SOLAR POWER SATELLITES: LEGAL, ECOLOGICAL AND INSTITUTIONAL IMPLICATIONS

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Abstract

Numerous studies have been conducted to evaluate the feasibility prospects of the Solar Power Satellite concept. These studies pointed out that the path to making power from space available to mankind is long and difficult, because, if the concept is technically viable, its costs are not easily assessed and many problems, particularly of ecological and institutional nature, require further research. The purpose of this paper is to assess this promising concept, emphasizing the legal aspects of its development and operation. The paper will cover legal topics in the context of space law and environmental law. After recalling the basic legal principles directly applicable to SPS, we will focus our attention on two fundamental issues:
- environmental considerations, including the protection of the global environment and the problem of liability in case of ecological damage;
- the internationalization of the project. In fact, the opening of SPS programs to full international participation would create a framework for the sharing of costs. Thus, it seems necessary to take appropriate steps to initiate the internationalization of SPS while research and development is still in its early stage. This approach would be in conformity with Art. I of the Outer Space Treaty, according to which exploration and use of outer space shall be carried out for the benefit and in the interests of all countries.

Introduction

One of the oldest dreams of scientists is to produce energy by means of solar stations in the geostationary orbit above the earth. Indeed, in the early seventies, P. Glaser (USA) launched the idea of capturing the energy of the sun through orbital solar stations, and send it back to earth in the form of a beam of microwaves, where it would be transformed into electricity and introduced into the distribution network. After several years of study, carried out mainly by NASA and the Department of Energy, the project was shelved because of its huge costs and the ecological and institutional problems which required further research. Two international conferences on Solar Power Satellites, organized in 1986 and in August 1991 in Paris by the 'Société des Electriciens et des Electroniciens', have allowed to evaluate this problem and demonstrated that space could well provide new solutions.[1]

The main trends that arose from these conferences led to a renewed interest in the concept of 'energy from space'. This renewed interest is particularly linked to the results of prospective research into the energy requirements of the 21st century, to the uncertainties concerning other sources of energy[2], as well as to considerations concerning the protection of the environment. To illustrate this, we may recall that since 1986, the Chernobyl accident has led to an increased distrust of nuclear energy, the Gulf war has renewed the problem of the world's dependency on crude oil from the Gulf states, and the greenhouse effect, mainly caused by fossil energy, has come into focus. As a consequence, the idea arose to use that inexhaustible and non-polluting source of solar energy in order to fulfil the energy requirements of future generations, while at the same time preserving the environment. This is also the idea behind an international project on energy from space which was presented, in the framework of the International Space Year 1992, to the United Nations Conference on Environment and Development at Rio de Janeiro.

Does this mean that solar stations in space are really more 'ecological' than coal or oil burning facilities or nuclear stations which are so unpopular? As a matter of fact, they too cannot escape the rule that each form of exploitation of energy has consequences for the environment: in the case under consideration, these consequences include the congestion of space and potential effects of microwaves on health, nature or the climate and their interference with telecommunication installations, as well as, of course, problems of noise and atmos-

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pheric pollution linked with transportation systems. A lot of research needs to be done. But already, three new scenarios for SPS development have come up these last years and have been presented at the SPS '91 congress.[3] Their aim is twofold: to reduce the cost of these megaprojects and to take into account the ecological constraints:

- The first project consists of using lunar resources (aluminium, iron, titan, silicium) as construction material for SPS and for solar cells. This means that factories need to be constructed on the moon, and that these structures will be launched into geostationary orbit from the moon. The cost of launching from the moon would be considerably reduced (because of the absence of gravity) and the risk of pollution caused by a launch would be much smaller as well.[4]

- The second project uses solar space stations which are placed on the surface of the moon and again transmits the energy to the earth through a microwave beam, only this time this is done through a complex system of mirrors in terrestrial orbit which link it with the hidden side of the earth (as seen from the moon).

- The third project is based on the exploitation of helium-3, widely available on the moon, which is brought to earth and used as fuel in nuclear fusion, another future source of energy which is still being explored.

Whichever scenario is chosen, these types of megaprojects, whose research and development phase will span a period of about twenty years, can only be realized in stages and will require such huge amounts of human, financial and material resources that broad international cooperation is imperative.

