ENVIRONMENTAL IMPACT OF SPACE ACTIVITIES AND MEASURES FOR INTERNATIONAL PROTECTION

*HE Qizhi**

The rapid development of space technology has created opportunities for enormous benefits to mankind. However, problems involving environmental impacts of space activities and concern for the protection of space environment are growing and will continue to grow in the space community.

Space law already recognizes the rights of states to explore and use outer space, including the moon and other celestial bodies. Since outer space activities are carried on from the earth's surface to outer space through the air space, they are a source of potential harm to the environment on earth's surface, in the air space and outer space. In approaching the subject of environmental protection, it must be remembered that the whole vertical space is indivisible, independent of disputes over the boundary between the air space and outer space.[1] Space activities have brought about different environmental impacts. In some cases the consequences are insignificant, while in others they may be serious. The existing space law though containing some general principles and certain specific rules regarding the prevention of environmental hazards, does not provide for adequate protection. It seems appropriate to make an overall examination in order to ascertain whether or what kind of measures should be taken to cope with the risks and harms brought by space activities.

Environmental Pollution

Since space activities must utilize existing elements in and release undesirable elements to the environment, they cause pollution-contamination in various degrees in different parts of the space environment. The term "pollution-contamination" here is used to denote an excessive presence of elements, substances and manmade events

* Member of Governing Board of the Chinese Society of International Law; Member of Board of Directors of the International Institute of Space Law; Corresponding Member of the International Academy of Astronautics.

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1. Gal, *Indivisibility of Environmental Protection in Vertical Space,* PROC. 27TH COLLOQ. L. OUTER SPACE 388-389 (1985).

resulting in adverse effects and detriment to space activities and the environment. Such adverse effects may be physical and tangible, or they may be nonphysical and intangible.

1. Chemical Pollution.

A spacecraft, while launching, produces a so-called "ground cloud" consisting of exhaust gases, cooling water, sand and dust, etc. At the present levels of launching, the resulting air and ground pollution pose no grave danger. But if launching activities increase greatly--for instance, if solar power satellite systems consisting of tens of satellites were developed--they would pollute the air and water around the launching site in a short period of time.[2]

The most affected part of space environment is the upper atmosphere where only very rarefied natural gas exists. It would be very difficult to mix up and dilute even a small amount of released exhaust gases and substances which could stay for a long time and spread horizontally over a large area. The chemical releases from spacecraft are mainly composed of nitrogen oxide, carbon dioxide, chlorine and hydrogen chloride, the latter two having a depleting effect on the ozone layer, which is situated about 16 to 48 km. above the earth. The ozone layer, by absorbing the sun's harmful ultraviolet rays, constitutes a very important protective ring around the earth. In an attempt to protect the ozone layer from depletion by the chlorine of chemical industries, the Vienna Convention for Protection of the Ozone Layer of March, 1985 by 20 countries[3] and the Montreal Agreement Protecting the Ozone Layer from Chlorofluorocarbons of September, 1987 by 46 countries[4] were successively concluded. As there are a number of natural and manmade events affecting the ozone layer, the issue must be studied further so as to determine to what extent the flight of spacecraft is an influencing factor.

The above mentioned chemicals and operational water releases may affect the ionosphere situated 80 km. above the earth. By reducing the density of the electrons therein, these elements may change the radiowave-reflecting properties of the ionosphere, thus distorting radio communications. As the atmosphere has a strong tendency to return to normal conditions after disturbances, it would be advisable to find a tolerable limit for each of the impacts on the environment.

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2. Impact of Space Activities on Earth and Space Environment, U.N. Doc. A/CONF.101/BP/4 (1981).

3. U.N. Information Service., Doc. UNIS/912 (1985).

4. *Ten Outstanding World News in the Scientific and Technological Field in 1987* People's Daily, December 17, 1987.

Satellites generally disintegrate upon re-entry due to the high temperature from air resistance. The resulting production of metal vapors can also influence ionospheric conditions affecting radio communication. But the present level of re-entry activities appears to be less than that of meteorites[5] and is not now of critical concern. In the future, if large numbers of satellites would be burned out on re-entry, the contamination of the upper atmosphere might be important. In this case, the introduction of reusable surface-space-surface vehicles would be helpful.

2. *Biological Pollution*

There are two kinds of biological contamination due to space activities:

(1) The risk that terrestrial micro-organisms carried by spacecraft might contaminate space, known as forward contamination.

(2) The risk that extraterrestrial micro-organisms might contaminate the earth. This is known as backward contamination.

