HISTORICAL AND PROJECTED POWER REQUIREMENTS

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SUMMARY

Since the inception of the U. S. national space program, power level requirements have been increasing steadily at about 100 watts per year for both civilian and military satellites. The demand could be expected to increase at about the same rate; however recent shuttle and shuttle follow-on planning activities (ref. 1, 2, 3) have introduced the eventual need for very large, multipurpose space platforms to be deployed. This would result in a step function in individual satellite power level requirements, demands for higher total energy requirements, and the need for different approaches to designing power systems for indefinite lifetime operation and periodic servicing and maintenance. Some of the proposed multipurpose space platforms could require power levels of over 200 kW. If the SPS (Satellite Power Station) is implemented then, of course, another massive step function would occur in space power requirements.

INTRODUCTION

Historical data can be extrapolated to provide a prediction of the future with a high probability of success in many situations and an examination of historical space power characteristics shows a steady evolutionary change. However, a radical change is about to occur in the method of access to space. The Space Shuttle will provide economical transportation and increased flexibility with the availability of man in low earth orbit, if required, in the early 1980s. In the late 1980s the capability of the IUS (Inertial Upper Stage) and SSUS (Spinning Solid Upper Stage) to transfer space systems to high orbit will be amplified by the development of the OTV (Orbit Transfer Vehicle) which will eventually permit man to become an intrinsic part of space operations out to geosynchronous orbit and beyond.

In order to fully exploit space and the flexible operational capabilities of the STS (Space Transportation System) and its derivatives planning studies (ref. 1, 2, 3) have examined the potential of very large multipurpose systems having indefinite lifetimes, which require deployment and/or assembly on orbit (and therefore the need for orbital space assembly facilities with their own power supplies), periodic servicing (either automated or manned) and possibly manned residence for extended periods of time. The space power requirements are likely to be quite different to the requirements of conventional single-purpose satellites.

HISTORICAL SPACE POWER TRENDS

PRIME POWER REQUIREMENTS

Using Refs. 4 through 7, a survey was made of satellites launched or planned to be launched during the 1959-1979 time period, together with their user group function, power system type, and prime power requirements. Scatter diagrams of power versus launch date for each user group were prepared (the details are discussed in Ref. 8) and are shown in Figs. 1 through 4. A trend line of 100 watts per year is shown which appears to represent the rate of increase over the time period examined. A general problem solving computer program (GYPSY) was used to perform a regression analysis of the historical prime power requirements data. A total of 175 launches were used, including 96 NASA, 44 DoD and 35 civil data points. The best fit to all data was found to be:

$$LnP = A + BM + CM^2 + DM^3$$

where: P = Prime power in watts
M = Number of months after June 1959

and the coefficients are as follows:

	A	B	C	D
NASA	6.41	-0.0186	6×10^{-5}	5×10^{-8}
DoD	6.9	-0.06	0.0005	-10×10^{-5}
Civil	5.4	-0.05	6×10^{-4}	-2×10^{-6}
All	6.5	-0.0377	-0.00029	-6×10^{-7}

Computer plots of the output are shown in Figs. 5 through 8.

POWER SYSTEM COSTS

Background. For a number of years the Aerospace Corporation has collected satellite and launch vehicle hardware costs on ongoing programs from government and private industry sources and incorporated them into a computerized cost data bank. This data bank has a number of uses, including being used as a base for developing future systems non-recurring and recurring costs, and is being constantly expanded. It has been found expedient to organize the data to suit the accounting procedures of industry as far as possible and the format used for documentation is illustrated in Table 1.

Cost Analysis. Historical electric power subsystem costs were analyzed for the years 1963 through 1977 and the percentage distribution by major component is listed in Table 2. The electrical subsystem cost per kilowatt-hour as a function of year of first flight is given in Fig. 9 and as a function of kilowatt-hour in Fig. 10. The data is scattered but some trends can be postulated. The ground rules used to develop the costs are listed in Ref. 8.

FUTURE SPACE POWER REQUIREMENTS

Two approaches were used in Ref. 8 to develop future space power requirements. One approach emphasizes a future in which large multipurpose, multi-user satellites will be the objective of early development and deployment; the other approach emphasizes a future in which many dedicated, single-user satellites will be deployed in the near and mid term, with large multipurpose satellites not being introduced until the far term. As far as total power requirements are concerned, the two approaches lead to more or less the same conclusions since, in general, the accumulation of several initiatives on one space platform results in a corresponding accumulation of total power. Where differences will occur, however, is in such areas as the need for supporting and folding large solar array blankets and the establishment of servicing and maintenance policies, and the establishment of policies for the design, development and deployment of remote space power modules. If remote space power modules are used to supply power to other satellites via laser or microwave links, consideration must be given to whether they have to supply a multitude of low-powered satellites or a small number of high-powered satellites.

MISSION/TRAFFIC MODEL APPROACH

Mission models and, from these, traffic models were synthesized to correspond to the average yearly budgets illustrated in Table 3. An iterative process was used to match the budgetary goals with specific mission/traffic models. The details of the procedure and the ground rules used are described in Ref. 8. Mission/Traffic models were developed to satisfy low and high average budgetary levels for the following mission categories*:

1. NASA Observation
2. NASA Communication
3. NASA Support
4. NASA Scientific
5. NASA Planetary
6. DoD Surveillance
7. DoD Communication
8. DoD Navigation and Meteorology
9. DoD Weaponry
10. Non-NASA/Non-DoD Communication
11. Non-NASA/Non-DoD Observation
12. Non-NASA/Non-DoD Support
13. Non-NASA/Non-DoD Scientific

The traffic models illustrated in Ref. 8 have no official approval, either of NASA or of DoD, and are intended to be representative only. Nevertheless, the component parts have been extracted from published documents in most cases and serve to provide a reasonable representation of the future.

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* The mission categories are themselves divided into groups of missions which have functional similarities.

The power requirements derived in the study described in Ref. 8 are summarized in Table 4 and Figs. 11 and 12. It should be noted that contributions from the SPS program are not included since they would tend to obscure the total picture.

ADVANCED SYSTEM SCENARIO APPROACH

Background. A very large number of future initiatives have been identified for both NASA and DoD and in order to handle the literally hundreds of known initiatives a rationale was established (Ref. 2) for categorizing the initiatives into five generic categories or eleven groups, as follows:

Category	Initiative Group	
Information	1.	Public Service Systems Using Microwave Multibeam Antennas
	2.	Public Service Systems Using Long Microwave Antennas
	3.	Active/Passive Radar and Power Distribution Systems
	4.	Observation and Designation Systems Using Optics at Low Altitude
	5.	High Altitude Navigation, Location, and Relay Systems
	6.	Observation Systems Using Synchronous Altitude Optics
Processing	7.	Space Processing and Manufacturing
Energy	8.	Large Scale, High Energy, Far-Term Systems
Science	9.	National Operations Facilities
	10.	Scientific and Research Experiments
Planetary	11.	Planetary

The generic groups attempt to subsume each of the identified initiatives and are intended to be broad enough that other initiatives yet to be identified will be likely to fall within one of the groups. A natural progressive increase in capability can be postulated for each of the eleven groups, exemplified by the deployment of a series of space systems over a period of time, with each system having a considerable increase in capability over its predecessor (but not necessarily replacing its predecessor). The increase in capability and the time period between each launch impacts the needs for technology advancements, the launch vehicle and support facility needs, and the overall space program funding requirements.

The development plan for each group provides the development required to satisfy the initiatives contained within that group. An orderly step-by-step technology program is the primary determinant of the number of time-phased steps in each of the development plans. Each step is intended to culminate in demonstrated flight hardware capable of operational use; however, the operational option may not be exercised.

In the construction of the development plans it was found expedient to lump the low and high altitude optical concepts (Groups 4 and 6) together and also to combine the scientific and research experiments (Group 11) with the national operations facilities required to operate them (Group 9).

The construction of development plans in this manner provides maximum flexibility for dealing with an indeterminant future for the following reasons:

1. Each development plan is not linked to a single initiative, the need for which may change radically during the development time period.

2. The decision as to which initiative to promote can be delayed until late in the development schedule.

3. The unexpected need for crash programs is minimized.

Power Level Requirements. The development plans and estimates of the resulting prime power requirements are illustrated in Figs. 13 through 20. In general, the required power levels increase monotonically within each generic group. An optimistic and conservative schedule is approximated for each operational capability step. Representative initiatives are listed and coded to indicate their source as follows:

(OFS) = The NASA "Outlook for Space" study (Ref. 9)
(5-YP) = The NASA Five-Year Plan (Refs. 10 and 11)
(A) = The Aerospace Corporation "Advanced Space Systems Concepts and Their Orbital Support Needs (1980-2000)" Study (Ref. 1)

Power vs Time Requirements. Figs. 21 through 28 show the power requirements for each initiative group as a function of time. Of the two solid plots, one represents an ambitious, well-funded, overall NASA space program, and one represents a more conservative approach where procurement of major systems is delayed approximately a further seven years. (The seven-year cycle was selected in a relatively arbitrary manner. However, it represents an estimate of the average time necessary to procure a major advanced space system, from initial go-ahead to IOC.) The dashed plot, in each case, indicates a stretched-out program in which each development program commences at approximately the same time as the optimistic program, but the procurement of major line items is spread over a longer period of time.

Results. The data included in Figs. 21 through 28 can be used in a number of ways. One use is to perform a rough rank ordering of the power requirements of the initiative groups. This provides information to determine which initiative groups can be "captured" by a given space power development plan at a specific point in time. In general, the initiative group development plans are divided into a number of steps or subgroups providing the option of not consummating all of the possible steps. Table 5 lists the subgroups of each initiative group in power demand rank order. It lists also the approximate IOC dates for an optimistic, well-funded NASA space plan, a more conservatively funded plan, and a stretched-out plan. The table demonstrates the power levels necessary to capture individual initiative group and subgroup developments.

Table 6 lists the power demands (in rank order) of initiative subgroups as a function of approximate IOC date. The utility of the table is to demonstrate which subgroups or development plan steps can be captured by a given space power capability in a given year. For instance, a 10 kW space power capability achieved in 1988 would capture Subgroups 5/2, 9&11/2, and 4&6/3 in the case of an optimistic space plan, but not be required until 1996 to capture the same subgroups if a conservative space plan were to be implemented. The data can be used as a tool for space planning in two ways:

1. If a projection is made of the space power technology capability at a given time in the future, the subgroups of initiatives that the projected technology will be able to "capture" is determinable.

2. If a projection is made of the total space system capability (the specific initiative subgroups implemented) at a given time in the future, the space power technology capability that will be required is determinable.

With the aid of information on expected advancements in space power technology, an assessment can be made as to whether those planned advancements will meet the requirements objectives. If not, then the plans can be modified to attempt to meet those objectives.

CONCLUDING REMARKS

If national space planning embarks on a policy of deploying large multipurpose satellites the needs of DoD and the civil sector will not, in general, drive space power requirements since they will be trailing NASA needs. Present NASA space planning policy does appear to be leaning towards the eventual implementation of a few very large multipurpose satellites which can be serviced on orbit and have indefinite lifetimes. The rationale for such a policy is that it makes maximum use of the unique capabilities of the Space Shuttle and leads as rapidly as possible to the exploitation of space for the immediate benefit of mankind. The large multipurpose satellites can be designed to service vast numbers of different users equipped with small, cheap user terminals. Some of the possible uses are personal communications, electronic mail, educational, and health and welfare TV, and personal navigation. The implication is that NASA will not be restricted to its traditional R&D role but will show leadership to commercial and private users by participating in commercial applications in certain areas.

The planning policy outlined above would result in the need for such space facilities as the Space Construction Base and the increasing participation of man beyond low earth orbit. The large satellites may be self-powered or may receive their power from separate space (the Space Power Module) or ground-based power plants.

DoD needs are somewhat different. The implementation of a few large undefended multipurpose satellites makes the space system fleet more vulnerable to enemy attack. The alternatives are either to provide active defense systems or to orbit a larger number of smaller satellites. The emphasis on survivability and anonymity in the case of DoD systems means that the DoD criteria for selection of space power system, subsystems and components may be different than the NASA criteria. For instance, at high power levels the DoD is more likely to select a more compact system than a solar cell/battery system with its large radar cross section. Solar cell design would also have to consider the susceptibility of solar cells to, for instance, continuous-wave lasers.

At this time, official DoD planning shows a less intense drive towards large multipurpose satellites than NASA planning. Nevertheless, DoD is presently initiating a well-funded study on the orbital assembly of large spacecraft and a few high-powered systems are already described in DoD planning documents. In addition, during the studies conducted by Aerospace for NASA in recent years, a large number of DoD initiatives were identified which require high power. Many public sector initiatives have a parallel military application and DoD space power technology requirements, in many ways, parallel the needs of NASA.

