements to be made here if it is to serve that purpose as much as possible. Also on a national level, much can be gained by elaborating the relevant information duties currently in existence - or even by establishing national space legislation and/or a national information duty regarding space activities in the first place. Such a role for national (space) law is most important where private space activities are concerned, in view of the public nature of both international space law liability and of the regime of the Registration Convention.

The *economic perspective* offers a third angle. Is regulation desirable or even needed to establish a level or relatively fair playing field, or at least something akin to an open market, for launch and other space transportation services? To the extent that the (few) existing bilateral trade-in-launch services agreements fulfil this role, it is obvious that these present a rather haphazard approach. Whether a global regime is feasible, e.g. through the mechanisms of the World Trade Organization (WTO), or even desirable, is another question. Another aspect, in particular for the private launch industries in the United States and Europe, concerns the potential application of the respective US and EU competition regimes, occasionally even with the dreaded extra-territorial effects. Finally, attention might be paid to licensing for economic purposes, again especially in the cases where private launch service or other space transportation providers are involved. Again this is where national (space) legislation comes in.

Perhaps other types of regulation may be added, but the overarching question here is probably how the current global framework, to the extent that there is one, can be preserved or even further developed in a coherent and sensible fashion by the international community, maintaining a fair balance between the public interests and those of private participants in space activities. At the national level this touches upon issues such as the implementation of international rules and principles: to what extent does sovereign freedom to act still exist, is such freedom confined largely to interpreting these international rules and principles within a certain radio frequency range?

3.1.3. Findings

- 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 "launching State" has to be clarified.
- A pre-launch notification system is necessary, although the HCOC includes non-legally binding provisions for such notifications of Space Launch Vehicle launches.
- Obligatory information in cases of damage is relevant.
- An international level playing field for transport services should be aimed for, with a balance between public and private/economic interest.

3.2. The In-Orbit Operation Phase

3.2.1. Trends in Technology Developments

3.2.1.1. Collision Warning and Avoidance

Since the beginning of the space age, there has been one verifiable collision between two tracked, manmade objects in space - the French Cerise satellite collided with a fragment from an exploded Ariane upper stage. Of course, there are a number of known collisions of satellites with tiny debris, such as flakes of paint that recurrently pit the windows of the Space Shuttle Orbiter, but these debris objects can be countered by vehicle design. It is also possible that collisions involving non-tracked objects have occurred. There have been several unexplained fragmentation events, where a tracked object “exploded” creating a number of fragments, but the cause of these events cannot be verified as collisions, since there was no known object in the vicinity.

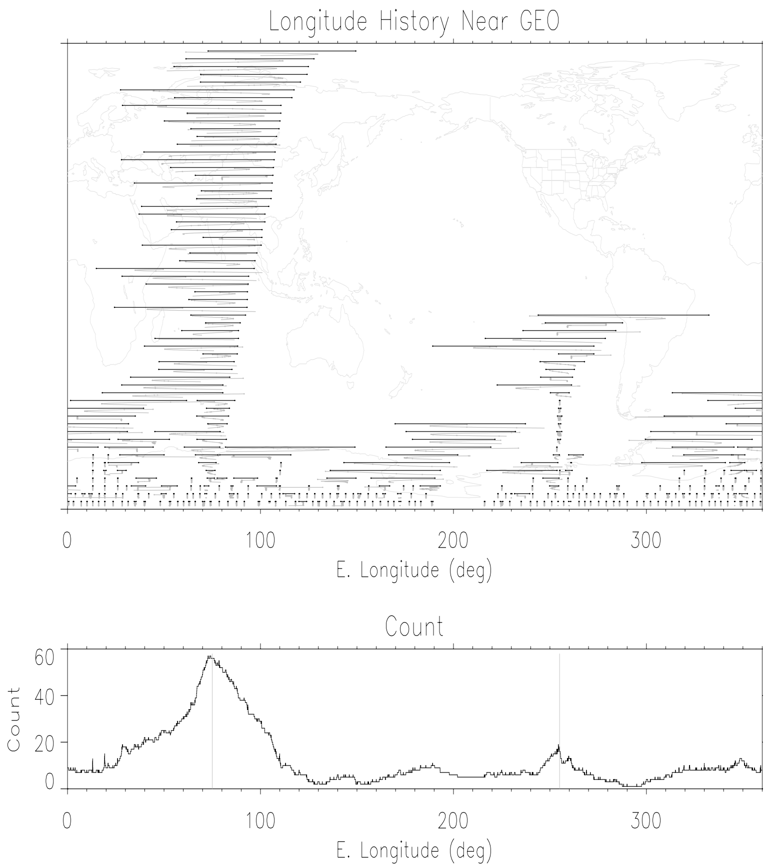
There are also cases where manned and unmanned spacecraft have been manoeuvred to avoid what was deemed an unacceptably close encounter with another tracked object. For example, the Space Shuttle Orbiter was manoeuvred eight times and the Space Station has been moved five times since mid-2002. Probability-of-collision thresholds for debris avoidance manoeuvres for manned systems are set at 1 in 100.000 for a class yellow alert and at 1 in 10.000 for a class red warning.

Given the increasing number of satellites, rocket bodies, and related debris in orbit, it is expected that close encounters will continue to occur and that the probability of collision events will increase over time. Recognizing this trend, space-faring nations are evolving new rules-of-the-road governing the release of debris during operations and mandating that spacecraft be de-orbited or moved to disposal orbits at end-of-mission. At the present time, these exist only as guidelines.

Satellite operations are also becoming more complex. Some operators have as many as seven satellites sharing a single geosynchronous orbital location, requiring the use of sophisticated control schemes to guarantee that separation distances are maintained while minimizing fuel consumption. Others are using low-thrust orbit transfers to slowly move a satellite to its operational location or to reposition it from one location or another. These transfers may move the spacecraft through orbital areas with high concentrations of debris or operating spacecraft, and the collision probability may increase as a result. In all cases, the actual probability of a collision in orbit remains very small. It is also possible that the assigned geosynchronous orbital slots for two or more satellites may overlap. On occasion, this may produce unacceptably close approaches.

Operators of manned and man-able spacecraft have been provided information for several years on objects passing close to their vehicles. While many adhere to the “big sky” theory, believing that the possibility of an operating satellite colliding with another object is very small, some operators of unmanned spacecraft are asking for information to enable them to take action should they feel the risk level is too high. Similar to manned systems, some operators currently use a 1 in 10.000 level of probability as a “class red” manoeuvre threshold.

Figure 3-2 Satellites Operating Near GEO (top figure shows longitude band for each satellite; bottom figure shows count of satellites crossing each longitude)



- Debris Avoidance vs. Avoidance of Active Spacecraft

There are two classes of encounters where collision avoidance is possible: an active vehicle vs. a tracked debris object (perhaps the most likely scenario, since over 90% of tracked objects are debris), and an encounter involving two active satellites. There are currently no available measures to keep one debris object from impacting another, although end-of-life disposal (see following discussion) is intended to reduce the risk of this occurring in high-usage orbits.

In the first case, the active satellite, may, if it has sufficient manoeuvre capability, move to avoid an oncoming debris object. Some satellites, such as the Hubble Space Telescope, lack the capability to thrust away from an encounter, but could potentially lower the probability of collision by reorienting.[74]

If both satellites are active, potentially either satellite could be manoeuvred. It is certainly possible that an uncoordinated action by either or both operators could enhance, rather than reduce, the likelihood of collision, so it is apparent that coordination between the operators is essential in such cases.

Should recurring close approaches be predicted, operators can work together to develop fuel efficient schemes for assuring that distances remain above minimum values. For example, the operator of a satellite in geosynchronous orbit could adjust the parameters of the control box of that spacecraft so that it does not occupy the same space as another satellite.

74 Patera, R. /Peterson, G., Space Vehicle Manoeuvre Method to Lower Collision Risk to an Acceptable Level, in: Journal of Guidance, Control, and Dynamics, (26,2) 2003.

- Data Requirements

The challenge for accurate predictions of close approach situations is the availability of accurate data on the approaching vehicles, accurate orbit propagators, and models that provide useful information to satellite operators. If data and predictions were perfect, it would be possible to simply look ahead and see when one space object would hit another. Unfortunately, data and tools are not perfect, and this fact must be included in the analysis. Errors in the position of tracked objects increase from the time of measurement and the uncertainty may exceed kilometres in size. Given that the location is not precisely known, predicting collisions or even close approaches can be very difficult.

One way to allow for errors in data and predictions is to place the object to be protected in a "keep-out box" and use a computer model to see when a threat object enters the box. This type of approach has been used since 1988 to protect the Space Shuttle. However, the Space Shuttle no longer uses this "keep-out box" criterion but employs a probability of collision calculation almost identical to that of the International Space Station.

Shuttle controllers have used a warning box that has dimensions 40 x 80 x 80 km. If predictions show an object penetrating this box, additional measurements are made to refine the orbit of the approaching object, and the close approach computations are repeated. If the object is found to also penetrate a smaller box with dimensions 4 x 50 x 50 km, the Orbiter could be manoeuvred to avoid the encounter. This type of analysis has led to approximately eight moves of the Orbiter between 1988 and 2000.

This approach is operationally heuristic and is not based on a quantitatively rigorous assessment of risk. An alternative is to use a probabilistic approach that accounts for the uncertainties in the locations of both objects. Output from this analysis is a probability of collision that operators can use to support decisions. For cases where the collision risk exceeds a pre-specified limit, additional measurement data may be used to refine the estimates and evaluate the necessity for a move. As mentioned earlier, this procedure, used by the International Space Station, is now used for the Space Shuttle.

Reliable collision probabilities for two approaching objects can be made only when reliable information exists on the orbital errors of both objects. In addition, if the errors for either object are very large, then it will not be possible to significantly reduce risk without excessive manoeuvres. Hence accurate orbital data and knowledge of the level of accuracy is required.

For an operating satellite, the satellite's operator may have excellent data on that spacecraft to satisfy requirements to make contacts, point antennae, and the like. Accurate information on a debris object requires a sufficient number of observations from radar and/or optical sites, an accurate orbit determination, and propagation of the object's orbit as it moves away from the measurement point (as described in 2.1.4.1).

If pre-screening based on low-accuracy data indicates a collision may occur between two operating satellites, operator data on each satellite can be combined to refine the collision predictions.

In general, space catalogues must be improved in order to provide meaningful collision avoidance services. In addition, a predicted close approach could be significantly in error if the approaching object manoeuvres or does a small station keeping burn. There is also the possibility that a manoeuvre could exacerbate the probability of collision. Collision avoidance services must know a satellite's planned trajectory, with manoeuvres included, to provide accurate predictions.