In the beginning of the space age, these two kinds of biological contamination were matters of serious concern. Since it appears that the conditions for existence of micro-organisms do not exist on other planets, these dangers are of little immediate concern. NASA, after the Apollo Programme came to the conclusion that there are no infectious substances on objects recovered from the moon, decided to stop further disinfection and quarantine of the crew, spacecraft and lunar materials. However, Soviet space lawyers held the view that this decision should be made only after international consultation with other states possessing appropriate experience and adequate information on space exploration.[6] There is also the fear that biological researchers working with infectious diseases in space may be engaged in an activity which will result in forward contamination.[7] Biological pollution can not be completely excluded in the course of developing space activities.

3. *Radiological Pollution.*

Radiological pollution occurs from emissions of radioactive materials of electromagnetic waves. Since the 1978 incident of the Soviet

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5. The total meteoric mass entering the atmosphere is estimated at 10,000 kg./day. *See supra* note 2, at 8.

6. S.Vinogradov, *Space Activity and Environmental Protection,* in SPACE AND LAW 165-169 (1985).

7. McGarrigle, *Hazardous Biological Activities in Outer Space.* 18 AKRON L. REV. 103 (1984).

nuclear powered satellite, COSMOS-954, the issue of the use of nuclear power sources in outer space has raised worldwide concern. The launching failure or disintegration of nuclear power sources produces radiological pollution, and several such incidents have already occurred. To prevent or at least reduce the dangers brought about by such incidents, a set of legal control measures assuring security will be elaborated by the Legal Sub-Committee of COPUOS.[8]

Nuclear explosion in the upper atmosphere or outer space will play havoc with the space environment. The radioactive fallout will travel over long distances, not only changing the structure of the space environment, but also killing the electronic devices of operating satellites.

The electromagnetic waves produced by high-powered radio transmitters on earth or by satellites in space will generate electric and magnetic fields over large areas which disturb telecommunication of other satellites and adversely affect radio astronomy. Exhaust gas and chemical releases interfere with infra-red astronomy. All these issues are matters of great concern and are being dealt with by ITU.

Finally, laser beams generated from space or earth will also have great impact on the space environment and activities. With intensified militarization of outer space, the development of high energy laser and particle beam weapons will constitute serious threats to the peaceful uses of outer space.

Harms to Space Activities

The greatest threat to space activities has been recognized to be the hazards coming from man-made debris of spacecraft. As early as 1965, a space lawyer pointed out the potential danger of space debris.[9] Since then the space debris accumulated in earth orbits have greatly increased, presenting larger risks of collision between spacecraft and debris.

In space treaties, the term "debris" has not been defined. In general use, "debris" consists of spent space objects,[10] used rocket

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8. He, *Towards a New Legal Regime for the Use of Nuclear Power Sources in Outer Space,* 14 J. SPACE L. 195-212 (1986).

9. Hall, *Comments on Traffic Control,* 31 J . AIR L. & COMM. 1 (1965).

10. There is dispute over the issue whether "debris" covers spent objects. In terms of space law, the term "debris" may be safely assumed to cover spent space objects. But other experts, like Dr. L. Perek, hold that "debris" always implies "something broken up," or "only a part of the whole" and a complete satellite out of fuel and out of control should be called not a debris, but an inactive satellite. *See* Diederiks-Verschoor, *Harm Producing Events Caused by Fragments of Space Objects,* PROC. 25TH COLLOQ. L OUTER SPACE 10 (1983).

stages, separation devices, shrouds, clamps, and all large and small fragments, including the particles remaining after disintegration of a space object. These are man-made products of space activities which, in certain earth orbits, have already exceeded the flux of natural meteoroids which is relatively constant.[11] As a result, the probability of collision between satellites and orbital man-made debris would be greater than for natural meteoroids.[12]

According to figures by the North American Aerospace Defense Command (NORAD), there were 6,746 objects in space orbit, 5,108 of which were debris.[13] The capability of NORAD to track earth orbiting objects is limited. Objects orbiting at 400 km. must have diameters of about 5 cm. to be tracked, while at 1000 km. objects must be at least 10 cm. in diameter to be seen.[14] So the total number of debris, including small unobserved fragments, is much bigger and the issue much more serious than is being shown in the NORAD catalogue.

The main sources of space debris are explosions and collisions of space objects. Both can occur accidentally or by intentional action. Most debris comes from accidental explosions resulting from failures of propulsion systems. Some U.S. rocket explosions known to be the worst satellite explosions occurred shortly after launch, while others occurred years after launch due to explosions of residual self-igniting propellants. Intentional explosions of satellites have occurred through military space activities, particularly the Anti-Satellite Tests (ASATS). The Soviet Union is reported to have conducted 20 tests of an ASAT system, while the U.S. has been carrying on its own tests of airborne ASAT systems.