In the civil sector, the U.S.'s lead in the commercial application of space is partly based on satisfying individual users by providing relatively small, reliable, cheap satellites that can be clearly identified with a specific customer. It is not clear that foreign countries will be willing to relinquish the prestige associated with having their own satellite or be willing or able to fund their own large multipurpose satellites. The utility and economic benefits of such systems will have to be clearly demonstrated, either by NASA or by domestic civil users, before they are accepted by foreign users. This will probably result, in the near term, in a greater tendency for foreign users to lease time on U.S. satellites rather than to purchase their own multipurpose systems.

It is concluded that within the context of the above arguments, the demands by civil users on space power requirements and technology can be subsumed within those of NASA. There are some differences between the power levels and the technology requirements of NASA and DoD in the near term but these are likely to be less apparent in the far term.

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Table 1. Satellite Power System Cost Summary Format

SATELLITE _______

__ Mo., Des. Life, ____ W, BOL Pwr, ____ W, Avg Pwr,

First Launch 19__

Cost Category \ Item	Solar Array (____ sq ft)	Battery (__A-H)	Power Control Unit	Converters	Wiring	Drive	Total
Non-recurring							
Design Engrg.							
Test & Eval.							
Recurring (5 Sat.)							
Syst. Engrg.							
Production							
Total (1977 $)							
Average (5 Sat.)							

Subsystem Weight/Satellite Weight

Cost/lb. (kg)

Cost/ft^2(m^2)

Cost/A-H

Cost/kW-H

Table 2. Satellite Electrical Power Cost Percentage Distribution by Major Components

Year of 1st Launch	Solar Array	Batteries	PCU Plus Converters	Wiring	Array Drives
1963	43.3	16.7	37.0	2.9	-
1964	23.5	22.6	15.8	23.6	14.6
1967	34.2	9.6	45.8	10.3	-
1967	21.6	10.9	23.1	-	44.4
1969	62.5	9.0	15.9	12.6	-
1970	46.2	13.2	32.2	8.5	-
1970	9.3	11.1	9.2	22.4	48.0
1971	46.0	12.1	28.9	13.0	-
1971	21.4	19.3	32.1	27.1	-
1974	26.9	8.9	26.5	37.8	-
1974	34.2	15.9	33.6	16.3	-
1975	23.3	12.1	36.7	28.0	-
1975	18.4	14.7	43.3	23.6	-
1977	10.8	9.9	41.6	9.4	28.4

Table 3. Assumed Average Yearly Budget Goals for 1980-1995

ORGANIZATION	CONSERVATIVE BUDGET ($B)	OPTIMISTIC BUDGET ($B)
NASA		
Institutional	2.0	2.0
Transportation	1.0	2.0
Programs	1.0	2.0
Total	4.0	6.0
DoD Programs	0.7	1.5
Civil (Non-NASA, Non-DoD Programs)	0.5	1.0

Notes:

(1) Budgets are in 1977 dollars.
(2) Budgets are averages and therefore peak budgets will exceed these values in certain years.

Table 4. Energy Demand (1981-1995)

ITEM	CALENDAR YEAR																	15 yr Total (1981-95)	15 yr Average (1981-95)
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995		
NOMINAL BUDGET																			
NASA	4.1	31.5	89.5	156.4	203.5	259.1	267.2	604.4	693.9	693.3	2649.6	2825.6	2754.3	2776.2	2870.4	3010.6	6842.5	26696.5	1779.8
DoD	-	85.7	174.7	198.7	364.3	411.0	527.0	1059.5	1226.7	1313.6	1451.4	1924.7	1928.6	2326.9	2949.7	3312.1	3319.0	22487.9	1499.2
CIVIL	52.7	137.4	201.6	237.0	309.3	321.2	364.0	288.8	409.0	451.9	465.0	512.8	617.9	594.8	534.2	463.3	434.4	6257.9	417.2
NASA & DoD & CIVIL	56.8	254.6	465.8	459.2	877.7	991.3	1158.2	1952.7	2329.6	2458.8	4566.0	5263.1	5300.8	5697.7	6354.3	6786.0	10595.9	55442.3	3696.2
OPTIMISTIC BUDGET																			
NASA	4.1	31.5	89.5	432.2	558.1	613.7	2790.3	2976.0	3144.3	3143.7	3917.1	3896.0	5007.3	2312.8	2801.1	2862.5	3370.6	37919.3	2528.0
DoD	-	85.7	174.7	198.7	443.1	450.4	1039.6	1288.3	1613.0	3166.6	3848.2	4392.7	6769.5	7325.2	6525.0	10344.7	10305.3	57884.9	3859.0
CIVIL	65.0	149.7	251.4	309.8	465.5	547.7	675.5	655.8	815.8	892.0	922.0	944.5	1074.0	1085.7	1111.1	1089.8	1107.4	11948.0	796.5
NASA & DoD & CIVIL	69.1	266.9	515.6	940.7	1466.7	1611.8	4505.4	4920.1	5573.1	7202.2	8687.3	9233.2	12850.8	10723.7	10437.2	14297.0	14783.3	107752.2	7183.5

Table 5. Initiative Group Rank Ordering

INITIATIVE		IOC DATE			
Group/ Subgroup	Title	Optimistic Program	Stretched Program	Conservative Program	Power Level
2/1	PUBLIC SERVICE SYSTEMS USING LONG MICROWAVE STATIONKEPT ANTENNAS - I	1983	1983	1990	1.0 kW
3/1	POWER DISTRIBUTION SYSTEMS AND ACTIVE/PASSIVE RADAR - I	1982	1982	1989	1.0 kW
2/2	PUBLIC SERVICE SYSTEMS USING LONG MICROWAVE STATIONKEPT ANTENNAS - II	1987	1991	1994	1.3 kW
5/1	HIGH ALTITUDE NAVIGATION, LOCATION, AND RELAY SYSTEM - I	1983	1983	1990	1.7 kW
2/3	PUBLIC SERVICE SYSTEMS USING LONG MICROWAVE STATIONKEPT ANTENNAS - III	1992	1999	1999	2.0 kW
4 & 6/1	OPTICAL OBSERVATION, DESIGNATION, AND MEASUREMENT - I	1982	1982	1989	2.0 kW
9 & 11/1	SCIENTIFIC/RESEARCH EXPERIMENTS AND NATIONAL FACILITIES - I	1984	1984	1991	2.0 kW
5/2	HIGH ALTITUDE NAVIGATION, LOCATION, AND RELAY SYSTEM - II	1988	1992	1995	2.2 kW
5/3	HIGH ALTITUDE NAVIGATION, LOCATION, AND RELAY SYSTEM - III	1994	2001	2001	3.0 kW
1/1	SERVICE PLATFORMS USING MICROWAVE MULTIBEAM ANTENNAS - I	1983	1983	1990	4.0 kW
3/2	POWER DISTRIBUTION SYSTEMS AND ACTIVE/PASSIVE RADAR - II	1986	1993	1993	5.0 kW
4 & 6/2	OPTICAL OBSERVATION, DESIGNATION, AND MEASUREMENT - II	1986	1988	1993	5.0 kW
9 & 11/2	SCIENTIFIC/RESEARCH EXPERIMENTS AND NATIONAL FACILITIES - II	1988	1991	1995	5.0 kW
4 & 6/3	OPTICAL OBSERVATION, DESIGNATION, AND MEASUREMENT - III	1990	1994	1997	10.0 kW
7/1	SPACE PROCESSING AND MANUFACTURING - I	1983	1983	1990	10.0 kW
9 & 11/3	SCIENTIFIC/RESEARCH EXPERIMENTS AND NATIONAL FACILITIES - III	1993	2000	2000	10.0 kW
4 & 6/4	OPTICAL OBSERVATION, DESIGNATION, AND MEASUREMENT - IV	1995	2002	2002	20.0 kW
1/2	SERVICE PLATFORMS USING MICROWAVE MULTIBEAM ANTENNAS - II	1987	1990	1994	25.0 kW
8/1	LARGE SCALE, HIGH ENERGY, FAR-TERM SYSTEMS - I	1982	1982	1989	25.0 kW
3/3	POWER DISTRIBUTION SYSTEMS AND ACTIVE/PASSIVE RADAR - III	1990	1997	1997	50.0 kW
7/2	SPACE PROCESSING AND MANUFACTURING - II	1988	1992	1995	50.0 kW
7/3	SPACE PROCESSING AND MANUFACTURING - III	1993	2000	2000	100.0 kW
1/3	SERVICE PLATFORMS USING MICROWAVE MULTIBEAM ANTENNAS - III	1993	2000	2000	100.0 kW
8/2	LARGE SCALE, HIGH ENERGY, FAR-TERM SYSTEMS - II	1984	1986	1990	210.0 kW
3/4	POWER DISTRIBUTION SYSTEMS AND ACTIVE/PASSIVE RADAR - IV	1994	2001	2001	300.0 kW
8/3	LARGE SCALE, HIGH ENERGY, FAR-TERM SYSTEMS - III	1987	1990	1993	2.0 MW
8/4	LARGE SCALE, HIGH ENERGY, FAR-TERM SYSTEMS - IV	1992	1996	1999	15.0 MW
8/5	LARGE SCALE, HIGH ENERGY, FAR-TERM SYSTEMS - V	1996	2000	2003	1.0 GW
8/6	LARGE SCALE, HIGH ENERGY, FAR-TERM SYSTEMS - VI	2000	2004	2007	15.0 GW

Table 6. Initiative Subgroup Power Demand vs IOC Date

OPTIMISTIC PROGRAM IOC											
1982-1984		1985-1987		1988-1991		1992-1994		1995-1997		1998-2000	
CONSERVATIVE PROGRAM IOC											
1990-1992		1993-1995		1996-1998		1999-2001		2002-2004		2005-2007	
Subgroup	Power	Subgroup	Power	Subgroup	Power	Subgroup	Power	Subgroup	Power	Subgroup	Power
2/1	1.0 kW	2/2	1.3 kW	5/2	2.2 kW	2/3	2.0 kW	4 & 6/4	20 kW	8/6	15 GW
3/1	1.0 kW	3/2	5.0 kW	9 & 11/2	5.0 kW	5/3	3.0 kW	8/5	1 GW		
5/1	1.7 kW	4 & 6/2	5.0 kW	4 & 6/3	10.0 kW	9 & 11/3	10.0 kW				
4 & 6/1	2.0 kW	1/2	25.0 kW	3/3	50.0 kW	1/3	100.0 kW				
9 & 11/1	2.0 kW			7/2	50.0 kW	8/2	210.0 kW				
1/1	4.0 kW			8/3	2.0 MW	3/4	300.0 kW				
7/1	10.0 kW					8/4	15.0 MW				
8/1	25.0 kW										