- Available Services (Status and Trends)

While some specialized services are used for manned spacecraft, at present only limited services are available to commercial space operators. Generally, these services focus on collision avoidance at geosynchronous orbit altitudes and cover less than 25% of the 250 active satellites at GEO. While some operators believe that it is in their best interest to be aware of close approaches and take action if they are concerned, others have not requested this type of service.

The probability of collision at GEO for a single active satellite is approximately one in 3.000 over a 10-year mission. However, the collective probability of a collision involving an active GEO satellite over the next 10 years is approximately one in 10. If a collision occurs, the relative velocity at impact can easily be high enough to result in the generation of tens to hundreds of additional debris fragments that will contribute to the threat population. Hence, it is in the best interest of operators that they be aware of objects coming close to their spacecraft, and some are requesting such information. Should there be an on-orbit collision of high-value assets, the demand for such services would be expected to grow substantially.

- Spacecraft's Manoeuvring Capabilities

Generally, moving a satellite to avoid an oncoming object is undesirable, primarily because it may induce a costly service outage, and also require expending valuable propellant. Thus, reliable predictions are required before a manoeuvre is warranted. In addition, as noted earlier, the majority of spacecraft, like the Hubble space telescope, have no thrusters and cannot perform any intentional changes of orbit.

Other factors that affect the capability to manoeuvre a spacecraft include the warning time (how far ahead of the close approach is the manoeuvre given), the manoeuvre capability available, and the ability to include the manoeuvre as part of ongoing activities. This latter factor is important in that it may make debris avoidance manoeuvres palatable by minimizing fuel usage for avoidance manoeuvres. Many spacecraft operate in an assigned station keeping "box" and regularly do small manoeuvres to remain within the box. Timing station-keeping burns carefully may be one way debris avoidance can be accomplished in a fuel-efficient manner. The debris avoidance manoeuvres performed by the International Space Station increase the station's orbit altitude so that no propellant is "wasted".

3.2.1.2. End-of-Life Operations

Satellites are very expensive to manufacture and put in orbit, and many satellites remain useful, producing revenue even as they slowly fail. For this reason, it was common for some satellite operators simply to let a satellite die in its mission orbit and take no special measures to reduce the potential of the vehicle exploding or otherwise producing debris or being a hazard in the future. The current realization of the increasing hazards that dead satellites and other debris pose to operational vehicles is leading to new guidelines for disposing of spacecraft.

- Current Status

Current guidelines for end-of-life operations include moving the spacecraft to a disposal orbit and safing the spacecraft, or de-orbiting and re-entering the spacecraft into an area where the hazard to people and property is minimized (of course, the latter option may only be available for some spacecraft as it may require substantial propulsive capability). The criteria for re-entering a spacecraft is based on the hazard posed to people should the hardware re-enter naturally.

Currently, there are approximately 650 operating satellites. Most of these were put into space before end-of-life disposal was considered seriously. Despite this fact, some operators are becoming sensitive to the potential hazard posed by dead spacecraft and are working to comply with current end-of-mission guidelines. For many spacecraft currently in the early design phase, measures are being taken to include disposal.

Satellites and hardware can be moved to designated disposal regions, e.g. about 300 km above GEO. Another recommended disposal option at end of mission is to place hardware into orbits whose lifetime is less than 25 years.

- Trends

Safing of Spacecraft and Rocket Bodies
Safing is defined as "making spacecrafts safeguarded against accidental break-ups after the end of active missions." Actions that can be taken to reduce the likelihood of satellite explosions are to vent propellant and other pressurized tanks at end of mission, and to discharge batteries, thereby leaving the vehicle with a minimum of stored energy. These actions apply to both satellite vehicles at end of mission and to rocket stages and other hardware left in orbit after their payload has been deployed.

End-of-Life Manoeuvring Capability
Actions can be taken at end of mission to manoeuvre a satellite or stage to a disposal orbit. Manoeuvring requires a relatively healthy satellite (functioning attitude control, propulsion, and other manoeuvre-critical systems) and also requires a suitable propulsion system and sufficient propellant. As satellite mission durations increase, the risk of disposal failure may increase. If a satellite's health begins to degrade during its normal life, it may be advisable for operators to take the conservative measure of de-orbiting or moving to a disposal orbit before onset of complete failure. In the past, mission goals have motivated operation of the satellite in its mission orbit until the bitter end. Emerging international guidelines and regulations may make this much less common.

New Designations of Disposal Orbits
Research on disposal orbits is finding that some may not have previously anticipated long-term characteristics. For example, recent studies have shown that some MEO disposal orbits can be unstable. This can lead to re-penetration of constellations that operate in MEO, such as GPS and Glonass. This instability can be delayed by precise targeting of disposal orbital parameters.

3.2.1.3. "Zoning" of Orbits

- Current efforts to manage key orbits

Zoning can be defined as the restriction of certain activities in certain regions. The key orbits are all to some degree limited resources. An infinite number of spacecraft cannot operate in each orbital regime due to the possibility of collision and other types of interference. In addition, debris in each orbital regime increases the risk (and thus reduces the utility) of the orbit. One approach to ensuring that key orbits remain useful for current and future space activities is to regulate the type of activities that can be conducted in each orbital regime. In a few areas, limited de-facto "zoning" efforts are already in place. For example, the International Telecommunication Union to a large degree determines where communications spacecraft can operate in geostationary orbit. The ITU, however, is mostly concerned with radio frequency coordination and does not regulate other aspects of geostationary spacecraft operations. However, the ITU has had a spacecraft disposal policy for more than 10 years due to concerns about physical interference, i.e., collisions. Individual nations and space agencies have also instituted guidelines and rules to protect key orbits, but these restrictions are not yet universal. For example, NASA guidelines limit the lifetime of objects passing through geostationary orbit.[75]

- Potential future "zoning" of orbits

Zoning may be used in the future to ensure the short- and long-term availability of key orbital management. Zoning may discourage certain uses of key orbits. This could entail:

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75 NASA Safety Standard 1740.14. Guidelines and Assessment Procedures for Limiting Orbital Debris. August, 1995.

Requiring some types of space activities to not interfere with key orbits. For example, space billboards or the launching of human remains into space might be restricted to certain orbits (e.g., extremely low orbits, escape trajectories) so as to avoid interference with other space activities.

Requiring activities taking place in heavily-used orbits to follow certain "environmental" rules, such as ensuring that rocket bodies are not left in intersecting orbits, minimizing the creation of "operational debris", or mandating the use of disposal orbits.

Different technical approaches will be appropriate to preserve and protect the different orbits. For example, debris in very low orbits is removed by the upper edges of the atmosphere, so fewer restrictions on the creation of debris may be needed in such orbits. Stringent regulation of debris creation, on the other hand, may be needed in geostationary orbit due to the persistence of objects in that orbit.

In some cases, certain space activities may be able to be conducted from alternate orbital regimes, outside of currently busy areas. For example, a number of alternate orbits could potentially be used by the future navigation satellite constellations, which theoretically can effectively operate from a wide variety of orbits. Such an approach will not work for all orbits - the geostationary arc, for example, is a narrowly defined area that provides significant advantages over other orbits.

3.2.1.4. Removal of Debris (Status and Trends)

If debris could be removed from an orbit, the hazard to space operations would decrease. Several schemes have been proposed to remove debris, including:

Removal of large debris with robotic spacecraft[76]
This approach typically involves the rendezvous of a robotic spacecraft with large debris objects. The robotic spacecraft grapples them and then moves them to other orbits. Developments in the next few years[77] may provide some of the rendezvous and docking technologies that would be required, and the ingenious use of tether systems[78] could reduce the energy requirements, but all indications are that this approach will be uneconomical for large-scale use.

Debris removal using lasers
Proposals have been made for the removal of debris using ground-based[79] and space-based[80] lasers. In these approaches, lasers typically are used to illuminate small debris, causing them to change orbit. Challenges to such a system include the technical difficulty of tracking small, often dark, fast moving, debris objects the political problem of the system's potential use to intentionally damage spacecraft, and the potential hazard such a laser beam would pose to operating spacecraft.

Removal of debris using "debris sweepers"
In this approach, large foam balls or foils are deployed to "sweep up" all small debris objects they come into contact with. This technique appears to pose a larger hazard to spacecraft than the debris it sets out to remove, and may even create additional debris.

76 Ramohalli, K./Jackson, J. Space Debris, An Engineering Solution with an Autonomous Robot, in: Space Energy and Transportation (1/2) 1997.

77 Notably the United States' Orbital Express program to develop and demonstrate autonomous techniques for on-orbit refueling and reconfiguration of satellites

78 Eichler, P./Bade, A., The Improved TERESA Concept for the Removal of Large Space Debris Objects from Earth Orbits, in: Proceedings of the First European Conference on Space Debris, 1993.

79 Bekey, I.,Project Orion: Orbital Debris Removal Using Ground-Based Lasers, in: Proceedings of the Second European Conference on Space Debris, 1997.

80 Bondarenko, S./Lyagushin S., Prospects of Using Lasers and Military Space Technology for Space Debris Removal, in: Proceedings of the Second European Conference on Space Debris, 1997.

In short, no scheme to remove existing debris from orbit has yet been implemented, and the technical consensus is that none of these approaches are likely to be effective in the near future.

3.2.2. Regulatory Aspects

This section sets forth certain issues that arise with the growing number of objects that are in outer space, and the lack of regulation regarding the use of non-geostationary orbits. It will focus on the in-orbit operations of spacecraft, such as station-keeping as well as the use of radio frequencies utilized to provide satellite telecommunications, which are allocated by the International Telecommunication Union (ITU) to different services. These include the Fixed-Satellite Service (FSS), the Broadcast-Satellite Service (BSS), and the Mobile- Satellite Service (MSS). The orbits and frequencies used to provide Radio Navigation Satellite services (RNSS) and by global positioning satellite systems (GPS) will not be discussed at length in this section.

It should be stressed at the outset, however, that the choice of orbits utilized is not regulated by any entity, neither national nor international. The orbits of choice -and the choice of orbits- are determined by the proponents / operators of the satellite system(s).

Similarly, the number of satellites comprised in any satellite system is the prerogative of the proponents of new systems, and operators of satellite systems already in orbit. Their decisions are based on technical, economic and political factors, and rarely on legal questions, since there is no world agency that has the authority to limit the number of satellites launched, or the orbits used. The exception to this “caveat” is that the number of satellites that can be located in geostationary orbit is limited by the number of optimal orbital slots available in that orbit. Further, some FSS and BSS satellites located in geostationary orbit are subject to plans devised by the International Telecommunication Union (ITU).

