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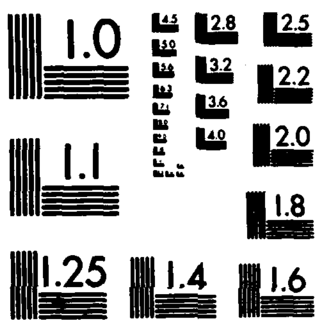

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FOREIGN TECHNOLOGY DIVISION

SPACE ENERGETICS

by

Afudu Yefusiji

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SPACE ENERGETICS

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SPACE ENERGETICS

Afudu Yefusiji [transliteration] et al./translated by Yu Futang

In the vastness of space, power plants will be built one after the other with large amounts of construction materials to be transported. In some concepts, a laser is used to propel a carrier rocket to transport the required materials up to the sky.

At present, the world energy consumption is about 3×10^{20} joules per year, approximately equivalent to 1/180,000 of the energy the Earth acquires from the Sun. If all the world regions attain the energy consumption level of the developed countries, the consumption should be raised to 3/180,000 of the solar energy obtained by the Earth. This is approaching the limit, and will have an irreversible effect on the Earth's climate (thermal contamination of the Earth). If the continual increase of world population and energy consumption of the developed countries (doubled every 10 to 15 years) are considered, the situation will be more severe. According to the estimate, the expenditures required to overcome the ecological crisis and maintain the ecological equilibrium will be 40 percent of the total society expenditures.

One way of thoroughly overcoming the above mentioned difficulties is development toward space. In other words, a considerable part of the power project and some production activities consuming a large amount of energy and of risky operations are moved to space near the Earth.

Advantages and Disadvantages of Space Power Plant

In synchronous orbit to the Earth at 36,000 kilometers from the surface, space power plants can be built one after the other (Fig. 1). The electric current produced by solar cells can be converted into microwave electric energy, which is transmitted to the surface of the Earth and then the energy is reconverted into electric current for user consumption.

As revealed in design study, parameters of a space power plant are: about 10 million KW in electric power, about 100,000 tons in weight, about *100 square kilometers in area of solar cells*, and about 100 square kilometers in area of microwave ground receiving antenna.

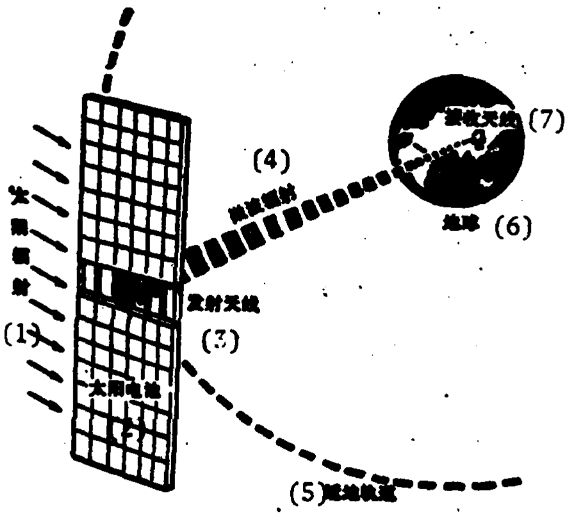

Fig. 1. A space power plant is transmitting power to the Earth.
Key: (1) Solar radiation; (2) Solar cells; (3) Transmitting antenna; (4) Microwave radiation; (5) Near Earth orbit; (6) Earth; (6) Receiving antenna.

Of concepts in the United States, 60 such space power plants can be built in the first 30 years of the 21st century; in a West European concept, 50 such plants can be built in the same period. After the power plants are completed, it is estimated that 40 to 50 percent of the electrical energy requirements can be met. The cost of each space power plant is estimated at 15 to 40 billion US dollars; this is, of course, not a small sum. Table 1 lists the expenditures of three prospect design schemes of a breeder nuclear reactor, thermal nuclear reactor and space power plant.

Table 1. Prices of different approaches of power generation.

[illegible] (e) / (a) [illegible]	(f) [illegible]	(g) [illegible]
[illegible] (b)	400~800	1.2~1.7
[illegible] (c)	1500~2500	3.4~5.7
[illegible] (d)	1500~4000	3.2~6.6

Key: (a) Design scheme; (b) Breeder nuclear reactor; (c) Thermal nuclear reactor; (d) Space power plant; (e) Expenditure; (f) Building cost in US dollars per kilowatt; (g) Cost of power generation, cents (in US currency) per kilowatt hour.