Of course there are a number of technical, legal, political and social problems which need to be solved before such an ambitious project like the use of SPS can be realized. The questions concerning the production of solar energy by means of space technology have not only been discussed by the UNCOPUOS and its Legal Subcommittee[5], they have also been on the agenda of the UNISPACE 1982 conference[6] and have been studied by the ITU.[7] Several eminent space lawyers have, at a very early stage, considered the legal consequences of the exploitation of solar energy from space, and their work has particularly contributed to the annual colloquia of the International Institute of Space Law.[8]

Taking into account the evolution of the technological concept of SPS, as well as the state of the art as established specifically at the SPS '91 congress, this paper will try to provide a lawyer's answer to the new scenarios and strategies which have been proposed, and will especially concentrate on two fundamental problems which have been mentioned previously: the environmental considerations and the problems caused by the necessity to internationalize this type of project from the very start of the research and development phase. However, it is first important to recall the fundamental legal rules which directly apply to SPS, taking into particular consideration the specific regime for the use of natural resources which are involved in this type of project, whether it concerns the geostationary orbit and/or extraterrestrial matter, specifically from the moon.

I. The legal framework of SPS

It is outside the scope of this paper about the use of SPS and international cooperation to discuss in detail the general rules of space law which are mainly embodied in the five treaties of the United Nations regulating the general conditions of access and use of outer space. It will suffice here to recall a few principles of space law which are of direct concern for the launch and exploitation of SPS.[9] Next, we shall consider the legal rules which more specifically concern the use of these satellites, taking into account the natural resources which are likely to be used for their construction and exploitation.

1. General rules of space law applicable to SPS

Let us first consider the main principle upon which space law is based: the *freedom* to explore and use outer space. This freedom basically consists of:

- equal access, without discrimination, for all states with space activities (even if, *a priori*, few states possess the technological capacity to have access to space, they can at least benefit from its use), and
- the non-appropriation and non-sovereignty by whatever means over all or part of outer space.

This freedom can only be exercized under certain conditions and restrictions, which are, in their turn, recognized principles of space law as well, viz.:

- the human purpose principle: space activities must be carried out in the benefit of all mankind;
- the principle of conformity with international law, including the Charter of the United Nations, of all activities for the exploration and use of space;
- the principle of international responsibility of states for their national activities;
- and finally the principles of international cooperation and use of space for peaceful purposes, and of course the principle of compulsory international cooperation for a state whose activities might cause potential harm to the activities of other states, a principle which we will discuss later in this paper.

Since SPS constitute a use of outer space, this use must be carried out in accordance with the general principles of space law which are specifically embodied in the Outer Space Treaty of 1967. This means in particular that:

- their stationing cannot be subject to national appropriation by claim of sovereignty (Art. II);
- they have to be carried out for the benefit and in the interest of all countries (Art. I). It must however be noted that the legal status and effects of the principle of common heritage of mankind which applies to space activities in general and to commercial activities in particular, are to a large extent subject to debate and to diverging interpretations;
- the launching state is internationally liable for damage to another state party, to natural or juridical persons by an SPS or its component parts on the earth, in air space or in outer space (Art. VII);
- the registration of SPS must be in accordance with the Outer Space Treaty (Art. VIII) and the Registration Convention, and SPS must avoid harmful contamination (Art. IX);
- like in other sectors of space activities which resulted in numerous international agreements, states must favour international cooperation in the field of the use of solar energy from space (Art. III), and must respect the principle that space must be used for peaceful purposes (Art. IV). In this respect, SPS cannot be considered as a "weapon of mass destruction" on the basis of Art. IV, but they could be used as a source of energy for such weapons or as a basis for their deployment. Such fears could be removed by international control of SPS and by regular inspection in order to assure that the use of these satellites is not diverted towards military aims.[10]

2. Principles of space law applicable to the natural resources of space used by SPS

The construction and exploitation of SPS will imply the use of various natural resources of outer space:

- sunbeams in order to produce electricity;
- radio-frequencies for both telecommunication purposes and the transmission of energy through microwaves to the earth, as well as orbital positions in the geostationary orbit;
- lunar materials for construction of these satellites, in a more economic and ecological manner.