The builders and/or operators of planned or potential satellite systems are the ones who decide in what orbit, and which radio frequencies they plan to use. They submit their proposals to their Administration[81], which in turn, assigns their orbital positions and radio frequencies, in accordance to the regional allotments made by the ITU, and in accordance to the ITU’s allocation of frequencies to the various satellite services. The Administrations submit their “Advance Notification” or request to the ITU, which publishes the information submitted to it. Any Administration which believes that (any of) its communication systems will be subject to harmful interference by the proposed system can respond to the ITU notices. Proponents of any new satellite system then need to coordinate it with other existing and planned communication systems (terrestrial and satellite) prior to bringing them into service, to avoid harmful technical interference between them. This process can take years, and is becoming increasingly more complex with technical advances and new technology, as well as the number of new satellite systems that are notified to the ITU[82].

81 The “Administration” is the entity designated by the national government to handle telecommunication matters. In most countries, a ministry is charged with this task. The USA is one of the few countries that has no ministry of communications. Rather, the Departments of Defense, of State, of Commerce, and federal agencies such as the Federal Communications Commission (FCC) and the Dept. of Commerce’s National Telecommunications and Information Administration (NTIA) are all involved in satellite telecommunication matters.

82 The ITU provides for certain time periods during which the notifying Administration is to bring the satellite system into service. The Administration has 6 years, plus a 3-year “grace” period from the date the system is registered with the ITU, to coordinate with potentially affected Administrations and systems, to build, launch and begin operations.

3.2.2.1. Information Needs / Notification (Prior to Launch)

- The International Telecommunication Union (ITU)

All satellite radio systems, whether in geostationary or non-geostationary orbit, are notified by the Administrations to the ITU. The ITU's Radio Regulations (RR), Resolutions and Recommendations are applicable to space radio stations in geostationary and non-geostationary orbits, as well as to terrestrial communication systems that use the radio frequency spectrum (RFS). Thus, prior to, and during the in-orbit phase, certain basic information is available to those in charge of "orbital traffic management".

Unlike satellites in the GEO, however, those in non-GEO orbits cannot serve a specific service area without interruption. Since these spacecraft are in lower orbits, their coverage area is more limited and more space radio stations are required to provide uninterrupted services[83]. (The ITU-RR pertinent to the Mobile Satellite Service (MSS) have been developed in the course of several World Radio Conferences, specifically those of 1992, 1995 and 1997). Certain unique characteristics of MSS systems are elaborated on.

- Mobile-Satellite Service (MSS) Systems

One of the distinguishing features of the GMPCS[84] is that they are being financed and developed by private parties. Another distinguishing feature is the large number of satellites in each constellation, and the increasingly complex task of their technical coordination with existing and planned telecom systems.

Another feature of the GMPSC is that, unlike satellites in GEO, they are changing their position relative to the ground terminals and this limits communication times. While many Administrations are concerned with the "saturation" of the geostationary orbit and associated frequencies, since there are a few optimal orbital positions in the geostationary orbit, they do not seem to be concerned about the effect of a few hundred active satellites in LEO or MEO. Even though the Administrations notify the ITU of their space radio systems, in regard to the GMPCS systems they only have to notify the frequencies, not the orbits, which they plan to use. Consequently, some of the GMPCS operators are finding that there are systems already operating in the orbits (and sometimes even the frequencies) they were or are planning on using.

Currently, the principal regulatory framework for the operation of space radio systems is provided by the technical coordination process among Administrations, in accordance with the ITU Radio Regulations applicable to the different services (Fixed-Satellite, Broadcast-Satellite, Mobile-Satellite Service, etc.). This coordination process is lengthy and complex, and takes place (usually) prior to both the launch and entering into service of the satellite system.

- In-orbit Operations other than Normal Procedures - Moving satellites from one orbital position to another

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83 IRIDIUM is comprised of 66 satellites at an elevation of about 750 km; in at least 8 orbital planes; Globalstar 48 + 12 in-orbit spare satellites at 1450 km.; TELEDESIC planned to launch at least 288 satellites to an elevation of 400 km, but has modified its plans. After its acquisition of ICO Global Communications' assets, it plans to launch at least 10 satellites to a medium earth orbit (MEO) at 10350 km.

84 GMPCS is the acronym for "Global Mobile Personal Communication Services/Systems/Satellites, which comprise satellites in geo and non-geo orbits, using radio frequencies allocated to the mobile as well as to fixed satellite services. The GMPCS Memorandum of Understanding (GMPCS MOU) was drafted in the course of the ITU's First World Policy Forum in 1996, and signed by more than 125 entities. While the GMPCS MOU includes principles that should be adopted, it is legally unenforceable, unless and until these principles are incorporated into national legislation and subsequently, national regulations.

A satellite may be moved for several reasons. For instance, the operator may need to move the satellite from one orbital location to another, because of an exchange of positions with another satellite operator. This situation occurred within the framework of the 1988 Trilateral Arrangement between Mexico, Canada and the US. This agreement covers the use of orbital positions and the use of C and Ku bands between and including 121° W and 105°W, and thus required moving a satellite to within this portion of the orbital arc.

When a satellite has to be moved from one orbital position to another, which is a common procedure, the operator who manages the shift of orbital position needs to inform the operators of other satellites in other orbital locations that the satellite is going to be moved, using an orbit slightly higher or lower than the GEO, which may cause some temporary interference while the satellite is being moved. The satellite operators also notify the users of their spacecraft, since they have to repoint their antennas or Earth stations to maintain continuity of service while the satellite drifts to the new orbital location.

Another in-orbit procedure occurs when a satellite presents a technical anomaly in orbit, and cannot provide the services as planned. In this case, the traffic carried on the transponders of the malfunctioning satellite is frequently transferred to other transponders, or to a "spare" or replacement satellite, which is usually already in orbit, to ensure continuity of service. The spare satellite is moved from its "warehouse" orbit to the correct orbital position, and activated to provide services with minimal interruption.

Yet another in-orbit scenario presents a big challenge: what to do with a satellite that does not reach its proper orbit? When this occurs, the press states that the satellite is in a "useless orbit", but this is a misnomer. It is the satellite that is useless in that particular orbit, since it has not been coordinated to provide services from that particular orbital location (usually a lower orbit than the GEO). The owners/operators may declare the satellite a total loss for insurance purposes, or they may attempt to boost it to its proper orbital location[85]. A satellite in a "useless orbit" presents the hazard of causing technical interference with the operations of other satellites, as well as of colliding with other space objects, since it may be in a random orbit.

An even more challenging situation arises when the satellite has reached the end of its useful life in orbit. The operator has several alternatives, as described in part 2.1.6. In the future, there may be more traffic with autonomous robotic missions for servicing satellites. This will pose additional information requirements in order to avoid physical interferences.

In brief, at present there is no international legal regime governing the use by spacecraft of the different orbits, regardless of the service (FSS, BSS, MSS, etc.). The ITU's Radio Regulations and the coordination procedures among the satellite operators continue to be the fundamental parameters.

- Technical innovations

The use of new technology offers the possibility to co-locate several satellites in the same orbital position, which of course requires very precise orbital tracking and control, as well as improved use of the radio frequency spectrum ("frequency re-use") so that no interference is created between the co-located satellites. At present, at least five satellites can be co-located on one orbital slot, without causing interference, as demonstrated by EUTELSAT and SES. Another means of optimizing the use of these limited resources (frequencies and orbital positions) is to have the antennas on board the satellites pointed to different coverage areas (e.g., north or south of the Equatorial plane), as well as using different frequency bands (C Band /Ku Band) for their transmissions.

85 NASA has retrieved very few satellites and brought them back to Earth. In the early 1980s, one "Westar" and one "Palapa" satellites were retrieved, refurbished and sold to new operators. In 1993, NASA "reboosted" an INTELSAT satellite that had been launched into a "useless" orbit. Due to their high cost, very few of these "rescue missions" have taken place.

Despite technological and regulatory progress in the best use of the geostationary orbit (most players agree that currently there are sufficient regulations for the orderly bringing into service of the various satellite services), specific new rules may need to be drafted in order to address some particular issues. These are elaborated upon in the following section.

3.2.2.2. Regulatory Needs at the International and National Levels

- A more precise notification process for space radio systems in the GEO

The national Administrations themselves should ensure that they are not notifying the ITU of merely "paper" systems that will never be deployed. The Administration should institute certain basic but stringent requirements to obtain a license to launch and operate a satellite system. These should include financial milestones, as well as submission of realistic business /market share plans, within definite deadlines. Thus, if at the end of the designated time period, the system's proponent does not have adequate financing or a sound business project, the Administration would not notify the ITU of this system. In this manner, both the Administration and the ITU would ease their respective tasks of notification and coordination, since many "paper" systems would be eliminated *ab initio.*

Another means of mitigating the filing of "paper systems" would be to require the notifying Administration to submit information to the ITU not only of space radio stations but also of satellites having those stations on board[86]. The Administrations, under the title "Governments" should inform the UN Secretary-General (UNSG), not only of the launch of satellites, as mandated by the 1976 Registration Convention, but also of radio stations on board these satellites. This initial registration, or exchange of information among the national Administration, the ITU, and the UNSG, would give all concerned Administrations notice of the system(s) that have met the initial milestones, and which are likely to succeed. It would make the problem of "paper satellites" or "paper radio stations" transparent and its solution possible.

- The need to regulate non-geostationary space radio systems

Satellite systems at LEO and MEO are used for mobile telephony, data communication, Earth observation, remote-sensing, global navigation and positioning, inter alia. The early LEO voice and data communication systems (constellations) used the MSS frequency bands, and were known by the acronyms "S-PCS" and "GMPCS"[87]. Services were launched with much fanfare in the second half of the 1990s, with IRIDIUM being the first to come into service in 1998. However, market realities soon intervened, with the result that most GMPCS systems had to seek protection of the US bankruptcy courts. Although there are fewer so-called "Big LEO communication satellite systems" in operation than expected, they are still there. For instance, a "new" Iridium venture (comprised of the original 66-satellite constellation) was able to acquire the former IRIDIUM entity, albeit with a scaled-down array of services, and Globalstar (a 48-satellite constellation) continues to offer part of its original services despite its financial troubles. ORBCOMM, the only "Little LEO" system (for messaging and data transmission, but no voice services) that became operational, also underwent a financial reorganization and is still in service as authorized by the FCC in March 2002.

Since the deployment of GMPCS, new, more promising mobile services, utilizing the Ka-band (broadband), mostly dedicated to high-speed data transmissions, have been designed. They would

86 In the present practice, space radio stations appear in the ITU Quarterly Publication of the Space Network List under names or designations which, as a rule, differ from those of the satellites announced to the UNSG, making it impossible to find out which radios are on board of what satellites.

