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Space-Based Solar Power and Space Power

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ABSTRACT

Is there a single comprehensive theory that could shape future space? This paper examines the current state of space power theory. The method of research was a literature review of books, periodicals, government and private reports, and conference proceedings via Air University Library and the Internet. This effort identified basic elements of space theory—definitions, explanations and predictions—which then became a qualification as well as a framework for this paper. The major findings of this paper are that 1) Space power theory is emerging: it exists and is growing in the form of definitions, explanations and predictions of the nature, significance and functioning of systems in space; 2) A single comprehensive space power theory does not exist; and 3) Space power theory has much room for improvement in its definitions, explanations and predictions of space power. Finally, this paper recommends that future theorists 1) Expand all areas of space power theory to create a more robust body of literature; 2) Thoroughly examine the contributions of early space theorists 3) Address, in detail, the two "hot topics" in space power theory today—space control and space force organization; and 4) Seek a single Comprehensive space power theory to bring together the lasting ideas of space power for the purpose of Shaping space future.

Keywords: Power Sat, Rectennas

1. INTRODUCTION

On planet Earth, we're suffering from an energy crisis: we need gasoline to power our cars, and we need electricity to power our homes. Alternative sources of energy, such as solar power and wind power, can only provide a fraction of what we need, and nuclear power has inherent risks. Of course, the answer to this problem can be seen beyond the planet (into the space). By capturing the limitless energy of the sun and transforming it into electrical energy we can use, the world will have the energy it needs without being drained of its finite resources.

Figure 1 Space Solar System

Presently, the biggest obstacle to that vision is the expense of space travel. But recently the Power Sat Corporation announced the Patent for "Space-Based Power Systems and Methods." The patent includes two technologies-

1. Bright Star and
2. Solar Powered Orbital Transfer (SPOT)

These technologies will reduce launching cost and operation costs by roughly $1 billion for a 2,500 megawatt (MW) power system. Solar energy will be captured via solar power satellites (known as "power sat") and transmitted wirelessly via microwave to receiving stations at various points around the globe. The first technology, Bright Star, allows individual power sats to form a wireless power transmission beam without being physically connected to each other. This "electronic coupling," eliminates the need to handle large levels of power in a single spacecraft (power is of

the range of gigawatt). Because of Bright Star, one transmission beam may now come from hundreds of smaller power sats that effectively form one large satellite array. According to the CEO of Power Sat Corporation, William Maness, Bright Star will be on orbit for demonstration purposes in the 2017-2018,or at most within three years of that.

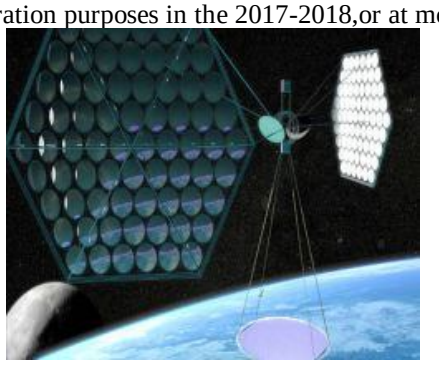

Figure 2 Solar Power Orbital Transfer

The most formidable hurdle during this work that has to overcome can be braked down into three parts-

1. Technical,
2. Financial, and
3. Regulatory.

1. Technical

Collecting solar energy and transforming it into usable electrical energy is being done every day with solar cell technology. However, transmitting electrical energy by wireless means has been well established and tested in the laboratory, but not in real life. Experiments have been done in sending energy from mountaintop to mountaintop, but that's not the same as beaming it from space to earth. The earth experiments had to traverse 200 miles of that same atmosphere, with the resultant loss of energy, but from space we only need to penetrate five miles of dense atmosphere. This means that there is a lot less loss coming down vertically from space than sending it horizontally through the atmosphere. That's where the big difference is.

2. Financial

It is not as horrendous as we might think. A step-wise approach has been taken, with the interested organizations taking a sequential risk reduction approach. That is, it's not expected from anyone to make an enormous investment all at once even before the processes are proven.

3. Regulations

Regulations are mainly concerned with radio frequency allocations. The two frequencies available for this kind of transmission are 2.45 megahertz (MHz) and 5.8 MHz. Mostly 5.8 MHz band is preferred, but that's the frequency most cell phones and related communication instruments use the whole world has no need to change its frequencies, and the problem can be solved if the use of the higher frequency for solar power transmission is allowed. That will probably be favorably received because the beam is un modulated, that is, it is not carrying data or voice—it's like a bare carrier wave on the 5.8 MHz frequency. Main advantage of it is that there is no need of much bandwidth or radio spectrum at all. When the energy is to be collected on Earth, which is being sent down from space, generally, because of the power lost from the transmitting wire, all electrical generating entities which are geographically oriented must be placed within 300 miles of the load they serve or rely on relay stations to compensate for the power loss. Space-based solar power is not limited like this because it's vertical. Receiving antenna is called as "rectenna". There are certain examples involving huge expanses of wire netting, similar to chicken wire, spread out over square miles of desert such as found in Nevada. A 'rectenna' in the Nevada desert could not serve Los Angeles, and certainly not Chicago or Detroit, because it's too far away. Also, if there is a sudden need for emergency power in another part of the country, say in Chicago or New York City, the current grid system relies on what is called "wheeling," or circulating power through the grid. That's expensive and complicated. With the power sat system, the beam can be shifted with the click of a switch on Earth to direct it where it's needed.

