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Early Concepts for Space Traffic

Luboš Perek
Astronomical Institute
Academy of Sciences, Prague, Czech Republic

1. Sources

Some aspects of space traffic have been dealt with in several papers in the past and some space traffic rules have been enacted without calling them traffic rules. Systematic treatments of the question are, however, rare. In the 1980's, two papers dealing with general problems of traffic in outer space were presented at the Colloquia of the IISL[1],[2]. Both papers pointed out that traffic problems had been known for a long time on the land, on the sea and in the air. Both papers also stressed that space environment differs substantially from the three environments around us and that traffic rules for outer space will have to reflect this fact. Both papers also referred to the Registration Convention and its possible modification. None of the two papers anticipated that in the year 2002 Traffic Rules for Outer Space would still be a matter for an undetermined future and not a matter, which already proved its value and usefulness.

The first paper discussed:

- Traffic Rules on the Road, on the Sea, in the Air,
- Travel in Outer Space,
- Principles of Outer Space Traffic Rules, such as
  - Coordination of Communications,
  - Traffic Separation,
  - Removal of Inactive Satellites,
  - Disposal Orbits,
  - Reducing the Amount of Debris,
  - Identification of Space Objects, and
  - Minimizing Environmental Pollution.

[1] L. Perek: Traffic Rules for Outer Space, Proceedings of the 25th Coll. on the Law of Outer Space, AIAA p. 37, 1983.
[2] P.Q. Collins, T.W. Williams: Towards Traffic Systems for Near-Earth Space, Proc. of the 29th Coll. on the Law of Outer Space, AIAA p.161, 1987.

The second paper dealt with:

- Spacecraft Orbits,
- Traffic Separation into Zones,
- The Geostationary Orbit,
- Satellite Power Station Scenario, and
- Space Tourism Scenario.

The American Institute of Aeronautics and Astronautics (AIAA) initiated in the 1990's a series of Workshops on international space cooperation. The Fifth Workshop[3] of that series, held in Bermuda, 12-15 April 1999, established a Working Group on The Growing Number of Satellites in Orbit: Facing the Issues. It dealt with:

- Orbital Resource Management,
- Collision Avoidance,
- Orbital Debris, and
- Regulatory Framework.

The Sixth Workshop[4], held in Seville, Spain, 11-15 March 2001, had a Working Group on Space Traffic Management. The discussions were directed to:

- Legal and Regulatory Environment,
- Developing Rules of the Road for Space,
- Enabling Collision Warning,
- Using Disposal Orbits,
- Actively Managing Launch and Reentry,
- Reducing the Creation of Orbital Debris, and
- Protecting the Geostationary Orbit.

Let us summarize the contents of those four sources from today's point of view.

2. Traffic Rules in the Three Environments

Traffic rules play an important role in three environments: on the road, on the sea and in the air. Although the conditions are quite specific for each of the environments, there are some general features. The main aim is to maintain safety of traffic by:

- **Establishing rules for avoidance of collisions**. Knowledge of traffic rules enables drivers, helmsmen or pilots to anticipate the actions of their counterparts and to choose the optimal action. Many rules exist in the rules of the road, such as rules on right of way, priority at crossings, etc. Marine traffic is regulated by special International Regulations for Preventing Collisions at Sea. For the prevention of collisions in the air sophisticated practices and technical elements have been introduced.

[3] Report of an AIAA, UN/OOSA, CEAS, CASI Workshop, April 1999, International Space Cooperation: Solving Global Problems, AIAA, 1999.
[4] Report of an AIAA, UN/OOSA, CEAS, IAA Workshop, March 2001, International Space Cooperation: Addressing Challenges of the New Millenium, AIAA, 2001.

- **Separating traffic in opposite directions**. This principle is very efficient because it diminished relative velocities of vehicles. It is being used on highways, in channels near ports, and in the air space.

- **Establishing specific rules on inactive vehicles**. Such rules deal with parking places, with signals to be exhibited by automobiles and ships. For inactive balloons specific rules have been established.

- **Requiring proper identification of vehicles**. Vehicles in all three environments have to exhibit names, license plates, or other designations.

- **Requiring high quality of technical equipment and qualification of personnel**. Technical elements for safety are numerous, certificates of safety of vehicles and competence of drivers or pilots are obligatory. Safety in traffic, though very expensive, is generally recognized as preferable to the risk and cost of accidents.

- **Establishing rules on protection of environment**. Rules and obligatory equipment restricting the pollution of the environment apply in all three environments.

Some of these principles can be applied also to space traffic, if the very specific conditions of outer space are respected. Manned spacecraft are rather the exception than a rule. The vast majority of objects in space are inactive and have no means of maneuvering, objects "at rest" are moving under natural forces at high velocities, and no scavenging service is operating, to name just some examples.

3. Space Traffic Rules in Force

Surprisingly, some space traffic rules are in force and, what more, are followed by all space users. The International Telecommunication Union has been applying traffic rules to geostationary satellites for a long time, almost since the beginning of the use of that orbital belt. An assignment of a nominal position in the GEO (Geostationary Orbit) is, in fact, equivalent to traffic separation of one satellite orbit against another. Close encounters among active satellites can happen only in cases when the same nominal position has been assigned to more than one satellite or when satellites are being transferred to another nominal position. The present practice is to leave the coordination of relative positions to operators of satellites concerned. Difficult moments may arise also during the insertion of a satellite into, or removal from, the geostationary orbital belt.