87 Satellite-Personal Communication Services (S-PCS) is the acronym used in Europe. S-PCS systems were subsumed in the Global Mobile Personal Communication Services, GMPCS, at the 1996 ITU-sponsored World Policy Forum. GMPCS is broader than S-PCS, and comprises satellites in GEO as well as in LEOs. "GMPCS" includes Big LEOs, Little LEOs, MEOs, whether using the MSS, BSS or FSS (the latter for broadband services). (See note 5, supra)

utilize constellations of satellites located in LEOs. Teledesic was the fore-runner, but its system has undergone several re-designs, particularly since it acquired the former ICO Global Communications and its assets: 10 satellites to be launched into MEO. Teledesic's mutations were followed by the announcement that another Broadband system planned in the mid 1990s, SKYBRIDGE (an 80+-satellite constellation), was withdrawing this project for the time being[88]. Even though many of these systems are not a financial success, their satellites are in orbit, and some of them, like IRIDIUM's, may be replaced as they are approaching the end of their useful life in orbit. Thus, utilization of these low orbits is likely to remain quite intense. Like other GMPCS, many new LEO constellations have not fulfilled all their promises nor materialized yet, but if their proponents are to be believed, and based on the fact that they are expected to alleviate the alleged future saturation of terrestrial Internet (IP) networks, they will be heavy users of LEOs[89].

In addition to telecommunications satellites, other systems already use, or plan to use LEOs and MEOs. For example, there is the much discussed European-sponsored global positioning constellation GALILEO (27 operational satellites plus three in-orbit spares), in addition to the already operational US GPS NAVSTAR, and the Russian Glonass. All the satellites comprising these systems are, or will be in circular orbits at 19.000, 20.000 and 24.000 km respectively.

Most recently, commercial satellite operators have started coordination procedures dealing with radio-frequency interference issues. For this purpose, they established a Satellite Users Interference Reduction Group (SUIRG).[90] The results of this group's work show on the one hand, that commercial/private actors have started to act on their own in coordinating to avoid interference without waiting for governments to act. On the other hand, its work shows that the SUIRH has not yet taken up the issue of physical interference, which could also be dealt with in such a setting.

3.2.3. Findings

- Manoeuvring and in-orbit collision avoidance (with regard to other operational space objects as well as with regard to space debris) is increasing in quantity and importance.
- Manoeuvring in the GEO is utilised but with little regard to possible collisions.
- Reliable collision probabilities can be estimated only when reliable information exists, which currently is not guaranteed.
- There is already one-way traffic in GEO, as all satellites in GEO are orbiting eastward in the equatorial plane.
- No systematic zoning (restriction of certain activities in certain regions) of outer space is applied.
- The ITU system of nominal orbital positions is applicable only to satellites in the GEO.
- Private/commercial actors have started (i.e. through SUIRG and ITU) coordinating to prevent radio-frequency interference.
- Matching spacecraft with space radio stations on board could make the problem of "paper satellites" transparent and better understood.

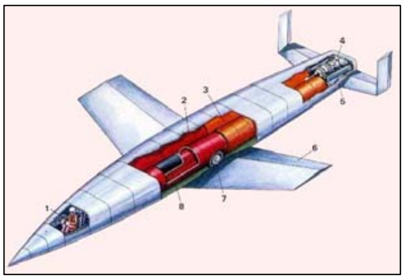
88 Teledesic returned its license to the FCC in 2004, while Skybridge received a license from the FCC in early 2005.
89 Fiber optic cable (FOC) networks were to be the backbone of the "Global Information Highway", yet some of the largest FOC operators, like Global Crossing, are now in "Chapter 11" reorganization, and there is an abundance of unused FOC capacity.
90 Ailor, William H., Space traffic management: implementations and implications, IAC-03-IAA.5.5.a.02., 8.

3.3. The Re-Entry Phase

3.3.1. Trends in Technology Developments

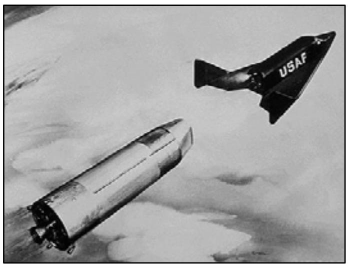
3.3.1.1. Reusable Launchers and Aerospace Objects

- History



Reusable launch vehicles (RLV) were conceived more than seventy years ago, well before Sputnik was launched into orbit on a converted SS-6 ballistic missile in 1957. The early rocket pioneers Oberth, Tsiolkovskiy, and Goddard wrote of them as logical extensions of the rapidly emerging aircraft industry during the 1920's and Sänger and Brendt refined these early ideas and produced RLV designs in the 1930's and 1940's capable of delivering munitions anywhere in the world from orbit. [91]

The end of World War II and the beginning of the nuclear arms race derailed this progress, initiating the era of ELV. Although some spacecraft concepts such as the DynaSoar (pictured) were reusable, the tremendous investment in ICBMs during the 1950's facilitated the rapid production of a series of ELVs by both the US and USSR, while reducing the emphasis on the development of RLVs.



In the 1960's, the USSR, Europe, and the US spent over $50M (1.960$) on RLV studies. At least ten distinct RLV programs have been identified, but none produced any appreciable hardware. In the late 1960's the US coalesced its efforts into the fully reusable Space Shuttle program, expected to reduce launch costs to under $10M (1.970$) depending on flight rate. By 1971, the US had settled on a partially reusable design leading to the first flight of the STS in 1981. Since its development, the US Space Shuttle has launched over 110 times with two catastrophic failures, proving the technical feasibility of RLVs. The remaining three Orbiters are to be taken out of service by 2010. In parallel with the US efforts of the 1970's, the USSR developed an un-crewed, partially reusable vehicle named Buran, which successfully flew its only unmanned test flight in 1988.

By the mid-1980's, it became apparent that the Space Shuttle would not meet cost or operational goals necessary to enable the transformation of the space industry. Since then, NASA and the US Air Force have funded a number of operational and demonstration RLV efforts without success. Post-Space Shuttle, over $5B have been spent on RLV-related projects including the National Aerospace Plane (NASP), the DC-X/A, X-33, X-34, X-37/40, and X-43.

- Status

Following the X-33 and X-34 demonstration programs, NASA's 1999 Space Transportation Architecture Study (STAS II) charted a new course for the development of RLVs. Starting in 2001, the US Congress allocated $4.8B through 2006 for the Space Launch Initiative (SLI), with a decision on full-scale RLV funding due upon its completion. However, in 2004, NASA announced a reprioritization of activities that essentially ended the agency's programs to develop reusable launch vehicles in favour of a renewed focus on human and robotic exploration of the solar system.

91 Jenkins, Dennis, Space Shuttle. The History of Developing the National Space Transportation System, 1996.

Although nascent RLV programs exist in at least five countries other than the US, no significant sources of long term funding are apparent. Government funded RLV designs for crew transfer, cargo transfer, space servicing, military missions, and human exploration may be demonstrated in flight by as early as 2009, but an operational program or programs will likely not reach full operational capability until 2015.

- Trends

From its inception, RLV development has been a cyclical proposition. Significant technology risks, procurement costs, time between design-to-flight iterations, uncertainty in operations costs, and indeterminate launch demand elasticity have been strong counterpoints to the promise of "aircraft-like" access to and use of space. In past decades, the different RLV-enabled space access has drawn governments and entrepreneurs to attempt to overcome these obstacles and develop a cost-effective and reliable reusable launch vehicle.

The German *Silverbird* and *Amerika Bomber* concepts of the 1940's were focused on global delivery of munitions. Global bombing requirements blended with space control missions in the 1950's and 1960's, as the US significantly funded systems such as the *Aerospaceplane* and *DynaSoar* and the Soviets systems such as the *Raketoplan* and the *Spiral OS*. A human crew was seen as a necessary element of many of these systems' concepts of operations. In this era, almost every design combination of staging, propulsion, and launch/landing modes was explored, but none produced a technically feasible or affordable design.

In the 1960's and 1970's, governments' focus turned toward "routine" access to space and servicing commercial, civil, and military launch demands with a single system. ICBMs reduced the perceived need for prompt global strike, and "space transportation" was the primary design driver for systems. National will and significant compromise of design requirements enabled the completion of the world's only operational RLV, the US Space Shuttle.

The 1980's brought the promise of space solar power, space tourism, and increased human exploration of the solar system. These projects required a significantly more cost-effective and more reliable launch system, sparking European (Sanger II) and US (AMLS/Shuttle II) RLV programs. When these growth areas failed to materialize, RLV plans were shelved or cancelled.

In the late 1980's, the technology for a combination global transportation system, global strike, and small satellite launch system based on hypersonic jet (rather than rocket) power appeared feasible. Systems such as the JSP Spaceplane (Japan), the National Aerospace Plane (US), and the Tu-2000 (USSR) reached various levels of design before ultimately being cancelled in the early 1990's due to technical difficulty.

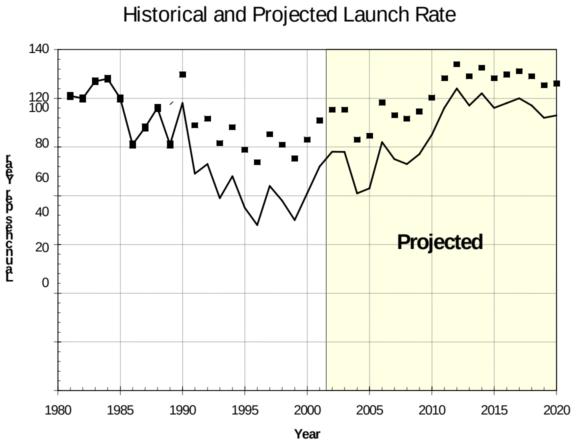
The promise of a burgeoning telecommunications satellite market initiated a flood of privately funded RLV companies in mid-1990s. Companies such as KST, Kistler Aerospace, Pioneer, Rotary Rocket, and Space Access have spent in excess of $100M of venture capital to develop their concepts to service this market, but none has yet completed a test launch. The telecommunications and economic downturns of 2000 and 2001 have stalled many of these efforts, although some remain optimistic about servicing civil and commercial markets and competing with ELVs.

The catalyst for the development the next RLV or family of RLVs will likely come from the areas mined for support in the past. The justification for this RLV may be one or a combination of:

- *Civil*: Routine, reliable access to a space station or for human exploration
- *Commercial Launch*: Delivery and/or servicing of a commercial space venture (e.g., telecom or space power)
- *Commercial Transportation*: An RLV derived from a hypersonic aircraft
- *Military*: Global strike and/or rapid access to orbit
- *Space Tourism*: Trips to orbit or sub-orbit for entertainment

Figure 3-3 Historical and Projected Launch Rate

While projections for the worldwide launch rate for the next 20 years[92] do not see an increase from historical levels, the expansion of any of these missions would significantly change these forecasts. The level of launch demand where an RLV makes fiscal and operational sense will not be settled unless an program is successful, but the promise of routine, affordable, and “aircraft-like” access to and use of space will ensure that RLV programs will be eagerly pursued for the foreseeable future.



