STRATOSPHERIC OZONE, SPACE OBJECTS, AND INTERNATIONAL ENVIRONMENTAL LAW

*Carl Q. Christol**

INTRODUCTION

Within the past several years, and with increasing present concern, attention has been called to what has been described as the stratospheric ozone problem.[1] A layer or belt of ozone is situated between 10 and 20 miles above the earth's surface. If the ozone in this belt is reduced, it will become increasingly possible for larger amounts of ultraviolet radiation to be received at ground level. This may lead to a larger incidence of skin cancer for human beings as well as other harms to earth and ocean-oriented events and activities.

Atmospheric ozone, as a global and renewable resource, is subject to scientific, economic, and social (including political and legal) considerations. In order to maximize the condition in which earth and ocean needs will be sustained through the presence of an optimum amount of ozone in the ozone layer, it is necessary to consider the costs of its improvident use and conversely the benefits to be realized from its proper use.

At the outset it must be stated that there is a considerable amount of uncertainty on the part of experts in the field of atmospheric chemistry as to the seriousness or potential seriousness of the present situation. This results from the fact that a number of forces are thought to be contributing to the perturbations of the stratospheric ozone layer. Differing outlooks have resulted from uncertainties as to the completeness and finality of scientific data and conclusions. This has the potential for clouding the policy responses available to decision makers charged with protecting public safety and welfare.

One major effort to assess the causes of potential danger has reached the conclusion that "There are more than 30 possible causes of observable changes in UV radiation on the ground."[2] Factors—both natural and man-made—identified either in theory or through verifiable experimentation, or both, suggest that one or more of the following do have or may have the potential for inducing changes in surface UV radiation levels: supernova explosions, volcanism, the effluents of high-flying jet and other fuel-burning vehicles (including space objects), earth-based industrial activities, agricultural activity including the use of nitrogen-based fertilizers and the application to crops of pesticides

---

*Professor of International Law and Political Science, University of Southern California.

[1]This subject has been treated in greater detail in my paper on The International Legal and Institutional Aspects of the Stratosphere Ozone Problem, A Report, U.S. Sen. Comm. on Aeronautical and Space Sciences, 74th Cong., 1st Sess. (August 15, 1975).

[2]A. Grobecker, S. Coroniti, and R. Cannon, Jr., Report of Findings, The Effects of Stratospheric Pollution by Aircraft, Final Report, U.S. Dept. of Transportation XXIV (1974).

and fungicides, accumulated chlorofluoromethanes from refrigeration systems and aerosol spray cans, and nuclear weapon testing, among others.

Concern over the possibility of man's inadvertent adverse influence upon the atmosphere first came to prominence with an awareness that high-flying aircraft produce carbon monoxide and hydrocarbons which interact with the atmosphere thereby producing nitrogen oxides (NO_x) and sulfur oxides (SO_x). More recently the possibility that the chlorofluoromethanes may produce ozone perturbations has been a subject under scientific inquiry and a matter of public awareness and concern. From the scientific point of view it is known that a chain of causation exists for the chlorofluoromethanes and that the steps in the chain proceed somewhat as follows: artificial and natural chlorine sources are transported through the troposphere and possible sinks, there is transport in the stratosphere, there is the condition of photodissociation with the release of chlorine atoms, there is an entry of the chlorine into a catalytic chain with the resultant destruction of ozone, there is a transport back to the troposphere, and there is a loss by precipitation.

Scientific methodology requires the gathering of data, an analysis of such data, the formulation of a hypothesis, a prediction of consequences, the testing of such consequences, and the modification of the hypothesis on the basis of facts and logic. Taking this methodology into account, some scholars who have examined the role of the chlorofluoromethanes as they interact chemically with other substances in the ozone layer have arrived at the conclusion that earth needs, at present, have been or are likely to be prejudiced.

Others take the position that there is no empirical evidence to support the theory that ozone is being destroyed by man's activities, and they assert that at this time it is not possible to draw valid conclusions merely from laboratory experiments and theoretical reasoning. The latter group point out that ozone is a renewable resource and that it is constantly being formed even as it decomposes. It is also their view that the mechanisms of decomposition are numerous, and that natural causes may be affected by many variables. Moreover, both man-made and natural inflences upon ozone take place at various levels of intensity. Thus, these experts do not know if there is a serious problem of ozone destruction at this time. Hence, they require more empirical evidence than is presently available before they acknowledge that there is in fact a meaningful ozone depletion problem. This outlook has been influenced by the numerous possible causes of observable changes in UV radiation on the ground, as well as by the complexity of the causative interactions.

