SURVEY OF SPACE POWER REQUIREMENTS--1962 TO 1976

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Abstract

In this paper the probable space power requirements are assembled and reviewed for all expected military and nonmilitary space missions during the next 15 years. The data is presented in graphs that show average power requirements vs calendar years for eight important mission classes. In addition to rough estimates of the number of power plants needed as a function of power level and calendar time, several important technological trends are noted. First, there is a distinct grouping of requirements around the power plants presently under development. Second, there is a strong trend toward standardized space vehicles that are capable of many functions. As a result, vehicle power levels are higher with increasing calendar time, though the actual number of plants needed in a given power range drops sharply as bigger power plants and the more versatile space vehicles become operational. Finally, booster development leads power plant development.

Objective and Scope

There are approximately 70 space missions that are sufficiently defined to merit a code name or acronym. The space vehicles associated with these missions range from well proven systems like Discoverer to those in the early research and development stages like Apollo.[1] It affords a kaleidoscope of changing power requirements. Missions are conceived, cancelled, uprated and otherwise modified

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daily. There are, nevertheless, some stabilities and trends. This paper presents a snapshot of this changing space power picture.

A careful search was made for defined space missions to permit an estimate of specific vehicle power requirements. Then, the more tenuous missions that may evolve 10 to 15 years from now were examined. The restraints used were primarily the practical aspects of space technology: a finite budget; extremely long lead times for large, nuclear power plant development; and the basic physical laws of nature. All results are presented on plots of average power vs calendar time. The well defined missions are spotted on the charts if security permits. Approximate power-time regions are labeled with the mission type when precise information is lacking or classified. An attempt to show the number of power plants needed per year is accomplished by appropriate cross-hatching. The data assembled represents the best design values and, in some cases, the best guesses of a number of engineers and scientists who were interviewed during this survey.

Average power as used in this paper refers to the time average of the power available to the load. Despite all attempts to flatten a power profile in the time dimension, there always will be peaks and high temporary loads and in some power plants a variable energy input from the source. The power profile usually is flattened physically through energy storage or power dumping. Another important point concerns power conditioning. Raw power from the energy source, whether it be solar, chemical, or nuclear, must be processed carefully through a series of refining operations until it possesses the right quality; i.e., voltage, frequency, and degree of regulation must all be acceptable to the load. These necessary conditioning processes inevitably reduce the power that is available to the load.

Space vehicles and their power requirements often change even during the countdown. Engineering fixes and changes create uncertainty around the mission power points shown in the figures and because of this, many operational space vehicles are preceded into space by prototypes; viz., Transit, Telstar etc. The power requirements of the prototypes are generally much less than those of the operational system. The graphs in this paper give the best data available at the time of publication.

Realities and Assumptions

Which comes first, the power plant or the requirement? In space power, the answer to this version of the chicken-and-the-egg problem is not clear cut.

The space power plant development cycle is a long one, particularly for large nuclear systems. The research and development cycle for Snap 50 is about 10 years. Although some type of long-lived power plant that produces hundreds of kilowatts will be needed in the next decade, no firm missions are scheduled yet. The actual development of such a power plant will stimulate requirements. The same reckoning applies to Snap 8. The result is that even though one might expect a continuous distribution of power requirements in time, one will have in actuality a quantization of requirements clustered around power plants that have moved along the research and development cycle far enough to engender confidence in the vehicle designers. The Figs. 1-9 clearly show power requirements to be coalescing around 500 w, 3 kw (Snap 2), 30 to 60 kw (Snap 8), 300 to 1 Mw (Spur and Snap 50). These large nuclear power plants are being developed largely on the basis of intuition and expectations.

An important assumption intrinsic in the graphs is that space technology will move rapidly from many specialized vehicles to fewer that are larger and more generalized. The Orbiting Solar Observatory and Orbiting Geophysical Observatory, for example, with their standardized facilities, may be expected to replace many smaller satellites. In a similar fashion, the advent of manned space stations will further this trend. Requirements will increase in time, but the total number of power plants will be smaller than it would be if this shift in emphasis did not occur. Undoubtedly the power requirements of the more generalized space vehicles will require the larger power plants that will be available through present research and development programs.