3.3.1.2. Intentional De-Orbiting

- Reusable spacecraft

History

Reusable spacecraft are a natural extension of routine, affordable access to space. The first acknowledged reusable spacecraft programs included the US Air Force DynaSoar and the Soviet Kosmoplan[93] of the 1960’s. The DynaSoar was a reusable orbital asset launched on an ELV designed to be capable of orbital supply, rendezvous and inspection, and orbital bombing. The KosmoPlan was a family of unmanned spacecraft built using modular elements. These elements included high performance storable liquid propellant engine modules; nuclear reactor modules for high power space applications; ion engine units for inter-orbital transfer and interplanetary flight; and re-entry vehicles permitting return of payloads from space with landing at conventional airfields. Almost all elements were designed for re-use.

In the early 1990’s, Boeing (then Rockwell) developed designs for a reusable satellite bus named ReFly™. This bus would host and return up to 800 lb of sensor or experiment weight and provide full satellite bus services for up to 1 year on orbit. The system would have significant manoeuvring capability and would land on conventional runways. The X-40A was built by Boeing and the Air Force in the late 1990’s, and it successfully tested the low speed flight and landing characteristics of Boeing’s design.

92 The Global Demand for Launch Services, P. McAlister. Futron Corporation,STAIF, February 12, 2001.

93 Mark Wade’s Encyclopedia Astronautica. http://www.astronautix.com.

Status and trends

A number of countries have employed recoverable and partially reusable experiment recovery systems. The Chinese have successfully launched and recovered space experiment modules, and some of the hardware is reused after flight. The Chinese (*FSW*) and Russians (*Kosmos*) launch film satellites for reconnaissance, and the film is returned to Earth in partially reusable re-entry vehicles. The Japanese have proposed a commercial experiment recovery system in both expendable (*USERS*) and reusable (*HOPE*) versions. Funding for these programs has been cut in recent years. India has designs on a recoverable and reusable micro gravity module named *MARS* that would be launched on a PSLV, but the status of the program is undetermined. The US has planned several recoverable test platforms including *COMET* (*METEOR*), but none has flown to date.

As follow-on to the X-40A drop tests, Boeing has a contract with NASA to develop the X-37, a reusable satellite bus with significant manoeuvring capability. While the project status is currently in question, the ultimate plan calls for the X-37 to be launched into LEO on an ELV. It would carry up to 500 lb of experiments in a payload bay and provide power, thermal control, communications, and other basic services to the payload. After several days or weeks in orbit, it would return to Earth and autonomously land on a conventional runway.

Intentional de-orbiting of RLVs is essential, and future developments in this area will depend on the demand for the capabilities offered by such systems.

- Hardware disposal

History

Since the beginning of the space age, some care has generally been exercised in the disposal of hazardous debris from launch vehicles. Once a spacecraft entered orbit, it became impossible to predict where debris would land when the spacecraft decayed and re-entered the atmosphere. Periodic high-profile examples of surviving debris serve to reinforce the concept that large hazardous objects and hazardous materials can and do survive re-entry. Three noteworthy examples:

- Cosmos 954 re-entered in 1978, spreading highly radioactive material over a 260 km long footprint on northern Canada
- Skylab re-entered in 1979, depositing debris in remote areas of Australia
- The second stage of a Delta launch vehicle re-entered in 1997 after nine months in orbit, dropping a 570-pound fuel tank 50 yards from a Texas farmhouse.

A measure of the hazard associated with re-entering objects is that, to date, only one individual is known to have been struck by a piece of debris from a re-entering object that a small, lightweight fragment which caused no injury. This means that over the last 40 years, despite the re-entry of over 3.000 large objects and possible impact of some 2.000 metric tons of surviving debris, there have been no recorded casualties. It has been estimated that the likelihood of an individual somewhere on Earth being struck and injured by surviving debris from a large object re-entry is on the order of 1 in 10.000.

Re-entry of hardware received increased attention when the disposal of the entire Iridium constellation was proposed. Given the de-orbit of the entire constellation of 70-plus satellites, hazard predictions were that the casualty expectation exceeded 1 in 250 worldwide (i.e., if the full constellation were de-orbited 250 times, one person would likely be injured or killed somewhere on the planet). This hazard, though very small, increased the exposure of re-entry disposal to legal and other challenges, with possible heavy liability for the re-entering hardware’s owner, and also increased understanding of the hazard posed by debris from re-entering objects.

Despite the low casualty expectations, some satellite operators have regularly turned to disposal of potentially hazardous hardware (such as Progress cargo spacecraft, Salyut and Mir orbital stations and

Compton Gamma Ray Observatory) in ocean areas as a means of assuring themselves that the hazard is essentially eliminated.

Status and trends

The international space-faring community is evolving guidelines that require satellite operators to dispose of hardware when the casualty expectation for the re-entry of that hardware exceeds $1x10^{4}$. This guideline has already been imposed in some agencies (e.g., NASA), and will likely become a rule in the future. Unfortunately, much hardware currently in orbit was designed and launched before this guideline was recommended and the capability to be de-orbited does not exist.

At the same time, where the hazard has been quantified and is of concern, the hardware has been or is being de-orbited. Examples are the Mir Space Station and NASA's Compton Gamma Ray Observatory.

In the case of 135.000 kg Mir, estimates were that as much as 40.000 kg of material might survive re-entry and impact the Earth's surface over a footprint of possibly 2.000 km in length. The Mir was successfully de-orbited into an ocean area in March 2001.

It is likely that the increased realization of the possible, but very remote, hazard posed by re-entering hardware will lead to increasing use of planned and targeted de-orbit of satellites. These actions, of course, will be increasingly common as agencies and governments adopt rules governing re-entry hazards.

3.3.1.3. Uncontrolled Re-Entry

Many existing spacecraft and space objects do not have the capability of de-orbiting; i.e., they do not have sufficient propulsive or control capability to impart the velocity change necessary to target the hardware to re-enter in a specific location. If the hardware is in LEO, it will decay and the hardware will re-enter the atmosphere and "burn up." In this document, uncontrolled re-entry is equivalent to unintentional de-orbiting of hardware.

History

Since the beginning of the space age, approximately 3.500 large objects have de-orbited in an uncontrolled fashion. These objects were broken apart by re-entry heating and loads, with perhaps 25% of the mass surviving to impact the Earth's surface. Approximately 75% of these re-entries deposited materials in ocean areas. Only a very small percentage of the material that impacted on land areas has been recovered and analyzed.

Status and trends

Currently, there are approximately 9.000 catalogued objects without de-orbit capability in orbit, and many of these will re-enter in years to thousands to tens of thousands of years, depending on their orbit altitude. In addition, satellites and associated hardware without de-orbit capability will continue to be placed into orbit, or will fail in orbit, an eventually re-enter.

In the future, it is expected that unintentional de-orbit of large objects will become less common as emerging rules require that sizeable hardware be actively de-orbited. Smaller and less hazardous objects will continue to use orbit decay as the means for removal from orbit.

3.3.2. Regulatory Aspects

Analyzing regulatory aspects of the "re-entry phase", it has to be considered that - with regard to the already existing regulatory status quo as well as with regard to the (remaining) regulatory needs -"re-entry" activities are and will be governed by the general rules and regulations applicable to all kinds of space activities as well as special rules and regulations applicable to the specific "re-entry" activity.

As concerns specific or special rules in place or to be put in place for "re-entry" activities, it should be clear and defined to which kinds of activities such special rules shall apply. It might thus be necessary to obtain a certain common understanding of the process of "re-entry". While the term is repeatedly used (also referring e.g. to the "re-entry into the Earth's atmosphere") in the United Nations Principles Relevant to the Use of Nuclear Power Sources In Outer Space[94] (NPS-Principles)[95], the international Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Space Objects Launched into Outer Space of 1968 (ARRA) only mentions the "return of space objects to Earth"[96] or the "unintended landing [of personnel]"[97]. Some national space laws, e.g. the Australian Space Activities Act 1998 No. 123, 1998[98] also regulate "return" of space objects to Australia, defining "[to] return a space object" as "to return the space object from outer space to Earth, or the attempt to do so".[99]

A recognized definition of the "re-entry phase," however, does not seem to exist at the level of international law.[100] The technical questions of a more detailed international space traffic management might raise (again) the question of an international agreement on the delimitation of the (upper) airspace and outer space.[101] This question however has been a matter of continued discussion in the Legal Subcommittee of the United Nations Committee on the Peaceful Uses for Outer Space (UNCOPUOS), without that any agreement on a possible solution likely in the near future. Therefore, for the purposes of a possible international agreement, "re-entry" may be defined as any movement of a space object close enough to and in direction towards the Earth's atmosphere that may technically result in a subsequent use of airspace of the Earth or a landing (whether controlled or uncontrolled) on the Earth's surface.

3.3.2.1. Information Needs (Information/Notification)

Information needs in the strict sense arise from the technical repercussions and substantive hazard of a re-entry, whether in the form of a ballistic return or controllable powered flight, and the possible effects, dangers and coordination needs it implies for individuals, governments and authorities. A re-entry event however is most critical with respect to co-ordination needs since in such case a space object crosses the airspace or might affect areas of the sea or land on the ground and thus possibly affect not only other modes of traffic but also the population. Prompt exchange of information is most important to avoid collisions or hazards.

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94 UNGA Resolution 51/122 of 14 December 1992.

95 Cf. in particular Principles 5 and 7 NPS Principles.

96 Cf. e.g. Article 5 ARRA.

97 Cf. Article 2 ARRA.

98 The Act is i.a. available on the Website of the United Nations Office for Outer Space Affairs, http://www.oosa.unvienna.org/SpaceLaw/spacelaw.htm.

99 Section 8 Australian Space Activities Act 1998.

100 The NPS Principles use the term re-entry, its definition however does not seem to have been a matter of much discussion when adopting these principles; cf. Marietta Benkö/Gerhard Gruber/Kai-Uwe Schrogl, The UN Committee on the Peaceful Uses of Outer Space: Adoption of Principles Relevant to the Use of Nuclear Power Sources in Outer Space, in: German Journal of Air and Space Law ZLW (42,1) 1993, 36-64.

101 Cf. email by Prof. Perek in connection with this study dated 26 April 2002, with reference to Section 2.3. of the FAA's Concept of Operations for Commercial Space Transportation in the National Airspace System, Narrative Version 1.1 of January 14, 2000.

- Exchange and availability of information as essential for mitigation of possible damages – International information and co-ordination

Responsibility and liability for damages caused by space objects or its components ensue not only from international space law[102] but also from the general provisions of national (tort) civil and administrative law. Since possible damages may be avoided in the course of a re-entry activity by providing sufficient and sufficiently precise information,[103] in this context, provision of information is not only in the interest of the persons, authorities or governments of states possibly affected by a re-entry activity, but also in the vital interest of the authorities or persons responsible for a space object that may re-enter the Earth's atmosphere. Thus, the necessity of exchange of information between those who are in the widest sense responsible for the "re-entry" and those who are affected by a re-entry is evident.

