RULES OF THE ROAD FOR SPACE TRAFFIC*

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0. ABSTRACT

After almost 50 years of space flight, time has come to think about standards for navigation of space vehicles in outer space, „rules of the road". But since space navigation is not the first means of navigation, such rules exist already. Rather than re-inventing the wheel, this paper examines, in a comparative approach, air law principles for their suitability to traffic in Outer Space. While considering the absence of national airspace and the characteristics of orbital dynamics, the attempt is made to establish prototype standards for space traffic and navigation including the use of Global Navigation Satellite Systems (GNSS) for space vehicles.

1. SPACE TRAFFIC RULES

In this first part selected standards and recommended practices of the General Rules of Annex 2 (Rules of the Air) to the Convention on International Civil Aviation (Chicago Convention) are analyzed for their suitability for space traffic. The more specific Visual and Instrument Flight Rules[1] and the airspace structure do not make sense for navigation in Outer Space.

1.1 Responsibility and Authority

A cardinal principle of air law is the responsibility and authority of the pilot-in-command of an aircraft. He shall "whether manipulating the controls or not, be responsible for the operation of the aircraft in accordance with the rules of the air, except that he may depart from these rules in circumstances that render such departure absolutely necessary in the interest of safety"[2]. "The pilot-in-command of an aircraft shall have final authority as to the disposition of the aircraft while he is in command"[3]. Historically, this principle has evolved because the pilot-in-command was the person at the controls and the only one who could take responsibility of what he was doing. Even in today`s highly automated environments with on-board flight management systems, computerized

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air traffic management and data links, this principle does not appear to change in the foreseeable future. However, the technological developments will make it increasingly unacceptable for the pilot-in-command to accept responsibility for automated and remotely linked processes that are not any longer in his hands alone.

As a matter of the technical evolution the command of a space vehicle is vested, de facto, in ground-based control centers. These control centers and thus the operator of the space vehicle bears the responsibility[4] and authority for the space vehicle. Unmanned space vehicles are the rule and no commander on board can potentially be vested with the responsibility and authority. On manned missions with more than one crew member, normally commanders designated. Yet, concerning the navigation of the spacecraft it is questionable if a crew member on board should take over the legal responsibility for compliance with future rules of the road in space, as long as ground control centers have a more comprehensive oversight of the navigational situation of the space vehicle.

1.2 Protection of Persons and Property

1.2.1 General Obligation to Act Diligently. Rules of the road typically contain a general principle stipulating that operations must be conducted diligently. Also standards for navigation in Outer Space should state that the operation of space vehicles is not to be exercised in negligent or reckless manner so as to endanger life or property[5]. In the existing legal instruments, general considerations of standard of care for space navigation have a significance only in connection with liability, i.e. Art. VII of the Outer Space Treaty (OST)[6] and the Liability Convention[7]. The more detailed rules of the road evolve, the clearer can violations of the same be determined. They will also provide a basis for determining liability, in case damage is caused by a violation of the standard.

1.2.3 Minimum Heights. Minimum heights, one of the regulatory elements for operation of aircraft[8], do not make sense for space vehicles operating in Outer Space.

1.2.4 Cruising Level System. More examination is required whether a system similar to aviation´s (semi-circular) cruising level scheme[9] could be applied to Outer space navigation. Under this scheme, the course of an aircraft determines its flight level and thus reduces the risk of head-on collisions. Theoretically such a system could be superimposed on a structure of orbits around the Earth. However, the numerous parameters of orbits, be it inclination or (non)centricity raise some doubts if such a system could reduce collision risks. In the end, it may be up to a scientific analysis, if the risk of collisions could be reduced by assigning bands of orbital altitudes to polar, eastbound and westbound orbits. In any case, trajectories of space vehicles transiting to regions farther away from Earth would cut through these assigned orbital bands – as do climbing and descending aircraft in ICAO´s cruising level scheme.