THE ROLE OF SPACE OBJECTS

Space objects can be used in two quite opposing ways in the context of the stratospheric ozone problem. In the first instance it is necessary to determine if fuels employed by such objects are likely to contribute to perturbations in the ozone layer.

Secondly, there is the prospect that space objects can serve as vehicles for the carrying of sensing or monitoring equipment so that scientific data can be acquired and subsequently used for socially desirable purposes.

There has been some concern, which is not so acute at this time as it has been earlier, that the Space Shuttle might contribute to atmospheric pollution. As planned, the Space Shuttle will possess a main engine. It will also have a second component in the form of a solid rocket motor or boosters. The main engine has been designed so as to employ three liquid oxygen/liquid hydrogen, high chamber pressure engines.[3] The solid rocket booster elements of the Space Shuttle employ a fuel which includes chlorine. Effluents from these engines will be disposed of in the troposphere and in the stratosphere, as well as beyond.

Space Shuttle operations using the foregoing fuels can produce effluents consisting of water, oxides of nitrogen, hydrogen chloride, carbon, carbon compounds, and silicon. The main engines use a hydrogen/oxygen fuel, with water being the only exhaust product. While water does have the potential for enacting catalytically with ozone, it has been reported that "because of the relatively high ambient concentration of water in the stratosphere (about 10^{12} molecules/cm^3) the water from the Shuttle's main engine has negligible effects."[4] This finding has also been supported by data gathered concerning water emissions from high-flying jet aircraft, where there has been an increase in the ozone as a result of emissions of water, rather than depletion.

The solid rocket booster elements of the Space Shuttle system will consist of two "reusable solid propellant rockets."[5] One major effluent from the solid rocket boosters will be hydrogen chloride (HC1).[6] It was once believed that the presence of hydrogen chloride in the stratosphere might possibly produce adverse effects on the stratospheric ozone. Thus, as recently as January, 1975, Dr. James C. Fletcher, NASA Administrator, stated that

> Chlorine atoms are known to catalyze the decomposition of ozone in a way very similar to the oxides of nitrogen. If the hydrogen chloride exhaust product is converted to chlorine atoms, primarily through reaction with hydroxyl radicals, then depletion of ozone could occur.[7]

This particular concern has surfaced as early as 1972 and was reflected in the Environmental Impact Statement for the Space Shuttle Program prepared in July of that

---

[3]H. R. Rep. Nos. 93-918, 93d Cong., 2d Sess. (1974) cited hereinafter as H. R. Rep. Nos. 93-818.

[4]Hearings on Planetary Science and the Earth's Upper Atmosphere, 94th Cong., 2d Sess., at 203 (1975), cited hereinafter as Hearings on Planetary Science.

[5]H. R. Rep. Nos. 93-918, *supra* n.3, at 8.

[6]Hearings on Planetary Science, *supra* n.4, at 195, 204.

[7]*Id.* at 204.

year. This concern has led to studies of the relationship of such hydrogen chloride and stratospheric ozone. One such study accepts the view that each shuttle launch will "deposit 227,600 kgm of HC1 in the atmosphere by combustion of the perchlorate oxidizer."[8] These authors concluded that since it is expected that there will be no more than 50 Space Shuttle launches in any one year, chlorine in the atmosphere from this source would constitute only a "minor" element of the totality of chlorine compounds to be found in the stratosphere.[9] These authors considered chlorine produced by major volcanism and by the use of chlorofluoremethanes to constitute larger potential environmental hazards.