Is one limited by power plants or boosters? Solar cells and radioisotope-thermoelectric power plants have provided the needed power for the last five years. However, the booster capabilities and vehicle ambitions are far exceeding the development of power plants that will produce reliable high power levels for a year. In just a few years when Titan III and Saturn are developed fully, space payloads will be an order of magnitude larger than they are now. The difficulties now being encountered in developing large nuclear power plants reinforce the feeling that the lack of power sources may restrict operations in space. Less power could be used, but underpowered space vehicles would probably be more dangerous than underpowered airplanes.

Mission Taxonomy

In the vast mass of potential space missions, eight separate mission classes may be discerned. These are separated in Figs. 1 through 9 to lend order to the space power panorama. This is not a paper on mission categorization, but the mission class definitions given in Table 1 help define the few points concerning the power plant characteristics of the several mission classes. In the interests of brevity, all comments and interpretations concerning Figs. 1 through 9 are summarized in Table 1.

Table 1 Interpretation of the figures

Mission	Mission definition	Trends and implications
Communications satellites (Fig. 1)[2,3]	Includes all except passive systems. Any system that relays or rebroadcasts radio, FM or TV. Power for station keeping not included (see Fig. 8). Very long-lived power (3 yr) required. Unmanned.	Many small plants needed for military and commercial relay systems. Video satellites will probably use Snap 8 for power and station keeping. Standardization to few proven types inevitable. Space stations probably also act as communications satellites.

Table 1 (continued)

Mission	Mission definition	Trends and implications
Weather satellites (Fig. 2)	Systems designed to observe and measure weather phenomena. Unmanned.	Standardization to vehicles using about 500 w expected. Space stations also act as weather satellites.
Scientific satellites (Fig. 3)	Satellites devoted to scientific and engineering measurements. Excludes reconnaissance and ferret types. Long-lived, manned, and unmanned.	Most common type of satellite during next 5 years. Use of large, standardized, "streetcar" types impending. Orbiting space stations will do much of work in future. General power levels are low; will increase toward larger, standard vehicles.
Space and planetary probes (Fig. 4)	Includes all unmanned solar, lunar and planetary probes. Lunar beacons included. Interstellar probes a remote possibility. Long-lived.	Wide spread power requirements, distinctly higher power levels than satellites used for scientific purposes. Standardization will lag satellite classes.
Manned space exploration (Fig. 5)	All manned space vehicles used for peaceful purposes. Lifetimes generally just few weeks for early systems. Fuel cells and other chemical sources possible.	Space laboratories and lunar bases are main nonmilitary justification for large plants. Could probably use Snap 8 or multi-Snap 8 plants.

Table 1 (continued)

Mission	Mission definition	Trends and implications
Passive military space vehicles (Fig. 6)	Includes all unmanned reconnaissance warning, and ferret satellites.	Security prevents identification of specific missions. Power requirements will center around 500 w and a few kilowatts.
Active military space vehicles (Fig. 7)	Military space systems with offensive capabilities. Generally manned.	Power requirements are usually much higher than nonmilitary. Security prevents identification of missions. If orbital bombing is practical, many small power plants will be needed. Offensive satellites will need many power plants in low kilowatt category. Countermeasures and radiation weapons yield highest of space power requirements.
Electric propulsion (Fig. 8)	Ion, plasma, and MHD propulsion.	Very large power plants in small quantities. Attitude control, interplanetary probes and station keeping most probable uses.
Summary sheet (Fig. 9)	Accumulates all preceding mission requirements.	Quantized requirement structure centers on plants already under development. Field unquantized at low power levels where solar cells and radioisotope power supplies can be easily custom built to vehicles.

References

[1]Finger, H. B. and Schulman, F., "Power requirements of the NASA space program," Space Power Systems, edited by N. W. Snyder (Academic Press, New York, 1961), pp. 615-624.

[2]Atomic Industrial Forum: Special Committee on Communication Satellites, Report on Power Needs and Nuclear Capabilities (June 1962).

[3]Hamilton, R. C. and Laue, E. G., "Spacecraft secondary power requirements during the sixties," Electrical Engineering in Space Technology, Am. Inst. Elec. Engrs. T-126 (December 1960).