The use of each of these resources entails specific legal regulation.

a) Solar energy

Solar energy, as an unlimited, inexhaustible and renewable source of energy, can be considered as a *res communis*, and thus as the common heritage of mankind. This can be sustained by various legal arguments:

- the legality of the collection and use of solar energy is primarily based on a principle of international customary law, as satellites have regularly used solar panels since a long time without any state objecting in whatever way.
- the capturing of solar energy as such does not constitute an appropriation of space as prohibited by Art. II of the Space Treaty. As a matter of fact, since the sun may be used freely, the capturing of its beams is subject to that same freedom and does not constitute an appropriation in the sense of space law, because of its inexhaustible and renewable character.
- in conformity with Art. 11 of the 1979 Moon Agreement - which in its Art. 1 extends its field of application to the other celestial bodies as well -, the sun and its natural resources, i.e. the sunbeams, belong to the common heritage of mankind. States parties must therefore undertake, as we will see, the establishment of an international regime for the exploitation of the natural resources of the moon and other celestial bodies "as such exploitation is about to become feasible". We will not discuss the meaning of "natural resource" of the moon and other celestial bodies as this has already been done extensively in legal doctrine[11], nor will we discuss the qualification of sunbeams as natural resources of the moon, whose exploita-

tion must be regulated by the international regime under Art. 11. We will merely recall the idea that, in conformity with Art. I of the Space Treaty, as reiterated in the 1979 Moon Agreement, solar energy, as an inexhaustible and renewable resource, must be considered as a *res communis*, which can not be subject to exclusive rights, but which is instead subject to common use "for the benefit and in the interests of all countries". This principle will find its materialization in international cooperation, which is essential for the realization of SPS, and which we will discuss later in this paper.

b) The radio-frequency spectrum and orbital positions in the geostationary orbit

We are all well aware of the exceptional characteristics of the geostationary satellite orbit situated above the equator at an altitude of approximately 36.000 km, and where a satellite appears to remain stationary in respect of the ground station, thus allowing to maintain the receiving antenna at a fixed point. Taking into consideration that the radio-frequency spectrum as well as the geostationary satellite orbit are limited natural resources, the ITU has regulated the use of frequencies reserved for space radio-communications, primarily in order to allow for an optimum use of the radio-frequency spectrum by avoiding harmful interference and by assuring an equal right of access for all states. Since they are placed in the geostationary orbit, SPS will have to conform to the rules governing the use of this orbit. As a matter of fact, an SPS will occupy quite an important amount of space in the geostationary orbit, and thus reduce the space available for other uses, such as satellite, terrestrial or mobile telecommunications. Problems of congestion and crowding could result, and could lead to difficult choices between the various demands and to the setting of priorities.

- Use of radio-frequencies

SPS will use the frequency spectrum for two purposes: telecommunication and the transmission of energy through microwaves. As a consequence, they will fall under the rules of the International Telecommunication Convention (as amended at the 1989 Plenipotentiary Conference) and the rules of the Radio Regulations which are annexed to that Convention. At first it was uncertain whether the ITU would be competent to allocate frequencies for the transmission of electric energy through microwaves. But these doubts were taken away by the 1979 WARC - on the basis of a report by the CCIR - which decided that the transmission of solar energy would not be defined as a new service, and thus fall under the service "industrial, scientific, medical and other applications", and that the frequency band of 2450 MHz could be used for this purpose.[12] The procedures for coordination of frequency allocations, notification and registration of frequencies to space stations which are usually applied by the ITU should allow for the avoidance of any interference with existing services.

- Use of the geostationary orbit

Since the assignment of frequencies for the transmission of energy through microwaves is connected with the attribution of orbital positions in the geostationary orbit to SPS, the most important problem to be solved - one which we all know well - is that of the most rational and equitable use of the limited natural resource which the orbit/spectrum resource is for space services. Even though technical progress has allowed to minimize potentially harmful interference between satellites in the geostationary orbit by means of using frequencies attributed to specific orbital positions, by means of the orientation and the width of the transmission band, and by means of polarization and the type of modulation, thus obtaining a more efficient use of the orbit/spectrum resource, it still remains a fact that this natural resource is limited and has been designated as such by the ITU. Even if the construction of large structures in geostationary orbit complies with the different technical criteria in the field of interference and even if these structures are able to function very close to each other[13], it still constitutes a quasi-permanent occupation of this orbit, which can be considered as a *de facto* appropriation, contrary to the provisions of the 1967 Space Treaty. But we know by experience - and the world administrative radio conferences for satellite broadcasting and the WARC-ORB of 1985/88 will confirm this - that if the ITU does not undertake a planning of frequencies and orbital positions for this service on an international basis according to the needs of states or groups of states before the development of these stations, the result may be that the famous rule "first come - first served" will be applied, which will lead to a *de facto* appropriation of this orbit. The "first come - first served" rule has been a source of conflict and frustration especially for developing countries, to whom the attribution of geostationary orbital positions for other uses could well be refused.

