Apr 1st, 8:00 AM

Air Force Space Requirements: Can Industry Meet the Challenge for Space Systems?

Edward S. Houston
GM-14 Space Sector Program Manager, USAF SD/PDP Los Angeles Air Force Station, California

Mark W. Phillips
Group Leader, Industrial Sector Analysis HQ AFSC/PLMI, Wright-Patterson AFB, Ohio

AIR FORCE SPACE REQUIREMENTS:
CAN INDUSTRY MEET THE CHALLENGE FOR SPACE SYSTEMS?

by

Mr. Edward S. Houston, GM-14
Space Sector Program Manager, USAF SD/PDP
Los Angeles Air Force Station, California

Captain Mark W. Phillips
Group Leader, Industrial Sector Analysis
HQ AFSC/PLMI, Wright-Patterson AFB, Ohio

ABSTRACT

A major issue in achieving the optimum employment of aerospace forces in space is the capability and capacity of the industrial base to produce the space systems necessary. The increasing number of space vehicles required by the Air Force and other U.S. Government, civilian, and foreign programs will have a profound impact on the industrial base. This paper presents the findings, conclusions, and recommendations resulting from an analysis of the space industrial base. The analysis, titled United States Air Force Production Base Analysis (PBA), is an ongoing assessment of the health and surge/mobilization capabilities of the defense industrial base. This paper focuses on the space industrial base; the space industries capability and capacity to produce space systems the Air Force needs through the year 1990.

THE ANALYSIS STRATEGY

A systems approach to Industrial Base Program Planning objectives and activities was necessitated by the complex interrelationship among the space industrial base. The keystone to this approach was the formulation of an Analysis Strategy and the use of the Space Sector Top-Down Structured Analysis Model.

The Global Space Sector (GSS) concept used recognized that DoD space missions must compete with other US Government, Civilian, and foreign programs for a common and limited industrial base, Figure 1. The GSS is defined as consisting of four major segments:

* Requirements-Space system needs which compete for the industrial base resources.
* Producers-The GSS industrial base.
* Technology-Those technologies needed to meet the requirements of present and planned space systems.
* Users-Organizations responsible for utilizing space systems.

Three grounds rules were established for the analysis strategy. The first rule was to focus on productivity relative to the manufacturing discipline in the space industrial base.

The second ground rule was to look at the "system" itself rather than a single element. A higher level approach to productivity, rather than attempting to identify singular problems in each space program, would lead to a greater probability of reducing development problems and result in a positive impact on the rate of productivity throughout the space industry.

The third ground rule concerned the area of data collection. A determination was made to use information already available as much as practicable. This included the identification of existing data bases and the information in them as well as on-going or specialized research relating to space industrial base parameters.

A large portion of the data reviewed and analyzed to produce the 1985 Space Production Base Analysis was collected by surveys and visits to Space Division program offices and space systems contractors.

Interviews were conducted at the U.S. Air Force Space Division with program management and manufacturing management personnel in Program Offices listed below to obtain detailed production related data.

- Automated Remote Tracking Station (ARTS)
- Consolidated Space Operations Center (CSOC)
- Defense Meteorological Satellite Program (DMSP)
- Defense Satellite Communications system (DSCS)
- Expendable Launch Vehicle (ELV)
- Global Positioning System (GPS)
- Inertial Upper Stage (IUS)
- Space Transportation System (STS)
- TEAL RUBY
- Traveling Wave Tube Amplifier (TWTA) Program

To accomplish the PBA review and analysis objectives for the Producer portion of the GSS, a survey was developed and forwarded to twenty-nine major contractors producing systems or components for Space Division. On-site discussions were conducted at nineteen space system producers, several of which provided input from two or more divisions or groups. Many of the contractors visited enlarged on their response to the producers survey in addition to discussing topics selected for investigation.

Also, a survey was sent to an additional twenty-six space system producers who were identified by the primes and major subs as lower tier subcontractors, suppliers, and vendors. It was the belief that this approach would result in more detailed information from the program offices and producers interviews
while exploring the next sub-tier

level of space system producers through a written survey.

The thrust of the 1987 study was an analysis of the subcontractor tier of the space industry to identify deficiencies and constraints experienced by this segment for the successful production of space related products and systems. It represents a following step to the previous studies performed. A total of 76 companies participated in this years survey; 38 of these by interviews with manufacturing personnel in on-site reviews and the remainder by a mail-in survey questionnaire.