2. POWER SAT

Three hundred small receiving and transmission units called "Bright Star" are clustered in geosynchronous Earth orbit (GEO) 330 miles above the earth. This cluster, or "cloud," makes up a "power satellite" or "power sat." The units function just the same as the hundreds of solar collectors found on the International Space Station and the multitudes of satellites and spacecraft such as the Mars and moon rovers. The Bright Stars communicate with each other and the earth controllers via microwave transmissions, precisely focusing the energy beam to where it's needed on earth.

Microwave Beam

Sometimes it may happen that beam varies from its intended target. In the millisecond it takes for the target to discover that it's not receiving its signal, the beam shuts down. In other words, the microwave beam neither strays nor it fries a nearby community. If the beam doesn't reach the target, it stops. Second, the power of the microwave beam itself is smaller than what we normally use for a cell phone. That's one reason why this won't be used as a military weapon, as some fear. It's just too weak. I suppose if you were standing directly under the rectenna trying to make a call on your cell phone, you'd experience some interference, but that's about all. In fact, birds and airplanes fly through microwave beams all the time without harm. It's not strong enough to harm the birds, and the aluminum shells of airplanes deflect the waves without any effect. There is little chance for microwave energy being used as a weapon. Thus, this would be a way to provide electrical power to remote or forward military operations not dependent on ground-based generation and transmission. Many other non-military opportunities may arise.

RECTENNAS

The receiving material itself is basically a wire mesh. In North America, the "footprint" is calculated to be an ellipse approximately one mile wide by one-and-one-half miles long. The mesh will be supported on poles 30 to 60 feet tall, much like the current power and telephone poles. One of the beauties of this system is that since it is wire mesh, it will not interfere with crops or animals under it. Rain and sunshine pass right through it. The microwave energy does not penetrate the mesh, so there's no danger there. In fact, once the novelty wears off, those near the rectenna will probably not even notice it's there. The rectenna will of course be fenced in and monitored, so the opportunity for sabotage or vandalism is no greater than any other power generation plant.

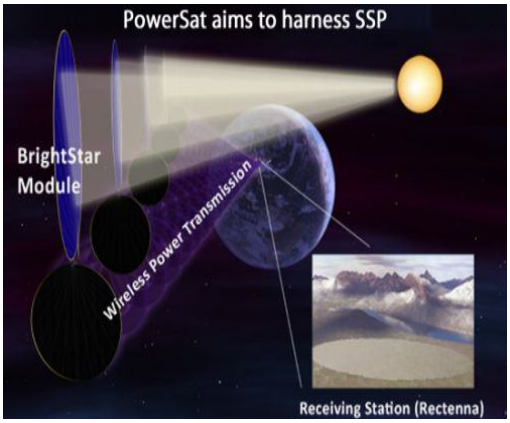

Figure 3: Power sat Rectenna

Satellites into orbit

When space solar power was first proposed forty years ago, a very large satellite collector to generate gigawatts of electricity was envisioned. Since then the technology has evolved rapidly and continues to do so with the development of ever-thinner film just microns thick and very flexible. This helped for the development of Bright Star, since we can make them much smaller and thus easier and cheaper to put in orbit. In physical dimensions, the Bright Star weighs about ten tons and is designed to ride a top to low Earth orbit (LEO). The Bright Star will take care of its own propulsion from LEO to GEO. In terms of physical dimensions, the inflatable stowed Bright Star will fit inside the payload envelope of both the Atlas and Falcon,, or 4.5 meters in diameter by 11.3 meters long, tapering to match the payload shroud. Deployed, each Bright Star looks like two thin plates, supported inside the rim. The larger of these two "disks" is the photovoltaic array and is 350m in diameter, separated and supported by an inflatable torus with a diameter of two meters. The smaller disk is the transmitter, about 100m in diameter, also thin-film in construction supported by the same inflatable outer rim. Each Bright Star will generate about 17 megawatts (MW) on orbit. Conventional liquid-fueled rockets lift the Bright Star into LEO. From there each Bright Star will continue on its way powered by its own electric ion propulsion engine. In this way we save 67% of the weight needed to reach GEO, and ion propulsion doesn't care much about orbital parameters. Granted, it may take six months or so to reach GEO, but the cost is relatively insignificant.