c) Lunar materials

The importance of using lunar materials for the construction of SPS and of carrying out launches from the moon into the geostationary orbit has been demonstrated in the introduction to this paper. At this point, we will sketch the legal regime governing the use of these resources. Developments in this field would justify a separate paper on this point. I refer the interested reader to the research carried out by Ch. Koenig at the SPS '91 Congress in Paris.[14] Contrary to the 1967 Space Treaty which is silent on the matter of the natural resources of the moon, the 1979 Moon Agreement specifically states in its Art. 11 that such resources are "the common heritage of mankind (Art. 11§1), which finds its expression in the provisions of the Agreement and in particular in §5 of this Article". That paragraph provides for the states parties "to undertake to establish an international regime ... to govern the exploitation of the natural resources of the moon as such exploitation is about to become feasible". "The main purposes of this international regime to be established should include:

a) the orderly and safe development of the natural resources of the moon;
b) the rational management of those resources;
c) the expansion of opportunities in the use of those resources;
d) an equitable sharing by all States Parties in the benefits derived from those resources..." (§7).

The absence of definition of the expressions "common heritage of mankind" and "international regime" has led to different interpretations with regard to their practical implications.[15] I will not comment here, but it should be pointed out that neither Art. 11 nor the Moon Agreement as a whole give any reason to conclude that there is a moratorium on the exploitation of lunar resources until such an international regime is established.[16] Therefore, states and private enterprises under their jurisdiction and control could not be prevented on this ground from using moon resources for the supply of energy from space to earth as soon as such a procedure is economically feasible. Thus, for the time being, and as long as the Moon Agreement has not been ratified by a sufficient number of space powers, any state or international organization which is considering to undertake the conquest of the moon and its resources would in fact only be restricted by the provisions of the 1967 Space Treaty, which guarantees the freedom of use of space and the celestial bodies for all states. This being said, the only state which recently confirmed its intention to return to the moon is the USA[17], which, as we know, has not ratified the Moon Agreement. It is however probable, in view of the enormous costs which the conquest of the moon entails, that its exploration and use for scientific or economic purposes will either be worldwide or not exist at all, and this will in our opinion facilitate the application of the provisions of Art. 11 on the common heritage of mankind and the international regime which is to be established.

Another important legal aspect of the realization of SPS which more specifically relates to the theme of this session, concerns the potentially dangerous effects of these structures on the environment. We shall examine these in the second part of this paper.

II. Damage to the environment and responsibility for the use of SPS

As in any space activity, there are general risks inherent to space activity which are not specifically related to space energy, such as risks of collision, crashes of satellites, space debris caused by the orbiting and functioning of large space structures, etc., whose legal consequences have been examined by other participants in this colloquium. Concerning solar energy from space, there are specific risks, some of which are known, and other are still under detailed research. We will not provide a detailed inventory of those risks here, nor will we provide a scientific analysis. We refer the interested reader to papers published in this field.[18] We will however rapidly identify these potential risks in order to clarify the legal answers to these problems.

1. Identification of damage to the environment caused by SPS

The realization of an SPS structure in geostationary orbit could have an effect on the environment and on health in various ways:

- sound and atmospheric pollution by launchers. Effects on the climate, the ozone layer and the ionosphere are to be expected, although they cannot yet be evaluated precisely;
- biological consequences of working in space, although certain parts of the construction of the SPS are carried out by robots;
- biological effects of the microwave beam and major concerns about the long-term impact on the environment of the energy beam;
- electromagnetic interference.

These various damages have been analyzed excellently by Isabella Diederiks-Verschoor in her 1982 IISL paper. To characterize them in an even shorter way, we can divide them in a first category: biological effects (damage to health), a second category: specific risks for the space and terrestrial environment or "ecological damage", and in a third category: interference with telecommunication systems of other services (e.g. with magnetic and electronic aerial navigation systems etc.). To these potentially harmful effects we must add those which could result from the introduction of extraterrestrial matter on earth or its environment, taking into account the new scenarios which were mentioned earlier.

The next question which we shall examine is whether in view of these potential damages there are preventive measures or standard norms of exposure which should be respected, like for instance for ionizing radiation, and whether the present structure of international space law is sufficiently geared to cope with the problem, particularly in matters of liability in cases where it will sometimes be difficult to determine the causal link and to evaluate the damage.