Another main source of space debris is collision between orbiting objects. Collision and explosion are closely related, as debris ejected from explosion can collide with other objects, thus creating additional debris. Collisions between two space objects can generate hundreds of trackable debris and probably millions of untrackable particles. Thus, the continued testing of space weapons by collision constitute further serious threat to the space environment.

The existence of space debris in earth orbit poses grave danger to operating satellites and space transportation systems. According to one estimate, with about 10,000 trackable objects in space, a large satellite at an altitude where debris is concentrated may have a probability of

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11. *See supra* note 5.

12. Kessler, *Orbital Debris Issues* in 5 ADVANCES IN SPACE RESEARCH 3-10 (2nd ed. 1985).

13. NORAD Catalogue, July 30 1987.

14. Johnson, *History and Consequences of in Orbit Break-Ups* in 5 ADVANCES IN SPACE RESEARCH 11-19 (2d ed. 1985).

collision of 10% over its lifetime and with predicted increase of trackable objects to 20,000 by 1995, the probability of collision could increase to 20%.[15] Satellites which suddenly stop functioning for unknown reasons may have suffered from collisions with untrackable debris. A notable example is Challenger's window being hit by a tiny paint chip during its seventh mission in 1983. The window had to be replaced at considerable costs.[16] Such accidents have repeatedly occurred. Unless proper measures are taken in time, it may be too late to correct the situation in the future.

Relevant Protection Provisions of Existing Treaties

During the past years of use and exploration of outer space, a number of international agreements have been concluded, containing relevant provisions on the protection of the earth and space environment. First among these is the 1963 Partial Test Ban Treaty which prohibits nuclear explosions in the atmosphere and beyond its limits, including outer space.[17] This can be marked as an attempt concerned with prevention of environmental effects of specific human activities in space. The People's Republic of China, though not a party to the Treaty, did solemnly declare that it "had not undertaken nuclear tests in the atmosphere for many years, and will never undertake any more nuclear tests in the future."[18] This statement represents China's positive attitude towards the aim of banning nuclear testing, and avoiding radioactive contamination in space.

The 1967 Outer Space Treaty and 1979 Moon Agreement are two chief documents relating to environment protection. These two treaties protect the moon and other celestial bodies from the environmental impact of military activities by essentially demilitarizing them.[19] But these treaties only partially demilitarize the whole outer space, particularly the near earth space by merely banning the placement of nuclear weapons and "any other kinds of weapons of mass destruction" in earth orbit.[20] Thus they leave the following loopholes: (1) no ban on testing and deploying other space weapons, including ASAT weapons; (2) no ban on warheads carried by strategic missiles on trajectories

15. Jasentuliyana, *Environmental Impact of Space Activities: An International Law Perspective,* PROC. 27TH COLLOQ. L. OUTER SPACE 390 (1985).

16. "Shuttle Hit by Man-Made Debris," Space World, March 1985.

17. For text of the Treaty, see 480 U.N. Treaty Ser. 43-49.

18. Statement by Chinese Premier Zhao Ziyang in *The Chinese People's Conference for Maintaining World Peace,* People's Daily, March 22, 1986.

19. Art. IV, para. 2 of the Outer Space Treaty; Art. III of the Moon Agreement.

20. Art. IV, para. 1 of the Outer Space Treaty.

travelling through outer space; (3) no definition of "weapons of mass destruction". In short, these treaties leave open the possibility of testing, deploying and utilizing space weapons other than nuclear weapons, enhancing the possibility of further worsening of the debris situation.

The 1976 Convention on the Prohibition of Military and Other Hostile Use of Environmental Modification Techniques also contributes to the protection of the environment, since such techniques include any means of modification of the motion, composition or structure of the earth or outer space, through intentional control of natural processes.[21]

After touching upon the military aspect, it is appropriate to focus on specific provisions of environmental protection. Article IX of the Outer Space Treaty obliges states parties to: (1) avoid harmful contamination of outer space or adverse changes in the environment of the earth resulting from the introduction of extraterrestrial matter and (2) enter international consultation if their activities would cause potential harmful interference with activities of other parties. It can be seen from the wording of the provision that it is of a rather limited character, since "harmful contamination" has to be related to outer space, whereas "adverse changes" only refer to effects on Earth's environment because of the introduction of extraterrestrial matter. With regard to consultation envisaged in the Article, this is a very important principle. However, there is a deficiency in that the consultation therein provided is not mandatory, nor is any procedure established or recommended. If the party concerned does not initiate consultation or refuses consultation demanded by other party, it does not constitute violation of the Treaty.