More recently Professor H. S. Johnston of the University of California has compared the respective threats to the global ozone by the Space Shuttle, supersonic transports, and chlorofluoromethanes. He has stated that

> Fifty space shuttles per year would inject 0.003 megatones of chlorine per year into the stratosphere . . . One megatone per year of natural stratospheric NO_x destroys 70% of the naturally produced ozone. On the basis of simple comparisons between stratospheric pollution rates and one megaton, we see that the space shuttles do not pose a serious threat to global ozone but that both supersonic transports and chlorofluorocarbons do pose such a serious threat.[10]

NASA has conducted investigations of the effects of HCl on the stratospheric ozone through its Shuttle Environmental Effects Program. By January of 1975 the situation merited this description:

> Preliminary calculations, using one dimensional models, incidated a potential ozone reducation of 0.4% based on a projected 60 Shuttle launches a year. This is an aggregate reduction that would take 20 years to attain, not the reduction per year. Also, the calculations indicate that the 0.4% value would be reached after 20 years of Shuttle operations averaging 60 flights per year. If Shuttle operations cease or if the propellant in the SRM's is changed to a nonchlorine containing compound, the ozone would be restored to its original level in less than thirty years. There exists a large uncertainty in the 0.4% number because of uncertainties in the rate of key chemical reactions and the fact that ambient stratospheric concentrations of many of the important chemical species have never been measured.[11]

Because of uncertainties as to the possible adverse impact of HC1 on the stratospheric ozone, NASA in August, 1974, initiated a study for an alternate propellant. NASA has indicated that it would change the solid rocket motor chlorine propellants if it were demonstrated that this fuel, and its effluents, would have an adverse effect on man, other animals, and plants.

---

[8]R. Cicerone and D. H. Steadman, The Space Shuttle and Other Atmospheric Chlorine Sources; Hearings Before the Subcommittee on Public Health and Environment of the House Comm. on Interstate Commerce, Fluorocarbons–Impact on Health and Environment, 93d Cong. 2d Sess. 266 (1974). Cited hereafter as "Fluorocarbons–Impact on Health and the Environment."

[9]*Id.* at 267.

[10]H. S. Johnson, The Application of Newly Obtained Data from Studies of Supersonic Transports to the Chlorofluorocarbon Problem 5 (n.d.).

[11]Hearings on Planetary Science, *supra* n. 4, at 204.

A second major effluent from the solid rocket boosters will be oxides of nitrogen (NO_x). Early in 1974 NASA considered that it was possible that the interaction of the booster exhaust with stratospheric constituents might produce oxides of nitrogen, and that this might react with stratospheric ozone thereby depleting the quality of the ozone. During the intervening period this concern seems to have become groundless.

By July, 1974, it was possible for NASA to report to the Senate Committee on Aeronautical and Space Sciences that important progress has been made with respect to the hypothesized effects on the stratosphere of oxides of nitrogen. As to space objects at altitudes of 50,000 feet NASA reported that

> The primary source of NO_x has been shown to be atmospheric nitrogen and oxygen entrained in the plume, rather than constituents of the rocket propellants. Also, the amount of NO_x so generated appears to be insignificant. These calculations must still be extended to higher altitudes and must further consider the parallel burning of the solid and liquid rockets of the Shuttle. However, inclusion of these factors is not expected to yield a significant increase in the predictions of NO_x quantities.[12]

Following further investigations of Space Shuttle fuels it has been possible for NASA to conclude that "it appears very likely that the space shuttle will have a negligible effect on the protective ozone layer."[13] This appears to be attributable to two specific facts. First, the fuels to be used appear not to be composed of elements which have substantially adverse influences on ozone, nor has it been proven that prior general launches have produced such harms. Second, the number of projected Space Shuttle flights is quite limited. The contrast with hundreds of daily flights by jet aircraft in the lower stratosphere is marked.

Additional studies have been directed toward determining if the Space Shuttle would produce atmospheric-changing conditions in the mesosphere—lying above the earth between 30 and 50 miles—during reentry. It has been suggested that it is possible that the Space Shuttle might produce such atmospheric contaminants as nitric oxide, carbon, carbon compounds, and silicon in the mesophere. However, this concern seems ill-founded and one study has concluded that "long-range environmental effects of repeated flights appear negligible."[14]

It would be somewhat ironic if the Space Shuttle and other space objects, which have the capacity to serve as a means to assist in the gathering of data relating to the condition of the atmosphere, were to constitute a source of environmental deterioration. In commenting on this possibility Cicerone and Stedman have observed that

---

[12] *Id.* at 180-182.