The U.S. Department of Commerce (DOC) provided a great deal of general Aerospace Industry information. The data provided is under three Standard Industrial Classification (SIC) codes: Guided Missiles and Space Vehicles (SIC 3761), Space Propulsion Units and Parts (SIC 3764), and Space Vehicle Equipment (SIC 3769). Two documents of interest to this analysis are the 1984 U.S. Industrial Outlook, January 1984, and three 1982 Census of Manufacturers reports on the three specific SIC codes of interest. The DOC will update the Industrial Outlook and the three census reports in 1985.

Other sources of information were the Air Force Wright Aeronautical Laboratories (AFWAL), the Military Space Systems Technology Plan (MSSTP), Manufacturing Technology (MANTECH) and information from the Industrial Modernization Incentives Program (IMIP).

SPACE INDUSTRIAL BASE CHARACTERIZATION

The Space Industry historically has been characterized by extremes. Very high technology, at or exceeding the state-of-the-art, is routinely required. The role the Space Industry has played in national defense has evolved over the years from incidental to supportive and might even be dominate in the near future. This increasingly vital mission role has led to more sophisticated designs that require incorporation into operational systems at a much more rapid pace than in the past.

Low production quantities together with extreme reliability testing, and unique requirements continue to drive the cost of space systems. The increasing complexity of satellite design requires the ultimate in manufacturing technology to meet the stringent demands necessary to produce space systems.

The production base for space systems continues to consist of a relatively small number of manufacturers capable of being prime contractors for major Space Division programs. The subcontractor base is composed of highly specialized companies providing goods and services to the primes. The stringent requirements for high reliability makes it difficult for many companies to enter this sector of the industrial base. It is also difficult for subcontractors to increase their business base in areas other than highly specialized, new technology functions since prime contractors are well established and have more efficient facilities and equipment at their disposal to handle existing manufacturing technology operations. Thus, the trend observed in contractor visits and survey responses is toward a relatively stable number of existing prime contractors performing the "packaging" of present and future space systems.

Four specific trends impacting the space industrial base were identified. These trends are the Budget, Work Force, Technology and Strategic Defense Initiative (SDI) areas.

The Defense space budget , Figure 2, has increased dramatically over the past several years, with a growth from $2.4 billion in 1977 to $10.6 billion in 1984. The 1985 estimate is approximately $13.0 billion, 1986 is approximately $13.5 and the 1987 projection is $14.0 billion. (Source: Office of Management and Budget). With the addition of the Strategic Defense Initiative (SDI) program, increases in space defense spending will show an even more dramatic growth rate.

Since the space industry is characterized by high technology, extreme reliability requirements, and state-of-the-art manufacturing techniques, an experienced and highly skilled work force is in great demand. Space is a very people-sensitive and labor-intensive industry, requiring constant training and retraining to keep pace with the evolving technology. In some cases, the lack of availability of trained people may become a bottleneck to a production schedule to the extreme that one key person off work can require a work-around situation.

The availability of selected skilled workers is closely tied to geographical location, Figure 3. Most space system producers are located in areas which have a large labor force to draw upon and have little problem in obtaining unskilled or semi-skilled labor due to the large concentration of Aerospace companies. Companies in the "Silicon Valley" area have little problem with software/computer personnel while these skills may be critical in other areas. Demographically, isolated aerospace companies have experienced difficulty in attracting young people into the manufacturing labor area, stating a need for Government-funded apprenticeship and college programs to expand the manufacturing labor base. The below figure illustrates the geographic distribution of the companies visited and surveyed which identified critical skills problems.

Engineers of various types are the most prevalent of the critical skills cited by both space system producers and Space Division program office personnel. Companies visited and surveyed were asked to identify types of chronic critical skills within their industry. Specialized engineering disciplines were identified as critical, as well as general engineers and technicians.

Certain critical skills identified by some of the companies indicated that there would be future nation-wide problems. These critical areas include electro-optical engineers, skilled machinists, manufacturing engineers, Radio Frequency (RF) and optics engineers, test engineers, and systems engineers. One company alone stated that SDI requirements could call for 200-500 additional electro-optical engineers. It was noted that there seems to be a general lack of interest among top engineering graduates to enter into production/manufacturing careers and that Government and industry should work together to reverse this trend. A problem alluded to was there are few engineering colleges in the country that stress production/manufacturing curriculum versus design.

The technology segment of the space industrial base was identified as having a major impact on the manufacturing management issues to be resolved in planning for future space systems. The process did not assess the technology trends area in-depth, but rather, identified certain on-going initiatives as well as perhaps performing reverse technology analysis to meet AF requirements.