Satellites in the GEO keep their nominal orbital positions – within permitted tolerances – by periodical application of corrective impulses, i.e., during their active lives only. Objects left in orbit after the termination of their activities pose a hazard of a destructive collision.

The ITU takes care also of assignments of communication radio frequencies in space and of service areas on the ground. All operators comply with the coordination rules.

4. Traffic Separation

Traffic separation could apply, in a form different from that used in GEO, to Low Earth Orbits, in particular to communication satellite systems. Each of the systems consists of a number of satellites located in a fixed configuration in an orbital shell, defined by its altitude above the ground. Reserving a shell for each satellite system would separate orbits of one system from orbits of all other systems, excluding thus collisions under normal operating conditions. Passage through a shell for satellites launched into higher shells or for de-orbiting maneuvers would have to be coordinated.

5. Avoidance Maneuvers

Avoidance maneuvers have been used in particular in the GEO. Whenever the computed distance between an active and an inactive satellite became smaller than a predetermined limit, the active satellite used its station keeping capability to perform a maneuver to get out of the way of the inactive object. In order not to spend valuable fuel on unnecessary maneuvers, the orbits have to be calculated with high precision. The current databases and catalogues are incomplete and inaccurate. Therefore it was felt (see footnote 3,4) that:

Finding -- A mechanism is needed to warn satellite operators of close encounters and to provide guidance as to optimum actions. The service provider, be it government or commercial entity, should be reviewed by an international body that includes representatives of both government and industry.

6. Disposal Orbits

De-orbiting of satellites from the GEO to the ground or to the dense layers of the atmosphere would be too costly because large amount of fuel would be necessary for the maneuvers. Less fuel is needed to raise the perigee of the orbit in such a way that the new orbit, called disposal orbit, does not interfere with active satellites located in the vicinity of the nominal GEO. The first to recognize and use the advantage of disposal orbits was INTELSAT. In May 1977, the perigees of three INTELSAT satellites were raised by 400 km, or more, beyond the nominal GEO. In the following years, other operators used the same procedure. Finally, in 1993, the ITU adopted a recommendation to re-orbit satellites approaching the end of their active lifetimes into disposal orbits. The necessary distance, following from the ITU definition of the GEO, is at least 300 km above the nominal orbit. A more refined formula for determining the minimum distance for the disposal orbits was developed by the IADC in 1995. The formula respected the degree of compactness of satellites and the resulting distance is between 245 km for very compact satellites to 435 km for loosely built objects.

The recommendation is being followed by some operators but not by all. Possibly the technical difficulties connected with the complex maneuver of re-orbiting has not been mastered, or commercial operators are reluctant to stop a profitable operation and to use the remaining fuel for re-orbiting. The situation is not likely to change if the respective recommendations are not made into binding provisions through incorporation into the ITU Radio Regulations[5].

Finding – Since the recommendation to re-orbit geostationary satellites into disposal orbits is not followed in all cases, it should be changed into a binding provision through incorporation into the ITU Radio Regulations.

The principle of disposal orbits could be used at other altitudes for the 12 hours orbits of the navigation satellite systems. It could be useful even for lower orbits as long as they are less costly than de-orbiting.

7. Space Debris in Orbit

The total mass of objects in space up to about 2000 km altitude is between 2000 and 3000 tons. About one quarter of that amount is in active spacecraft, three quarters in space debris. If all the inactive objects are left in orbit, they will eventually be fragmented by collisions into smaller debris. In particular large objects may generate very large number of small, but still deadly, fragments. The collision probability may consequently increase dramatically in the future. It is rather probable that the amount of mass of objects in space will have to be reduced, in order to keep near-Earth space fit for future space activities. Even if available technology and financial means do not allow any significant cleaning of near-Earth space at present, there are theoretical studies of methods to de-orbit inactive objects. There is a good chance that such efforts will be successful and that adequate ways and means will appear in the future.

The Outer Space Treaty, in its Article VIII, is quite clear on the provision that launching state retains the jurisdiction and control over a space object while it is in outer space. The ownership of objects is not affected by their presence in space. In this sense also the agreements on anti-satellite activities support the rights of the owner. Unless specific provisions are introduced for space debris, space law will pose an important obstacle to de-orbiting of space debris.

Source 3 addressed the problem of on-orbit debris and proposed 1) moving large debris, such as satellites at the end of operational lifetime, out of the way of active satellite orbits; and 2) by the active removal of visible but untracked smaller debris.

Finding -- In a long perspective, also the active removal of large bodies has to be considered. Legal obstacles in the form of protection of all space objects, including space debris, by the Outer Space Treaty should be reconsidered.