Article VII of the Moon Agreement makes an improvement on the general obligations contained in the Outer Space Treaty. It obliges states parties to: (1) take measures to prevent the disruption of the existing balance of the environment of the moon and other celestial bodies by introducing adverse changes, by harmful contamination or otherwise; (2) avoid harmful effects to the earth environment through the introduction of extraterrestrial matter or otherwise; (3) inform the United Nations of the measures being adopted to prevent the disruption of the existing balance of the environment of the moon and any plans to place any radioactive material on it. In this Article, the prevention of disruption of the existing balance of the environment of the moon is the key obligation of all states parties, and the insertion of "or otherwise" is intended to cover other sorts of contamination. As a whole, this provision of the Moon Agreement on environment protection makes up some of the deficiencies characteristic of the corresponding provision of the Outer Space Treaty.

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21. For text of the Convention, see G.A.Res. 31/72 of December 10, 1976.

The 1976 Registration Convention requires the registering of launchings with the United Nations, but it does not require notification of explosions or out-of-function space objects, nor registration of the type or amount of fuels or exhaust, chemical or radioactive substances, etc., which affect the space environment.

The ITU Convention and Radio Regulations prohibit harmful interferences of space communications and provide two procedures in this respect. The first is notification and registration of frequency assignment in the Master of Register, maintained by the International Frequency Registration Board (IFRB). The other is through coordination by various conferences.[22] But these procedures have been criticized for being inequitable and disadvantageous to developing countries.

The liability aspect of environmental protection had been partially dealt with by the 1972 Liability Convention, which established the launching state's absolute liability for all damages caused by its space object on earth or to aircraft in flight. It also covers damages caused by collision to another space object on condition that such collisions were caused by the fault or negligence of the launching state. According to the definition given in Article I of the Convention, "damage" could cover damage to the environment of the earth as far as this means the surface of the earth under jurisdiction of states. In dealing with the damage caused by the COSMOS-954 incident, Canada based its demands to the Soviet Union mainly on relevant provisions of the Liability Convention and it was settled accordingly by diplomatic negotiation between these two countries.[23] If damage consists of impairment of the environment of air space or outer space, or international public regions, such as high seas, Antarctica, etc., such damage does not seem to be covered by the Convention. This appears to be one of the lacunas which has to be filled by further elaboration.

Strengthening International Protection Measures

Space activities have brought with them impacts on the environment in various aspects, some of which should be more fully ascertained by further observation and study. It is now generally accepted that proper measures should be taken on the basis of a comprehensive and in-depth understanding of the situation. In recent

22. Art. 35 of the International Telecommunication Convention (Nairobi, 1982); Arts. 11 and 13 of the Radio Regulations (1982).

23. *Supra* note 8, at 108-109.

years, discussion on this issue has been brisk[24] and space law circles are going to demand that space legislative bodies direct their attention to this issue for gradual improvement and perfection of a legal framework for protection of the space environment.

As space activities involve the whole space environment, including earth surface, air space and outer space, protection measures have to deal with the whole indivisible vertical space. On the other hand, in view of the fact that impacts on various parts of the space environment are different, the main thrust should be directed to the issue of space debris--the most harmful pollution and which is growing in seriousness. The existing international treaties, though containing some general principles in this respect, are neither complete, nor adequate to cope with the developing situation. For filling this gap, many proposals have been made. Among them, the suggestion of elaboration of a comprehensive international instrument placing emphasis on the issue of space debris to be discussed by both the Scientific and Technical and Legal Sub-Committees is a possible approach. For the envisaged set of rules, the following recommendations might be worthy of consideration.

1. Definition of terminology. In space treaties, legal terminology relating to environmental harms has been "harmful contamination", "adverse changes in the environment", "harmful interferences", etc.[25] But no definition was given, nor any standard or criteria established, thus easily giving rise to dispute over whether a particular activity contravenes the general obligation under the treaty. So, it would be necessary to define the key terminology, such as pollution-contamination and other related terms. Among them, the term "debris" should be interpreted to cover spent space objects as generally understood. [26]

2. Ban on intentional destruction and fragmentation of space objects. The testing and deployment of space weapons, including ASAT and ABM weapons and the flight of strategic missiles on trajectories in outer space would cause explosions and collisions of such weapons leading to an increase on an unprecedented scale of space debris, thus bringing havoc to normal space activities. In view of the welcome signs in the arms talks between the two super-powers, it seems to be time to strengthen this trend and search for some interim agreement for a stop or

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24. Space environment was among the topics of discussion in the 23rd (1981), 25th (1983), 27th (1985) and 29th (1987) IISL Colloquiums on the Law of Outer Space where a number of papers were presented. More recently, the Institute of Air and Space Law of Cologne University held an International Colloquium in connection with the 600th anniversary of the University, entitled "Environmental Risks Arising from Activities in Outer Space - State of the Law and Measures of Protection," attended by space law experts the world over.

