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I. INTRODUCTION

Four instruments of international law dealing explicitly with outer space are now in existence: (i) the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, (ii) the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, (iii) the Convention on International Liability for Damage Caused by Space Objects, and (iv) the Convention on Registration of Objects Launched into Outer Space. Moreover, outer space is referred to also in other documents, *e.g.*, in the Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space, and Under Water, ratified in 1963.

The area of application of the above instruments has, however, not been defined and, in a concrete case, diversity of opinion may arise. Such a diversity of opinion arose, for instance, during the World Administrative Radio Conference for the Planning of the Broadcasting Satellite Service in the 12 GHz Frequency Band, held in Geneva from January 10 to February 13, 1977. During that Conference, delegates of equatorial countries raised claims of sovereignty to segments of the geostationary orbit above their countries while delegates of other countries refuted such claims.

Without attempting to touch on the merit of the problem of the geostationary orbit, we give two quotations¹ from that conference in order to illustrate the relation of the above question to the definition of outer space: The delegate of Colombia stated on January 11: "There is no definition of outer space that is valid and satisfactory for the international community such as might be cited to support the argument that the geostationary orbit is included in outer space. Therefore, it is imperative to arrive at a legal definition of outer space, since to apply the 1967 Treaty without one would be merely to ratify the presence of the states that are already using the geostationary orbit...."² The delegate of Australia stated on January 31: "The status of the geostationary orbit is measurably connected with the definition and/or delimitation of Outer Space and it cannot be considered in isolation...."³

*Chief, Outer Space Affairs Division, United Nations Secretariat. This article is an expression of personal views of the author and in no way represents the opinion of the United Nations. This article is an elaboration of a paper presented to the 19th Colloquium on the Law of Outer Space. *See* Perek, Remarks on Scientific Criteria for the Definition of Outer Space, Proc. 19th Colloquium on the Law of Outer Space, 185 (1977).

¹International Telecommunication Union, Broadcasting Satellite Conference (Geneva, 1977).

²*Id.* Doc. No. 81, at 19.

³*Id.* Doc. No. 181, at 1.

There may be many reasons for the absence of a definition or a delimitation of outer space, the most important being, possibly, that States have neither agreed on a particular criterion for a definition of outer space acceptable to all nor on the necessity to adopt such a definition at the present time.

It should, however, be noted that definition and delimitation of outer space is on the agenda of the Legal Sub-Committee of the United Nations Committee on the Peaceful Uses of Outer Space which has been charged by the United Nations General Assembly with the task of defining outer space. It has been giving consideration to the subject in co-operation with the Scientific and Technical Sub-Committee without yet being successful in its task. In particular, at the sixteenth meeting of the Legal Sub-Committee held from March 14 to April 7, 1977, a wide range of opinions was presented. Some delegations saw no need for a definition of outer space or considered such a definition premature. Other delegations expressed the view that a definition was important or that it should be discussed as a matter of priority. One delegation stated that a legal system whose scope of activity was not defined, was inconceivable. Some were of the opinion that the definition should be consistent with scientific criteria and should be derived from legal and political principles. Three delegations mentioned a numerical value to be adopted as a limit of outer space of 90 to 100 km while one delegation favored "a very low limit." Some delegations said that the definition should take into account the quite special character of geostationary orbit.

Evidently, the international community is in the stage of stating opinions. It can be expected that in the future, common elements in various opinions will be formulated but considerable time may be required for a thorough exploration of all possible aspects and consequences of an agreed and adopted definition of outer space.

Another reason for not having arrived at a definition of outer space may be that most attempts were directed at solving all aspects of the problem: the extent of sovereignty of States, the regime for the space between the Earth's surface and the limit of the outer space, frequently called "airspace", the implications of a distinction between "air travel" and "space travel" based on technological achievements at a particular time in history, etc. The aim of this paper is much more modest. It endeavors to show that reasonable scientific criteria can be found for a possible geometrical delimitation of outer space. Almost all space activities, especially the orbits of artificial satellites of the earth, would lie above such a limit, while all of the present and most, if not all, of the future air traffic would take place below the limit. It is also shown that measurements can be performed, even at the usual high speed of space objects, to determine the instantaneous position of such objects with respect to an exactly defined limit.