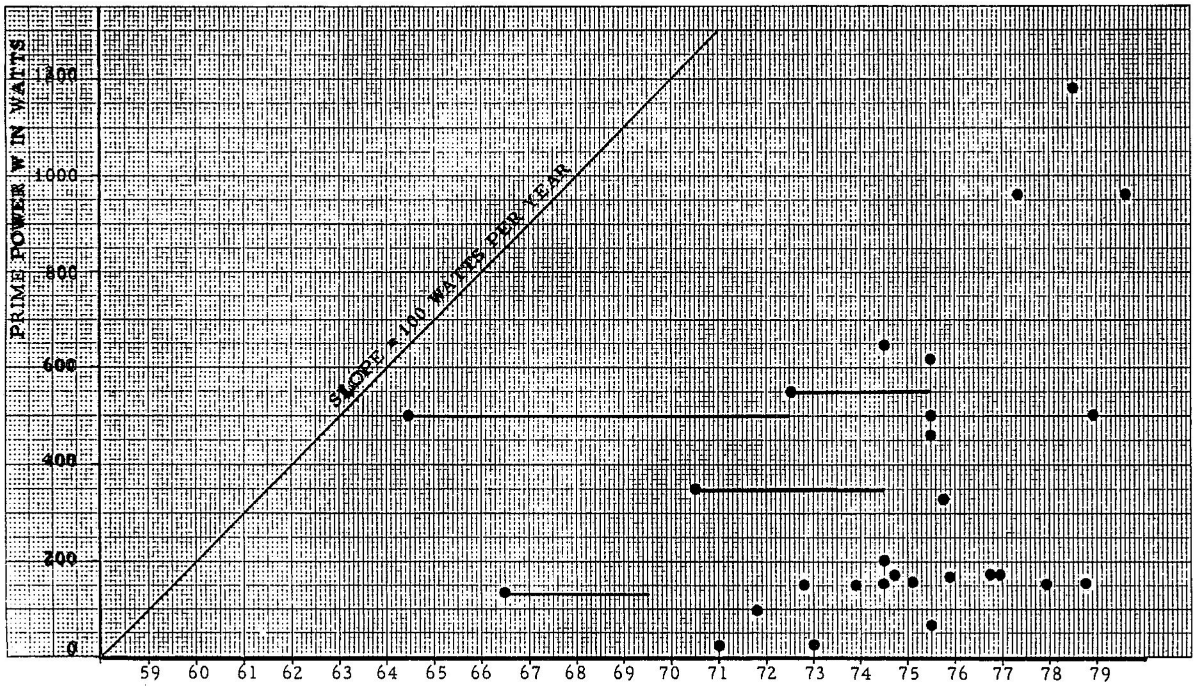

Figure 1. NASA Satellites Prime Power Trend, 1959-1979

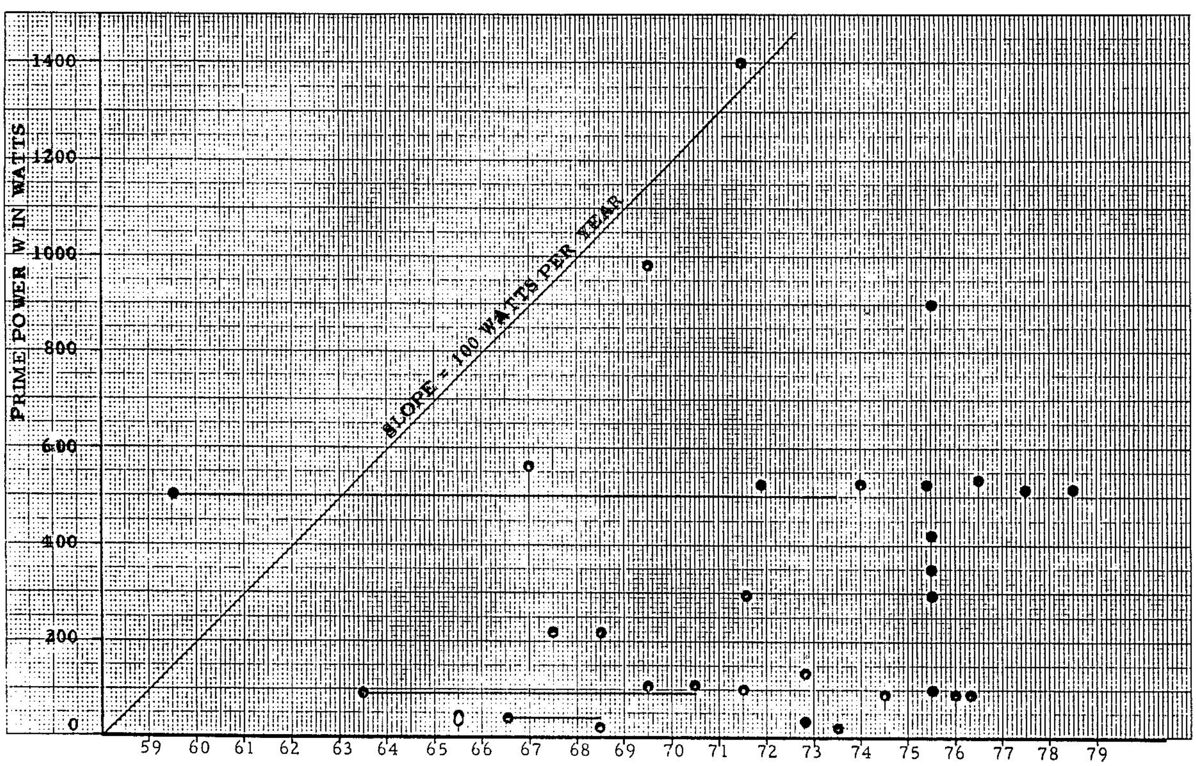

Figure 2. DoD Satellites Prime Power Trend, 1959-1979

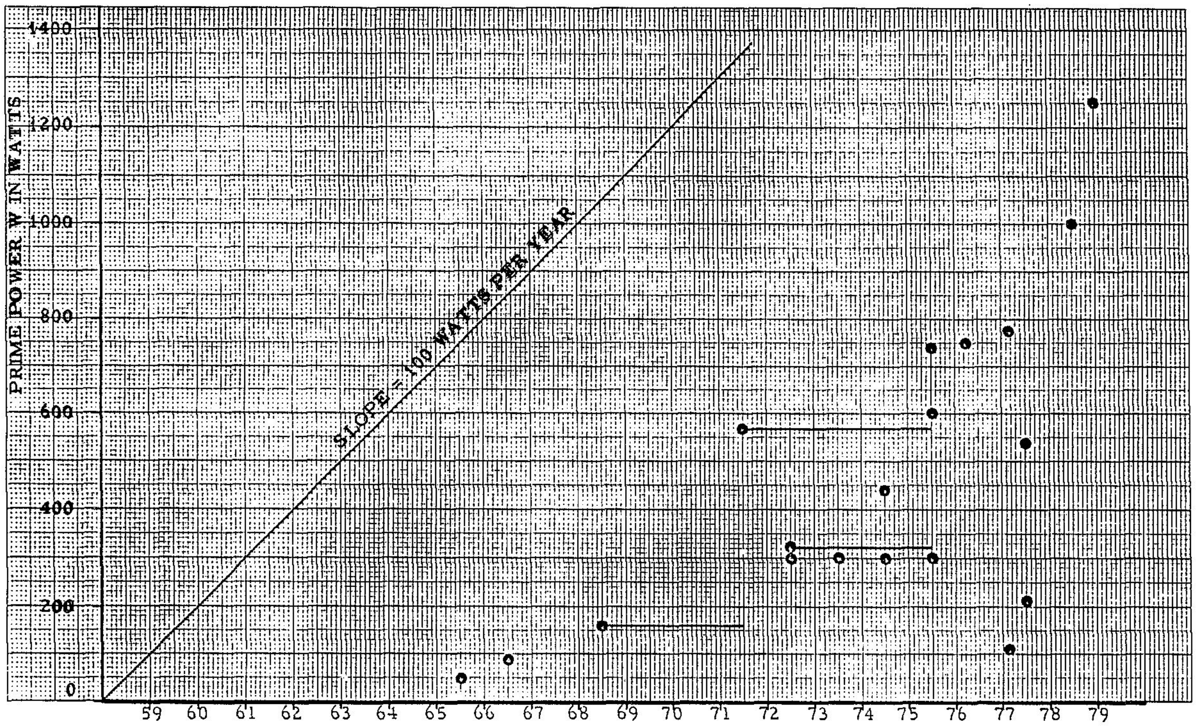

Figure 3. Civil Satellites Prime Power Trend, 1959-1979

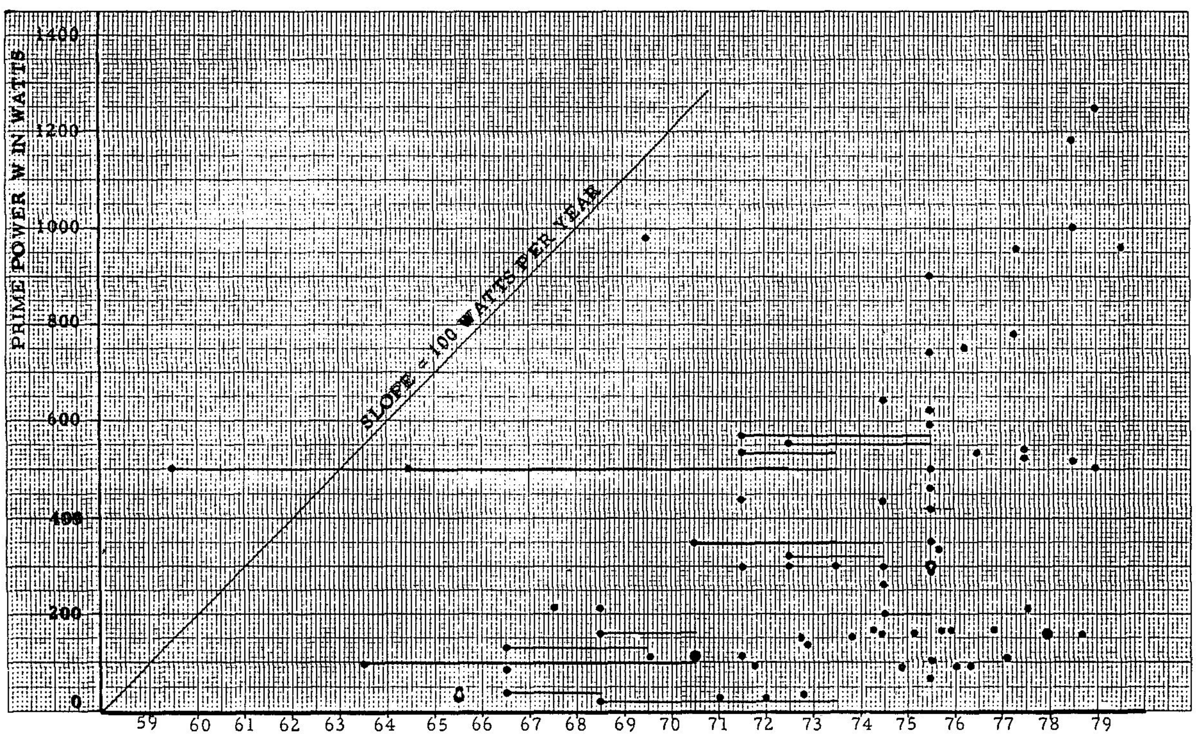

Figure 4. All Satellites Prime Power Trend, 1959-1979

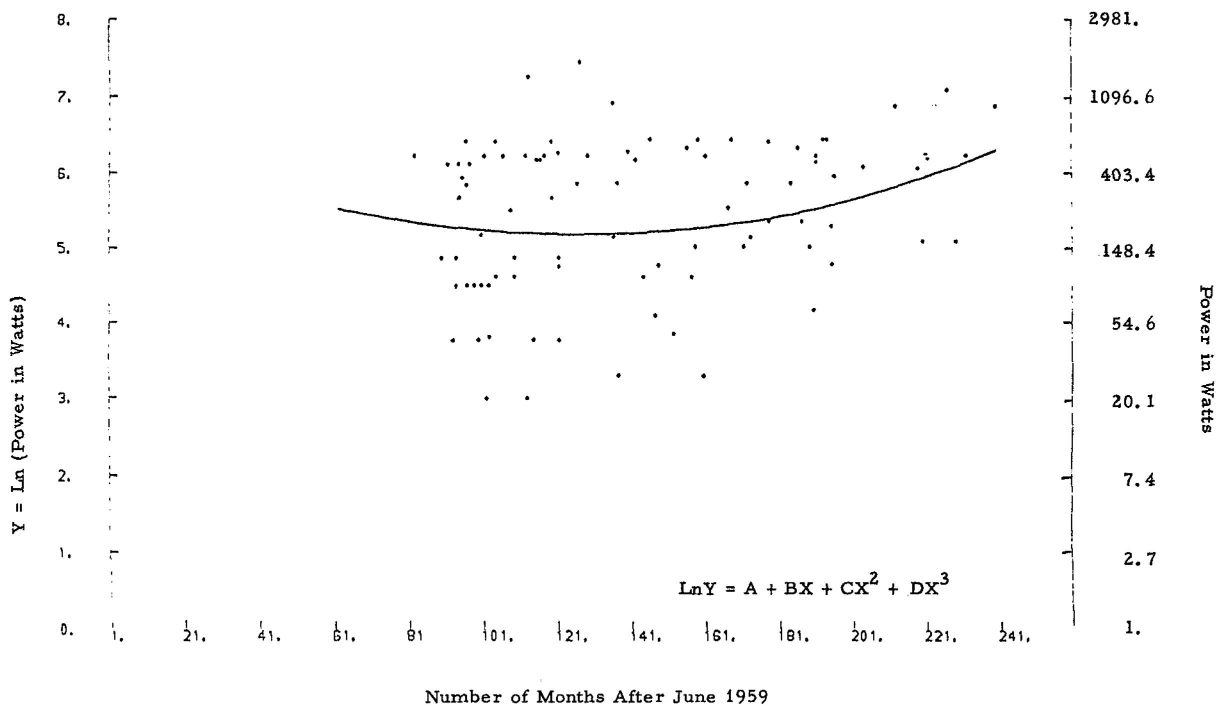

Figure 5. Satellite Prime Power Regression Analysis - NASA

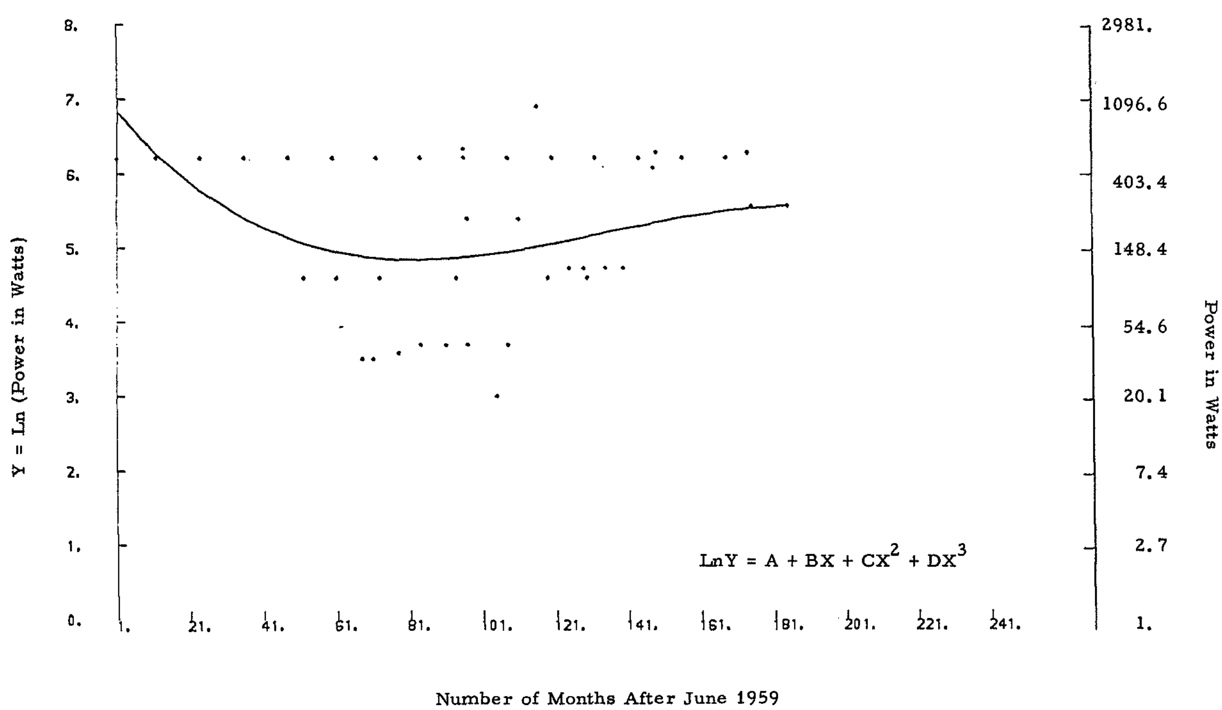

Figure 6. Satellite Prime Power Regression Analysis - DoD

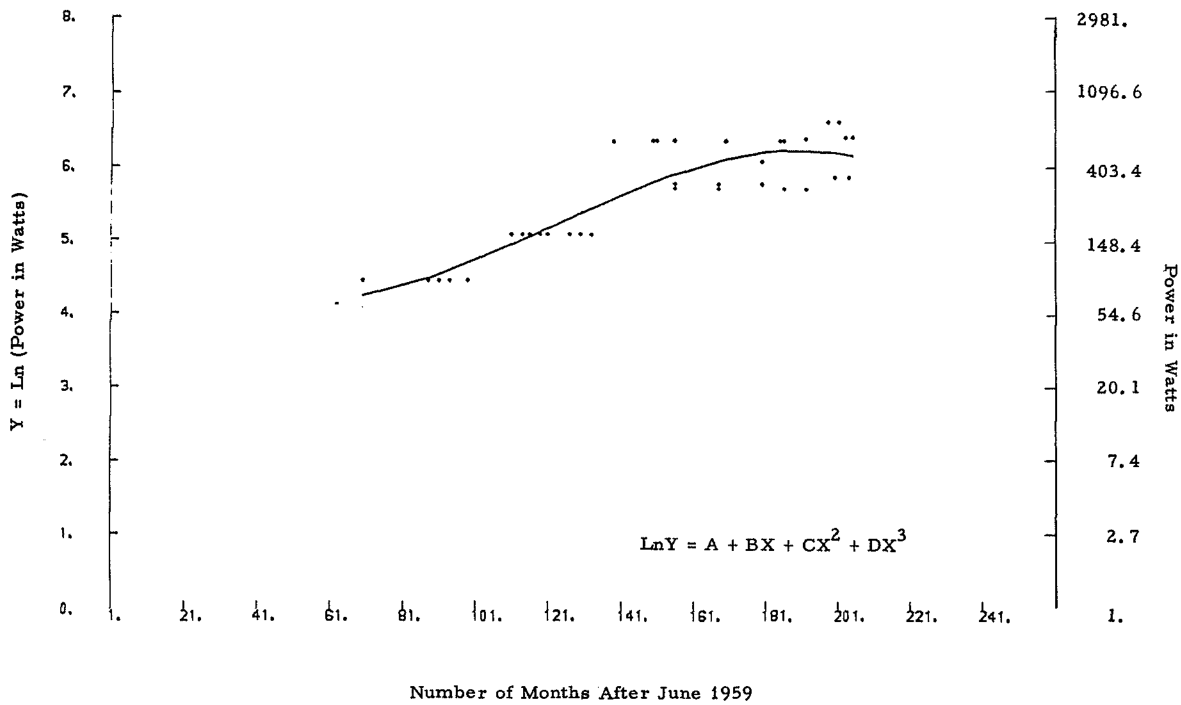

Figure 7. Satellite Prime Power Regression Analysis - Civil

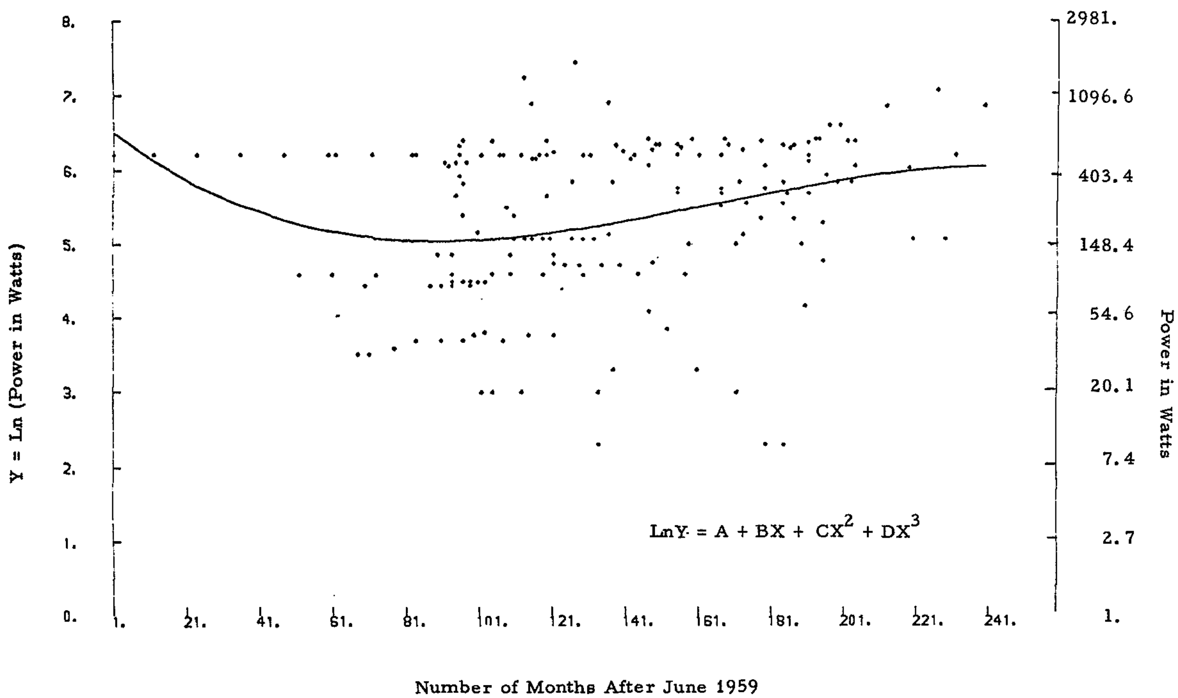

Figure 8. Satellite Prime Power Regression Analysis - All Launches

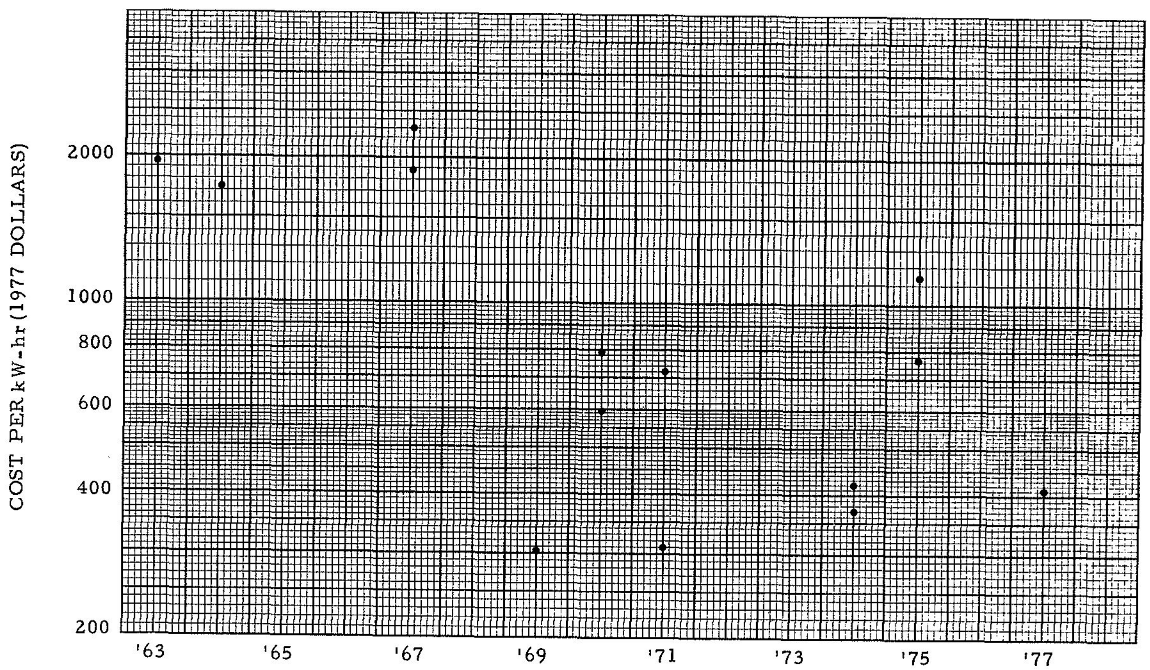

Figure 9. Electrical Subsystem Cost per kW-hr vs Year of First Flight