From Table 1, at present the most economical power plant is the breeder nuclear reactor. However, there are serious drawbacks because the nuclear reactor expels large amounts of radioactive wastes which are potentially dangerous. In addition, the raw materials used are uranium and thorium with limited reserves.

The economic effect of space power plant is not much different than that of thermal nuclear power plant. Hence, at present there are sufficient reasons to consider space power as one prospective energy source.

Of course, there are considerable difficulties in building space power plants. One of the difficulties is the very gigantic structure. For example, if we rely on a liquid fuel rocket to propel components (weighing some 100,000 tons) of the power plant onto the synchronous orbit, then large amounts of fuels should be transported to a supply base in near Earth orbit. Thus, the total weight is no less than 300,000 tons. To transport that much cargo from the ground surface to space, ridiculously large carrier rockets should be built. Another difficulty is confronted in ground launch of these rockets because an alarming quantity of fuel should be burned in the Earth's atmosphere--eight million tons for only a single power plant.

If the power consumption on the ground is 1 percent of the energy the Earth acquires from the Sun, and if 10 percent of the power consumption is supplied by space power plants, then 10,000 space power plants each having a capacity of 10 million kilowatts should be required. It is not difficult to calculate that eight million tons of fuel are consumed for launching a single power plant. Then, for launching 10,000 power plants, the fuel consumed is $10^4 \times 8 \times 10^6 = 8 \times 10^{10}$, approximately 10^{11} tons. The mass of carbon dioxide gas in the Earth's atmosphere is the same magnitude as the launch fuel consumption approximately 2×10^{11} tons. Very clearly, with such a vast amount of combustibles falling into the atmosphere, a very significant effect will be produced on the Earth's climate; this is not allowed from ecological viewpoint.

New Concept of Space Power Engineering

From what was mentioned above, it is clear that the three following points should be satisfied and some other approaches should be adopted in order to rationally solve the problem of space power:

1. Maintaining the same effective power, approaches of considerably reducing the weight of the space power plant should be sought.

2. On the condition of reducing contamination as much as possible, the effective payload is transported to the near earth orbit as the supply base.

3. The most desirable method is taken to ensure these effective payloads to be transported to a synchronous orbit.

In the third point mentioned above, cargo spaceships need to be built for moving between orbits; the best method is the building of ion rocket engines, and the working substance should be the ion beam or plasma under acceleration in an electromagnetic field.

There is a series of important advantages in moving the payload to a synchronous orbit by relying on ion rocket engines. First, the space power plant itself can provide solar energy, and secondly, this kind of engines is very economical. In addition, the acceleration produced by the ion rocket engine is very small, no greater than 10^{-3} to 10^{-4} g. Hence, the strength requirements on power plant components can be reduced with corresponding reduction of the total weight of the power plant.

However, it is still relatively complex to build a new engine installation for ground launch of rockets. This mission may possibly be solved with a successful laser technique.

Propelling of Carrier Rocket by Laser

Laser engines can be used in a carrier rocket; the work principle is generally the same as the ion rocket engine. The difference between laser engines and the ordinary chemical fuel rockets is the separation of working substance and energy source of the engine. However, the energy source (solar power installation and nuclear reactor) of an ion rocket engine is enclosed in the rocket, but the energy source of a laser engine remains on the ground. The laser energy source is precisely focused into a laser beam before its transmission to the rocket. After the working substance of the rocket is illuminated and heated by the laser beam to a high temperature, then the working substance is expelled at high speed through supersonic nozzles. The energy source remains on the ground. Since the flow speed of the working substance is quite high, the laser engine can obtain a sufficiently high acceleration, 1 to 2 g.

There can be two ways of providing the energy source of a laser engine by the space power plant itself. In the first approach, the space power plant directly illuminates the precisely focused laser beam onto the rocket with transmission of energy (Fig. 2); the advantage of this approach is that no intermediate energy converter and energy storage device are required. However, when the rated power of a power plant is 10 million kilowatts, only relatively limited weight of payload (1 to 10 tons) can be moved from the ground to the nearth Earth orbit by rockets.