Another problem will be space debris, which, in case of explosions, will be scattered into a myriad of orbits beyond the assigned bands. Similarly, atmospheric friction in lower Earth orbits does not

warrant a constant altitude without measures of station keeping that require fuel. As proposed for the avoidance of space debris, the designation of cemetery regions (beyond the geo-stationary orbit) appears a workable solution. This would need to be coupled with the obligation to actively remove a space vehicle at the end of its service lifetime either into the cemetery band or force it to decay in the atmosphere.

The existing regulation on the rational use of the geo-stationary orbit under Art. 33 of the Convention on International Telecommunication (ITU Convention) does not primarily aim at avoidance of collision risks. It is a tool for allocating a resource.

1.2.5 Prohibited and Restricted Areas. Given the nature of orbital dynamics, the designation of prohibited areas and restricted areas[10] is not directly applicable in Outer Space. From a practical viewpoint, they blur with the concept of assigning orbital bands to certain flight directions, because these areas would similarly need to be shaped as bands of orbits. From a legal viewpoint prohibited and restricted areas can only be established in territorial (air)space. In line with aviation and maritime practice, outside the sovereign territory, territorial waters and airspace, States may only notify other States about "danger areas".

1.3 Avoidance of Collisions

1.3.1 General Obligation to Avoid Collisions. In aviation regulations, avoidance of collisions is based, inter alia[11], on a general obligation to avoid collisions hazards[12] and rules on the right of way[13]. The general obligation for avoiding collisions is suitable for space navigation without change.

1.3.2 Right of Way and Priorities. The aviation rules on the right of way are not directly applicable to space traffic. However, some concepts could be adapted.

For Space traffic, concepts do not fit which require that two aircraft, approaching head-on, have to alter their heading to the right or that an aircraft, that has another on its right, shall give way.

More interesting is a priority listing of aircraft types according to their maneuverability[14]. Maneuverability is a factor in Outer Space, in case an uncontrolled space object is to collide with a controlled space vehicle. Then, indeed, as a matter of self protection the operator will attempt to prevent the collision. But this scenario should not be the basis for a right of way regulation, because no priority needs to be determined if one of the space vehicles is uncontrolled and cannot change its course anyhow.

In case of two controlled space vehicles on collision course, a potential collision between two controlled space vehicles will be foreseeable with longer lead time than in aviation. Advance contact of the operators of converging space vehicles is highly desirable. But it must be determined who has to burn up the limited fuel of its space vehicle in order to avoid the collision. Therefore it is recommended to establish an order of priority for the right of way in accordance with two factors: (a) the vulnerability of a space vehicle and (b) the damage potential. This could result in the following order of priority:

- manned space vehicles in an emergency,
- manned space vehicles,
- unmanned space vehicles
- unmanned space vehicles with a high damage potential, e.g. with nuclear powers source.

In addition, a controlled space vehicle violating other rules of the road, e.g. orbiting counter-wise to the direction designated for an orbital band cannot benefit from this order of priority.

1.4 Avoidance of harmful interference

Alternatively, collision avoidance in Outer Space could be covered by a new broadened concept on avoidance of harmful interference. If avoidance of interference were to include not only the radio spectrum, as in Art. 35 ITU Convention, but also physical impacts, i.e. collisions, and perhaps even the optical part and other scientifically important parts of the radio magnetic spectrum, a new concept beyond the roots of aviation and radio communication could be established.

2. GNSS FOR USE BY SPACE VEHICLES

This second part of the paper deals with the use of Global Navigation Satellite Systems (GNSS) for navigation of space vehicles. The International Civil Aviation Organization (ICAO) has studied extensively the use of GNSS for civil aviation. Aviation is a user group with very stringent requirements for terrestrial and atmospheric navigation within the territories of states and over the High Sea. Given the timely study in ICAO, the principles contained in the Charter on the Rights and Obligations of States Relating to GNSS services, adopted by ICAO Assembly Resolution A 32-19[15], can be considered as a useful regulatory basis also for other terrestrial user groups. But since GNSS will also be used for navigation of space vehicles[16], these principles require a review for uses in Outer Space by states other the providers of GNSS. The existing ICAO principles apply to terrestrial and atmospheric users, but not to users in Outer Space.