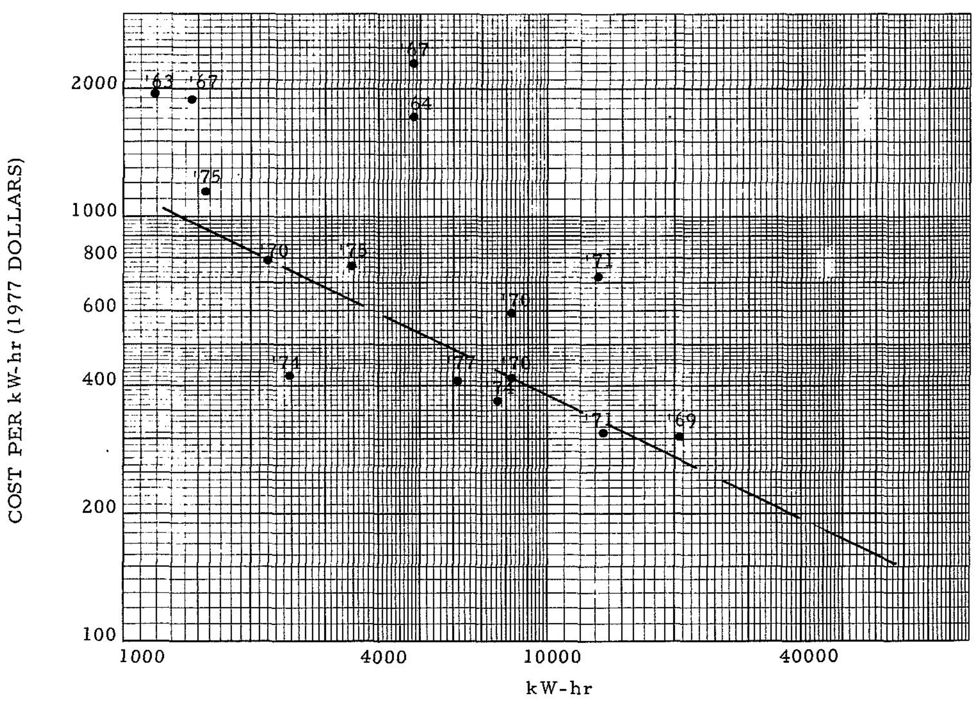

Figure 10. Electrical Subsystem Cost per kW-hr vs kW-hr

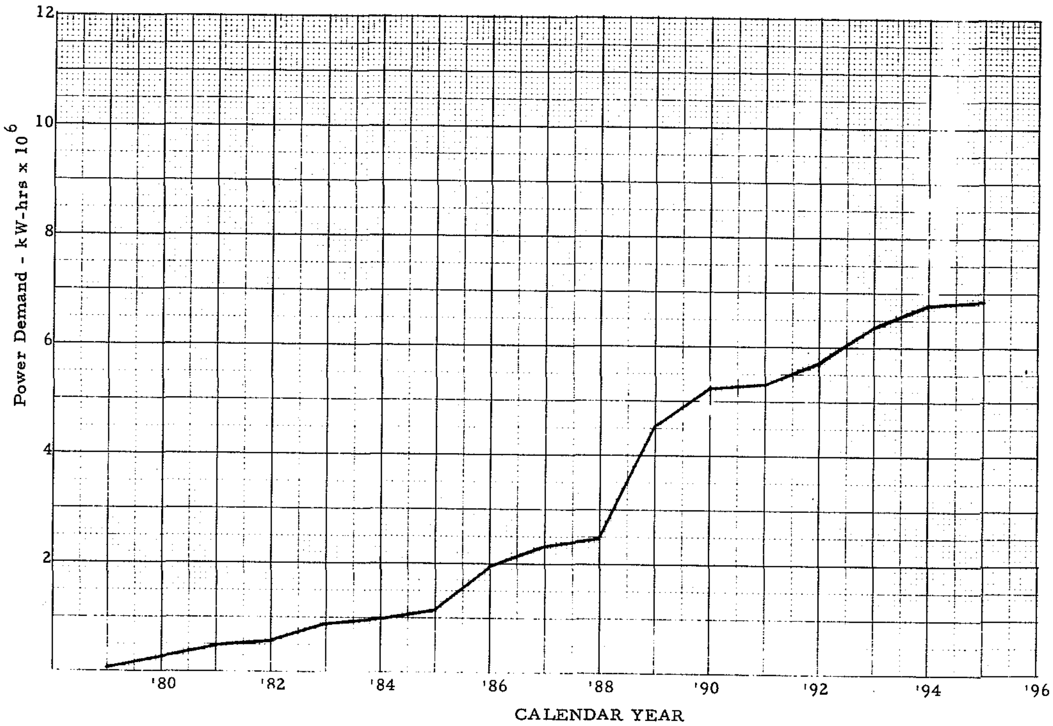

Figure 11. Total Space Energy Demand, 1985-1995 - Nominal Budget

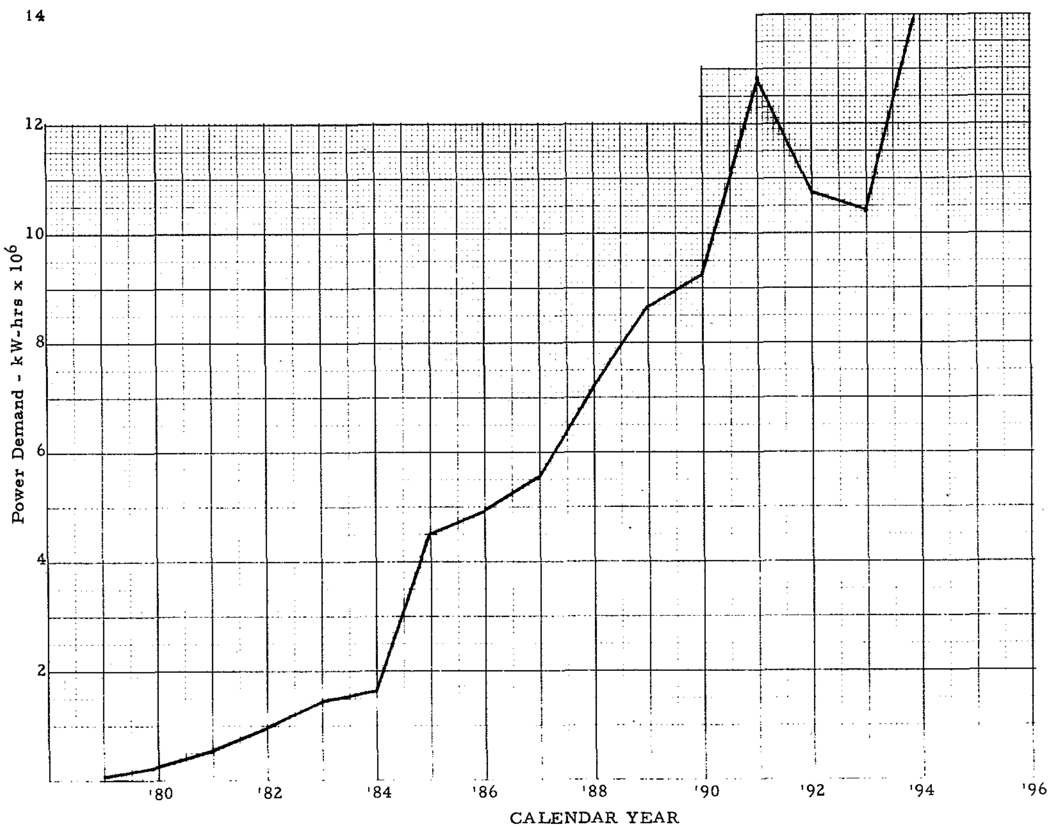

Figure 12. Total Space Energy Demand, 1985-1995 - Optimistic Budget

DEVELOPMENT, TEST AND DEMONSTRATION	• 10-ft Antenna (lens) • 50 Beams • 1000 x 1000 Switch • 1 kW RF Transmitters • 2000 lb • Launch assembled • Test in LEO, GEO	• 50-ft Antenna (lens) • 200 Beams • 50,000 x 50,000 Switch • 7 kW RF Transmitters • 5000 lb • Unfolded/Locked in Space • Test in LEO, then GEO	• 200-ft Antenna (lens) • 1600 Beams • 10^6 x 10^6 Switch • 70 kW RF Transmitters • 20,000 lb • Orbital Assembly in LEO • Test in LEO • Raise to GEO, re-test
RESULTANT CAPABILITIES	- Operate in GEO - Perform One Function Below, (or Time-Share) - Launch Additional Units for More Functions	- Operate in GEO - Perform One Function Below, (or Time-Share) - Launch Additional Units for More Functions	- Operate in GEO - Perform One Function Below, (or Time- Share) - Launch Additional Units for More Functions
	• All-Nation Hotline (A) • Search/Rescue (5 YP, OFS) • Mobile Telephony (5 YP, OFS) • Mobile Broadcast (5 YP, OFS) • Military Communications (A)	• Nuclear Fuel Locator (A) • Electronic Mail-High Density (OFS, 5 YP) • Rail Car Locator (A) • Personal, Police Communications Demonstration System (A) • Military Applications (A)	• Personal Communications (A, OFS) • Electronic Mail - Thin Route (A, OFS) • 3-D Teleconferencing (A) • Burglar/Intrusion Alarms (A) • Military Applications (A)
INITIATIVE GROUPS	1 A	1 B	1 C
ORBIT	SYNC	SYNC	SYNC
POWER LEVEL	4 kW	25 kW	210 kW
SCHEDULE (Optimistic/Conservative)	1983/1990	1987/1994	1992/1999