8. Restricting New Space Debris

All the sources recommend that it is necessary to restrict the formation of space debris in the near term on a worldwide basis, because the hazards could

[5] See footnote 4, p.12.

escalate significantly within 10 years. Of particular importance are standards adopted by national and international space agencies, recommendations of the IAA Position Paper, and standards developed by the IADC. The standards deal with control of debris released during launch and operation, with the prevention of explosions, with re-orbiting into disposal orbits and de-orbiting from space. Let us quote, in a succinct form, from the recommendations in sources 3 and 4:

Recommendation – The Working Group participants strongly support work being done by the UN, the IADC, the IAA, and others to develop guidelines designed to minimize the creation of new debris objects. However, the acceptance of these guidelines is not yet universal. Industry standards, based on these guidelines should be developed for consideration by the International Organization for Standardization.

9. Status of Space Objects: Valuable Asset or Space Debris

An important lesson can be learned from the early, as well as from the not quite so early, discussions of space traffic rules. It concerns the frequent use of the term "active space object". The term is very important because any rules will be different for active spacecraft from those applying to inactive objects. In other words, the status of a space object is the most important characteristic to be considered in the discussion of traffic rules or management of space.

The number of trackable active space objects is relatively small. There are only some 600 to 700 active objects compared to the total number of all trackable objects, which exceeds 9000. Active objects, however, are very valuable assets. The cost of manufacturing, launching and operation is high. The investment yields considerable profit, if the satellite provides continuous services. Inactive objects, i.e. space debris, on the other hand, have no value and pose a hazard to active objects.

With regard to their importance, it is rather curious that there is no officially recognized list of active space objects. There are good estimates of the total number, there are unofficial and unpublished lists, but when it comes to enumerating all such objects, authoritative sources are silent.

The adjective "active" could be understood as referring to receiving or emitting radio signals. But spare communication satellites, which will be put into service at a later time, do not receive or emit radio signals for extended periods of time. Or scientific satellites, such as those used in investigating the field of gravity, may not send any messages, their only function being to reveal their position by reflecting light.

A launching state may keep being interested in the fate of a space object even after it has become non-functional. That may happen when the object contains industrial or military classified information. The term "active" could be understood to cover also the keeping of classified information.

Finding -- The opposite to space debris are not only objects, which are active in the narrow sense of the word, but all spacecraft which are considered valuable assets by their launching states or operators.

In fact, the change of an "active space object" into space debris occurs only by decision of the owner and that is the launching state. There are examples: The Mir station or the Compton Gamma Ray Observatory were functional objects as long as the respective launching countries considered them functional and useful. It was only after a decision of the launching state that the object became officially non-functional[6].

Information on the status of a space object is quite important for scientists and technicians investigating all aspects of space debris. It is vitally important for objects, which are more or less intact and of a large size, because these can be confused easily with active objects.

Two scenarios have to be considered. If launching states provide information on which of their space objects are active spacecraft, then all other objects could be considered space debris. The second scenario may be more probable. If launching states do not provide information on all of their active satellites, perhaps they might be willing to provide information on which space objects terminated their activities and are not considered valuable asset anymore.

There is, fortunately, a mechanism for authoritative announcements on the status of objects in space, which could be useful in either of the two scenarios. The Registration Convention contains a provision for announcements by launching states not only on the launching but also on other important phases in the life of space objects. Practically all launching states -- and some launching organizations -- keep announcing the launching of space objects. Some launching states have even made use of the opportunity in a wider sense and announced the termination of activities of their satellites[7]. That practice should become universal. With the appearance of the Online Index of Objects Launched into Outer Space[8], the relevant information could be easily and widely accessed.

Finding – Existing space law does not use the term *space debris* and does not differentiate between valuable spacecraft and worthless space debris. The value and status of a space object can be important in determining how the object is to be treated. Launching states should keep announcing changes in the status of their objects.

Objects, which cannot be confused with active spacecraft, may not require individual announcements. Their status as space debris may be recognized by their small size, or, by agreement, by their characteristics as rocket bodies, stages, component parts, or fragments.

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[6] L. Perek, Definition of Space Debris, Paper IISL-01-IISL.4.01, presented at the Int. astron. congress, Toulouse, 2001.

[7] E.g., Sweden announced the termination of activities of three of its satellites in UN documents ST/SG.SER.E/318, 335, and 364.

[8] Online Index of Objects Launched into Outer Space is an index of governmental announcements made by launching states to the UN Secretary General in compliance with the Registration Convention. It was prepared by the Office of Outer Space Affairs at the website registry.oosa.unvienna.org/oosa/index/index.stm .

10. Conclusion

Setting up traffic rules for outer space is a very complex problem. Conditions in outer space differ radically from traffic conditions in the three environments, we are familiar with: the road, the sea and the air. Yet, some of the general principles encountered in traffic around us might find their way into space, such as traffic separation, collision avoidance or protection of environment.

A very special problem concerns the status of a space object. As long as the spacecraft is active, it is a valuable asset providing important services. Once the object terminates its activities, it becomes a burdensome piece of debris posing a potential hazard to active spacecraft. The status of a space object depends on the decision or intention of its owner, that is its launching state. Without learning about that decision or intention, other users of outer space, in particular those who intend to devise traffic rules, are left in the dark about the true nature of some vehicles participating in the traffic.