2. Exposure norms for microwaves

One of the major concerns involving the transmission of microwave beams is the important question of what effect the exposure to such transmission will have on humans and biota in the receiving area, on the ground and in the space and air environment which the beams transverse. Peter Glaser, in one of his publications[19], reports that "short exposure would not harm anyone. ... At the edges of the receiving antenna site the power densities associated with the microwave beam will be well below US permissible level for continuous exposure to microwaves, which is 10 milliwatts per square centimeter, and more than likely they will also meet the Russian levels which are 1000 times less". Other countries use intermediate standards. The microwave power flux density would be the greatest in the center and would decrease towards the edges and it is estimated that beyond 10 kilometers from the beam center the microwave power density would meet the lowest foreign levels set for continued exposure to microwaves. Since past practice appears to indicate wide divergence of use with respect to the determination of standards by different countries, it would be necessary to formulate and adopt acceptable international standards of microwave exposure, and possibly more stringent standards for SPS transmission of microwaves, because of the high density of microwave radiation. The formulation of these acceptable international standards of microwave exposure could be achieved within the framework of UNCOPUOS, as was the case for the guidelines concerning the use of nuclear power satellites, or in the framework of other specialized organizations dealing with this type of problem, like the International Atomic Energy Agency or the World Health Organization.

In view of the provisions in the Outer Space Treaty requiring avoidance of "adverse changes in the environment of the Earth" and "appropriate international consultations" in case of "potentially harmful interference" (Art. IX), it will be necessary to define as fully as possible the potentially harmful consequences of SPS, including the environmental effects discussed before. But as there is no rule of space law which obliges states to act in such a way as to preclude any possibility of contamination of the environment, the establishment of international standards, such as the allowable microwave exposure, will be an important part of this process, as they will form the basis for actions in case of damages under the 1972 Liability Convention. But precisely another loophole in the present legal structure is the absence of adequate rules of liability in this matter, as we will see below.

3. International legal framework

Since we have seen that SPS may entail specific risks for the environment, the question is which rules of international law apply to these kinds of risk. On the one hand there are general rules, and on the other hand specific rules. As we have indicated earlier, space law does not really contain compulsory rules in the field of environmental protection. It is rather 'soft law', contained especially in Art. IX of the Space Treaty in conjunction with the general provisions of Art. I of the same Treaty. These two articles suggest, rather than impose,important rules of behaviour for states in their activities in outer space, that is to say the obligation to respect each other's interests, and more precisely the obligation "to avoid the harmful effects of contamination of outer space as well as adverse effects". On the other hand, and also on the basis of Art. IX, a state considering to engage in space activities is obliged to enter into consultations with other states whose interests could be harmed. Therefore, in the case of SPS it is neces-

sary to define as precisely as possible their potentially harmful consequences. Finally, in conformity with Art. III of the 1967 Treaty, it goes without saying that any SPS operation will have to be carried out in accordance with international law and particularly with international environmental law applicable to space activities, such as the 1987 Montreal Protocol to the Vienna Convention for the Protection of the Ozone Layer, the Environmental Modification (ENMOD) Convention of 1977, banning environmental modification techniques, etc. These general rules of protection and prevention apply to all types of damage to the environment which could be caused by the functioning of SPS.

In addition, other rules of international law apply to certain specific risks. This is in particular the case for technical measures which must be observed for the exploitation of microwave systems, in order to prevent harmful interference with radioelectric communications of other states, in accordance with the binding rules of the ITU and especially the Radio Regulations. It must also be noted that in order to prevent damage which may result from the introduction of extraterrestrial matter on earth, Art. 7 of the 1979 Moon Agreement obliges the concerned states "to take measures to avoid harmfully affecting the environment of the earth through the introduction of extraterrestrial matter or otherwise", and Art. 14 mentions the consequences regarding responsibility and liability.

Concerning (political) responsibility for damage caused by SPS, it is clear that, in accordance with Arts. VI and VII of the 1967 Treaty, in conjunction with the provisions of the 1972 Convention, states are internationally responsible to activities of their nationals or of private enterprises under their jurisdiction. This principle can be of great significance in certain development scenarios of SPS, as it will encourage a certain degree of state control on private enterprises undertaking to build or exploit SPS.