Figure 13. Group 1 Initiatives

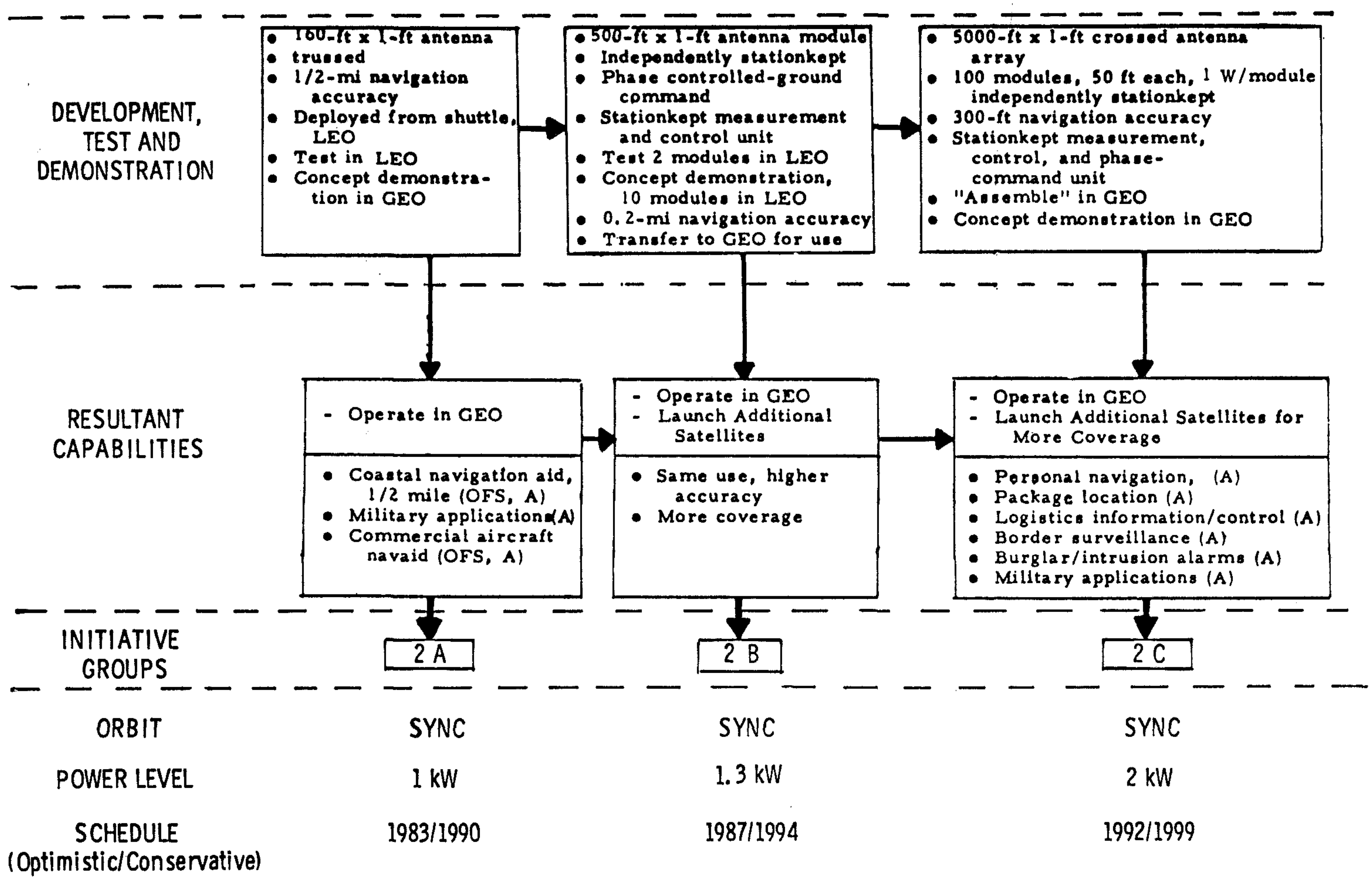

Figure 14. Group 2 Initiatives

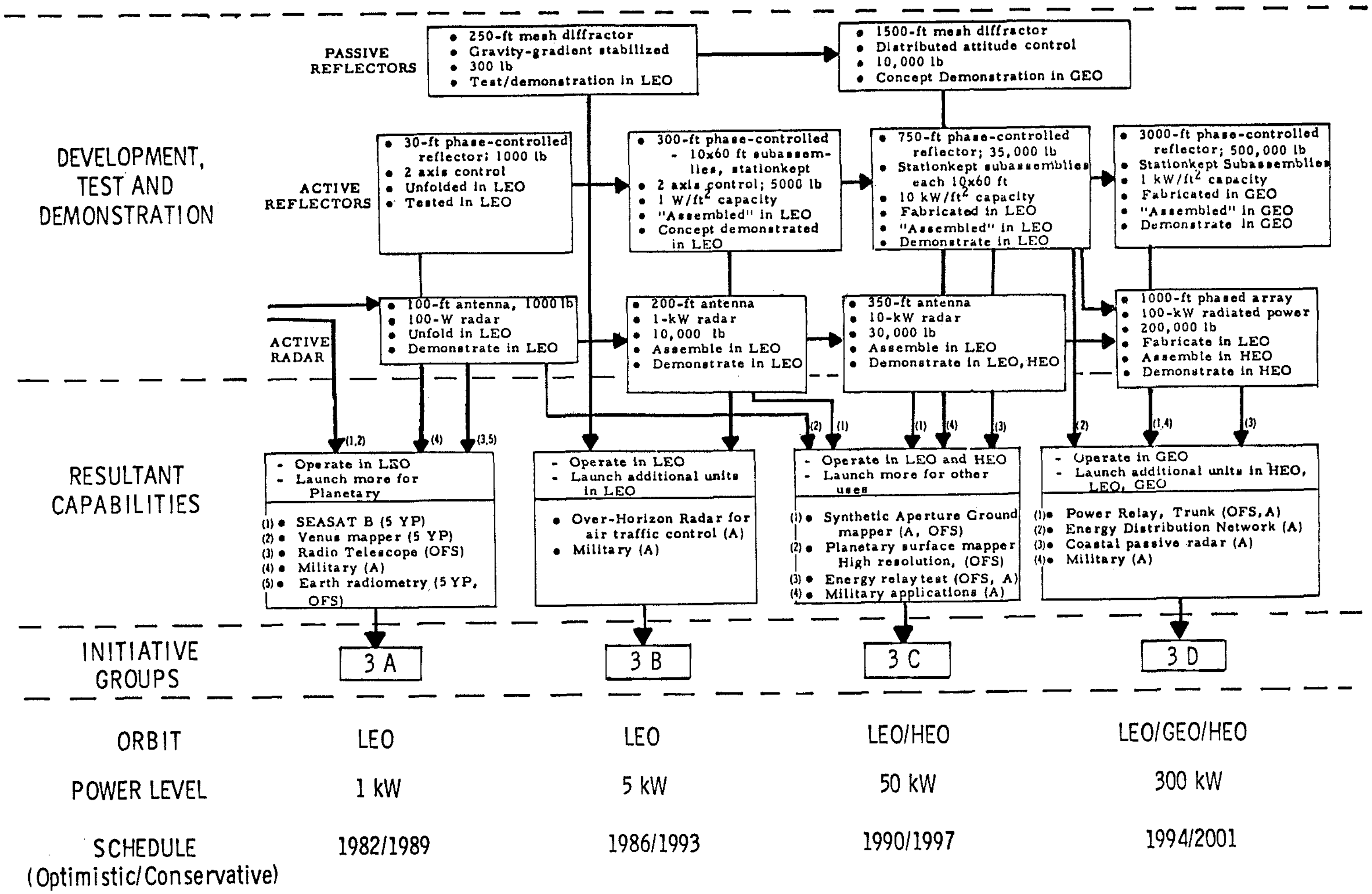

Figure 15. Group 3 Initiatives

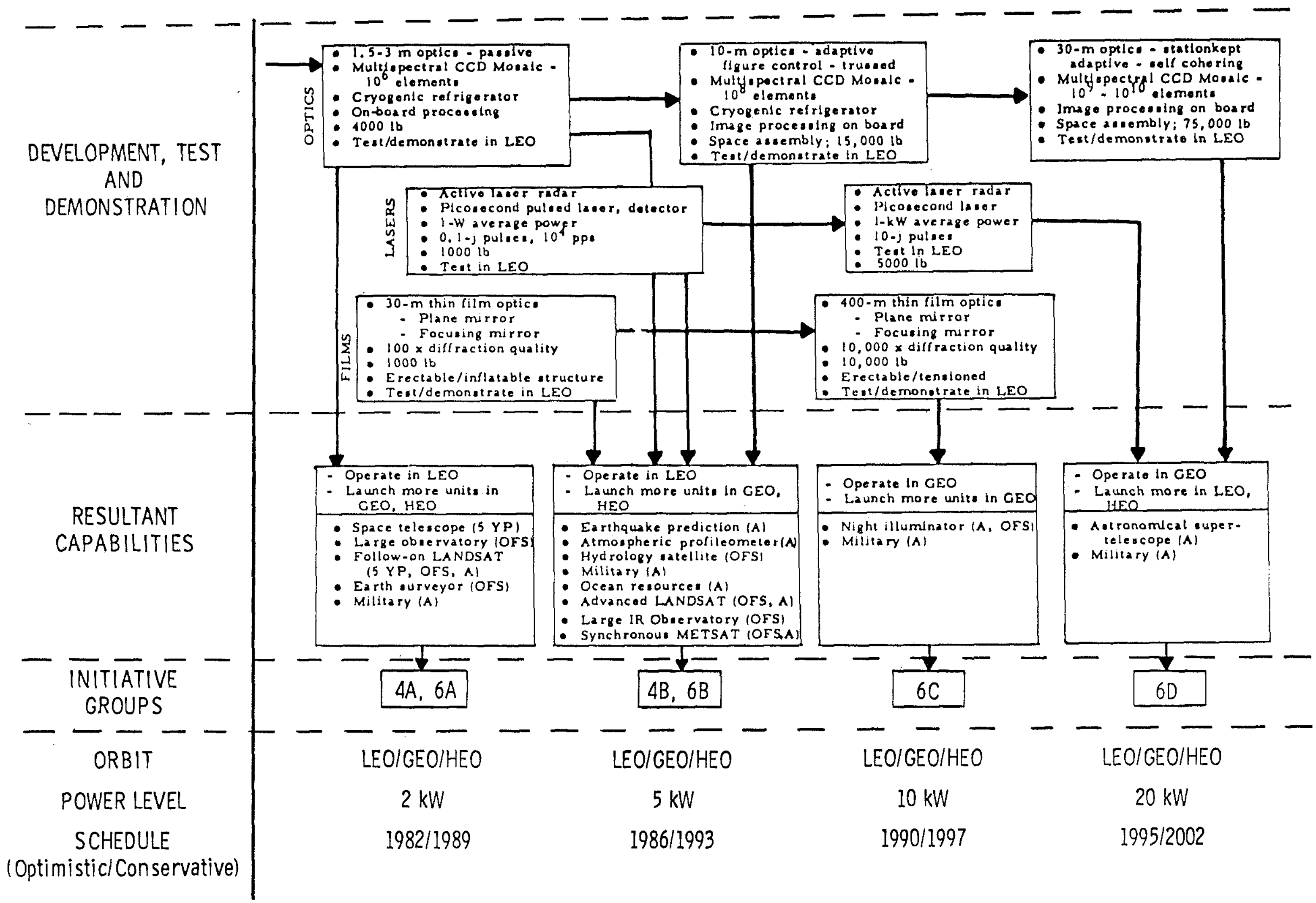

Figure 16. Group 4 and 6 Initiatives

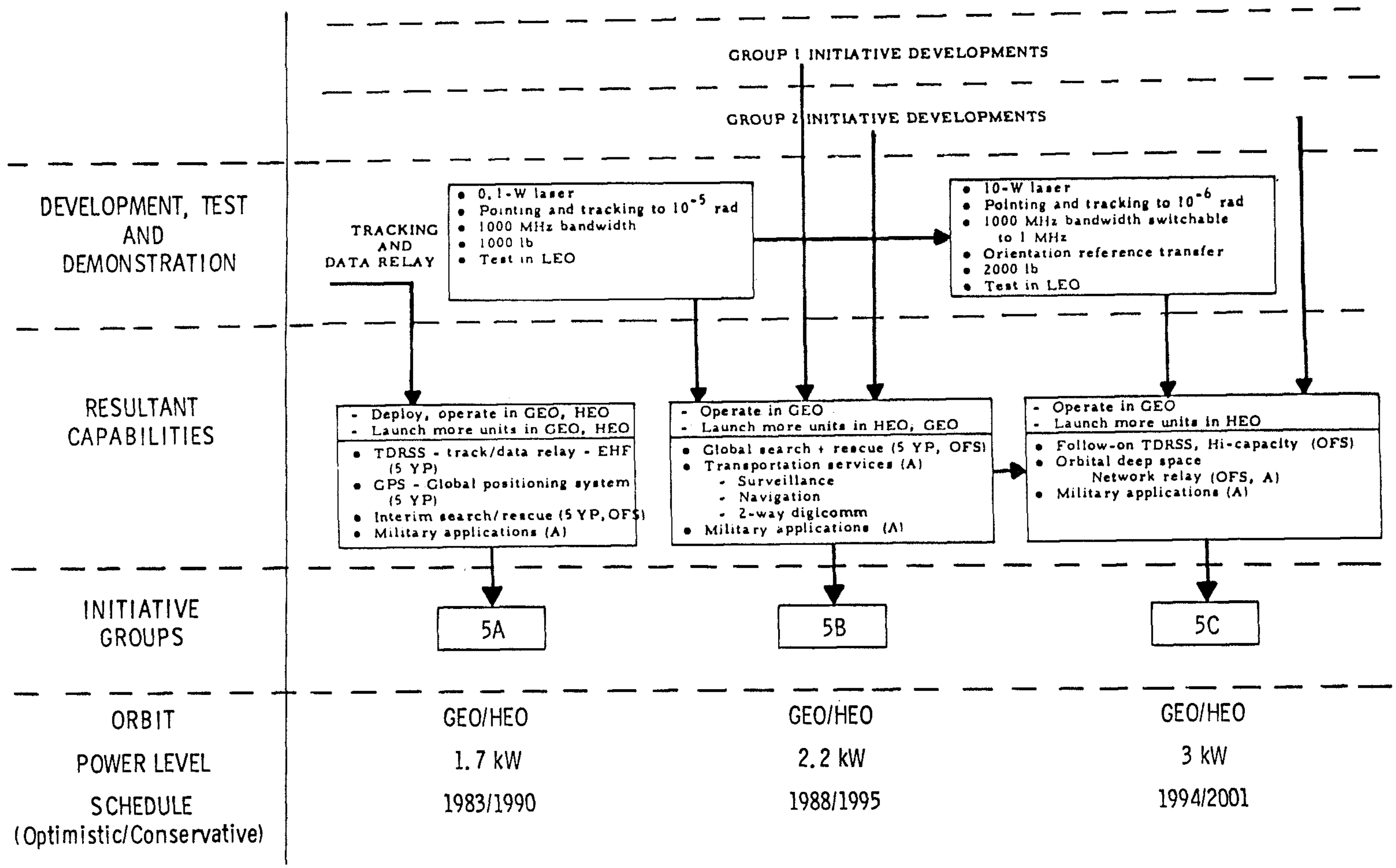

Figure 17. Group 5 Initiatives

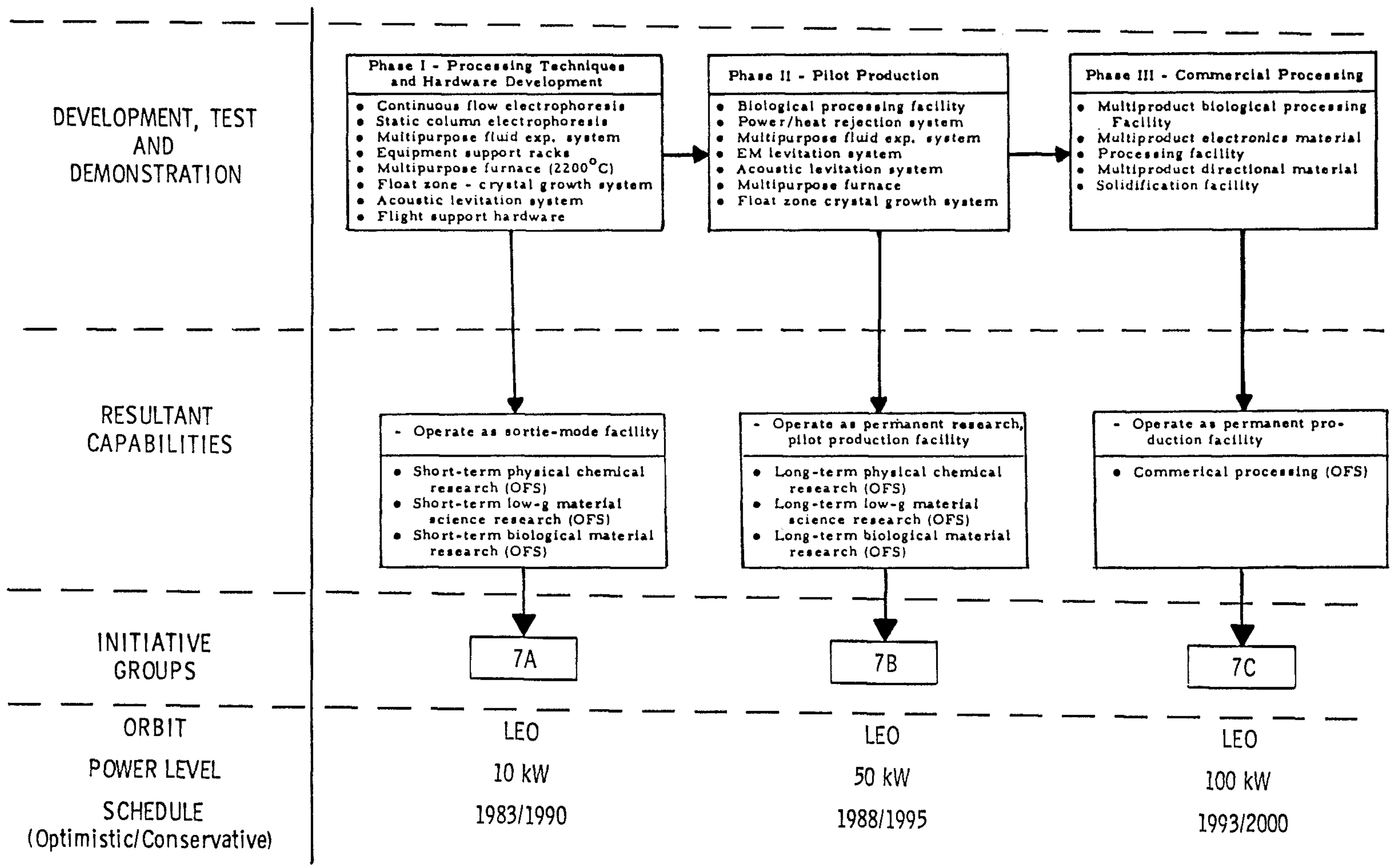

Figure 18. Group 7 Initiatives

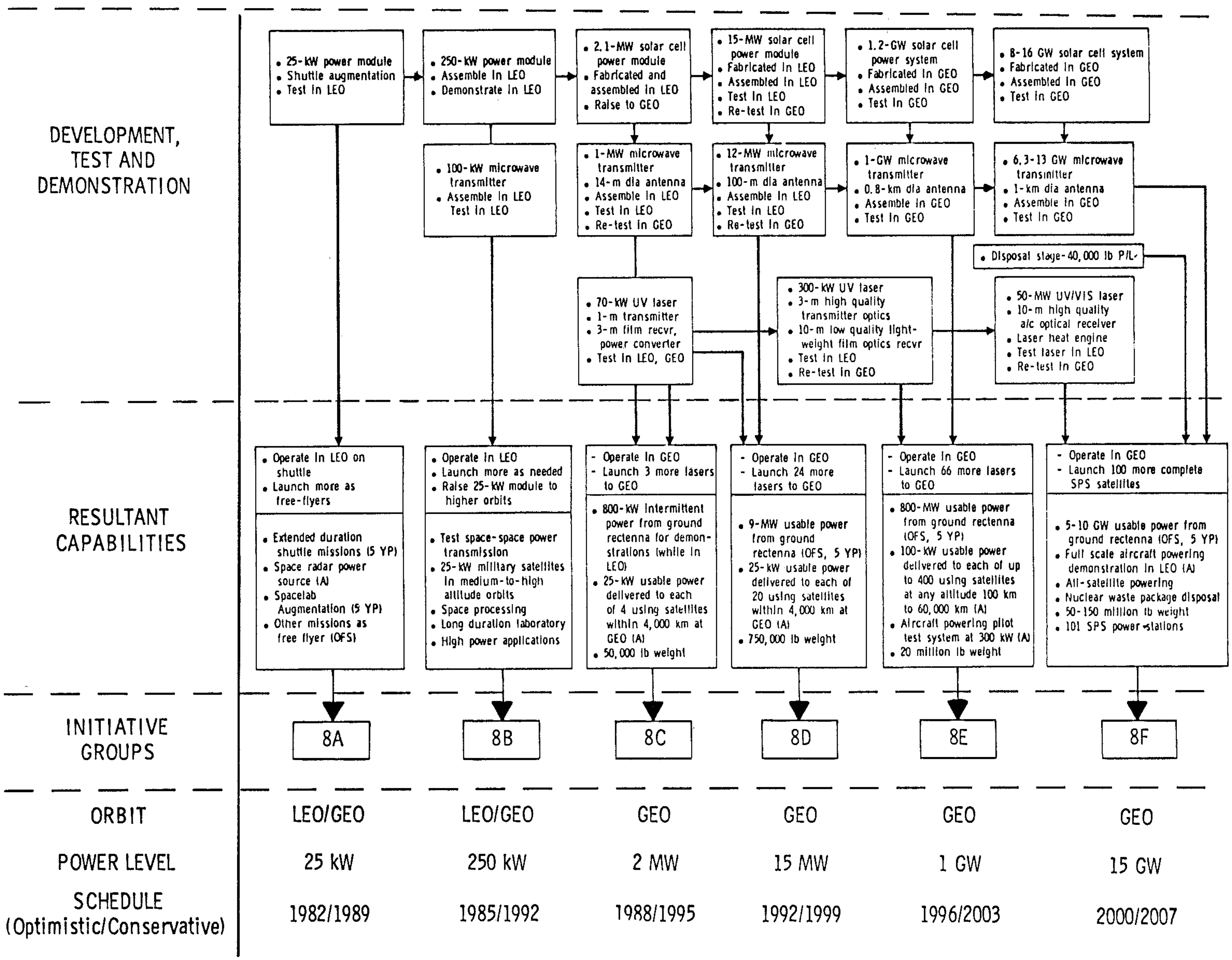