Sources and availability of information in most cases will not only be restricted to the persons or authorities responsible for a space object and its intentional or unintentional re-entry. It might be the case that a person or authority responsible for a space object and its possible re-entry does not even possess sufficient information on the space object and has to provide availability of such information from other sources. As an example, one might take a similar but more complex aspect raised during the controlled descent and re-entry of the Mir Orbital Station. The Mir re-entry flight control and navigation support was undertaken by the TsNIIMAsh Mission Control Center, but surveillance from Russian territory could be conducted only for a half of daily orbits. To provide full monitoring availability, agreements were reached with NASA and ESA to make available additional and appropriate technical facilities for the MIR orbit tracking.

Regulatory needs regarding both issues, the provision of information between persons and authorities directly involved or concerned with the re-entry and the availability and possible obligation to provide information from any party or authority that might be able to provide such information, follow from the technical needs of coordination and have to be measured with respect to the regulatory framework already in place.

- Regulatory status quo and possible need for international regulation

While international responsibility and liability can be and is increasingly regarded as an incentive for the provision and exchange of information, it is not an explicit obligation to do so. International space law as well as respective UN resolutions however already spell out certain obligations for information.

Article IX, 3rd sentence 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 (OST) yet minimizes information obligations to harmful interference with space activities of other States Parties, since it reads: "In the exploration and use of outer space (...) States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space (...) with due regard to the corresponding interests of all other States Parties to the Treaty. (...) If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in

102 Such responsibilities and liabilities ensue, as is well known, from general international space law: Art. VI Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies of 1967 (OST) states responsibility for all "national activities in outer space" and in view of the liability provisions of Art. VII OST and the Convention on International Liability for Damage Caused by Space Objects of 1972 (Liability Convention) any "launching State" has a certain natural interest to avoid damage. While it is true that these provisions regulate responsibilities on the international level only, it still remains the role of the national legislator to provide for the proper "organization" and "regulation" of the space activities coming forth from a certain country. It may be noted that the causation of damages on the surface of the Earth entails the absolute liability of the "launching State".

103 Cf. American Institute of Aeronautics and Astronautics, International Activities Committee, 6th International Space Cooperation Workshop Report, March 2001, 12: "Because the ability to control launch and re-entry in real-time is very limited, planning activities constitute the most practical measures to ensure safety and success." No planning or coordination activities however are possible without (exchange of) information.

outer space (…) would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space (...) it shall undertake appropriate international consultations before proceeding with any such activity" [emphasis added]. This provision in the strict sense would only be a basis for information and traffic coordination of traffic while in outer space.

Art. XI, OST however says: "In order to promote international cooperation in the peaceful exploration and use of outer space, States Parties to the Treaty conducting activities in outer space, including the Moon and other celestial bodies, agree to inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities. On receiving such information, the Secretary-General of the United Nations should be prepared to disseminate it immediately and effectively." In view of the above stated general interest of an exchange of information of the persons and authorities concerned ensuing from international responsibilities and liabilities, a re-entry operation can very well be considered as a part of the "conduct" as well as "locations" of a space operation. However also here, the qualification that the information must be "practicable" renders the provision relatively vague in its obligatory content.

Additional general obligations to provide information are those found in the Convention on Registration of Objects Launched into Outer Space (Registration Convention). The information to be provided however only includes basic orbital parameters (Article IV 1st paragraph Registration Convention). In this context, a State of registry may provide additional information concerning a space object carried on its registry. Further, each State shall notify the Secretary-General of the United Nations, to the greatest extent feasible and as soon as possible, of space objects concerning which it has previously transmitted information, and which have been but no longer are in Earth orbit (Art. IV paragraph 3 Registration Convention). Thus, the information to be provided under the Registration Convention includes in any case information on the re-entry of a space object, while it is sufficiently processed, since after initiating re-entry the object would no longer be "in Earth orbit".

In addition, initiating a process of re-entry could also be considered as a "change of orbital parameters". However, the problems of adherence and implementation of the provisions of the Registration Convention (relatively few signatories, slow and delayed registration) are well known. Thus, the information provided under the Registration Convention may very well serve as a general source of information on space objects, but in its current implementation it does not satisfy the need for speedy and detailed information in case of a re-entry process. However it should be recognized in this context that there are also efforts to increase adherence to this Convention and to widen the scope of parameters to be internationally notified under Registration Convention.

In view of these relatively meagre general information requirements, it is not surprising that the NPS-Principles of 1992 contain several sections on the issue of re-entry. Information needs are laid down in principle 5 "Notification of re-entry", which reads: "Any State launching a space object with nuclear power sources on board shall in a timely fashion inform States concerned in the event this space object is malfunctioning with a risk of re-entry of radioactive materials to the Earth. (...)" The obligation also contains a list of system parameters that have to be included in the information, such as name of the launching State, address of the authority which may be contacted for additional information or assistance in the case of accident; information required for best prediction of orbit lifetime, trajectory and impact region, and information on the radiological risk of the nuclear power source. The information shall also be transmitted to the Secretary-General of the United Nations and be provided as soon as the malfunctioning has become known. It shall be updated as frequently as practicable and the frequency of dissemination of the updated information shall increase as the anticipated time of re-entry into the dense layers of the Earth's atmosphere approaches so that the international community will be informed of the situation and will have sufficient time to plan for any national response activities deemed necessary. The updated information shall also be transmitted to the Secretary-General of the United Nations with the same frequency. According to principle 6 NPS Principles, States providing information in accordance with principle 5 shall, as far as reasonably practicable, respond promptly to requests for further information or consultations sought by other States.

Thus, principle 5 NPS Principles in comparison with other provisions of international space law spells out a rather clear and relatively detailed duty to provide information on the international level. However, necessary recipients of the information are only "States concerned", a qualification which might be subject to interpretation[104] and only then, i.e. if there are "States concerned", the information shall also be transmitted to the Secretary-General of the United Nations. Even stronger yet, is the provisions of principle 7: "Upon notification of an expected re-entry into the Earth's atmosphere of a space object containing a nuclear power source on board and its components, all States possessing space monitoring and tracking facilities, in the spirit of international cooperation, shall communicate the relevant information that they may have available on the malfunctioning space object with a nuclear power source on board to the Secretary-General of the United Nations and the State concerned as promptly as possible to allow States that might be affected to assess the situation and take any precautionary measures deemed necessary. While they contain extensive obligations of mutual information, the NPS Principles only apply to the risk of re-entry of radioactive materials. Furthermore, the set of principles on NPS is a UN General Assembly resolution and as such is not binding international law.

Information provisions regarding re-entry are also set forth in the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (ARRA),[105] mainly concerning the return of astronauts. According to Article 1 ARRA "Each Contracting Party which receives information or discovers that the personnel of a spacecraft have suffered accident or are experiencing conditions of distress or have made an emergency or unintended landing in territory under its jurisdiction or on the high seas or in any other place not under the jurisdiction of any State shall immediately (a) Notify the launching authority[106] or, if it cannot identify and immediately communicate with the launching authority, immediately make a public announcement by all appropriate means of communication at its disposal; (b) Notify the Secretary-General of the United Nations, who should disseminate the information without delay by all appropriate means of communication at its disposal. Most interesting in this provision is that each of the Contracting Parties receiving information has to forward such information (to the launching authority) and the Secretary-General for general dissemination, thus achieving the widest possible range of availability and distribution of information.

It may also be noted that the range of information as regards recipients of the information to be disseminated by the UN Secretary-General is not further specified, but rather vaguely refers to means of communication instead of clarifying to which authorities and persons the information should be disseminated as a minimum standard. Further, a re-entry activity is only encompassed by this concrete provision if it also can be considered an emergency situation of personnel of a spacecraft while in outer space or at the moment when an emergency or unintended landing has already occurred. Article 5 (1) ARRA states that "Each Contracting Party which receives information or discovers that a space object or its component parts has returned to Earth in territory under its jurisdiction or on the high seas or in any other place not under the jurisdiction of any State, shall notify the launching authority and the Secretary-General of the United Nations". While this provision encompasses the re-entry of any spacecraft or its component parts, it only refers to the period in time after landing and is restricted in its territorial application. An entirely different kind of information provision is contained in Article 5 (4) ARRA, which states that "a Contracting Party which has reason to believe that a space object or its component parts discovered in territory under its jurisdiction, or recovered immediately by it elsewhere, is of a hazardous or deleterious nature may so notify the launching authority, which shall im-

104 "Concerned " is any State, whose territory and perhaps atmosphere might be affected by the possibly re-entering radioactive material. The minimum elements of the information to be provided are also intended to provide a vague idea which States this could be and what kind of danger they might have to face; cf. Marietta Benkö/Gerhard Gruber/Kai-Uwe Schrogl, The UN Committee on the Peaceful Uses of Outer Space: Adoption of Principles Relevant to the Use of Nuclear Power Sources in Outer Space, in:German Journal of Air and Space Law ZLW (42,1) 1993, 46. However, it seems questionable who determines, whether there are "States concerned", since only in this case information has to be provided at all.

105 It may be emphasized in this context that the status of signatories and ratifications of the ARRA is quite high.

106 Article 6 ARRA defines the term "launching authority" as the State responsible for launching, or, where an international intergovernmental organization is responsible for launching, that organization, if certain conditions of direct application (i.a. declaration of acceptance etc.) are fulfilled.

mediately take effective steps, under the direction and control of the said Contracting Party, to eliminate possible danger of harm."

Thus the existing provisions in international space law already provide certain obligations or express a need for mutual information or information to be provided to the UN Secretary-General. However, these provisions only cover certain aspects of a re-entry or are restricted to the re-entry of nuclear material. Furthermore some provisions are stated in rather general terms and mostly the range of States who are obliged to make information available or who are to be informed is restricted. Another aspect of these provisions is that except for the provisions where the Secretary-General is to be informed, information is to be provided from "State(s)" to "State(s)", without naming or having to name clearly which authorities or institutions exactly are to be informed. Thus, in case information has to be disseminated or forwarded quickly, it is neither clear from the provisions who exactly will be responsible for disseminating the information, nor is it clear who is to receive such information.

In addition, States still have the duty to provide information and also to arrange for the necessary obligations and information needs they have to obtain from private spacecraft operators. Another aspect of the provisions, is the implied idea that a return of spacecraft or astronauts technically is restricted to a rather uncontrolled or uncontrollable ballistic return, which may be deduced from the fact that coordination with air traffic is not explicitly foreseen or contemplated.