2.1 Paramount Principle of Safety

There is no doubt that safety is the paramount principle for the use of GNSS. But more broadly than in ICAO`s first principle[17], this safety aspect can be extended beyond international civil aviation and include safety of space vehicles and other human activities in Outer Space, in the Earth´s atmosphere and on the ground[18].

2.2 Non-Discriminatory Access

Likewise, non-discriminatory access under uniform conditions to GNSS services should be available not only for aircraft, but also for space vehicles of all states[19]. However, non-discriminatory access to GNSS need to be excluded for military space vehicles. Based on the concept of sovereignty in national airspace[20], where every state can (legally) control the military air traffic, this is not the case for military space vehicles in Outer Space. Also, ICAO principles do by definition not apply to state aircraft[21]; hence ICAO principles do not apply to military applications unless specifically agreed so by the member states. Also the "interest of maintaining international peace and security", as contained in Art. III OST, would become hollow if providers of GNSS were mandated to provide navigation services on a non-discriminatory basis to military space

vehicles of another state[22].

Non-discriminatory access does not mean that navigation services are provided for free. Indeed, it can be argued that making use of GNSS signals for the navigation of space vehicles justifies the levying of user charges, even when terrestrial and atmospheric users do not have to pay.

Regional augmentation systems also mentioned in this ICAO principle, e.g. the Wide Area Augmentation System (WAAS) in the United States of America and the European Geo-stationary Navigation Overlay System (EGNOS), do at the moment not seem to have a role for applications in space.

2.3 State Authority and Responsibility

Under Art. VI OST States bear the responsibility of the space activities of its nationals. As a consequence, some states adopted a licensing and supervision system. Any reference in ICAO's GNSS principles relating to state authority and responsibility of safety and operations linked to national airspace[23] do not fit to the safety and operations of space vehicles. But within the framework of Art. VI OST every State definitely preserves its authority and responsibility to control operations of space vehicles to enforce safety and other regulations onboard.

Without any limitations, the GNSS principle on State sovereignty, authority and responsibility in the control of navigation and safety regulations[24] can be extended to space navigation. The fact that the GNSS of one State may be used for the space activities of another can definitely not result in any infringement or restriction of the user State's sovereignty, authority or control. Likewise the user State's authority must also be preserved in the coordination and control of ground-based or space-based communications and augmentation segments for space navigation services.

But any such augmentation that is usable also in Outer Space, is subject to the non-discriminatory access and quality principles[25]. In this instance the user State will become a provider State for the given augmentation segment.

2.4 Quality of Services

The central principle on the technical and organizational quality of services applies to space navigation as it does to air navigation[26]. Every provider state is to ensure the continuity, availability, integrity, accuracy and reliability of space navigation services[27].

The *"effective arrangements to minimize the operational impact of system malfunctions or failure, and to achieve expeditious service recovery"*[28] should be interpreted as to maintain the *technical* means of minimizing failure impacts and providing for a recovery. These "effective arrangements" cannot mean to establish a new liability system. The liability regime for space activities is based on the fault-based principles and types of damages enshrined in Art. VII OST. At the moment, it appears too far-fetched to aim at non-fault based liability regimes in case of damages resulting from wrong navigation inputs of a provider.

References to *ICAO Standards* and *aeronautical information* in relation to the quality of services are not appropriate for space navigation. Also any reference to aviation related principles on navigation charges[29] have no footing for space traffic.

2.5 Co-operation, Interest of other States, Joint Provision of Service

The ICAO GNSS principles mention co-operation in different contexts. One relates to the (technical and institutional) uniformity in the provision of services[30], another to the global planning and implementation on a bilateral or multilateral basis[31]. Furthermore it provides that "*every State shall conduct its GNSS activities with due regard for the interests of other States*"[32] and "*nothing ... shall prevent two or more States from jointly providing GNSS services*"[33].