Figure 19. Group 8 Initiatives

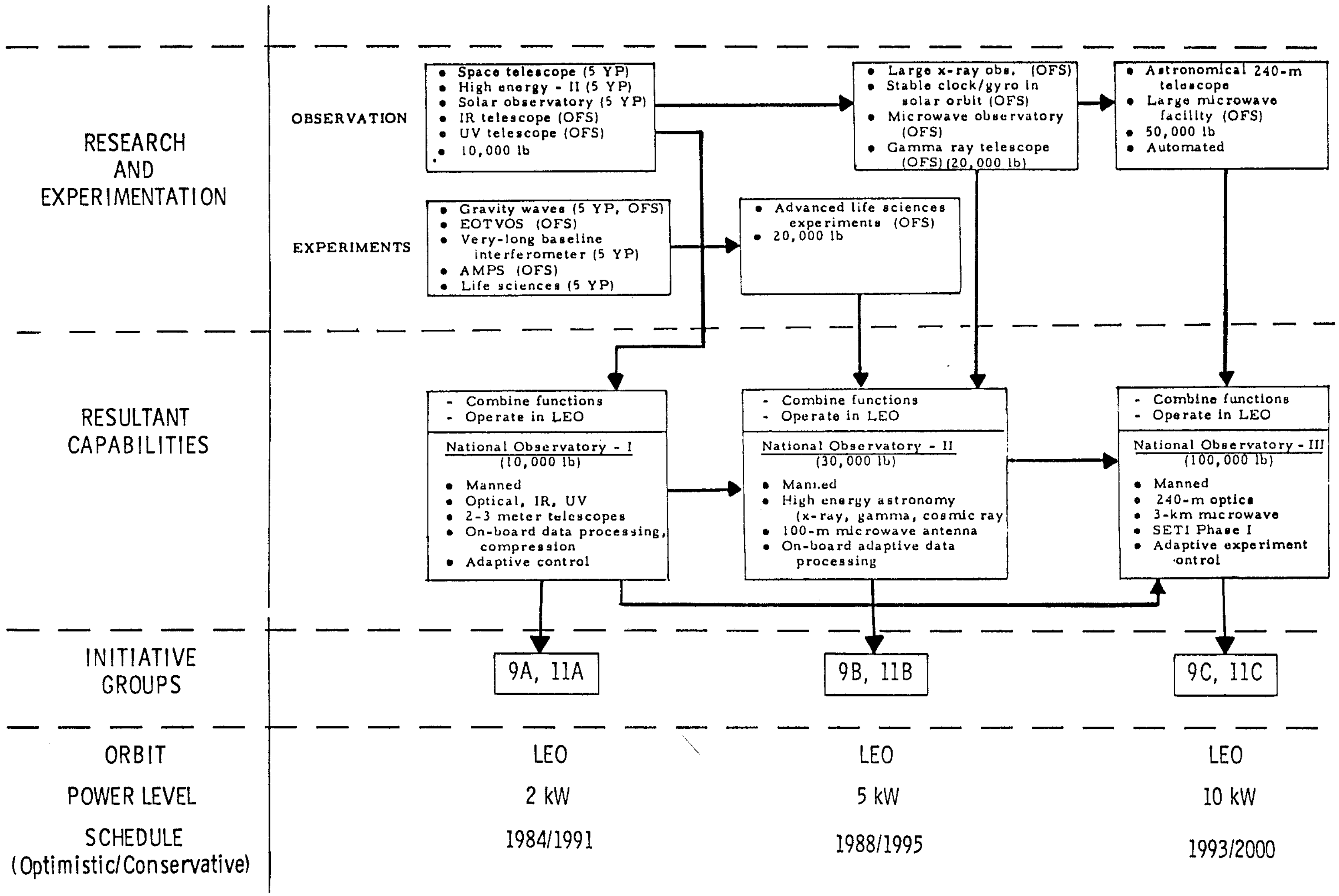

Figure 20. Group 9 and 11 Initiatives

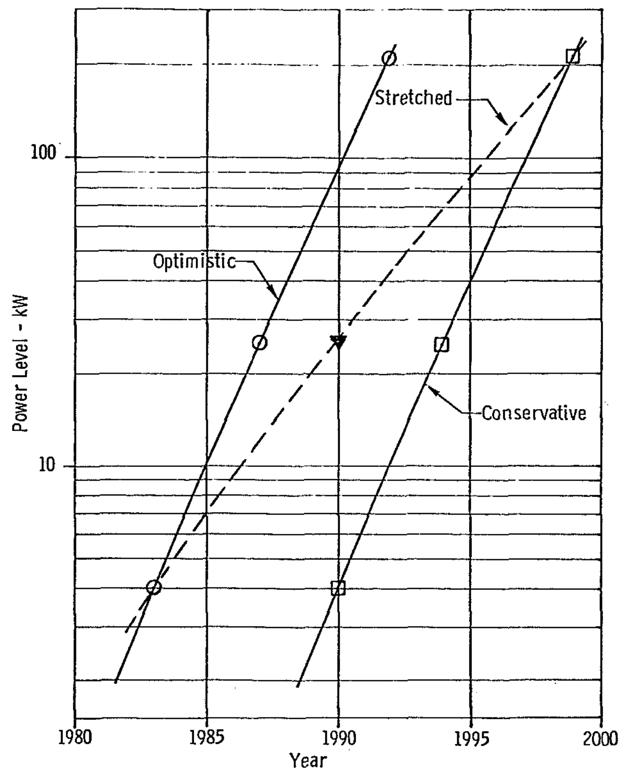

Figure 21. Power Requirements - Group 1 Initiatives

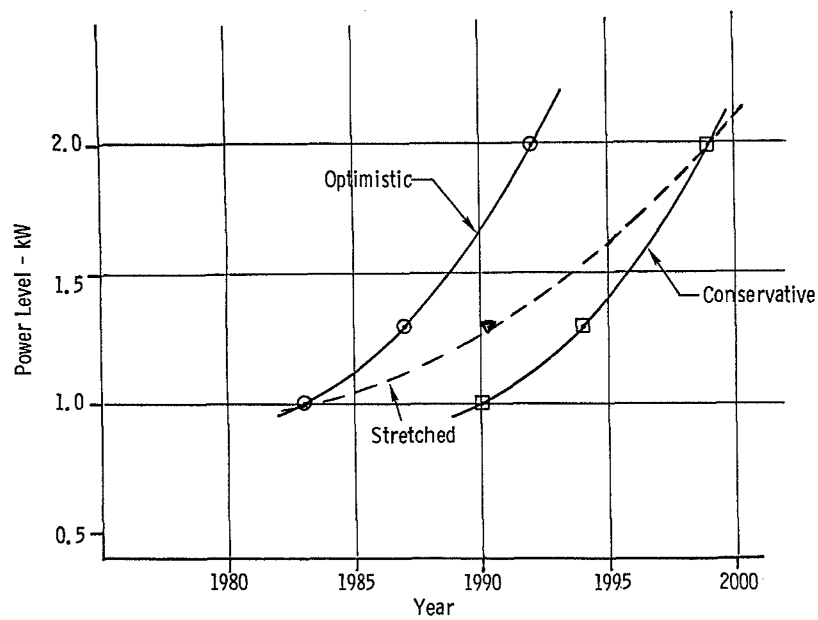

Figure 22. Power Requirements - Group 2 Initiatives

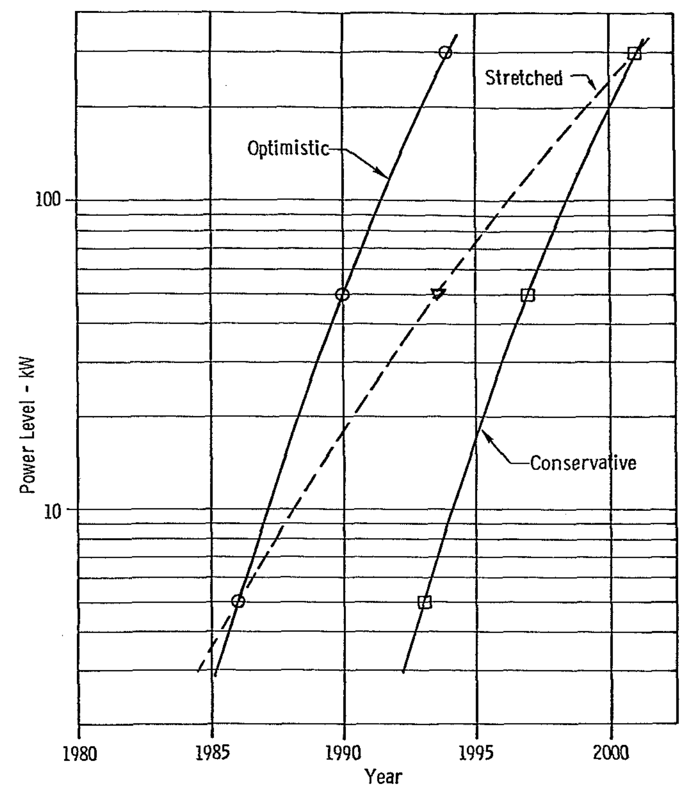

Figure 23. Power Requirements - Group 3 Initiatives

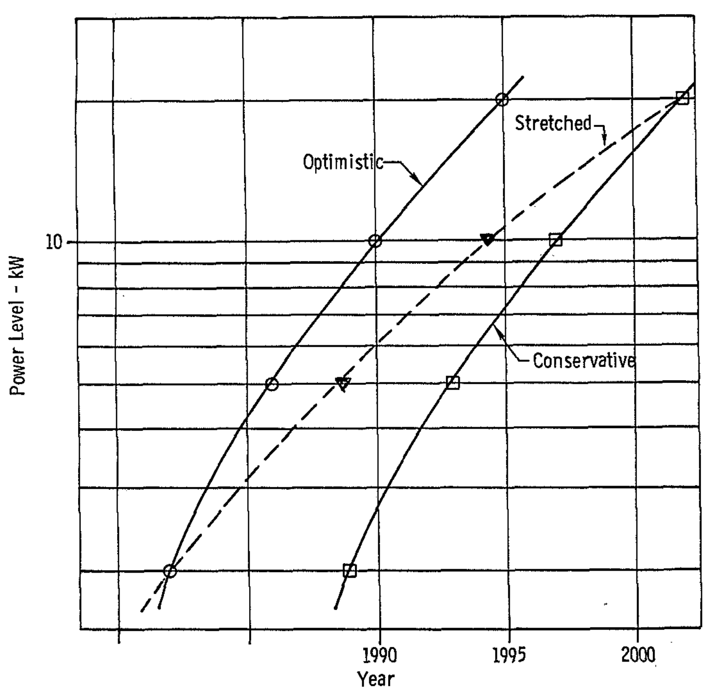