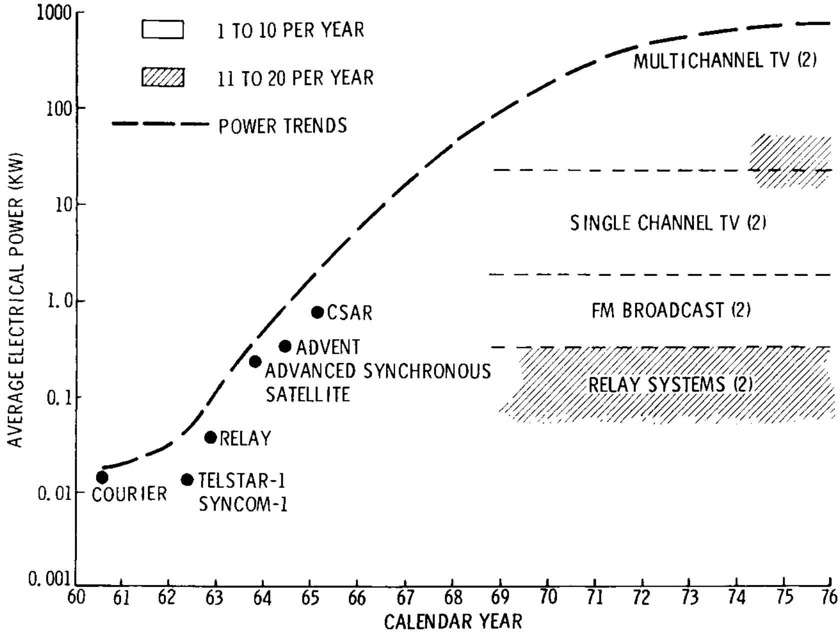

Fig. 1 Power requirements for communication satellites

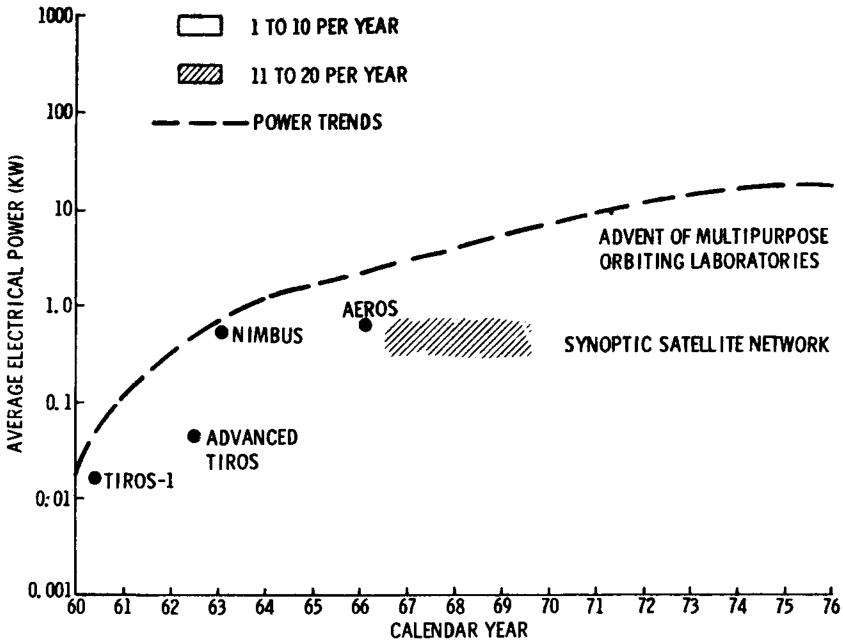

Fig. 2 Power requirements for weather satellites

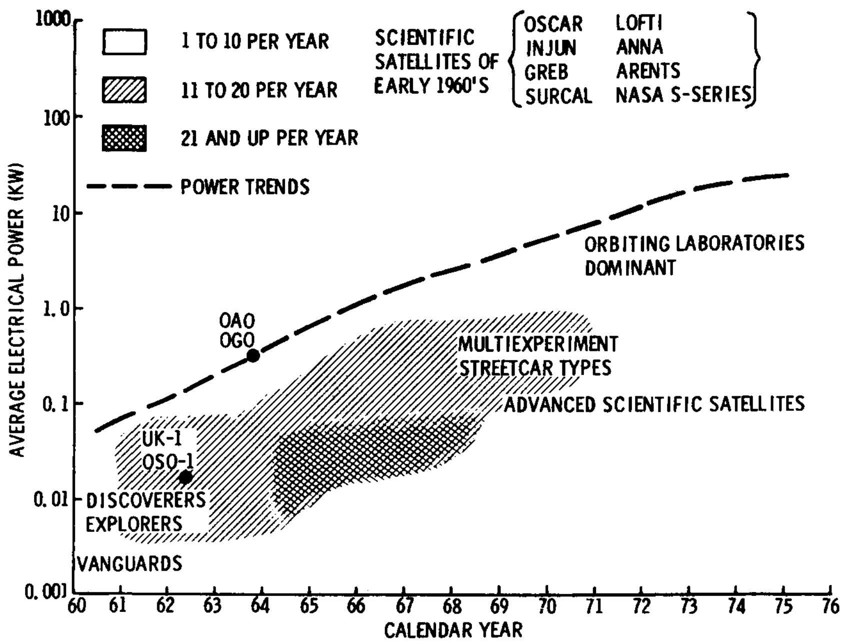