In terms of (legal) liability, the legal situation in case of interference caused by the transmission of energy remains unclear. As far as damage on earth caused by beams is concerned, the potential consequences of the microwave beam on the environment and on man are not yet exactly known. In some cases therefore, it may be difficult to establish the causal link and to evaluate the damage. Even if certain damages, like "ecological harm", are not mentioned in the 1972 Convention, material damage has been defined very precisely, and thus would also cover the physical consequences of this type of transmission. As such, states using energy transmission techniques which could have harmful effects, such as "loss of life, personal injury or other impairment of health, loss of or damage to property of States or of persons, natural or juridical, or property of international organizations" (Art. 1), will be responsible for those effects. No mention is made of damage to the environment, but the definition is sufficiently vague and lacking in precision to admit that it covers all damages caused by the transmission of energy from space to the environment, to telecommunications, or to aerial navigation. Nevertheless, in the case of damage caused by microwave beams from an SPS, it will probably be necessary one day to supplement the Liability Convention, taking into account the result of research into the ecological and biological effects which could be dangerous for man and for the environment, as well as of the internationally accepted exposure norms.

Besides environmental problems, there is also another aspect which is essential for the realization of SPS, and which requires further detailed study, and that is the need to internationalize this kind of project from the very start of its research and development phase. We will end this paper by examining the main characteristics of international cooperation applicable in this field, which is a *conditio sine qua non* for its inception.

III. Internationalization as an imperative for the realization of the SPS concept[20]

1. The necessity of international cooperation

Various reasons necessitate international cooperation to realize a project like this. On the basis of the previously examined legal principles of especially the Space Treaty and the Moon Agreement, the internationalization of the SPS concept must comply in particular with three series of requirements:

- the need for equitable sharing of resources used for the benefit of all countries (geostationary orbit/spectrum, lunar material, solar energy);
- respect for the interests of other states (protection of the environment, internationally accepted microwave exposure norms, prevention of electromagnetic interference);

- sharing of the costs of such an undertaking which are of a greater order of magnitude than anything done in the past.

The establishment of an international regime for the exploitation of solar energy from space, as such exploitation is about to become feasible, with specific obligations for states, could fulfil the first two series of requirements. Regarding the sharing of costs, international collaboration should be undertaken as of the first feasibility studies, that is to say, as of the research and development phase.

There are indeed a number of factors which need to be considered when planning a megaproject like the SPS concept, which implies major technological innovations over a very long development period, as well as human and financial resources of such magnitude that they are beyond reach of even the wealthiest states. It is therefore essential to share the costs not only among the public sector and the private sector of national economies, but also internationally, among space powers and other interested states.

2. Favourable elements and obstacles to international cooperation

The end of the cold war has created an entirely new international situation, which at the same time renews the concept of national interest and opens original new ways of cooperation and changes in international relations. Taking into account the budgetary restraints, in Western countries as well as in Russia, it becomes ever more pressing for large scale projects to make all possible efforts for closer international cooperation. Nevertheless, it is crucial that a long term project like SPS - or the international space station - is supported by a stable political and financial framework. Now one of the most disputed points in international cooperation in space in the past has been the inability of partners involved to agree on long term financial commitments. A high-level political decision framework , like the summit of 7 industrialized states, would allow to obtain the political support which is essential for a project of this size. It would provide the necessary impetus and would favour budgetary allocations, leaving thereafter to the space agencies the task to execute the programme.

The problems encountered for the realization of international cooperation in the field of SPS are quite similar to those of other major energy projects (such as controlled thermo-nuclear fusion) or major programmes for remote exploration of space (f.i. Mars). The SPS case is even more complicated because of the fact that it is both a space project and an energy project and because of the necessity of coordinating a large variety of national, private and public interests. Under these conditions, the question is which institutional form would be most suitable for the realization of such a concept, in order to guarantee equal access to new energy sources to all states. The only answer lies in the establishment of a structure which is adapted to the various stages of development of the project.

3. An evolutionary approach to the organizational structure

In this type of very long-term projects, three development phases can be identified:

- the phase of technical and economic research and of basic technology development;
- the demonstration phase;
- the phase of operational development and functioning of the system.

The level of cooperation to be established will not be the same in all phases. It is therefore appropriate to adopt an evolutionary approach towards the future organizational structure, which can start with a simple forum for exchange of basic scientific and technical information, and end with the classical structure of an intergovernmental international organization, via the intermediate solution of a provisional international cooperation mechanism.