All this fits likewise to navigation services provided for and used by space traffic.

3. DRAFT STANDARDS

Based on the foregoing considerations, the following draft standards for space traffic and the use of GNSS by space vehicles are compiled. They are not a comprehensive and exhaustive set of "rules of the road", but a starting point for further elaboration.

3.1 Draft Standards on Space Traffic

1. The operator of a space vehicle shall be responsible for the operation of the space vehicle in accordance with these standards, except that he may depart from these standards in circumstances that render such departure absolutely necessary in the interest of safety.

2. The operator of a space vehicle shall have the final authority as to the disposition of the space vehicle.

[3. The operator may designate a person on board a space vehicle to exercise the authority for certain portions of the flight.]

4. A space vehicle shall not be operated in a negligent or reckless manner so as to endanger life or property of others.

[5. Assignment of orbital altitude bands to certain flight directions (e.g. polar, eastbound and westbound orbits)]

6. A space vehicle shall not be operated in such proximity to other space vehicles as to create a collision hazard.

7. When two space vehicles have converging trajectories, the right of way shall be in the order of priority as follows:
- manned space vehicles in an emergency,
- manned space vehicle,
- unmanned space vehicles,
- unmanned space vehicles with a high damage potential.

8. The operators of space vehicles shall inform each other, as soon as possible, when they detect that the trajectories of their space vehicles are converging as to create a collision hazard. The operators of the affected space vehicles shall co-operate in undertaking the necessary measures, in accordance with these standards, in order to prevent a collision.

[9. Space vehicles shall be operated in a manner as not to harmfully interfere, radio-magnetically, optically and physically with space vehicles operated in accordance with these standards (and operations on the Earth and other celestial bodies).]

3.2 Draft Standards on the use of GNSS by Space Vehicles

1. States recognize that in the provision and use of GNSS services, the safety of

international navigation shall be the paramount principle.

2. Every State and space vehicles of all states shall have access on a non-discriminatory basis under uniform conditions, to the use of GNSS services within the area of coverage of such systems.

3.a) Every State preserves its authority and responsibility to control operations of space vehicles and to enforce safety and other regulations for space vehicles under its jurisdiction .

b) The implementation and operation of GNSS shall neither infringe nor impose restrictions upon State's sovereignty, authority or responsibility in the control of navigation and the promulgation and enforcement of safety regulations. State's authority shall also be preserved in the coordination and control of communications and in the augmentation, as necessary, of satellite based navigation services.

4. Every state providing GNSS services, including signals, or under whose jurisdiction such services are provided, shall ensure the continuity, availability, integrity, accuracy and reliability of such services, including effective arrangements to minimize the operational impact of system malfunctions or failure, and to achieve expeditious service recovery. States shall provide in due time information on any modification of the GNSS services that may affect the provision of the services.

5. States shall co-operate to secure the highest practicable degree of uniformity in the provision and operation of GNSS services.
States shall ensure that multilateral arrangements are compatible with the principles and rules set out in this principles and with the global planning and implementation process for GNSS.

6. With a view to facilitating global planning and implementation of GNSS, States shall be guided by the principle of co-operation and mutual assistance whether on a bilateral or multilateral basis.

7. Every State shall conduct its GNSS activities with due regard for the interests of other States.

8. Nothing in this principles shall prevent two or more States from jointly providing GNSS services.

Endnotes:

[1] Chapters 4 and 5, Rules of the Air, Annex 2 to the Chicago Convention

[2] Standard 2.3.1, Rules of the Air, Annex 2 to the Chicago Convention

[3] Standard 2.4, Rules of the Air, Annex 2 to the Chicago Convention

[4] Of course, under Art. VI OST the state of the operator bears the responsibility under public international law.

[5] Standard 3.1.1 Rules of the Air, Annex 2 to the Chicago Convention "An aircraft shall not be operated in a negligent or reckless manner as to endanger life or property of others."