Fig. 3 Power requirements for scientific satellites

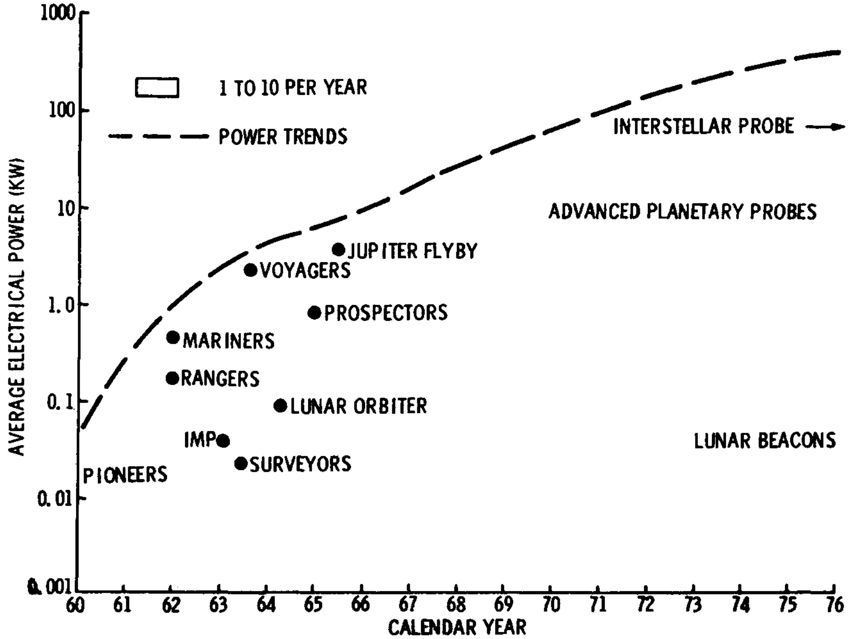

Fig. 4 Power requirements for space and planetary probes

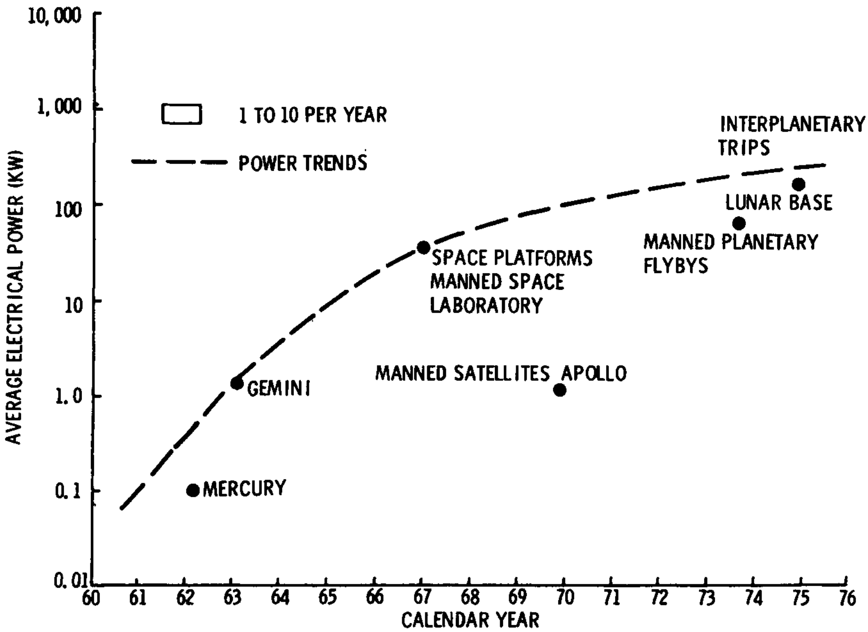