State-of-the-art manufacturing processes are routinely required to satisfy the needs of the space industry. The following is a partial list of the types of technological innovations being used in the manufacturing arena at the companies visited and surveyed for the 1986 PBA:

- Flexible Manufacturing Systems (FMS)
- CAD/CAM systems
- Robotized welding shops
- CNC/NC machine tools
- Robotics sensors
- Cellular manufacturing
- Artificial Intelligence (AI)
- Computer Integrated Manufacturing Systems (CIMS)
- Automatic material handling-storage retrieval
- Chemical processing and finishing
- Nonmetallic/composite and metallurgical processing
- Paperless assembly/factory (Factory of the Future concepts)
- Robotic paint facilities
- Automated mounting of surface devices
- NC metal and circuit board fabrication systems
- Automated machine shops
- Modular work stations

This listing represents many of the technological innovations that are commonly being addressed by members of the Space Industry. Several companies made available five and ten year plans showing when they believed the improved manufacturing technology would be available for implementation. Many companies are limited in the manufacturing area only by money, not by imagination or technology.

The in-house interview process showed a very positive trend as to where most companies are applying their manufacturing modernization dollars. A majority of them are improving generic areas of production and test. Emphasis is heavy in non-touch labor areas such as improving communications between support functions. In touch labor areas, some contractors are striving to improve areas such as wave soldering and printed wiring board fabrication. Capital investments are generally made not for a specific product or program but rather will benefit all hardware that will flow through and use that process. This generic approach at reducing costs and leadtimes can only help improve the industrial base capabilities and yield more competitive pricing in the future as these contractors bid on future programs based on manufacturing space hardware using these more efficient processes.

The impact of SDI on the overall capacity of the Space Sector industrial base remains uncertain. Analysis of the initial information acquired from visits to primes/major subcontractors indicates that there is a surplus physical capacity at the prime and subcontractor level, with the exception of unique electronic parts manufacturers and RF parts suppliers, Figure 4.

FINDINGS AND RECOMMENDATIONS

The past PBA efforts have established some thirty findings and recommendations about the abilities of space industries to produce Air Force requirements in space systems through the 1990's. This section of the paper will discuss some selected findings and the benefits that came out of the 1985, 1986 and 1987 PBA efforts.

"S" Level Piece Parts Production Base

An example of projected benefits following a Space Sector PBA Recommendation is in the management of the space qualified, "S", Level Piece Parts Production Base. The procurement of high reliability, "S" level electronic piece parts is an issue applicable to all space programs and was identified by both producers and program offices as being an industry-wide concern. Specifications applied to "S" level electronic piece parts require a higher level of inspection and testing than that required for non-"S" level components. Additionally, the 1985 PBA process identified low volume requirements and limited numbers of qualified suppliers as negatively impacting program schedules and costs.

A Space Parts Working Group (SPWG) was formed at the Space Division and conducts working level meetings with industry. In conjunction with the SPWG recommendations, the Defense Electronics Supply Center (DESC) will inventory selected class "S" parts, creating a stockpile to alleviate current long leadtimes. With established costs and reduced leadtime on "S" level parts, contractors will be able to more realistically bid for programs and plan schedules without fear of being non-competitive. This effort to stockpile long leadtime components will lower costs, improve schedule delivery times and increase potential surge capability for critical systems.

SPACE POWER TECHNOLOGY

Space power technology projects will require emphasis for at least the next ten years for assurance of achieving the required power levels for space systems through the year 2000, Figure 5. This emphasis will be required in both battery and solar cell technology, as well as other space power source technology development.

The transition to the EHF band creates a need for more on-board satellite power. The above figure illustrates the increasing power requirements from the defense communications satellites of today to the projected requirements of future systems. These power requirements can only be met by larger or more efficient solar arrays and more back-up batteries. Larger electrical systems result in a more massive satellite, because spacecraft power is proportional to mass.

Numerous government agencies are working in the area of space power source developments. NASA, the Department of Energy, and the Department of Defense have selected the reactor thermoelectric power system for further design, development and ground demonstration in Phase 2 of the SP-100 space reactor power program in FY 1986-91. The Air Force Wright Aeronautical Laboratory has announced plans for exploratory development of rechargable sodium-sulfur battery cells for low-earth orbit applications.

Precision Instruments Bearings Production Base

Problems with the production base for precision instruments bearings was another finding of the 1985 analysis. Precision instrument bearings for space applications are no longer available from some manufacturers and not standardized because each buy is a custom order.

Further, bearing sources are in jeopardy due to foreign acquisition of domestic suppliers and the potential dropping of low volume lines.

Aeronautical Systems Divisions (ASD/YZD) has initiated an IMIP with a goal toward improving the US industrial base of the precision instrument bearings industry. The primary purpose of this program is to advance the state-of-the-art in manufacturing and quality for any bearing manufacturer who meets the qualifications and desires to participate.