It goes without saying that the adoption of this cooperation instrument should be preceded by a declaration of intention of the interested states, expressing their political will to reach agreement. The summit of 7 industrialized states could be the starting point for such a political initiative, but it seems that the United Nations would be better suited to express the political will of states and to achieve the international cooperation required for the realization of an SPS system. It should be recalled here that the United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE '82)[21] has already considered in its recommendations that the concept of SPS could well be suitable for an initiative for international cooperation. Such a solution would have the advantage of taking into consideration, right from the start, the North-South dimension of this project.

The next stage, phase 1, could make use of existing cooperation frameworks in the two fields concerned: space and energy. It should be noted that research concerning this phase has already been carried out by national bodies (such as the Sunsat Energy Council, universities, industrial enterprises) and by international non-governmental organizations (like the International Astronautical Federation, the International Space University, Eurospace...).

The second - demonstration - phase should be carried out under the auspices of an international organization, like for the ITER (International Thermonuclear Energy Research) project - a very costly long-term fusion project based on a newly developing technology - which is carried out under the auspices of the International Atomic Energy Agency of the United Nations system.

Phase 3 - operational functioning - could take the private international track, like INTELSAT has done for satellite telecommunications.[22] The institutional form of INTELSAT, which allows states to participate in the investment according to their means and to benefit from the system according to their needs, would have the advantage of combining the interests of the public and the private sector in a commercial enterprise, and of allowing, in exchange for a small contribution, the developing countries to participate in the realization of this concept, whose objective is to fulfil the future energy requirements of the 12 billion terrestrials of the 21st century.

Meanwhile complex negotiations will be necessary to reach an appropriate sharing of costs and benefits of the system, but it is probable that, if the SPS concept proves capable of supplying power economically to a majority of nations, the resulting fundamental convergence of interests should provide a basis for agreement.

Conclusion

SPS can contribute to the fulfilment of the energy requirements of our planet. They must be developed and operated in accordance with existing international space law, and must take into account the legal constraints which may exist when these systems become operational. In any case, the exploitation of solar energy from space in the framework of broad international cooperation must be carried out "in the interests of all countries", taking into account the developing countries, in accordance with the general recommendation expressed by Art. I(1) of the Space Treaty, and at present on the agenda of UNCOPUOS.

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1 Cf. *Proceedings of SPS '91, Power from Space*, Second International Symposium (Paris, 27-30 Aug. 1991), SEE, 1992, 641 p.

2 Cf. J. Collet, "L'espace: une solution aux problèmes d'énergie de la terre?", in *ESA Bulletin*, No. 69, Feb. 1992, pp. 90-95.

3 The reference project, which was studied simultaneously by NASA and the DoE in 1981, provided for a system of 60 installations in geostationary orbit, each with a 50 km^2 field of solar cells for a mass per unit of 50,000 tons, and each providing a power of 5000 Mw. The launching cost was exorbitant (about $100 billion, which is about twice the amount of what the British invested for the exploitation of oil fields in the North Sea) and the technology was far from realized. Cf. L. Deschamps and A. Dupas, "Les centrales solaires spatiales", in *Revue Générale de l'Electricité*, May 1985, No. 5, pp. 374-387.

4 Twenty times less energy is required to launch a charge from the moon than to launch the same charge from the earth.

5 Cf. especially UN Doc. A/AC.105/L.91, 1976; A/AC.105/181, 1976; Add. 1 & 2, 1977; A/AC.105/216, 1978; and D. Kassing, "SPS under consideration by the United Nations", in *ESA Bulletin*, No. 25, Feb. 1981, pp. 53-59.

6 Cf. UNISPACE '82 Report, A/Conf. 101/10, §302-304.

7 Cf. *infra*, p. 4.

8 Besides the first articles published on the subject by Ch. Okolie, S. Rosenfield, H. Safavi and H.L. van Traa-Engelman on "The legal aspects concerning solar energy" in *Proceedings of the IISL, 21st Colloquium*, Dubrovnik 1978, pp. 40-74, and by S. Gorove, "Internationalization of SPS: some legal and political aspects", in *Proceedings of the IISL, 23d Colloquium*, 1980, p. 169 ff. and I. Diederiks-Verschoor, "Legal aspects of SPS impact on the environment", in *Proceedings of the IISL, 25th Colloquium*, 1982,

p. 355 ff., we may also mention K.H. Böckstiegel, "Energy from space, chance and limitations from a legal point of view", in *Symposium on earth oriented space activities and legal implications*, Montreal, 1983, p. 204 ff., F. Nordlund, "Le régime juridique de l'utilisation des centrales solaires spatiales", in *Proceedings of SPS '91*, *supra* note 1, pp. 142-145, and the work of N.M. Matte, *Space activities and emerging international law*, Montreal 1984, p. 473 ff., C.Q. Christol, *Space law: past, present and future*, Kluwer, 1991, and S. Gorove, *Developments in space law - issues and policies*, Nijhoff, 1991, pp. 77-95, 101-123, 175-179.