Fig. 5 Power requirements for manned space exploration

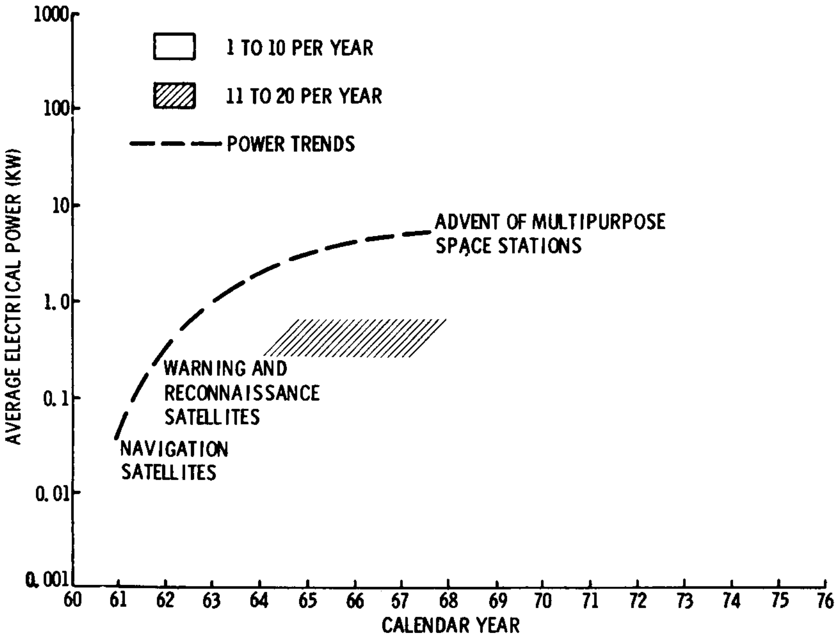

Fig. 6 Power requirements for passive military satellites

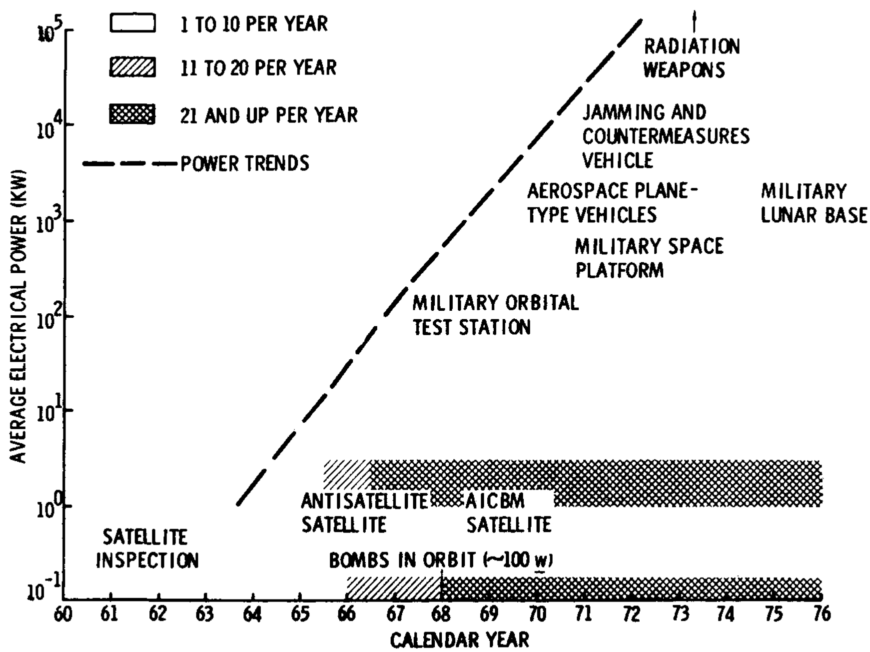