[6] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies

[7] Convention on International Liability for Damage Caused by Space Objects

[8] Standard 3.1.2, Rules of the Air, Annex 2 to the Chicago Convention

[9] Standard 3.1.3, Rules of the Air, Annex 2 to the Chicago Convention and Procedures for Air Navigation Service - Aircraft Operations, ICAO Doc. 8168

[10] Standard 3.1.9 Rules of the Air, Annex 2 to the Chicago Convention

[11] Other standards relate to aviation specific areas which have no bearing for space navigation: landing, take-off, surface movement, lights, simulated instrument flights, operations in the vicinity of aerodromes and on the water, standards 3.2.2.4 to 3.2.6 Rules of the Air, Annex 2 to the Chicago Convention

[12] Standard 3.2.1.1 Rules of the Air, Annex 2 to the Chicago Convention "An aircraft shall not be operated in such proximity to other aircraft as to create a collision hazard."

[13] Standard 3.2.2 Rules of the Air, Annex 2 to the Chicago Convention

[14] Standard 3.2.2.2 Rules of the Air, Annex 2 to the Chicago Convention establishes the following order of priority: power driven heavier than air, airships gliders and balloons.

[15] Reprinted in Vol. XXIII AASL 325 (1998) and Vol. XXII Air & Space Law 219 (1997)

[16] See public announcement of the European Space Agency (ESA) of 9 May 2003 "Communication satellites telling us where they are". New onboard GNSS (Global Navigation Satellite System) receivers are being developed for communication satellites in low Earth and geo-stationary orbit in a project funded by ESA.

[17] Principle 1.: "States recognize that in the provisions and use of GNSS services, the safety of international civil aviation shall be the paramount principle."

[18] It is a political question, if this principle should expressly also mention protection of the Earth´s environment.

[19] Principle 2.: "Every State and aircraft of all states shall have access on a non-discriminatory basis under uniform

conditions, to the use of GNSS services, including regional augmentation systems for aeronautical use within the area of coverage of such systems."

[20] Art. 1 Chicago Convention

[21] Art. 3 (a) Chicago Convention

[22] Another issue will be the technical implementation of preventing a military space vehicle to receive GNSS signals while providing non-discriminatory access to civilian space vehicles.

[23] Principle 3.a): "Every State preserves its authority and responsibility to control operations of aircraft and to enforce safety and other regulations within its sovereign airspace."

[24] Principle 3.b): "The implementation and operation of GNSS shall neither infringe nor impose restrictions upon State's sovereignty, authority or responsibility in the control of air navigation and the promulgation and enforcement of safety regulations. State's authority shall also be preserved in the coordination and control of communications and in the augmentation, as necessary, of satellite-based air navigation services."

[25] See principles 2 and 4.

[26] Principle 4.: "Every state providing GNSS services, including signals, or under whose jurisdiction such services are provided, shall ensure the continuity, availability, integrity, accuracy and reliability of such services, including effective arrangements to minimize the operational impact of system malfunctions or failure, and to achieve expeditious service recovery. Such State shall ensure that the services are in accordance with ICAO Standards. States shall provide in due time aeronautical information on any modification of the GNSS services that may affect the provision of the services."

[27] For the definitions of these parameters see ICAO Guidelines for the Introduction and Operational Use of the Global Navigation Satellite System (GNSS) , 1996, Circular 267 AN/159 at 97 pp.

[28] See Principle 4 at endnote 26

[29] Principle 6.: "States recognize that any charges for GNSS services shall be made in accordance with Art. 15 of the Chicago Convention."

[30] Principle 5.: "States shall co-operate to secure the highest practicable degree of uniformity in the provision and operation of GNSS services.

[31] Principle 7.: "With a view to facilitating global planning and implementation of GNSS, States shall be guided by the principle of co-operation and mutual assistance whether on a bilateral or multilateral basis."

[32] Principle 8

[33] Principle 9