3. SPACE POWER

Definition:

"The capability to exploit space forces to support national security strategy and achieve national security objectives." The authors also provide categories of space power. First, they suggest that the subparts to space power can be seen as national, DOD, civil and commercial space systems and their associated infrastructures. Secondly, these parts can be further subdivided as follows: space-based systems, ground-based systems, and launch systems.

Explanation:

Explanations of space power include discussions on the nature, importance, and functioning of space power. Many authors explain the nature of space power in terms of various attributes of the space environment and space forces. Lupton used three categories of attributes: 1) Environmentally Influenced Characteristics such as global presence, the positional nature of motion in space (as opposed to maneuver-oriented operations in the air), and long-range electromagnetic weapon effects; 2) Logistically Influenced Characteristics such as long and difficult lines of communication and few inhabited assets in space; and 3) Politically/Legally Influenced Characteristics such as legal over flight (over sovereign territories) and vehicular sovereignty.15 Other authors added to the list of space power attributes. Colin Gray offered the following Defining Characteristics of space power: 1) Space is the "high ground" of all combat arenas; 2) Space is both global and of all but infinite military depth; and 3) astrodynamics translates to satellites globally available as a regularly repeating, overhead presence.16 Gray balanced these potential advantages of space power by identifying the following Limitations: 1) Cost of transportation into orbit; 2) Laws of motion limiting maneuver in space; and 3) Long distances from terrestrial events.17 In contrast, Larned argued that the three key attributes of space power are Continuity, Dispersion and Timeliness.18 Finally, in a rare integration of air and space power, Maj Bruce DeBlois Brought air and space power attributes together in his article, "Ascendant Realms: Characteristics of irpower and Space Power," where he discussed the characteristic advantages of air and space power in terms of politics, deployment and employment, 10 Realm access, realm environment, and realm-afforded capability.19 Detailed lists of these and other space power attributes are listed in Appendix B. A second aspect of space power that military thinkers explain is its importance. A common method for this purpose is the use of analogies; especially analogies of land, sea, and air power. Several authors used Carl von Clausewitz' theory of land warfare and applied it to space power. For example, in his paper "Clausewitz on Space War," Lt Col Donald Baucom projected Clausewitzian concepts onto space operations.20 Baucom translated the unpredictability of war into space and argued that danger, uncertainty, chance, fog, and friction will influence space wars.21 He also discussed how moral factors such as courage, intuition, battlefield experience and genius will effect space wars.22 Baucom causes the reader to wonder what unmanned, computer-controlled systems battling in space would do to the predictability and moral factors of space wars. To that end, he made the following supposition: in a space war, human beings would be removed a minimum of 100 miles from the location of actual combat. "Death" may now become the destruction of a space system, and this sterile, unemotional event may only be "sensed" through electronic data that are translated into a command post display.

Predictions of Space Power

A final element of space power theory is predictions of space power. While some Explanations of space power enjoy a strong predictive power as a side benefit, other Thinking is predominantly focused on space power's future nature, significance and functioning. These stand-alone products are the focus of this section. Two notable methods for expressing these predictions are discussions about the weaponization of space and Air Force studies designed to envision the future. Theory concerning the weaponization of space can express powerful predictions of the future of space power.63 Lt Col Mike Mantz wrote one of the most thorough theories

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purely scenarios that used fictitious (but realistic) examples of space power to send powerful messages of the possible importance and uses of space power in the future. These scenarios highlight the importance of space-based information and weapon systems by discussing what might happen if a nation that did not have them fought an adversary that did. The message of such writers is that space weapons are inevitable, space weapons are essential to the survival of third wave nations, and to wait to develop space weapons until after an adversary takes hostile action would be disastrous. Finally, there was a recent wave of Air Force studies that explored future possibilities. These efforts include Space cast 2020, Air Force 2025, and New World Vistas—Air and Space Power for the 21st Century. Janushkowsky's also captured future oriented themes in his predictions on future space requirements. Janushkowsky's eight predictions, supplemented with matching comments from the three Air Force studies

4. CONCLUSION

This paper defined a framework in which to assess space fundamentals and space power theory. Within this framework, it identified and analyzed a sizable cross section of current space theory. The analysis revealed three observations about space power theory—it is emerging, it is not comprehensive in form, and it is immature. First, space power theory is emerging. By emerging this paper means that it exists and is growing. Space power theory exists in the form of definitions, explanations and predictions. The definitions of space power help to set limits on the concept while providing categories of space power's actors, capabilities, functions and purposes. This paper recommended space power theory development be aimed at improving the rigor of the definition, explanations and predictions of space power as well as creating a single comprehensive space power theory.

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