Still another reason why no definition has been adopted may be a communication gap between experts in aerospace law and scientists working in relevant areas such as geophysics, aeronomy and astronomy. Indeed, it seems that the only case of a fruitful

co-operation is reported by Andrew Haley⁴ in discussing T. von Kármán's proposal of an outer space limit at 84 km where the aerodynamical lift is exceeded by the centrifugal force.

The communication gap was extremely well perceived by Haley when he said that: "Ironically enough, the lawyer finds the main crackpots and nuisances among engineers and sociologists who assume the role of amateur lawyers and give vent to rather silly if harmless rhapsodies in a field wholly unfamiliar to them."⁵ *Mutatis mutandis*, this is an exact description of the feelings of a scientist perusing treatments by lawyers of physics involved in criteria for the definition of outer space.

What evidently is needed is a closer co-operation of experts of all professions concerned in the spirit of another of Haley's statements that: "The sound scientist, on the other hand, avoids legal interpretation while at the same time making an essential contribution by staying within his technical expertise and keeping the lawyer well advised on appropriate physical phenomena."⁶ The sound lawyer, by the same basic principle, should ask the scientist for advice in all matters relating to science, keeping in mind the extremely important difference between the everyday physics of the surface of the earth and the sometimes surprising but well known physics of outer space.

II. THE GENERAL PROBLEM

The outer space, whatever its definition, is a three dimensional continuum which, topologically, can be bounded by (a) one, (b) two, or (c) more than two simply connected surfaces.

In the first case, the limiting surface would be the near boundary dividing the inner space, possibly called airspace, from the outer space. In the second case, besides the near limit, there would also be the far limit, beyond which another term might be used. Such a distinction appears, *e.g.*, in the ITU Radio Regulations.⁷ In the ITU Radio Regulations the term "deep space" has been introduced for regions at distances from the earth equal to or greater than the distance between the earth and the moon.⁸

⁴A. Haley, *Space Law and Government* 97 (1963).

⁵*Id.*

⁶*Id.*

⁷Administrative Regulations (Radio Regulations), annexed to International Telecommunication Convention (signed Malaga-Torremolinos, 1973), 23 U.S.T. 1527, T.I.A.S. No. 7935.

⁸The ITU definition of the deep space is ambiguous because it does not state what distance of the moon was meant. It could be either the instantaneous distance or the mean distance. The latter would be more convenient for the purpose of the definition because the instantaneous distance, as the term suggests, changes with time.

The third case would apply if it was considered necessary to exempt the neighborhoods of some bodies from the concept of outer space and introduce regions such as "atmospheric space of a planet" or "contiguous space of the moon."

The present space legislation is one and the same for all parts of outer space making it thus superfluous to introduce any additional divisions of space. The terms such as "deep space," "interplanetary, interstellar, intergalactic space" should be used only in their descriptive qualities but without any legal consequences. A possible development of terminology and legislation connected with different regions of the universe, should be kept in mind although it is to be expected, probably, at a rather remote future time. The important question, for the present, concerns the first case, *i.e.*, the near limit of outer space.

III. THE COMPETENCE OF SCIENCE TO PROPOSE A CRITERION FOR THE DEFINITION OF OUTER SPACE

Physical phenomena in such a complicated system as the earth do not yield exact limits. Most transitions are continuous but physics is able to suggest regions within which the changes have some particular significance. As an example, let us consider the border between the sea and the land. There is a region which may extend up to some kilometers in width which, due to surf, wind and tide is sometimes a part of the ocean, sometimes a part of the land. Nevertheless, for practical purposes, the shoreline has to be mapped and defined exactly, using, *e.g.*, the line of mean high water.

In space, science is in a position to indicate, *e.g.*, the region of lowest perigees of artificial satellites. This region is quite definite and the present state of knowledge and experience with satellites launched since 1957 is sufficient to pinpoint the region with an accuracy of about 10 km. Due to variations in the density of the atmosphere and due to various designs and materials used for the construction of artificial satellites, the accuracy cannot be expected to improve in the future.