In order to provide a more seamless information regime, obligations regarding re-entry activities which technically require planning and coordination[107] existing gaps in information obligations in the current international legal framework could be closed by extending the respective obligations for information to all States and their respective authorities, tracking stations etc.; i.e., those who own or receive any information on a space object with a risk of re-entry or intention to bring about a re-entry. With respect to the dissemination of information the Secretary-General may act as a "focal point" for collection and examination of information[108] and further dissemination e.g. to the public or other authorities. For a very quick and timely exchange States should name the respective authorities to whom the information should be disseminated, either by the Secretary-General or directly by the disseminating national authority. Furthermore, the NPS Principles may be a good starting point for defining and specifying the minimum content of information that should be provided. Experience with regard to the Mir re-entry, however, shows that it may not be so much a matter of regulation being in place to arrange for a proper exchange of information on re-entry activities, but that it mainly depends on the States' willingness and practice of providing such information.

Other issues related to international regulation of mutual exchange of information depend on the international technical co-ordination requirements in international air and maritime traffic control and co-ordination. Since air as well as maritime traffic are the genuine as well as the more frequent modes of traffic in their "own" medium, and moreover, a co-ordination and exchange of information requirement arises between the different users and control authorities of these three different modes of transportation, technical co-ordination requirements here would have to be regulated in consideration and co-ordination with the existing rules and standard procedures on air and maritime traffic.

107 Cf. American Institute of Aeronautics and Astronautics, International Activities Committee, 6th International Space Cooperation Workshop Report, March 2001, 13.

108 Also with regard to the exchange of re-entry information it seems (in view of the hazards and the general public concern regarding re-entry of large objects) necessary to develop and apply an effective information-handling protocol to avoid the dissemination of incorrect information and to somehow co-ordinate dissemination of information, which on the international level might be very well applied by the UN Office for Outer Space Affairs, cf. American Institute of Aeronautics and Astronautics, International Activities Committee, 6th International Space Cooperation Workshop Report, March 2001, 11 et seq.

- Need for distribution of information to national authorities – Regulatory needs at the national level

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.[109] In this respect, the AIAA Working Group on Space Traffic Management also considers that a promising approach for developing rules of the road for space traffic management (in particular for private space activities) is to incorporate rules into national space regulation and licensing regimes.[110]

However, existing national space legislation seldom mentions re-entry risks or activities, let alone information requirements. Thus, the Australian Space Activities Act 1998 No. 123, 1998 requires a license for re-entry activities (“return”), but does not additionally spell out concrete information or coordination requirements, except the substantive requirements for the permit or authorization, e.g. that the return must not be conducted in a way that it is likely to cause substantial harm to public health or public safety or to cause substantial damage to property. According to the US Code of Federal Regulations (CFR), Title 14 (Aeronautics and Space), Chapter III (Commercial Space Transportation) Appendix A to Part 440, Section III D, any person requesting a maximum probable loss determination within the licensing process for a space launch activity, shall submit information including a re-entry risk analysis assessing risks to Government personnel and individuals not involved in licensed launch activities as a result of re-entering debris or re-entry of the launch vehicle.

Although it is generally considered as the most developed national legal framework for space activities, the US laws and regulations on space activities have been judged inadequate for commercial reusable launch vehicles due to the need to address international issues of overflight, re-entry and indemnity.[111] In addition, it is difficult to draft regulations for vehicles that do not exist yet. And, in-orbit activities are specifically omitted from the regulations in order to give the private sector freedom to design uses for in-orbit activities. When and if in-orbit activities on a reusable vehicle become realities, then there may be a need for additional regulatory actions. A rather extensive regulation can be found in the Russian Federation (R.F.) Law on Space Activity. According to Article 19 of the R.F. law, which entered into force in 1993 and was last amended on 4 October 1996[112] space flight control at all stages from the launching of a space object of the R.F. to the completion of the flight, shall be exercised by the (state) organizations in charge of the ground and other objects of space infrastructure.

It is also explicitly stated that manoeuvring of space objects in air space is executed in accordance with the requirements of legislation regulating the use of air space in the R.F. Furthermore, a space object of a foreign state can execute a single innocent flight through the airspace of the R.F. with the purpose of inserting such an object into an orbit around the Earth or further in outer space, as well as with the purpose of returning it to the Earth, under the condition of advance notice to the appropriate services of the R.F. about time, place, trajectory and other conditions of such flight. It is also set forth in this law, that certain government authorities inform the appropriate government and management authorities of the R.F. about launching and landing of space objects of the R.F. and in case of necessity - interested foreign states and international organizations as well. In case of launching, landing or terminating the existence of space objects of the R.F. beyond its boundaries, the appropriate services of the R.F. execute their functions as agreed with competent bodies of the interested foreign states.

The efforts of the US Federal Aviation Authority (FAA) have shown that at the latest with the beginning of operations of commercial reusable launch vehicles, even more detailed information exchange

109 American Institute of Aeronautics and Astronautics, International Activities Committee, 6th International Space Cooperation Workshop Report, March 2001 p. 12.

110 ibidem, p. 10.

111 Williamson, Ray, US Space Law and Policy for Commercial Space Activities: Launch Vehicles and Remote Sensing, paper in: Institute of Air and Space Law, Cologne University/Deutsches Zentrum für Luft- und Raumfahrt, Needs and Prospects for National Space Legislation, Project 2001 Workshop Proceedings Vol. VI, Cologne 2001, 124.

112 Available on the Web-Site of the FAS at http://www.fas.org/spp/civil/russia/pol_docs.htm.

management and coordination become necessary. The need for such regulations regarding information in a more detailed manner will in this context mainly be information required to co-ordinate in detail space traffic with national or regional air traffic controls and – where necessary – maritime traffic. In this context the reader may be referred to the FAA's first version of a Concept of Operations for Commercial Space Transportation in the National Airspace System of January 2000, which gives an idea of the different needs of exchange of information in relation to air traffic control, should re-entry activities become more frequent.

National space laws therefore seem to reveal in most cases not only major shortcomings in spelling out the explicit obligations e.g. of a private licensee to provide the necessary information (e.g. on a malfunctioning that could result in a re-entry of a space object or on the end of life of a space object) to the national authorities and in the establishment of a properly identifiable point of contact for providing such information,[113] but also a certain lack of concrete co-ordination requirements with air traffic control and other national authorities.[114] However, it would also be necessary to more thoroughly examine the respective national air traffic regulations to determine the exact status of regulations in this regard.[115] Many states (e.g. in Europe) currently see no necessity to regulate space traffic on a detailed national level, since due to dense population and lack of a proper reusable launch vehicle, such regulation currently seems not to be warranted.[116]

3.3.2.2. Regulatory Needs at the International and National Levels

With regard to general regulatory needs several issues are raised, which – to obtain a certain standard – in principle might be solved and determined at the international law level and then implemented and also supervised at the level of national licensing procedures.

The International Space Cooperation Workshop Report states with respect to re-entry: "Artificial space objects fall to Earth on a weekly basis. Most such objects pose little threat to people or property(...)"[117] This raises not only the question as to which kinds of re-entry events need further regulatory attention,[118] but also the question as to how technically different kinds of re-entry events should be made subject to different intensive regulations. This aspect, together with the generally shared wish to reduce space debris, raises also the question, whether such regulation should also set a standard under which conditions a re-entry activity is in general legitimate and under which conditions it is not. Such a standard would also concretize the provision of Art. IX 1st sentence OST which states that States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space with due regard to the corresponding interests of all other States Parties to the Treaty. Principle 3 Section 2 and 3 of the NPS Principles could be a model or example for regulation encompassing all kinds of re-entry activities on the international level.[119]

These provisions already contain general technical requirements that make reference to technical conditions regarding re-entry events: Thus the sufficiently high orbit in which a nuclear reactor must be operated according to the NPS Principles, is also determined in consideration of the necessity for the

113 Information requirements and other obligations could however also be set out in the national space license document itself.

114 In the context of hazardous re-entry events, it has also to be kept in mind by national regulators that not only air traffic control but also emergency and disaster management authorities must be informed in time to prepared.

115 It may not only be the case that spacecraft are subjected to national air traffic law (as is e.g. the case in Germany), but also RLVs which may be similar controllable as aircraft and can serve as spacecraft.

116 Marina Köster, Legal Problems Related to a Combined Use of Airspace by Air- and Spacecraft, in: Böckstiegel Karl-Heinz (ed.), 'Project 2001' – Legal Framework for the Commercial Use of Outer Space, Cologne 2002, 103-108.

117 American Institute of Aeronautics and Astronautics, International Activities Committee, 6th International Space Cooperation Workshop Report, March 2001 p. 13.

118 A question which was referred in the Report to the IADC.

119 Principle 3 NPS Principles sets guidelines and criteria for safe use of NPS in outer space. Sections 2 and 3 describe the situation in and conditions under which nuclear reactors and radioisotope generators may be operated

parts of a destroyed reactor to attain the required decay time before re-entering the Earth's atmosphere [principle 3 Section 2 (b) NPS Principles] and radioisotope generators may be used only in Earth orbit if, after conclusion of the operational part of their mission, they are stored in a high orbit [Principle Section 3 (b) NPS Principles]. A regulation regarding the legitimacy of re-entry activities could include an international obligation to observe certain safety standards to avoid re-entry, e.g. fuel and technical protocols to move a spacecraft into a proper disposal orbit instead of letting it re-enter towards the Earth's atmosphere. Among the already existing provisions on nuclear power sources there is, for instance, Principle 3 Section 2(e) NPS Principles, which states that "the design and construction of a nuclear reactor shall ensure that it cannot become critical before reaching the operating orbit during all possible events, including rocket explosion, re-entry, impact on ground or water, submersion in water or water intruding into the core."[120]

Another question is the issue of passage of a re-entering space object through the airspace or upper airspace of a country other than the states responsible for the spacecraft. One problem in this respect is that the Chicago Convention of 1944 is not applicable to spacecraft and that its applicability even to "aerospace" objects may be doubtful, since its Article 3 restricts its application to aircraft and extends this application in Article 8 to pilot-less aircraft.[121] In view of Article 6 of the Chicago Convention this might not be such an undesirable result, since it gives the possibility for a different agreement at the international level with regard to passage rights of "aerospace" objects. Also Article 9 of the Chicago Convention, regulating certain air traffic management rights of States,[122] still is applicable to air traffic management itself, and thus gives a basis to take space traffic re-entry events into account within the general air traffic management. However, Article 12, 1st sentence Chicago Convention, which says that "each contracting State undertakes to adopt measures to insure that every aircraft flying over or manoeuvring within its territory and that every aircraft carrying its nationality mark, wherever such aircraft may be, shall comply with the rules and regulations relating to the flight and manoeuvre of aircraft there in force" would not be applicable to spacecraft, and the applicability to aerospace objects would also be questionable, except that it has to be considered as an expression of a general international principle of a state's sovereignty over its airspace.

