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REPORT OF WORKSHOP ON CLEAN AND INEXHAUSTIBLE SPACE SOLAR POWER AT UNISPACE III CONFERENCE†

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Abstract—The third United Nations Global Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) was held from 19 to 30 July, 1999 at Vienna, Austria. The theme of the Conference was "Space Benefits for Humanity in the Twenty-first Century". The IAF Power Committee organized the Workshop on Clean and Inexhaustible Space Solar Power (SSP) as a part of the Technical Forum.

At the beginning of the workshop, current research and potential interactions of SSP with the environment were presented, together with the outlook for worldwide energy requirements. The feasibility, benefits and disadvantages of SSP were discussed for different countries, especially developing countries. Presentations included reports on field research in equatorial countries and China. Useful findings and recommendations were submitted to the relevant committees at UNISPACE concerning international cooperation and collaboration on both political and technical issues in order to realize SSP in the near future.

1. SCOPE OF THE WORKSHOP

Humanity is now facing a major environmental crisis, and it is widely recognized that we must reduce CO_2 emissions, especially from electric power stations. However, worldwide energy demand is growing so quickly that we need to investigate and develop new clean energy sources as soon as possible. The SSP is a unique and promising candidate for future electricity generation that could help satisfy the ever-increasing demand for energy without destroying the environment. Recent NASA studies have indicated the feasibility for SSP to deliver power as cheaply as terrestrial power stations in the foreseeable future, an idea once dismissed as unrealistic "science fiction". At this workshop, Solar Power Satellite (SPS) was discussed as an opportunity for mutually beneficial collaboration between industrialized and developing countries.

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2. PROGRAM OF THE WORKSHOP

The following 10 papers were presented in the workshop.

(1)	Energy Outlook in the World	Bryan Erb
(2)	Concept and Study of the Solar Power Satellite	John Mankins
(3)	Environmental Issues	Marvin Goldman
(4)	Microwave Power Transmission Experiments on the ground and in space	Nobuyuki Kaya
(5)	Demonstration of Microwave Power Transmission	Guy Pignolet
(6)	Case Study of Microwave Power Transmission in Reunion Island	Gluy Pignolet
(7)	Opportunity in France	Didier Vassaux
(8)	Options for international collaboration	Dieter Kassing
(9)	Ten Powerful Ways Solar Power Satellites can Assist Developing Countries	Alex Lightman
(10)	Field Research in Developing Countries	Patrick Collins

3. FINDINGS CONCERNING SPACE SOLAR POWER

Energy demand in the world, especially in developing countries, is growing rapidly. Fossil fuels, presently the dominant source of primary energy, present significant problems. The most critical concern is over the risk of significant environmental damage stemming from the use of these fuels. Environmental impacts include local and regional pollution, and the threat of global climate change due to the emission of various greenhouse gases, particularly in electric power generation. Oil and natural gas will, toward the middle of the next century, become increasingly expensive and, eventually, sufficiently scarce to create noticeable shortages. Coal supplies are sufficient for many years, but, of all fossil fuels, coal releases the most carbon as a ratio to energy provided. Some mitigation in the impact of fossil fuel use can be achieved by an increase in efficiency of use. Furthermore, there is some prospect of using fossil fuels without venting combustion products into the atmosphere. However, the technology for this is daunting and needs to become more economically feasible before it can be seriously considered. Hence, neither of these avenues should be relied upon as a solution within the next several decades. Therefore, there is an urgent need to develop new, clean energy sources.

SSP is a promising candidate for future baseload electricity supply that could contribute to the growing worldwide demand for high-quality energy. The environmental impacts associated with SSP and wireless power transmission that will convey it to the markets on Earth, are believed to the minimal, especially in comparison with most of the present sources of baseload electric power. Recent studies in the United States have indicated the feasibility for SSP to provide electric power at prices that in the not-distant future will be competitive with alternative sources. Further studies and a substantial amount of research and development will be needed to validate this approach to meet the world's energy needs.

The following findings were recognized through our discussions.

(1) Solar power facilities in space can provide abundant and clean new electric power for Earth.
(2) Solar electric power from space can
   - accelerate ongoing global electrification,
   - lead to decreasing electric energy costs through ongoing technological advancements in electronics, and
   - progressively reduce pollution and the uncertainties associated with present large scale commercial power systems. (oil, coal. natural gas, nuclear, terrestrial renewables).
(3) Some two billion people now live without the services that commercial energy provides. Without a new supply of abundant, clean and low-cost power, this number will increase with resultant poverty and worldwide inequity.
(4) The concerted efforts of many individuals and organizations internationally are required to enable new renewable global energy—including SSP.