The view that science is competent and able to propose a reliable criterion is not being shared by all authors on space law. Matte⁹ perceives a basic uncertainty in measurements and calculations of position and motion in outer space. He gives some examples from Einstein's theory of relativity such as the dilation of time, the curvature of the four-dimensional space-time continuum, the advance of Mercury's perihelion, and the bending of light by sun's gravitational field. He also gives some examples from spherical trigonometry, such as the excess of spherical triangles, or the deviation of the shortest trajectory on the earth's surface from the circle of a parallel, called straight line by Matte. According to Matte, such examples seem to be sufficient to demonstrate that the calculation of the vertical height of sovereignty would be much more complicated than it may seem. Matte also states that "astronomy has succeeded in establishing

⁹N.M. Matte, *Aerospace Law* 51 (1969).

spatial distances by taking as guidelines various celestial bodies and their movement, but calculation is not done in the same way as on an even surface. Einstein's theory of relativity helps to understand the complexity and, moreover, the uncertainty of such calculations."¹⁰

This statement might create the impression of inherent uncertainty in scientific criteria for the definition of outer space. Such an impression would be incorrect. If there were such a basic uncertainty, how was it ever possible to place satellites very accurately into predetermined orbits, how was it possible to place space probes on the moon or on the planets Venus and Mars? The statement that the laws of mechanics, as formulated by Galileo and Newton, apply only to flat surfaces¹¹ is incorrect. Newton's mechanics apply to the three-dimensional Euclidean space. Today's mechanics, with all its developments achieved since Galileo and Newton, respecting such effects as the very complicated shape of the earth, the lunisolar gravitational perturbations of satellite orbits, the solar radiation pressure and other minute forces,¹² is capable of solving problems of satellite motion with certainty and great precision.

None of the above consequences of Einstein's theory of relativity has any influence on the determination of satellite orbits or on the measurements and calculations of a vertical height of sovereignty. Spherical trigonometry is being daily used in maritime and air navigation and its calculations are quite certain and unequivocal.

IV. REQUIREMENTS FOR A WORKABLE DEFINITION

The requirements for a workable definition of outer space include: (a) the limit of outer space should be fixed exactly and by international agreement within a region indicated by physical criteria. A functional definition has not been considered here. A purely functional definition, which would not use any numerical value of a particular altitude, might be more complicated to deal with in concrete cases, because the determination of which particular object is performing what function could be considerably more difficult than a simple measurement of distance. Any function, unless stated in very general terms, may become obsolete by technological progress; (b) the definition of outer space should be global and the same for all countries. And (c) the definition should be expressed in simple terms and the determination of a relative position of an object with regard to the limiting surface should be possible, easy and rapid.

As an illustration, let us examine whether a fixed distance above the surface of the earth would meet the requirements. In the first place, it would be necessary to agree on

¹⁰*Id.* at 49.

¹¹*Id.* at 50.

¹²See U.N. Doc. A/AC. 105/164, at 28 (1976).

a well-defined basic surface from which the distance would be measured. The most suitable reference surface is the geoid which coincides with the mean level of the oceans and is well defined also on the continents as a theoretical continuation of the ocean level. The form of the geoid is at present known with an accuracy of $\pm 3\text{m}$ ¹³ and this accuracy might improve in the future when measurements from satellites over the oceans are taken into account.

Measuring the distance of an object moving hundreds of kilometers above the earth is possible with a radar and such measurements can be performed under all weather conditions. If a very high precision is required, a special satellite laser ranging telescope can be used in clear weather. Such instruments are at present operating in several countries. They are capable of measuring distances up to several thousands of kilometers with a repetition rate of several seconds and with an accuracy of about one meter. Second generation systems might be capable of measuring distances with an accuracy of about 10 cm, if the satellite or object is equipped with laser retro-reflectors. The distance of objects not equipped with the retro-reflectors can be measured with an accuracy approximately equal to the dimensions of the object in question. The direction of measurement is most suitably defined by the direction of the force of gravity, *i.e.*, perpendicular to the geoid.

It might also be necessary for the space vehicles themselves to determine whether they are inside or outside the adopted limit. Standard navigation methods are available for this purpose. Moreover, it has been shown¹⁴ that a navigation satellite system is feasible, although not yet planned for a world-wide use, which would enable space objects equipped with appropriate receivers to determine their positions. The accuracy would depend on the instantaneous position of the navigation satellites and would be 9 m horizontally and 10 m vertically at 90 percent of the time.

Briefly stated, the measuring of distance of any object in space can be made quickly with equipment which is not exceedingly expensive. Also the space objects themselves could, in principle, make such determinations. From such data, the altitude of any object above the geoid can be easily computed and thus the presence of the object inside or outside a limit can be determined if the definition is stated in terms of height above the geoid. The total accuracy of the determination is of the order of 3 m if measured from the ground with a satellite laser ranging telescope and 10 m if measured from a space object and utilizing a navigation satellite system.

