International Legal Issues on Developing Space-Based Solar Power

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I. Introduction

American scientist Peter Glaser proposed the idea of constructing space-based solar power station in 1968. Nearly half a century, the United States, Canada, Britain, France, the European Space Agency, Japan, Russia, India, China, and many equatorial countries not only have been more interested in space-based solar power station,[1] but also put forward various construction programs of space-based solar power station.[2] It is predicted that the success of space-based solar power station will fundamentally change the way of humans to use energy acquisition and may lead to a new technological revolution.[3] For this reason, in the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, the legal community unanimously called for various organizations around the world in the coming years to further study the technical and economic feasibility of the use of space solar power.[4]

But it is undeniable that the construction of space-based solar power station requires not only large scale space launch activities to carry all kinds of components from the earth to the space, but also large-scale space transportation systems to provide complex logistical support. These launch activities will produce a large number of space debris, and also take up a lot of orbit resources. In addition, space-based solar power station may also provide directly energy to military activities and military facilities, and even microwave transmission technology can be used to develop weather weapons for military purposes.

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1 National Space Society (US), Rouge J D. *Space-Based Solar Power As an Opportunity for Strategic Security*[M]. National Security Space Office, 2007, p. 41.

2 The existing constructive models include the SunTower Modular of the U.S., European SailTower and Japanese Modular. www.chinanews.com/gn/2011/07-12/3174700.shtml. available on 2014-10-20.

3 Hongbo Zhou, The Chance for the developing Space solar power, www.cubn.com.cn/News3/news_detail.asp?id=10393, available on 2014-10-20.

4 UN documents: A/CONF.184/6 : the report of the 3rd UNISPACE.

Therefore, the development of space-based solar power station is bound to bring a series of challenges to the current international law.
This paper will focus on the construction of space-based solar power station and the particularity of its operation to analyze the legal issues for the construction and operation of space-based solar power station and study the development of space-based solar power station bringing a series of challenges to the current international law to put forward some suggestions for improvement and development of the current international legal system that will promote and regulate the construction and operation of space-based solar power station.

II. International Legal Issues on the Construction and Operation of Space-Based Solar Power Station

Space-based solar power station in earth's orbit is a power system of converting solar energy into electric energy, and transmitting it to the earth through the way of wireless. In general, space-based solar power station is composed of three parts. The first part is a solar power system in earth's orbit to convert solar energy into electric energy; the second part is a kind of energy conversion and launching device in earth's orbit that can convert electric energy into microwave or laser and then emit energy beam to the ground by using of an antenna; and the third part is a receiving and conversion device to convert energy beam receiving from the space into electric energy.[5]
For the construction of space-based solar power station, it is needed to launch construction materials, film set light microscope, a solar panel, microwave transmission antennas and other equipment into the low-orbit space in which an antenna or solar cell array is assembled, and then transfer them from the low-orbit to the earth geosynchronous orbit.
Taking the construction of a million kilowatt space-based solar power station for example, it is estimated that you need 10 square kilometers of space solar photovoltaic panels, antennas up to 2 kilometers in diameter, and its weight is up to 10,000 tons.[6] In addition, what is needed is solar cell array, condenser and the microwave transmitting device assembled in orbit, which requires a series of manipulators to assemble and maintain the space solar power system. In the 1970s, NASA and the US Department of Energy designed a large-scale universe solar power station called "standard model", which weighs about 50,000 tons with an area of 10 km × 5 km. But in Japan, as for the universe solar power station to be built in the 1990s, only the solar panel is

5 Hou xinbin, Wang Li, Zhu Yaoping, *The situation on the developing space solar power*, Journal Of Solar Power, 2009, 30(10): 1443-1448.
6 Zhang Junping. *The Idea on Space solar power and the development of technology*, Spacecraft Recovery and RemoteSensing, 2011 (5): 10-17.

up to 2.6 km in diameter and weighs 21,000 tons.[7] Therefore, although human greatly improve its carrying capacity which is raised 10 times in the present, it also needs such heavy launch vehicle to be launched nearly 100 times in order to build a million kilowatt space-based solar power station. Assembled in-orbit space-based solar power station is like a 10 square kilometers space station in orbit which is around 1000 times bigger than the current International Space Station.