With respect to uniform space traffic regulations, the Article 12, 2nd sentence of the Chicago Convention is of great interest. "Each contracting State undertakes to keep its own regulations in these respects uniform, to the greatest possible extent, with those established from time to time und this Convention. Over the high seas, the rules in force shall be those established under this Convention. Each contracting State undertakes to insure the prosecution of all persons violating the regulations applicable." For the establishment of rules for space traffic management, the proper co-ordination with air traffic rules should be taken into account from a substantive as well as an organizational point of view.[123] The international standards and practices for air traffic are adopted by ICAO in accordance with Article 37 Chicago Convention. Differences from such standards have to be notified by States according to Article 38 of the same Convention. Thus, an organizational framework and platform for the international coordination of air traffic rules with re-entry events is already in place. In regards to

120 Principle 3 NPS Principles also contains provisions on the technical requirements to avoid fragmentation of radioisotope generators in case of a re-entry.

121 Cf. on this issue Marina Köster, Legal Problems Related to a Combined Use of Airspace by Air- and Spacecraft, in: Böckstiegel, Karl-Heinz (ed.), 'Project 2001' – Legal Framework for the Commercial Use of Outer Space, Cologne 2002, 103-108.

122 According to Article 9 Chicago Convention each contracting State may, for reasons of military necessity of public safety, restrict or prohibit uniformly the aircraft of other States from flying over certain areas of its territory, provided that no distinction in this respect is made between the aircraft of the Sate whose territory is involved, engaged in international scheduled airline services, and the aircraft of the other contracting Sates likewise engaged. Furthermore, each contracting State reserves the right, in exceptional circumstances or during a period of emergency, or in the interest of public safety, and with immediate effect, temporarily to restrict or prohibit flying over the whole or any part of its territory, on condition that such restriction or prohibition shall be applicable without distinction of nationality to aircraft of all other States.

123 It has already been proposed elsewhere that rules concerning activities of spacecraft in the airspace should be developed by ICAO, in particular its Air Navigation Commission, cf. Fernàndez-Brital, Oscar, Legal Problems of Commercial Space Transportation, IISL 1990, 30-36.

unilaterally declared restriction areas in airspace in connection with launchings and re-entry of spacecraft concern has already been expressed that the general standards for air traffic at the international level should be amended for the sake of greater air flight safety.[124]

With regard to a more detailed space traffic regulation, technical standards and coordination requirements in case a (legitimate or illegitimate) re-entry takes place could be formulated at the level of international law in a more general way (e.g. responsible authority for re-entry coordination; coordination with air traffic control authorities; preparation of technical and weather/atmosphere data; number and setting of tracking stations; alert of emergency management in the area concerned for not controllable objects, etc.).

An additional aspect of detailed traffic regulation is the question whether 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.[125]

Future regulations could also include certain obligations of assistance by other States, in cases where the space object is difficult to control or where its re-entry presents a real hazard. Basic models for such regulations could be the provisions on assistance found in the ARRA or the NPS Principles. Such hazard or emergency assistance could include support in tracking the object, support in identifying weather conditions and conditions of the upper atmosphere, as well as consultations on an optimum flight path and re-entry path and the respective technical requirements.[126] Expenses incurred in the fulfilment of such obligations could be regulated like in the ARRA, i.e. that these shall be borne by the launching authority.[127] Furthermore, the launching authority/state or the state responsible for a space object that has re-entered can also be obliged to provide immediate assistance and relief for any damages occurred due to a re-entry activity.[128]

3.3.3. Findings

- 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.
- Responsibility and liability for damages caused by space objects or their components ensue not only from international space law but also from the general provisions in national legislation.
- The generally shared aspiration to reduce space debris raises the question, whether regulation should also set a standard, clarifying under which conditions a re-entry activity is considered 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 resolve the open issue of passage of space objects through airspace (the Chicago Convention does not apply to space objects in air space).
- The question arises, whether to introduce certain internationally recognized descent corridors and possibly even impact areas which are not frequently used by other traffic, and which could be dedicated to space traffic.

124 Nikolaević Maleev, Jurij, Internationales Luftrecht: Fragen der Theorie und Praxis (translation by E. Rauch), Berlin 1990, 119. seq.

125 On the national level, the FAA will probably introduce so-called “Space Transition Corridors” (STC) as well as “Flexible Spaceways”.

126 It would also be questionable whether possibly affected States should have the right to disagree on a certain flight path.

127 Cf. Article 5 (5) ARRA. Principle 9 para. 3 of the NPS Principles contains a similar provision.

128 Also see Art. 3 and 5 ARRA which are already in place and spell out on the obligation of rescue of astronauts and recovery of space objects landed on a different territory.

CHAPTER 4

RECOMMENDATIONS FOR RESEARCH AND REGULATION

As it has been pointed out in the Introduction (1.1), this study clearly recognizes that the time for immediate actions to implement a comprehensive space traffic management regime is not yet at hand. 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 implemented and also points to specific issues, which might be taken up at an earlier stage.

This concluding chapter sets forth a research plan, pointing out at issues which have been identified as not having been studied extensively enough so far (4.1). Following this, the findings of the study also comprise recommendations, which are summarized in a model for space traffic management. In this regard, building blocks are identified, which might also be tackled on a short-term basis (4.2).

4.1. Further Research

Analysis of space activities in the framework of this study have led to numerous insights, but also reached some conclusions, where it is clear that further research is needed. Thus, it could be compared with the manner in which the space debris issue was identified more than two decades ago, and then was studied further with a growing clearness of what is really important and where concrete action has to be taken. As it has been and to some extent still is the case there, space traffic management will require further research in both the technical as well as in the regulatory fields. These tasks could be taken up by the respective Commissions of the IAA and the IISL:

Technical issues to be studied further:

- Sufficiency of the current observation capacity.
- Technical set-up of a database.
- Cost efficiency.
- Technical feasibility of real-time collision warning.
- Mission costs related to collision avoidance.

Regulatory issues to be studied further:

- Conduct a study on whether priorisation of space activities makes sense, and whether certain space activities or specific use of outer space should be banned (e.g. funerals, advertising).
- Ways of linking/merging the ITU information/notification system with an improved UN registration system, the outcome of which would be one notification/information system.
- Relationship between international space law and Hague Code of Conduct against Ballistic Missile Proliferation (HCOC) regarding the concept of notification of launches.
- Dual use aspects of data utilization.
- Further inquiry into the interests and expectations of private actors and the economic benefit to commercial activities through space traffic management.
- Linking the issue of space traffic management to discussions in conjunction with the Conference on Disarmament on the prevention of an arms race in outer space.

- Identification of the expectations of military users of outer space with regard to space traffic management.
- Latest trends in technical international organizations like ITU, ICAO or IMO regarding the adoption of technical regulations/standards and making them binding thus providing more flexibility than the traditional system of negotiation and ratification currently provides; analysing these trends with regard to their relevance to a space traffic management regime.
- Maintaining a level-playing field and avoiding "flags of convenience" through space traffic management.

4.2. Outline of a Comprehensive Space Traffic Management Regime

Framework

In this section, a model is provided for what a comprehensive space traffic management regime for 2020 could look like. An international inter-governmental agreement on the status and use of outer space could be drafted, building on but not replacing the principles incorporated in the existing space treaties. It would also include provisions for liability and the basic principle that while States are the primary actors, provisions of the agreement are applicable to private activities as well through national licensing regimes.

This international inter-governmental agreement would comprise a legal text, which cannot be changed easily and technical annexes, which can be adapted more easily (modelled on the legal texts of the ITU, ICAO or IMO and WTO). The international inter-governmental agreement envisioned would 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

- Provides traffic management rules based on the use of the database for the purpose of collision avoidance, including:
  - Safety provisions for launches
  - Safety provisions for human spaceflight (including space tourism)
  - Zoning (selection of orbits)
  - Right of way rules for in-orbit phase(s)
  - Prioritization with regard to maneuver
  - Specific provisions for GEO (harmonized with ITU rules)
  - Specific rules for LEO satellite constellations
  - Debris mitigation mechanisms
  - Safety provisions for re-entries
  - Environmental provisions (pollution of the atmosphere/troposphere, etc.).

- Clarifies "space objects", including legal distinction between valuable objects and valueless space debris.
- Clarifies "fault" or liability in case of damage caused in outer space with regard to the implications of traffic rules.
- Sets delimitation for the launch phase and clarifies the concept of "launching State".
- Provides a framework and main features for national licensing regimes (including insurance provisions), which implement the provisions of the agreement.
- Sets forth an enforcement mechanism (e.g. renouncement of access to information) and dispute settlement.
- Clarifies institutionalized interlinks with ICAO, ITU and other relevant organizations.

4. Organization

- The provisions of the three agreements initially could be monitored by UNCOPUOS and handled by UNOOSA.
- Subsequently, post 2020:
  - The new agreement, together with the existing space treaties, could be superseded by a comprehensive Outer Space Convention.
  - The operative oversight, i.e. the task of space traffic management, could be taken up by an already existing forum or organization (such as UNCOPUOS/UNOOSA or ICAO), which would evolve into a body shaped for that purpose. Looking 20 years ahead, it could also be handled by a non-governmental entity tasked by the State parties to an Outer Space Convention.
  - Space activities by private actors will develop into the same legal status as in air traffic.

Possible First Steps for Improving the Situation in Space Traffic

Space Debris Guidelines

Current guidelines for mitigating space debris developed by the Inter-Agency Space Debris Coordinating Committee (IADC) are an important, positive step toward space traffic management. They should be endorsed by UNCOPUOS as a UN legal document with a view to making their acceptance and implementation universal.

Space Surveillance and Collision Avoidance

Cataloguing activities (US Strategic Command, European Space Agency, Russian Space Agency, and private companies) should be improved and coordinated with the aim of establishing a common data policy and infrastructure. Steps could comprise developing and deploying new sensors, improving analytical techniques, and incorporating data from sensors not primarily intended for tracking orbiting space objects. Improvements to the GSO catalogue could be considered a priority and could be treated as such by the IADC Subgroup on Measurement.

Enforcement and Checking Mechanisms

Neither the UN nor ITU has any enforcement or inspection mechanisms. These are within the jurisdictional powers of sovereign states. The ITU’s list of radio space stations as well as the UN Register of objects launched into outer space, reflect governmental announcements only. This situation should be changed, resulting in obligatory notification/registration and the provision of unified sets of relevant data.

Distinction between Valuable Spacecraft and Worthless Space Debris

UNCOPUOS should start discussing whether or not space debris are space objects in the sense used in space law treaties. If it is decided that space debris are space objects, an additional protocol should be elaborated stating what provisions of the treaties apply to valuable spacecraft and which provisions apply to space debris. If it is decided that space debris are not space objects, the protocol should determine under what conditions space debris may be removed or re-orbited in order to prevent collisions or close encounters with valuable spacecraft.

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