V. GUIDANCE FOR THE DEFINITION OF OUTER SPACE

Whatever limits or definitions of outer space are adopted, they should be as close as possible to the generally adopted meaning of the term "outer space". Some guidance

¹³U.N. Doc. A/AC. 105/165, at 5 (1976).

¹⁴D. Smith & W. Criss, *Astronautics and Aeronautics* 26 (1976).

can be found in the usage of the term in the resolutions of the General Assembly and other documents of the United Nations.

Resolution 1721 (XVI), "International co-operation in the peaceful uses of outer space", called upon States launching objects into orbit or beyond to furnish information promptly to the Committee on the Peaceful Uses of Outer Space, through the Secretary-General, for the registration of launchings.

Since the request has been made under the general heading given above, it can be concluded that objects launched into orbit or beyond move into outer space. In accordance with the above resolution, States began to furnish information to the Secretary-General on launchings of satellites. The first such announcement¹⁵ contains data on objects launched into orbit or beyond by the United States of America between February 7, 1958 and February 8, 1962. In an accompanying letter, it is stated:

The establishment of such a registry marks another step forward in the direction of open and orderly conduct of outer space activities. Outer space is the province of all mankind and the United States believes that the benefits of the exploration and use of outer space should accrue to all. We, therefore, particularly welcome the establishment of this registry in the United Nations and are pleased to supply this information to open it.

In the second announcement,¹⁶ the Union of the Soviet Socialist Republics transmitted information relating to the artificial satellites of the earth and the space objects launched in 1957-1962. It states:

The Permanent Mission of the USSR to the United Nations deems it necessary to point out that, in the opinion of the Soviet Union, the information furnished to the United Nations for registration will be of real value if the countries concerned will register now and will continue to register all the artificial satellites of the earth placed in orbit and other objects launched into outer space.

Announcements by other launching countries, in addition to those of the USA and USSR, appear in the series which reached number 344 on May 18, 1976.

The spirit of the above introductory statements seems to indicate that the region which is occupied by satellites in orbit is a part of outer space. This point of view is even more strongly supported by the text of the Convention on Registration of Objects Launched into Outer Space.¹⁷ This Convention uses the term "objects launched into outer space" in the preamble, and the term "space object" in Articles I, II, IV, V and VI, in all cases in the same sense. In Article IV, basic parameters of space objects are

¹⁵U.N. Doc A/AC. 105/INF. 1 (1962).

¹⁶U.N. Doc A/AC. 105/INF. 2 (1962).

¹⁷U.N. G.A. Res. 3235 (XXIX) (1974).

mentioned, such as the nodal period, apogee and perigee, all of them referring to orbits around the earth. These terms clearly indicate that artificial satellites of the earth are space objects and hence launched into outer space.

In looking for a definition of outer space we thus might be guided by the above conclusions that artificial satellites of the earth move in outer space. Our task then would be to delimit as accurately as possible the lowest altitude at which satellites can exist in orbits around the earth.

VI. LOWEST PERIGEEES OF SATELLITE ORBITS

A study on the subject has been prepared by Working Group I of COSPAR.¹⁸ Theoretical considerations supported by observations lead in the study to a conclusion that satellites of usual construction cannot survive for any appreciable length of time at 90 km or lower.

Statistics of satellite orbits show that satellites launched into a variety of orbits in the last 18 years, serving many different practical purposes of research and application, invariably decayed above 100 km height. The only possible exception listed in the Table of Earth Satellites¹⁹ is 1974-02A, Skynet 2A, which has a listed perigee of 96 km. This value does not seem to be very accurate and, according to D.G. King-Hele,²⁰ might be in error by about 10 km because it was based on a small number of observations and the satellite was subject to several maneuvers during its last day in orbit. The most reliable orbit with a low perigee is that of the satellite 1974-114F, Molniya 1S rocket. Its perigee, also according to King-Hele, 15 hours before decay was 105 km and 3 hours before decay decreased to 102.5 km. Satellites of very high mass-area ratio, such as the geodetical satellites Starlette or Lageos, could eventually descend into the 90-100 km region. If they survived at all, their activities would be severely impaired or made impossible by excessive heating.