Obviously, if a country starts to build a space-based solar power station, he tends to construct several or even dozens of space-based solar power stations to solve his energy problems. So, when more than one country build space-based solar power station at the same time, the legal community will launch intensively thousand times so that several space objects with an area of 10 square kilometers will appear in the earth's orbit. More importantly, with the operation of space-based solar power station, this type of massive power station is easy to directly generate not only collision risk to other space objects, but also signal interference and damage to other satellites because of its microwave or laser. To this end, the construction and operation of space-based solar power station may cause a series of issues of the international law.

Firstly, to build a group of space-based solar power station, what is required is to launch materials hundreds of thousands of times by the heavy launch vehicle, so it must generate a large amount of space debris. It is calculated that it is equal to the total weight carried by the satellite launched by humans fifty years ago to construct a million kilowatt space-based solar power station, the sum of its launch time is also close to that of all humans during nearly ten years. Meanwhile, space debris generated by the current space launch has been a threat to human space activities. Therefore, it can be predicted that space debris will seriously influence human activities if a group of space-based solar power station are built and if such space-based solar power station is commercialized, space debris is increasing, it will lead to the probability of the earth's orbit being full of a large amount of space debris so that our earth's orbit cannot operate normally.

Plenty of space debris is a serious threat not only to space objects in orbit and astronauts, but also to the space environment, which becomes important practical and legal issues in the construction of space-based solar power station. On the one hand, when space debris is increasing, the probability of in-orbit satellites being dashed by space debris will increase. So, it is an important issue that how to determinate the international liability for damage caused by space debris. On the other hand, there is no direct provision provided by the current international law to determinate the international liability for damage caused by space debris to the space environment.

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7 Zhou Qi. The Space Solar Power Sation is not a dream, Liberation Daily, 2002-4-26.

Secondly, one of the basic principles of the current international space law is that "outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means".[8] It is the principle to establish the legal status of outer space and celestial bodies, but for the legal nature of space resources like lunar natural resources and solar energy, only the Moon Agreement provides that the Moon and other natural resources are the common heritage of mankind.[9] However, there are no provisions for other celestial bodies and orbit resources around the earth, and it is more important that it has been ratified by only 13 States Parties so far, so there is doubtful of its universality.

Space solar power can be defined as space resources with the characteristic of renewability and non-exhaustibility. The main purpose that developed countries with advanced space technology develop space-based solar power station to make use of solar energy is to possess space resources for themselves. Under the framework of international law, it is a legal issue that whether a similar principle of "common heritage of mankind" is needed to be established to manage space solar power or not.

In addition, space resources also include orbit resources around the earth like geostationary orbit and low earth orbit resources. The lifetime of the in-orbit space-based solar power station is up to 30 to 40 years,[10] which is 5 to 8 times longer than that of current satellites. Although the current international law for the use of orbital frequency resources in the framework of ITU has its legal framework. Therefore, ways of constructing the legal regulation to such a giant solar cell array and to further improve the current international law should be proposed.

Moreover, electric energy will be transmitted to the ground receiving station by laser or microwave beams after space-based solar power station in outer space converts solar energy into electric energy. Although the microwave transmitting electric energy does not cause damage to organisms in the earth's surface and it will not cause a fatal disease,[11] when microwave beam gets to the ground through the ionosphere and atmosphere, high-power microwave will interact with space plasma and atmospheric particle, causing some changes in the region and adjacent areas through the beam, such as electrons being heated and ionization being increased, at the same time the characteristic of microwave beam will also be changed. Therefore, electric energy transmitted through satellite microwave may not only interfere with

8 Article 2 of the Outer Space Treaty.
9 Article 11 of the Moon Agreement.
10 Hou Xinbin. Space solar power station and its requirments to the technology on microwave wireless transmission, Space Electronic Technology, 2013(3): 4.
11 Space solar power station and the technology on microwave wireless transmission, http://wenku.baidu.com/link, 2014-11-20.

satellite and radio waves of other countries, but also cause damage to the aircraft and ground. It is expected that about 9000 sets of communication equipment will work in the earth's orbit in 2015,[12] so it will lead to severe consequences if the microwave beam causes interference. In addition, the microwave may also cause damage to the surface of the earth. Meanwhile, because that microwave can heat water molecules, once it deviates from the ground receiver, microwave beam with huge diameter (10km magnitude) can lead to natural disasters like drought, forest fire and sea typhoon because of its rapid evaporation and heating of the land area.[13]

As for international liability for damage caused by the wireless transmission, it is required to make further coordination and development for the current international communication law and international space law. Meanwhile, considering the damage to the space environment caused by the microwave beam or laser, ways of constructing the principle of responsibility and its implementation mechanism scientifically and to further improve the current space law should be proposed.