[13] Statement of Dr. M. S. Malkin, Director, Space Shuttle Program, Office of Manned Space Flight, in House Comm. on Science and Technology, Subcomm. on Space Science and Applications: 1976 NASA Authorization, Vol. II, pt. 3, 94th Cong., 1st Sess. 1861 (1975).

[14] Watson and Viegas, Preliminary Evaluation of Atmospheric Pollution by Reentry of a Space Shuttle Vehicle, NASA Technical Memorandum X-62, 130 at 1. (Ames Research Center, Moffet Field, Cal., Feb. 1973).

Current and future levels of atmospheric HC1 need to be ascertained. If Space Shuttle flights were to contribute to these needed measurements, then the understanding of the atmosphere generated could possibly outweigh their halogenous input.[15]

SPACE OBJECTS AND ENVIRONMENTAL SENSING

When modern sensing is accomplished by space objects nothing is being done that is not being done in other ways. The difference is that the other ways are slower, more tedious, more cumbersome, less specific, generally more ineffective, and, considering the return, probably more expensive. Among the platforms best suited to support remote measurements of the global, human, and marine environments is the space object.[16] However, for space object data to be accorded optimum reliability, it is frequently necessary to make comparative use of data acquired from ground-based facilities, balloons, aircraft, and sensing rockets, as well as space objects. Moreover, each type of vehicle has special capabilities allowing for the acquisition of a highly varied body of data.

Up to the present space objects have been used effectively for the gathering of atmospheric data. The Nimbus-type object has been used to obtain information on temperatures, presence of aerosols, the quality of the ozone, and the existence of water vapor. The Atmospheric Explorer E, to be launched in January, 1976, will acquire ozone data. The Space Shuttle which will become operational at the end of the present decade will carry a number of active and passive instruments for monitoring or sensing the contents of the upper atmosphere which runs upward from a point located 25 miles above the surface of the earth. It is expected that the Atmospheric, Magnetospheric, and Plasmas-in-Space Payloads (AMPS) will be able to study the atmosphere from the troposphere, which ranges upward from 7½ miles above the earth to a distance of 75 miles.[17] AMPS will include instruments including:

> cooled infrared limb scanning radiometers, spectrometsrs for the visible and ultraviolet infrared, occulation and airglow radiometers for the visible and ultraviolet, and lidars for backscatter, fluoroescence, sodium layer detection, temperature, and wind determination.[18]

At the present time the Stratospheric Aerosol and Gas Experiment (SAGE) is being conducted to determine the impact of aerosols on the quality of the ozone layer.[19]

Concern over the quality of the ozone in the stratosphere has called attention to

---

[15]Fluorocarbons—Impact on Health and the Environment, *supra* note 8 at 268.

[16]The term "the global environment" has been used to identify space, the moon and celestial bodies.

[17]See Hearings on S. 573, pt. 1, 94th Cong. 1st Sess. 280, 281, 607 (1975).

[18]Gille, Remote Measurements, in D. M. Hunten (ed.), The Stratosphere, 1975-1980, Report of a Workshop, May 28-30, 1975, at 27 (Goddard Space Flight Center, Greenbelt, Maryland, 1975).

[19]See Hearings on S. 573, 94th Cong. 1st Sess. pt.3, 78-79 (1975).

the need to improve the quality of instrumentation to measure accurately the presence of chlorofluoromethanes as well as a variety of other chemical substances, including nitrogen and sulfur, as they are found in the atmosphere. Such instruments, when mounted on space objects, have the present capacity—and over time will have an enhanced capacity—to monitor dangerous pollutants situated also on the ocean and on land.

INTERNATIONAL ENVIRONMENTAL LAW

A developing international environmental law is being accomplished by the perfection of instruments which can be mounted on space objects in order to gather evidence of the presence of pollutants. The emergence of international environmental law was stimulated by the United Nations Conference on the Human Environment, Stockholm, June 5-16, 1972. The 113 States in attendance adopted a Declaration consisting of 26 Principles, an Action Plan for the Human Environment consisting of 109 Recommendations, and a Resolution on Institutional and Financial Arrangements.[20] The meaning of the Stockholm Principles and Recommendations was summarized by Maurice F. Strong, Secretary-General of the Conference, when he stated that the States present attached importance to "every nation's responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or areas beyond the limits of national jurisdiction."[21]