The effect of heating is illustrated by evidence from the meteors. They move generally at higher velocities than artificial satellites and enter the atmosphere at a steeper angle. Heat is generated by air friction and the compressed air in front of the meteor and the meteor itself start to emit light. Within several seconds or a few minutes, most of the material evaporates and some remnants may fall to the ground. The analysis of the phenomenon yields particularly accurate results if photographs by special cameras can be taken during the light-emitting phase in the atmosphere and if meteorites can be subsequently located on the ground. Such complete data are available in two cases only:

¹⁸U.N. Doc. A/AC. 105/164 (1976).

¹⁹3 Table of Earth Satellites (1974-75).

²⁰*Editor's note:* Private communication between the author and Mr. King-Hele.

a 20 ton meteor started to shine at a height of 98 km²¹ and a 500 kg meteor at 86 km.²² Such meteors would start to shine as low as about 70 km²³ if they moved with a velocity typical for artificial satellites of about 10 km/s. It does not, however, follow from this low figure that the limit of outer space would have to be set to 70 km. The shining of the meteor indicated a very high temperature. The process of heating and thus the process of decay had to start at considerably higher altitudes.

The launching and re-entry trajectories of space objects cover a certain horizontal distance between the orbit and the ground. It appears from the COSPAR study²⁴ that some launcher rockets or landing vehicles might require up to 10,000 km in horizontal distance for landing from an altitude of 100 km.

At some launching ranges it would be possible to plan the launching or landing trajectories in such a way that they entirely lie either in outer space or over the territory of the launching state or over international waters. In other cases it might be necessary for the launched vehicle to travel through the airspace of some other State and such travel would possibly have to be regulated in a way analogous to international air traffic or by a special agreement.

The criterion of lowest perigees of earth satellites has the advantage that it is based primarily on physical concepts which are invariable. It depends on technological progress to a very slight degree. In principle it would be possible to construct a special purpose artificial satellite which would survive below 90 km, or at any height for that matter. There would, however, be no gain in any application of such a satellite and its cost would be out of proportion because an extreme mass-to-area ratio can be achieved only by using heavy materials such as lead, gold, uranium or platinum in large quantities.

VII. OTHER CRITERIA FOR THE DEFINITION OF OUTER SPACE

Many criteria have been proposed in the past and books on space law frequently quote them without making a clear distinction between physically meaningful criteria and those which are less so. The result, sometimes erroneously arrived at, is that the present state of science does not permit the establishment of reliable criteria. In this section, a brief evaluation of some criteria will be attempted.

²¹Z. Ceplecha, Bulletin of the Astronomical Institute of Czechoslovakia, 12,21 (1961).

²²R.E. McCrosky, A. Posen, G. Schwartz, C.Y. Shao, 17J. Geophys. Res., 76 (1971).

²³*Editor's note:* Private communication between the author and Mr. Ceplecha (1976).

²⁴See U.N. Doc. A/AC. 105/164, at 29 (1976).

A. Limit of Sovereignty at Infinity

This theory is generally considered very weak but some authors²⁵ give theoretical legal reasons for an infinite extension of sovereignty. This theory is a return to the medieval geocentric concept which was discarded by Copernicus in the fifteenth century. All sciences and humanities have accepted the fact that the earth is not the center of the Universe and consider the earth in its proper place. We shall not elaborate on absurd implications of the infinite limit, such as the propagation of the vertical extensions of national borders with a speed exceeding the velocity of light already at the distance of the planet Neptune.

B. Limits Based on the Field of Attraction

According to Newton's law, the attraction of a body is proportional to its mass and to the inverse square of its distance. Thus, the field of attraction of the earth extends to infinity (in Euclidean universe). Without trying to discuss the extent of the earth's attraction in other models of the Universe, let us state that:

(1) Kroell's limit, *i.e.*, *Where the mathematical value of the field of the earth's gravitation is nil* is not defined and cannot be used as a criterion.

(2) Another formulation of almost the same concept is a limit where *weight ceases its manifestation*.²⁶ It is, however, more ambiguous than the first one because weight ceases its manifestation for any object moving in such a direction and with such an acceleration as to cancel the acceleration due to the attraction of the earth. Thus, it is not suitable as a criterion.