Fig. 7 Power requirements for active military space vehicles

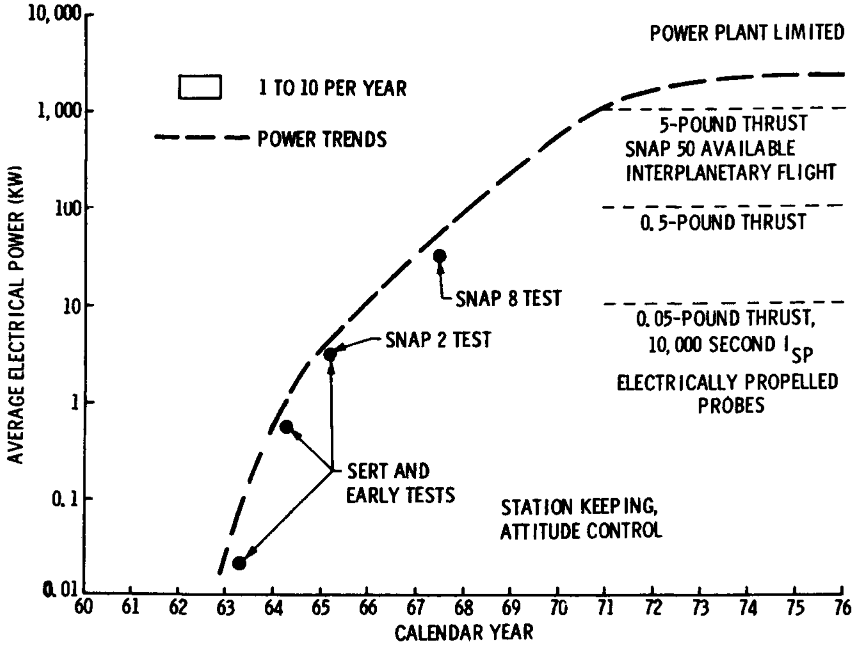

Fig. 8 Power requirements for electrical propulsion

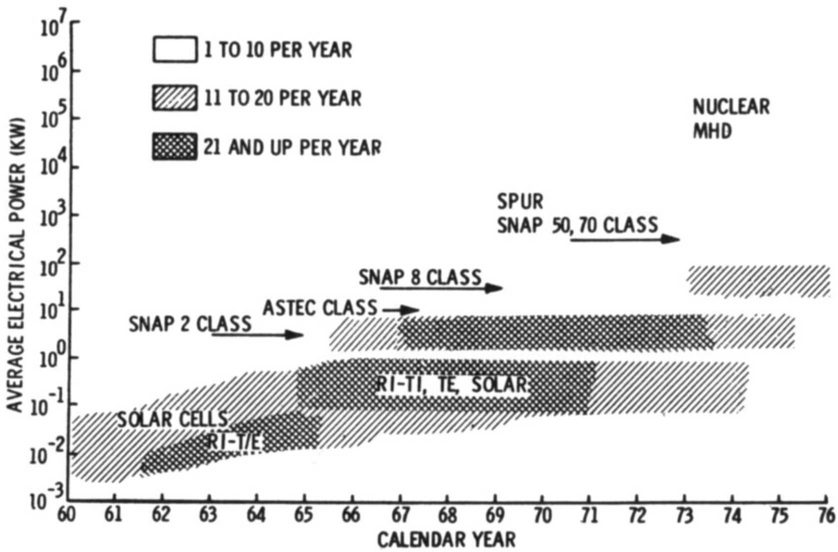

Fig. 9 Summary of power requirements