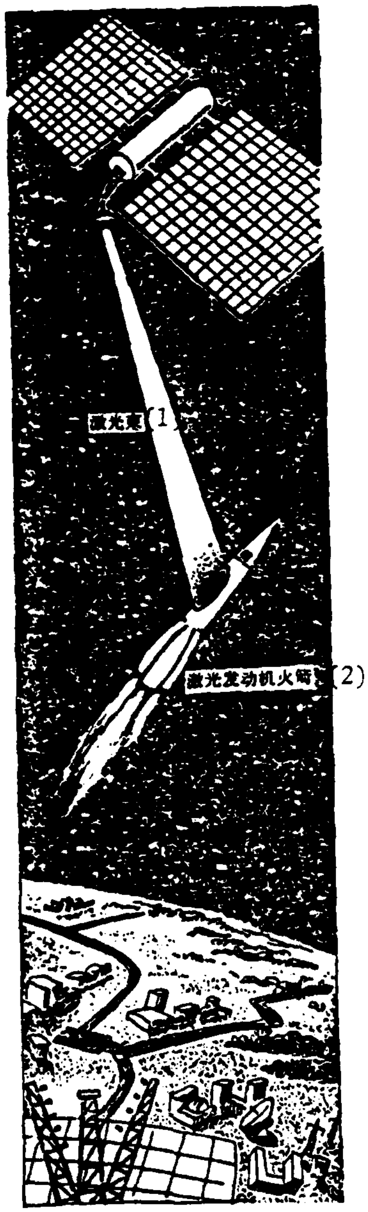

Fig. 2. Laser transmission to a rocket by a space power plant. Key: (1) Laser beam; (2) Laser engine rocket.

In another approach, the energy produced by the space power plant is first received by a ground installation to be deposited in an energy storage device (by using superconductive elements and voltage storage device), then energy is transmitted to the rocket (Fig. 3) through energy converter and high energy laser. Although this appraoch is relatively complex, it is still worth noticing.

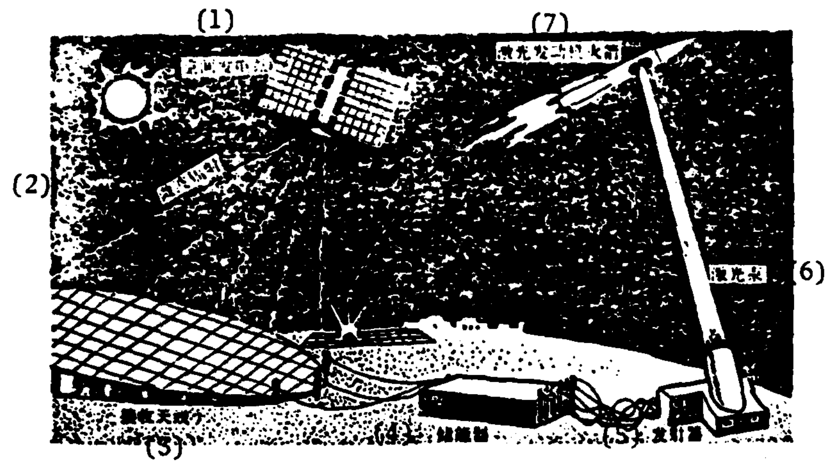

Fig. 3. A ground installation receives electrical power transmitted from a space power plant, and then transmits the laser to a rocket through a laser device.
Key: (1) Space power plant; (2) Microwave radiation; (3) Receiving antenna; (4) Energy storage device; (5) Transmitter; (6) Laser beam; (7) Laser engine rocket.

If the flow speed of the working substance is 20 kilometers per second and the payload is 100 tons, the weight of the rocket at launch is about 200 tons. Water can be used as the working substance, since it is economical and widely available without causing serious ecological problems as in the case of hydrocarbon fuels. Of course, special topic research is required on the effect of water vapor expelled from the rocket engine onto the ozone protective layer in the atmosphere. Another problem in the progress of laser technology helpful to the space industry is the considerable reduction of weight of a space power plant. For example, it is possible to build a high power laser to directly use solar energy to produce the laser. After precise focusing, the light beam is transmitted to the ground.

The use of a laser device by a space power plant will considerably reduce dimensions of the receiving antenna, and an artificial satellite can be used as the laser transmission station.

Zhang Zhenye prepared diagrams in the article.

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