(3) *Altitude whence something can be dropped*.²⁷ Interpreting the term "dropping" as "releasing with zero velocity with respect to the center of the earth," the criterion would lead to a very complicated limiting surface depending on the distribution of masses within and outside the solar system and changing with time. Other interpretations of the term "dropping" would lead to more difficulties and no advantages. This formulation is not suitable as a criterion.

(4) *Altitude where the attraction of the earth is balanced by the attraction of the sun* is by simple calculation 260,000 km at the mean distance of the earth from the sun. It varies by 2% up and down depending on the instantaneous position of the earth in its elliptical orbit around the sun. The above figure results from the comparison of two static values and is of no importance in the dynamical problem of motion of a satellite

²⁵N.M. Matte, *supra* note 9, at 35.

²⁶J. Kroell, *Éléments Créateurs d'un droit astronautique*, 16, RGA 222, 230, 233 (1953).

²⁷G. Gál, *Space Law* 72 (1969).

around the earth. Such a criterion would be purely formal. It was first proposed by J.C. Cooper²⁸ and has been incorrectly quoted by Brun²⁹ and in the document³⁰ as 26,000 km.

(5) *Limit of possible satellite orbits around the earth.* The motion of a satellite around the earth is a "problem of three bodies" involving the sun, the earth and the satellite. Its mathematical treatment leads to limiting regions in space within which the satellites have to move at all times. These regions are bounded by complicated surfaces which for earth's satellites resemble prolate ellipsoids. The more energy the satellite has, the larger its accessible region. The largest such region around the earth extends to 1.5 million km in the direction of the sun, to 1.4 million km in the opposite direction and to 1.0 million km in the direction of the orbital motion of the earth. A satellite at a still larger distance would orbit not only around the earth but also around the sun. This limit would be a good criterion for the outer boundary of the satellite region. Our present task, however, is to look for the inner boundary of the satellite region.

(6) *Limit at the distance of geostationary orbits.* Satellites in such orbits remain, if they move from west to east and above the equator, permanently above the same point of the earth. Their altitude is approximately 35,900 km. The above altitude is measurable and well defined, but it would leave most of the satellite orbits below the limit, thus not in outer space.

(7) *Lowest perigees of satellites* define a limit which meets all the requirements for a practical and meaningful delimitation of outer space. It has been discussed in more detail in the preceding section. This limit has been proposed many times. The first proposal is probably due to J.C. Cooper³¹ who gave an altitude of 160 km derived from data available at that time. A limit above the border of ordinary flight and below the perigee of artificial satellites has been proposed by G.P. Zhukov.³² V. Kopal³³ is also in favor of this criterion. In 1967 he stated that the lowest perigees might lie lower than 160 km and he was shown right by subsequent development. The most recent value which hardly will change in the future is between 90 and 100 km. M. Kolosov³⁴ stated that, possibly, the limit between the airspace and outer space will be fixed by agreement

²⁸J.C. Cooper, *High Altitude Flight and National Sovereignty*, 1951, C. L. Q. 411, 416.

²⁹See Proc. 11th Colloquium on the Law of Outer Space 374 (1969).

³⁰U.N. Doc. A/AC. 105/C.2/7, at 49 (1976).

³¹N.M. Matte, *supra* note 9, at 31.

³²G.P. Zhukov, *Kosmicheskie polety i problema vysotnoi granitsy suvereniteta* 60-61 (1967).

³³See Proc. 10th Colloquium on the Law of Outer Space 275 (1967).

³⁴M. Kolosov, *Bor'ba Za mirnyi Kosmos* 83 (1968).

at the level of suborbital altitude. The informal understanding reached in 1960,³⁵ qualifying as spacecraft any craft exceeding 100 km (62 mi), also supports this criterion.

C. Limits Based on Properties of the Atmosphere

The limits based on properties of the atmosphere include:

(1) *Boundary of the atmosphere.* It is impossible to state where the boundary of the atmosphere is. The atmosphere in the first 100 km is a homogeneous mixture of gases. The composition changes at higher altitudes and the transition of the atmosphere into the magnetosphere and finally into interplanetary matter is gradual and continuous. Outer layers of the magnetosphere exhibit very complicated shapes considerably deviating from any spherical forms. The boundary is entirely unsuitable as a criterion for a definition of outer space.