Principles 6, 21, and 22 of the Stockholm Declaration have direct applicability to the legal aspects of the preservation and protection of the environment. Principle 6 states that the discharge of toxic substances must be halted. Principle 21 accepts the view that States have the sovereign right to exploit their own resources pursuant to their own environmental policies, but it also prescribes that States possess "the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction."[22] Principle 22 provides that "States shall cooperate to develop further the international law regarding liability and compensation for the victims of pollution and other environmental damage caused by activities within the jurisdiction or control of such States to areas beyond their jurisdiction.[23] Conference Resolutions 70-109 relate to pollution generally including the view that it is the function of governments to minimize national practices involving the release into the environment of toxic or dangerous substances.[24]

---

[20]U.N. Doc. A/CONF.48/14 and Corr. 1 (1972); 11 Int'l. Legal Materials 1416 (1972).

[21]U.N. Doc. A/CONF., Press Release HE/S/80 at 2 (June 16, 1972); Strong, One Year After Stockholm, 51 For. Aff. 690 (1973).

[22]U.N. Doc. A/CONF.48/14 and Corr. 1 (1972); 11 Int'l. Legal Materials 1416 (1972).

[23]*Id.* at 1416.

[24]*Id.* at 1449-1464.

CONCLUSION

Undoubtedly it is too soon to say that final proof exists that effluents produced by the scientifically and technologically advanced States have produced such harms to the ozone of the stratosphere that substantial harms have been caused on the surface of the earth. But, if the quality of the stratospheric ozone layer is substantially reduced, it is likely that larger amounts of UV will be received on earth and that this will be detrimental to human health, for example, through a higher incidence of skin cancer.

Further, within recent years substantial efforts have been made to develop rules of law for the global environment of space, for the marine environment of the ocean, and for the human environment of man. For each portion of the whole environment there has been some attention given to the development of law allowing those who have suffered detriment from pollutants to recover monetary damages for such harms. For example, under the Auspices of the Inter-Governmental Maritime Consultative Organization (IMCO) a "Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage" was signed in Brussels on December 18, 1971.[25]

In considering the direction which international environmental law ought to take States have been forced to attempt to understand their interests and the genuine interests of their nationals. Advanced States, which are now experiencing the accumulated forces of past pollutional practices, are leading in the efforts to develop an international law of the environment. Outlooks respecting the status of national development cling to perspectives of future national rights and duties. Developing States are attempting to fathom whether the development of such environmental rights and duties will allow for the assessment of damages against them as they focus on their own industrial development. Sometimes in the interest of their own development they have coupled their developmental drive with the alleged "freedom to pollute." There is a need to ascertain the respective tolerances in international environmental law as it begins to apply to States possessing highly variant stages of development. In the formulation of such legal policies it is well to remember that the atmosphere is global by definition and that pollutants produced in one part of the world are readily transported to far distant parts of the world.

If there is to be an effective international environmental law there will be a basic need to be able to acquire evidence of the presence of pollutants and their sources. At this time there is no formal international agreement which specifically prohibits the acquisition of such data via sensing procedures, including sensing carried out by space objects. The trend as reflected in international practice is wholly in the other direction. At the present time a community of interest is growing in the accumulation of sensed data for the condition of the total environment. In the United States there are new-found concerns as to the condition of the ozone in the stratospheric ozone layer.

---

[25] 11 Int'l. Legal Materials 284 (1972).

It is highly probable that space objects will play an increasingly important role in the identification of the general health of the stratospheric ozone layer. The utility of space objects for this purpose, and the importance of acquiring verifiable scientific data, will allow for this activity to be characterized as a peaceful use of the space environment. Such activity will therefore qualify as comporting with the principles contained in the 1967 Treaty on Principles Governing the Activities of State in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.[26] Through the peaceful and continuing use of space objects in sensing activities there will be the progressive development of international space law. With the maturity of such law there will also be a very substantial inducement to international environmental law to enlarge its expanding frontiers. The mutuality of relationships between these two areas of international law will prove to be beneficial to both. Of more importance, the basic needs of mankind in an ever more interdependent world will be accorded suitable protection.

[26] 18 U.S.T. 2410; T.I.A.S. 6347; 610 U.N.T.S. 205.