Finally, space solar power can provide not only clean energy for the earth, but also energy needs for military activities and military facilities, such as to provide directly energy supply for in-orbit military satellite and military facilities in remote areas. The SBSP research group was set up by USA Naval Research Laboratory to research on space-based solar power station for the purpose of determining whether it can satisfy the demand of the America Navy, Marine Corps and the Department of defense. Compared to the ground solar energy, nuclear energy and wind energy, research group believes that it is the main program to develop space-based solar power station to ensure energy independence and dominant position to the army in USA. According to a report from the research group, they have made full analysis of technical and economic feasibility of space-based solar power station for military purposes such as the production of synthetic fuel in remote locations, and estimated its time and cost to put into use firstly. In addition, they also have compared energy consumption the army used in peace time with that in war time, and the result shows that it is an opportunity for us to construct space-based solar power station.[14]

In particular, microwave transmission technology can also be used to develop weather weapons for military purposes. The appraisal report shows that the

12 Wang Jingquan. Why did space activities need new rules. Space International, 2012 (3): 34-42.

13 Hongbo Zhou, The Chance for the developing Space solar power, www.cubn.com.cn/News3/news_detail.asp?id=10393, available on 2014-10-20.

14 W Neil JohNson. Space-based solar power: Possible defense applications and opportunities for NRL contributions[R]. Naval Research Laboratory, 2009: 5.

United States has possibly considered space-based solar power as a "space weapon" and paid more attention to it as an opportunity for strategic security.[15]
However, there is no legal norm in the current international law to regulate such a" space weapon" and also no provision for the use of space solar power to regulate its own military acts. Therefore, the issue needing further analysis includes: how to regulate its military acts legally in the use of such weather weapons and space solar power under the current principle of use of outer space for peaceful purposes.

III. The Current International Law on the Construction and Operation of Space-Based Solar Power Station

As is mentioned before, space-based solar power station is essentially a special spacecraft with super-size volume and weight, which means that it is an activity in outer space to construct space-based solar power station. Therefore, the construction and operation of space-based solar power station should follow the current international space law.
Firstly, the basic principles of the current international space law provide the legal regulation for the construction and operation of space-based solar power station, such as the following principles of international space law: the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind; outer space shall be free for exploration and use by all States; outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means; and the principle of use of outer space for peaceful purposes. So when constructing space-based solar power station, these principles above should be taken into consideration.
Secondly, Article 4 of The Outer Space Treaty and The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques of 1977 set out indirectly a number of general principles and provisions for the military use of space solar power. Article 4.1 of The Outer Space Treaty provides that States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner. And Article 4.2 also provides that The Moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on celestial bodies shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of

15 National Space Society (US), Rouge J D.*Space-Based Solar Power As an Opportunity for Strategic Security*[M]. National Security Space Office, 2007: 13-14.

any equipment or facility necessary for peaceful exploration of the Moon and other celestial bodies shall also not be prohibited. So, it is a violation of these regulations directly if space solar power is used to make any objects carrying nuclear weapons or any other kinds of weapons of mass destruction.

Furthermore, The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques of 1977 prohibits the States Parties from engaging in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party. Here, the term "environmental modification techniques" refers to any technique for changing-through the deliberate manipulation of natural processes – the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space. Therefore, Each State Party to this Convention is obliged not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party.

Thirdly, the current international custom and relevant international documents of The Space Debris Mitigation Guidelines are also important sources of law regulating the construction and operation of space-based solar power station.

The Space Debris Mitigation Guidelines of the United Nations Committee for the Peaceful Uses of Outer Space endorsed in UNGA Resolution 62/217(2007) and IADC Space Debris Mitigation Guidelines call for Each State Party to the Guidelines to take appropriate measures to minimize the possibility of accidents in space and collisions between space objects,[16] which actually provides directly legal principles for the construction and operation of space-based solar power station. Therefore, The Space Debris Mitigation measures should be adopted when States construct space-based solar power station.

Fourthly, the current Compensation for Space Damage provides an important legal basis of liability system for damage caused by space-based solar power station. Article 7 of The Outer Space Treaty provides that Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the Moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies.[17] Meanwhile, The

16 Li Shouping. *The Construction on the national mechanism on space debris mitigation*. Journal of Beijing University of Aeronautics and Astronautics, 2008(4): 35.