9 It is obvious that the terrestrial part of the SPS system, i.e. the reception antenna or so-called 'rectenna', which collects the energy transmitted by the SPS, remains subject to the national sovereignty of the receiving state, which applies its national laws in the field of property law and specifically its laws on energy supply.

10 On the potential military implications of SPS and the control of armaments, see the excellent analysis of Arthur D. Little Inc., Philip K. Chapman, Peter E. Glaser and Kalinka I. Csigi, *The solar power satellite concept*, prepared for EDF, Arthur D. Little, April 1982, ref. no. 86766, 310 p. (esp. section IX (d) and p. 222 ff.).

11 Cf. especially I. Diederiks-Verschoor, C.Q. Christol, S. Gorove, *op. cit.* note 8.

12 Cf. J. Busak, "Les aspects juridiques de la transmission d'énergie électrique au moyen de fréquences radio-électriques", in *Journal des Télécommunications*, Vol. 48, No. VI, 1981, p. 324 ff., and N.M. Matte and F. Nordlund, *op. cit.* note 8.

13 Cf. the Arthur D. Little report, *op. cit.* note 10, Chapter IX, pp. 207-252.

14 Cf. Ch. Koenig, "The legal regime of the Moon regarding the exploitation of natural resources", in *Proceedings of SPS' 91*, *op. cit.* note 1, pp. 618-624.

15 Cf. especially K. Tatsuzawa, "Political and legal meaning of the common heritage of mankind", *Proceedings of the IISL, 29th Colloquium*, 1986, pp. 84-87, and T.L. Masson-Zwaan and W.W.C. de Vries, "The establishment of a legal regime for the exploitation of the natural resources of the moon and other celestial bodies: when and how?", *Proceedings of the IISL, 34th Colloquium*, 1991, pp. 257-264.

16 Cf. C.Q. Christol, "The Moon Treaty enters into force", in *American Journal of International Law*, Vol. 79, 1985, No. 1, pp. 163-168; K.H. Böckstiegel, "Legal implications of commercial space activities", in *Proceedings of the IISL, 24th Colloquium*, 1981, pp. 1-17.

17 Cf. *Report of the NASA Lunar Energy Enterprise Case Study Task Force*, NASA Technical Memorandum 101652, July 1989, 173 p.; "Retour à la lune?", in *Le Monde*, 1 April 1992, and *Aviation Week and Space Technology*, 6 April 1992.

18 Cf. the Arthur D. Little report, *op. cit.* note 10, Chapter XIII: Environmental impacts; L. Deschamps and A. Dupas, *op. cit.* note 3, pp. 385-387, and *Proceedings of SPS'91*, *op. cit.* note 1, pp. 195-216.

19 P.E. Glaser, "Solar power from satellites", in *Physics Today*, Vol. 30, Feb. 1977, p. 37.

20 On this particular aspect, cf. especially S. Gorove, *op. cit.* note 8, Chapter 7, 8 and 9; J.L. Magdelénat, "Energie solaire via satellite et coopération internationale", in *Annals of Air and Space Law*, 1978, p. 467-482; for similar reasoning about the establishment of a lunar base as an international cooperation project, cf. S. Lessard, "Un pas géant pour l'humanité: aspects juridiques d'un accord pour l'établissement d'une base lunaire", in *Annals of Air and Space Law*, 1989, pp. 377-414. See also the articles by J.M. Logsdon, R. Mayur, and B.H. Chatel in *Space Solar Power Review*, No. 2, 1981, pp. 109-113, 127-133 and 135-141 respectively.

21 Cf. note 6.

22 See also in this respect the proposal for the creation of a 'Solar energy bank for humanity' presented by Ch. Okolie, *Proceedings of the IISL*, 1979, p. 11 ff.