(2) The definition proposed by B. Cheng³⁶ that *airspace is the entire space where air can be found under any form* defines airspace but does not define air. If air is defined as a mixture of gases found at ground level, then Cheng's definition would lead to 100 km where the composition changes.

(3) *Layers in the atmosphere.* The Working Paper submitted by Belgium to the thirteenth session of the Scientific and Technical Sub-Committee³⁷ gives a brief but complete survey of individual layers of the atmosphere. Among all the layers, the turbopause at 100 ± 10 km, seems to be best suited as the limit of outer space. It divides the homosphere from the heterosphere. The homosphere extends from the surface to the turbopause and is characterized by turbulent diffusion of atmospheric particles. As a consequence, the composition of the homosphere is practically the same at all altitudes as the composition of air at ground level. The heterosphere, lying above the turbopause, is of an entirely different nature. Its composition is highly variable with altitude because the atmospheric gases are stratified according to their molecular mass. As was stressed by V. Bumba at the same meeting,³⁸ any process which took place above the limit of about 100 km soon became a quasi-global phenomenon, influencing large areas of the earth's surface.

(4) *Von Kármán line*³⁹ is defined as the theoretical limit of airflight at an altitude where aerodynamic lift is exceeded by the centrifugal force. This happens at about 84 km. The definition is expressed in terms of physics but it makes the tacit assumption

³⁵IAF Congress, Oct. 1960.

³⁶Cheng, Recent Developments in Air Law, 1956 Current Leg. Mat. 210-213.

³⁷U.N. Doc. A/AC. 105/C.1/L.76 (1976).

³⁸U.N. Doc. A/AC. 105/C.1/SR.160 (1976).

³⁹A.G. Haley, *supra* note 4, at 97.

that airlift is necessary for flight. It is so at present and it may remain so in the future unless rockets on suborbital trajectories come into use. The definition is to some degree connected with a particular degree of technological development but it meets all criteria for a convenient definition. The satellite orbits lie above the line and the lowest perigees are only about 15 km higher. Had the definition been accepted in 1957 when it was first proposed by von Kármán, there would be no reason to change it now.

(5) *Functional definitions* would require an entirely different approach which is beyond the scope of this paper. The reader is referred to Matte.⁴⁰

VIII. CONCLUSION

It has been shown that scientific methods are sufficiently determinate and precise and that the experience with satellites launched over a period of 18 years is sufficiently extensive to suggest a specific region, between 90 and 100 km altitude, which has the property that almost all satellite orbits lie above it. From another point of view, the region between 90 and 110 km is the limit of air with the same composition as that at ground level.

It has also been shown that if a definition of an exact limit of outer space within the above regions is adopted, it would be possible to determine the relative position of any object with regard to such a limit with an accuracy of 3 m. Even the space objects themselves can determine their position with regard to the limit with a sufficient accuracy.

Support for using lowest perigees of satellite orbits for the definition of outer space is found in United Nations documents relating to registration of objects launched into outer space. No other criterion proposed for fixing the limit of outer space, with a possible exception of von Kármán's line of primary jurisdictional boundary, seems to meet the requirements for a practicable definition.

Unless the functional approach is preferred by the international community, any fixed value in the above regions would serve as the limit of outer space. A limit at 90 km altitude would be a suitable choice if it was found desirable that satellites spend their entire lifetimes, but for extremely rare exceptional cases, above the limit. A limit at the middle distance of 100 km would also keep practically all satellite orbits, at least during their useful lifetimes, in outer space. The infrequent crossings of the limit by decaying satellites could be regarded in the same light as the natural phenomenon of meteors. The choice of 110 km altitude would give States more headroom at the cost of some satellites spending hours or days below the limit before decaying.

⁴⁰N.M. Matte, *supra* note 9.

Let us assume, as an illustrative example, that the international community will agree, at some future time, on the following approach to the definition of outer space: The rounded off value of 100 km might be selected as the basic altitude of the outer space above the geoid, measured in a direction perpendicular to the geoid.

Since almost all space activities start, and some also terminate, at the ground, it might be found convenient to define functions which would be permitted and other functions which would have to be regulated between the ground and the 100 km altitude.

In outer space, *i.e.*, above the 100 km limit, the principles stated in the 1967 Outer Space Treaty apply in general. More detailed arrangements might be elaborated for specific celestial bodies, such as the Moon, or for specific parts of outer space, such as the libration centers or the geostationary orbit.