17 Article 7 of the Outer Space Treaty provides that each state party to the Treaty that launches or procures the launching of an object into outer space, including the moon

Liability Convention also provides that a launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft flight, and in the event of damage being caused elsewhere than on the surface of the earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible.[18] So, these legal principles above can be direct and indirect law sources of international liability for damage and space debris caused by space-based solar power station.

In addition, the Responsibility of States for internationally wrongful acts[19] endorsed by the United Nations International Law Commission sets out a number of general principles and provisions, for example, the responsible State is under an obligation to make full reparation for the injury caused by the internationally wrongful act. It also provides the source of law for international liability of damage caused by space activities.

Although the current international legal regime sets out number of general principles and provisions for regulating the construction and operation of space-based solar power station, for a range of new issues of international law arising in the construction and operation of space-based solar power station, the current international legal system is faced with serious challenges.

Firstly, there is no clear limitation to prevent space-based solar power station used for militarized purposes under the current international law. It is not the prohibited behavior under the current international law to provide national military installations or military activities directly with energy by using of space-based solar power station. As for space-based solar power station for commercial purposes, it can not be defined as military bases, installations and fortifications provided in the Article 4.2 of the Outer Space Treaty just because it provides national military installations or military activities directly with energy.

The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques of 1977 prohibits the States Parties from engaging in military or any other hostile use of environmental modification techniques, but it adjusts the behavior occurred in earth and weather weapons made by using of microwave or laser transmission of space solar is actually completed in outer space. So, it is a question to be considered that

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and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the moon and other celestial bodies.

18 Article 2 and 3 of the Liability Convention.

19 By resolution 56/83 of The Responsibility of States for internationally wrongful acts endorsed by the United Nations International Law Commission on 12 December 2001.

whether the behavior of making weather weapons in outer space should be constrained the Convention above. In addition, there is no further development about the issue of preventing an arms race in outer space discussed in the Conference on Disarmament.[20]

Secondly, there is no clear legal regulation to develop and utilize space resources under the current international law. Article 2 of the Outer Space Treaty provides that outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means. Professor Supancana I.B.R. explains that the term "not subject to national appropriation" includes four parts at least as follows: first, it should not subject to national appropriation by claim of sovereignty; second, it should not become "public property" that is, become the object of ownership; third, it should establish a kind of right regime in the international level before developing outer space resources; fourth, it should not be used indefinitely.[21] Clearly, the use of space solar power is appropriated by space great powers essentially. Notably, this article provides that outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, not including space resources.

Article 11 of the current Moon Agreement provides that the moon and its natural resources are the common heritage of mankind and States Parties to this Agreement hereby 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, but space solar power resources are not natural resources of the moon and it has been ratified by only 13 States parties so far, so the principle of the common heritage of mankind provided by this agreement can not be rule of customary law.[22] Therefore, countries can freely make use of space solar power without regard to the interests of developing countries under the current principle of use of outer space for peaceful purposes.

Furthermore, there is also no clear provision to dispose of such the large space-based solar power station at the end of its life cycle. Obviously, for such a large space object to be scrapped, the state of registration shoulder move it from the earth's orbit so as not to cause damage to other national space activities or space objects.

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20 Li Shouping. *Military use of outer space and its regulations*. Studies in Law and Business 2007 (3).

21 Supancana I B R. *Guaranteeing Accessof Developing Countriesto Outer Space*[J]. Jurnal Analisis dan Informasi Kedirgantaraan, 2010(3): 1.

22 Li Shouping, Zhao Yun. *Introduction to Outer space law*. Beijing: Guanming Press, 2009: 94-96.

However, there are no regulations to deal with the problem of removing space debris under the current international space law, which may limit the development of removing space debris.[23]

Finally, there's a lack of legal regulations of international liability for space damage caused by microwave or laser under the current international law. Although article 6 of the Outer Space Treaty provides that States Parties to the Treaty shall bear international responsibility for national activities in outer space,[24] there are no provisions for any form of liability and criterion of liability. In addition, article 9 of the Outer Space Treaty provides that in the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty.[25] It means that if other celestial bodies are damaged by space-based solar power station in the wireless transmission because of microwave or laser or other satellite signals are interfered, it can be regarded as violation of article 9 of the Outer Space Treaty.