25. Art. IX. of the Outer Space Treaty; Art. 7 of the Moon Agreement.

26. *Supra* note 10.

moratorium on the development and testing of any kind of space weapons. Since this issue is of serious concern to all countries, bilateral negotiations between the two super space powers should be supplemented by multilateral negotiations which would encourage and support the bilateral negotiations for a greater achievement. The agreement reached would be the key to arrest the debris issue from becoming worse.

3. Adoption by agreement of practical measures to minimize the production of debris. These measures include: improved design of launch systems, thus limiting the number of loosely attached mechanisms; elimination of unspent fuels, thereby reducing the chance of self-explosion; controlled re-entry and total burn-up in the atmosphere of satellites after completing their function; the use of disposal orbits;[27] and possible "space salvage" or a "scavenging mission,"[28] etc. These measures could be helpful to alleviate the debris situation through concerted effort by space-faring countries and international space organizations.

4. International Expert Group. Such a Group will be composed of well qualified space scientists and technicians entrusted to review, assess and establish standards of environmental effects of space activities. The Group will be provided with necessary data and information before and after launch, concerning type and amount of fuels, radioactive payloads, exhaust gases and other chemicals released in all stages of flights of satellites, as well as explosions, collisions and other causes producing debris, so that after full examination, international standards and recommended practices may be established. The standards thus adopted can be mandatory and should be observed by all states except those having reservations, while recommended practices are intended for states to make best efforts to follow in the interest of protecting the space environment from contamination. Such standards and practices will be subject to review, amendment and updating, and will be annexed to the principal instrument.

5. Further norms of liability. In addition to liabilities as provided in the Liability Convention, the launching state should be held liable for damage to any part of the space environment, including earth surface, air space and outer space. Environmental damage should also cover damage to the common resources of mankind, such as Antarctica

27. As regards disposal orbits, agreement could be made to use specific belts to dispose of spent satellites. Two such belts have been suggested: one between low earth orbit and geostationary orbit, i.e. somewhere above 17,000 km. from earth which is rarely used; the other is beyond the geostationary orbit. *Cf.* Perek, *Traffic Rules for Outer Space,* PROC. 27TH COLLOQ. L. OUTER SPACE 40-41 (1985); Jasentuliyana, *supra* note 15, at 392.

28. Schwetje, *Current U.S Initiatives to Control Space Debris,* 29TH COLLOQ. L. OUTER SPACE 163 (1988).

and the high seas. Compensation thus paid may make it possible to restore the damaged environment to previously existing conditions.

6. *Establishing mandatory consultation regime.* The principle of holding consultation between states concerned before carrying on potentially dangerous activity must be regarded as an indispensable condition for environmental preservation from the harmful consequences of space activity. Article IX of the Outer Space Treaty provides such a principle but it is only of a very general nature. It is not mandatory, nor is any procedure established or recommended. Today, the obligation of holding consultation before carrying on an activity affecting the interests of other states, is in the formation stage in some branches of international law.[29] The envisaged instrument should incorporate the principle of consultation as mandatory. This would have important constraining influences though it might not lead to an agreement.

7. *Strengthening international cooperation.* Article IX of the Outer Space Treaty stipulates: "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, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty." This means all states, particularly the major space powers, should exert their efforts by taking effective measures in the task of protecting the space environment from contamination by space activities. Further embodiment and specification of this principle is of vital importance.

The issue of protecting the environment from contamination from space activities has been put on the order of the day. Because of complicated political and other factors, it has not yet been on the agenda of the Legal Sub-Committee of COPUOS. But the trend in this direction is gaining ground. It has been increasingly recognized that only by taking concerted and effective measures in time will mankind have a reasonable chance to guarantee adequate protection against the hazards brought by space activities.

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29. For instance, Art. V. of the 1982 London Convention on Prevention of Marine Pollution by Dumping of Waste and other Matter, obliges a country, before special permit is issued for discharging certain harmful substances, to consult with both the affected countries and the appropriate international organizations..