4. RECOMMENDATIONS FROM THE WORKSHOP ON CLEAN AND INEXHAUSTIBLE SPACE SOLAR POWER

Many previous studies have indicated that SSP is a promising candidate as a future clean electric power system. SSP is quite different from many other renewable energy sources, because the SSP systems are launched into Earth's orbit and can supply electricity anywhere on the Earth, including the polar regions. This means SSP cannot be realized without

international cooperation and worldwide public acceptance. Especially, allocation of the microwave frequencies needed for the wireless power transmission from the Earth's orbit to the ground will be determined by international votes. Microwave power transmission cannot be used for SSP without acceptance and agreement of all countries. It is important to emphasize that the allocation of acceptable orbits is significant, as is the allocation of radio frequencies. These can only be solved by international cooperation, but those tools now exist and an appropriate process should be designed and implemented. These are the immediate concern for planning for the future. There will also be a significant land use issue for space solar power implementation — the receiving antenna (Rectenna) are not small and may be numerous, and their location should be determined using sound science and policy. On a relative scale, the research and development costs for the safety and environmental issues of SSP are quite small and will have the most positive effect if implemented at the earliest stages of engineering and demonstration projects.

It will also be important and essential to examine microwave effects on human bodies and the ecology. Additional collaborations are required with international organizations to investigate microwave effects, though many researches have indicated that microwaves are safe under existing standards for microwave power densities. The Electric Magnetic Field Project organized by WHO is a candidate organization to conduct such studies.

There is an urgent need to develop new clean energy sources in order to reduce CO_2 emissions from ground power stations. SSP emits no CO_2 gas in its operation, because the electricity is transmitted from space via microwave, which is pure energy. However, CO_2 is emitted in the production of materials and deployment of the SSP systems. Estimation of CO_2 emission from this source for the Solar Power Satellite (SPS) Reference System, designed in the 1970s, is comparable with that form nuclear power stations. Current sophisticated SSP models with newer technology are more compact and lightweight, suggesting that CO_2 emission from construction and deployment of SSP should be much less than that of previous estimates.

The feasibility of SSP is rapidly increasing with the remarkable development of technologies, though the SPS was once dismissed as unrealistic "science fiction". It is necessary to publicize the increased feasibility of SSP around the world. International conferences on SSP can give us good opportunities for discussions with both industrialized and developing countries. Demonstrations on the ground and in space would help people to understand SSP as well as verify its feasibility. Especially, it is very important to involve all affected countries in market analyses to examine how SSP might be uniquely suited to meet a portion of their energy needs. Only through their own analyses will countries become convinced of the importance of the SSP concept.

As mentioned above, SSP cannot be realized without worldwide cooperation and acceptance. We suggest that the United Nations is the appropriate organization to foster this cooperation. It could do so by creating an international committee addressing SSP, with the goal of promotion and negotiation between various official organizations worldwide with interest in SSP and its relationship to international energy matters, including health and safety regarding energy production and use, and the Earth's environment. We especially hope that the Committee on the Peaceful Uses of Outer Space will exercise leadership.

The following recommendations are submitted for the UNISPACE declaration from the workshop on Clean and Inexhaustible Space Solar Power.

(1) The Committee on the Peaceful Uses of Outer Space (COPUOS) in the United Nations should address how to facilitate the development and demonstration of clean and inexhaustible space solar power.
(2) The committee on the Peaceful Uses of Outer Space should consider the following potential actions:

- Encouraging organizations around the world to investigate further the technical and economic feasibility of SSP during the next several years, especially to perform demonstrations on the ground and in space that can validate needed technology advances and engender familiarization with SSP worldwide.
- Encouraging countries to examine the ways in which SSP might be uniquely suited to meet a portion of their energy needs.
- Identifying how SSP will improve the quality of life in all countries of the world (e.g., clean air, clean water, communications, and standard of living.)
- Stimulating international collaboration, cooperation and data sharing regarding SSP.
- Working with the appropriate national and international organizations responsible for standards and regulation to assure due consideration of SSP matters, for example, as they concern health, the environment,

spectrum management, orbit allocations, and other topics.
- Organizing and sponsoring an international conference on SSP involving both developing and developed countries.
- Forming a standing committee for the long-term consideration of SSP.

5. FINAL RECOMMENDATIONS IN THE UNISPACE DECLARATION

Our findings and recommendations were discussed in Committees I and II during the conference as to whether or not it should be accepted for the UNISPACE declaration. The following recommendations were consequently included in the UNISPACE declaration. It is very important to find out how to implement the recommendations as the next step.

Organizations around the world are encouraged: (a) to investigate further the technical and economic feasibility of space solar power over the next few years; (b) to stimulate international cooperation and data-sharing regarding space solar power, and (c) to give due consideration of space solar power matters, for example, as they concern health, the environment, spectrum management, orbit allocations and other topics.