The current Convention on International Liability for Damage Caused by Space Object provides that the damage caused by space objects is limited to personal injury and property damage, while it does not include environmental damage.[26] Microwave and laser are not space objects, so the compensation

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23 Nie Mingyan.Legal regime on actively removement of space debris. Yearbook of Space Law Research, 2013: 131.

24 Article 6 of the Outer Space Treaty provides that States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, …….

25 Article 9 of the Outer Space Treaty provides that in the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. ……If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon and other celestial bodies, may request consultation concerning the activity or experiment.

26 LiShouping. The liability regime on the damage caused by space objects under the framework of UN. Presentaday Law Science, 2009(2): 93.

problem of the damage caused by microwave or laser can not be solved under the current Outer Space Treaty and the Liability Convention. A launching State shall be liable only if the damage caused by microwave or laser is due to its fault when applying provisions of the Responsibility of States for internationally wrongful acts, which is obviously unfair. As we all know, The Liability Convention provides that a launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft flight, it is because that it is hard for victims on the surface of the earth to put to the proof of damages they suffered as they did not participate in launching space objects.[27]

In addition, Convention on International Liability for Damage Caused by Space Object can not be applied for the international liability of space and global environmental damages caused by microwave or laser transmitted by space-based solar power station. Although the general international law related to international wrongful acts can be applied, there are obvious limitations to define the fact of the environmental damage or its legal liability.

IV. Improvement of the International Legal Regime Regulating the Construction and Operation of Space-Based Solar Power Station

The analysis above shows that many new questions of the international law will be raised concerned with the constructing and operating of space-based solar power station.

With the development of space technology, it is predicted that space-based solar power station can be used commercially; therefore, it is required to perfect international provisions to regulate the construction of space-based solar power station in order to guarantee the peaceful use of space solar power.

(1) The further development of legal regime to prevent the military use of space-based solar power station

The current space activities are having dual-use in nature, such as global navigation satellite system of the US or Russian, but we can not regard its global navigation satellite system as a violation of the principle of the peaceful use of outer space. So it is obvious to prevent the manufacturing of weather weapons by using of space solar power is one of important measures to prevent weaponization of outer space.

It is important for the legal community to promote the international legislation to prevent an arms race in outer space and weaponization of outer space in order to prevent the manufacturing of weather weapons by using of space solar power fundamentally. In this regard, the issue on the treaty on the prevention of the placement of weapons in outer space has been proposed by the

27 Hobe, Schmidt-Tedd, Schrogl (ed), *Cologne Commentary on Space Law* (Volume II), Carl Heymanns Verlag, p. 116-130.

international community since 1981 in the UN General Assembly and also the draft resolution on the prevention of an arms race in outer space has been proposed. Since then, this issue becomes one of the most important issues discussed in the previous session of the General Assembly.

Furthermore, the draft Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force against Outer Space Objects (PPWT) was first proposed by China and Russia in February 2008 as an international legally binding treaty that would outlaw the weaponization of space and the threat or use of force against outer space objects. In August 2009, China and Russia jointly submitted their working paper responding to the questions and comments raised by the Conference on Disarmament members on the draft treaty. Therefore, to prevent weaponization of space-based solar power station, it must encourage the international community to widely accept the draft Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force against Outer Space Objects as soon as possible.

(2) Promoting of the international legal system of removing space debris actively

End-of-life space-based solar power station will be a big threat to human space activities if an international legal regime of removing space debris actively has not been established. On the one hand, end-of-life space-based solar power station will become huge space debris; on the other hand, it will continue to occupy huge orbit space. International practice shows that although the Space Debris Mitigation measures should be complied with by international community, these mitigation measures are not obvious so that the amount of space debris still increase. Therefore, to establish international obligations of removing space debris actively is an important measure of relieving the threat of space debris fundamentally.

There are no provisions to regulate the cost of removing space debris or the subject of the obligation under the current international space law. In this regard, some scholars have proposed a new international agreement to establish an international mechanism to remove space debris,[28] and others have suggested that international customary in the form of active international practice can establish the obligation of the State to remove space debris,[29] and also to amend the international space law to establish these international obligations

28 Lieutenant Colonel Joseph S. Imburgia, Space Debris and its Threat to National Security: a Proposal for a Binding International Agreement to Clean up the Junk[J], Vanderbilt Journal of Transnational Law, 2011(5): 636-641.