Figure 24. Power Requirements - Group 4 and 6 Initiatives

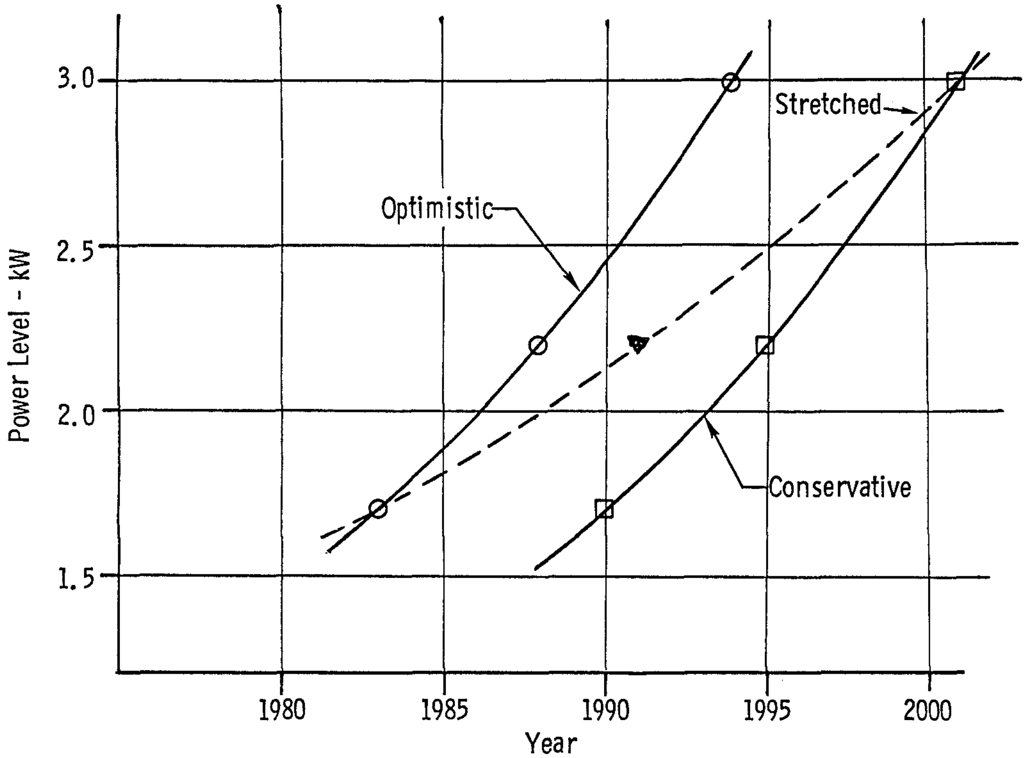

Figure 25. Power Requirements - Group 5 Initiatives

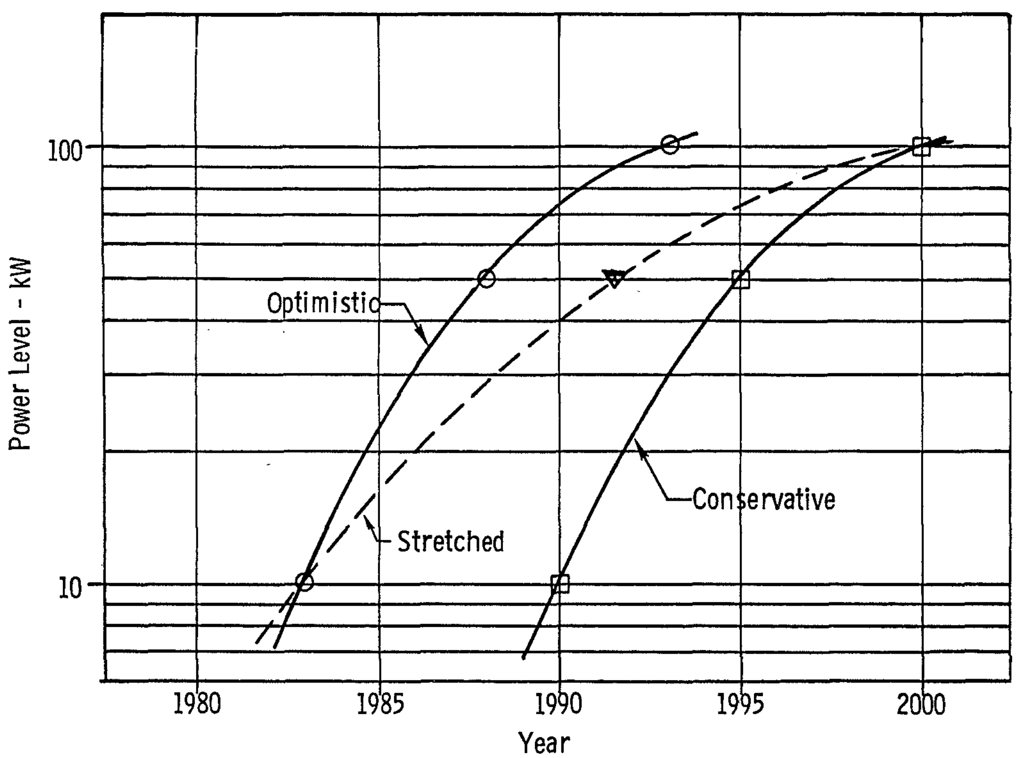

Figure 26. Power Requirements - Group 7 Initiatives

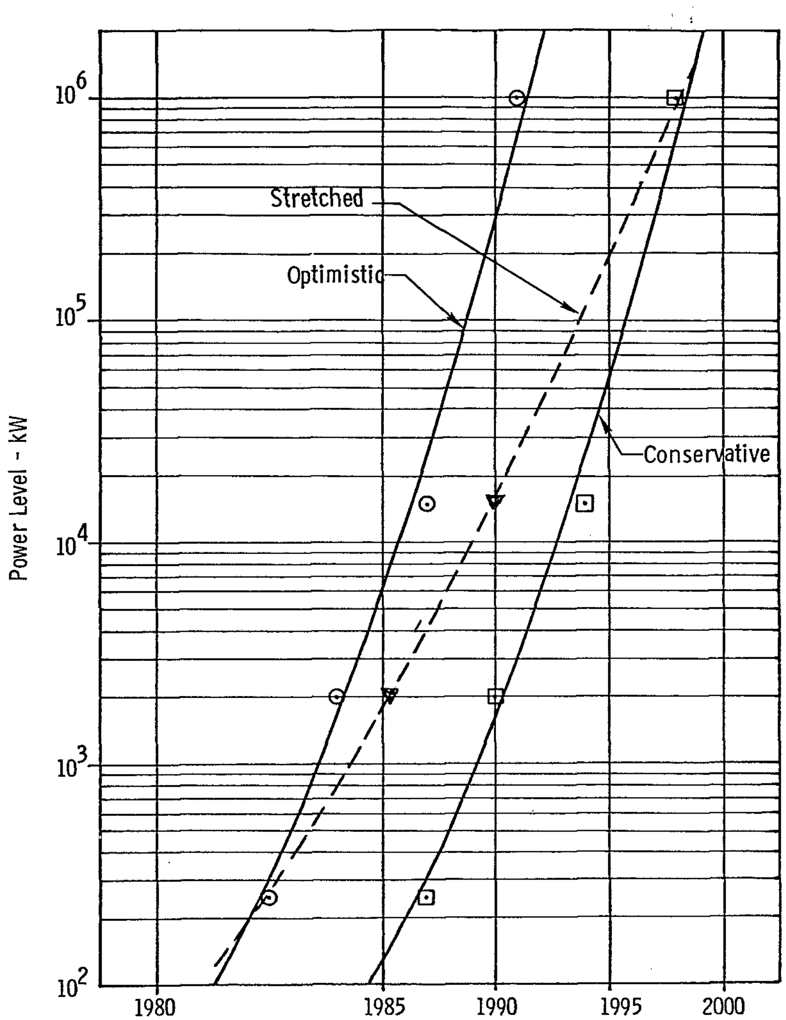

Figure 27. Power Requirements - Group 8 Initiatives

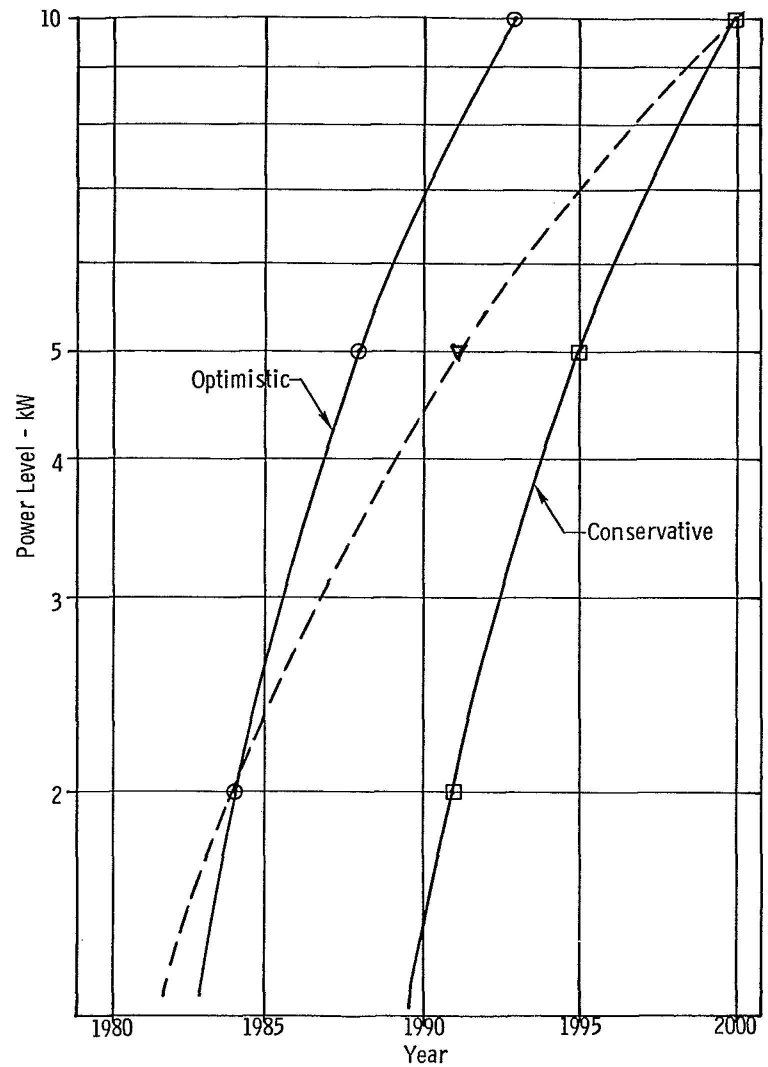

Figure 28. Power Requirements - Group 9 and 11 Initiatives