29 Meghan R. Plantz, Orbit Debris: out of Space[J], Georgia Journal of International and Comparative Law, 2012(40): 609-610.

has been proposed by other scholars.[30] From a practical point of view of international space law, the active removal of space debris involves the vital interests of the states or even the security of the national space assets, so it is very difficult to amend current treaties and develop new international treaties. Furthermore, it is also very difficult to identify and establish international customary because it not only requires long-term international practice from many countries, but also needs to achieve mutual recognition by the international community. Thus, there are slim hopes to establish the obligation of the State to remove space debris through international customary in the form of active international practice.

Therefore, based on the status of international space law, it may be the easiest way to be accepted by the international community to establish a framework of cooperation on the active removal of space debris through international documents without legally binding to countries. It is also the current major trends in the international space law to establish international customary from long-term international practice of many countries.

(3) The positive development of legal regime of Compensation Liability for damages caused by space activities

Based on limitations of the current compensation Liability for damages in outer space, such as the damage is confined to be caused by space objects and the scope of compensation for damages is confined to the personal injury and property damage, so considering environmental damage could be caused during the construction and operation of space-based solar power station, the international community should actively establish the legal regime of international liability for damages caused by space activities.

On the one hand, the current Liability Convention should be extended to international liability for damages caused by space activities so as to clear that a launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft flight, and shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible.

On the other hand, the scope of compensation of the current Liability Convention should be extended to damages of the environment in the earth and outer space. For damages of the environment in outer space, it should clear not only the compensation obligation of a launching State, but also the obligation of restituting the outer space environment and rights for any country to claim for environmental damages.

With respect to the Outer Space Treaty and the Moon Agreement, liability system has related to not only the security for all countries, but also areas

30 Lotta Viikari, The Environmental Element in Space Law: Assessing the Present and Charting the future[M], Martinus Nijhoff Publishers / Brill Academic, 2008: 100.

that countries concern. Therefore, it is relatively easy to achieve mutual recognition to amend the current Liability Convention.

(4) The exploration of the fair sharing mechanism to make use of space solar power

Space solar power is a kind of renewable, non-exhaustible resource, and there is no the system of developing and utilizing space resources under the current international space law. Article 3 of Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries provides that all States, particularly those with relevant space capabilities and with programmes for the exploration and use of outer space, should contribute to promoting and fostering international cooperation on an equitable and mutually acceptable basis. In this context, particular attention should be given to the benefit for and the interests of developing countries and countries with incipient space programmes stemming from such international cooperation conducted with countries with more advanced space capabilities. Thus, as for establishing the fair sharing mechanism to make use of space solar power, it not only considers the interests of developing countries, but also responds to the principle of not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.

The legal nature of space solar power is different from the common heritage of mankind such as moon natural resources and international seabed resources that can be developed and utilized freely. So considering the interests of developing countries, especially for that of countries without space capabilities, it is of great significance to establish the fair sharing mechanism to make use of space solar power.

To this end, on the one hand, it is required to take full account of the interests of developing countries, especially for that of countries without space capabilities to establish a reservation commission system with a fixed proportion of space solar power. In this system, according to the fair price auction mechanism, countries developing space solar power need to reserve a certain proportion of electricity to developing countries so that they can benefit space solar power every year.

On the other hand, countries developing space solar power can cooperate with developing countries to construct space-based solar power station by making use of funds of developing countries and techniques of space countries to develop and utilize of space solar power commonly.

V. Conclusion

The commercial use of space-based solar power station will not only fundamentally change the ways of obtaining the energy so as to solve the problem of energy crisis brought about by industrialization, but also may lead to a

technological revolution. But it cannot be avoided that various techniques are required from the construction of space-based solar power station to the commercial use of it completely, which means that it is required to perfect international provisions to regulate the construction of space-based solar power station.

New challenges for the basic principle of the current international space law and the current legal system on International Liability for Damage Caused by Space Objects have developed when constructing and operating of space-based solar power station. Furthermore, it will raise many new requirements of the legal regime concerned with preventing an arms race in outer space and weaponization of outer space.

To promote and regulate the construction of space-based solar power station, the legal community should actively not only promote the international legislation to prevent an arms race in outer space and weaponization of outer space and space solar power, but also make further development of legal systems of removing space debris, equitable sharing space solar power and damage liability for all activities in space.