This program will help the American bearing industry to be more competitive and produce higher quality bearings. Foreign competition from Japan and Europe have made severe inroads in the bearing industry. Improvements that result from this IMIP will allow for lower dependency on foreign manufacturers and increased potential surge capability.

Beryllium Availability

The 1985 Space Sector study identified concern about the availability and lead times of this single source material.

The finding was stated as:

"Beryllium is now available from only one domestic manufacturer. This has impacted supplier of spaceborne optical components. The scope of this finding and the specific impact on space applications was not identified..."

The 1986 Space Sector analysis obtained additional data substantiating that beryllium availability was indeed a concern with several contractors; an excerpt from the 1986 Space Sector Report:

"During the 1986 PBA interview process, several companies expressed concern about lead times of beryllium metal parts. One contractor has established its own $1M stockpile of beryllium metal in an attempt to reduce lead times and hedge against future shortage."

It was pointed out that President Reagan's decision to add additional amounts of this metal to the national stockpile will improve supplies of this unique metal. Should Title III action be taken as proposed in the 1985 Space Sector Report, the inventory of beryllium will be increased even more.

As part of the data collection efforts for this Space Sector Industry Analysis, an on-site review was conducted at Brush Wellman Corporation in Elmore, Ohio. Brush Wellman is the only source of beryllium metal and beryllium oxide powder in the Western world. Company personnel interviewed expressed surprise that space systems contractors thought that they (being the single source) were the cause of beryllium shortages and long lead times. It was brought out that most of these contractors do not do business directly with Brush Wellman but with the 15 to 20 beryllium machining houses across the country. Much of the shortage or lead time problems can probably be attributed to the backlogs of these suppliers. The Government can use the Defense Priorities and Allocation System (DPAS) to assure a supply of this material for critical programs.

Optical Lenses and Assemblies

Contractors who work in advanced optics applications expressed concern for the need to develop high-technology production and inspection/testing techniques.

Selected defense expenditure projects for 1985 through 1990 show the largest percentage category jump in the area of optical and photo equipment from $800M in 1985 to

$1.8B by 1990. SDI could make this even greater.

Special optics lenses assemblies and mirrors require unique skills and there are only two or three sources in the entire country. New technology is required that would enable manufacturers to consistently produce high quality items. Technology must be advanced to develop the inspection and testing techniques necessary for this consistency.

The Rapid Optics Fabrication Technology (ROPT) program sponsored by DARPA is concentrating on addressing the issue of rapid production, the most serious issue for producibility of large optics. It is planned that ROFT will transition to a MANTECH effort in about 1991, which at that point should fold the issues of integrating quality control into the manufacturing process.

Material Control System

Several contractors suggested the need for developing a standardized system of material control designed explicitly for space systems contractors. Specifically:

- The industry needs to mentally change from a development program attitude into a more production process oriented mode.
- There is need for an innovative computerized control for material; control the material flow and you control the program flow.
- A Material Requirements Planning (MRP) system tailored to the needs of the space industry is required.

Gaining control over the numerous unique part situations that occur in any Space program will allow contractors to make current decisions earlier in the process and determine program input as changes and problems take place. MRP information systems are based on a modular distributed basis rather than as a part of a highly integrated system. This fits space industry applications well.

This issue was investigated future in the 1987 PBA effort. Of the many MRP systems available, it appears that companies tend to choose various features depending on their particular needs. This condition makes the acceptance of a government standard system by industry questionable. An MRP system might be implemented at a particular company as part of an IMIP effort, but this would be done on a case by case basis. In view of the overall contractor responses and the complexities that exist for Government involvement in such a program, this finding is considered closed.

MANTECH/IMIP at Sub-tier Level

A need exists at the sub-tier contractor level for Government assistance in developing new and improved processes for manufacturing unique parts. There is also a need at selected firms for improvements in facilities and equipment necessary for more efficient production. Some of these sub-tier contractors are unaware of Mantech or IMIP programs; many that are believe they are too unwieldy with unreasonable overhead costs for a smaller company to effectively use.

Two predominant issues become apparent after analyzing the results of these interviews. First there is a need to expand publicizing of programs like Mantech and IMIP so that sub-tier producers who could use their benefits would participate. Second, these programs, as they are presently structured, do require significant contractor participation in overhead type functions. They are structured for large volume production and are unsuitable for the unique applications of space systems subcontractors with their relatively small unit quantities and high technology requirements.

Subtier IMIPs were a topic of discussion at the 1986 IMIP Workshop held 2-5 June 1986 in Atlanta, Georgia and at the 1986 IMIP industry Wide Review held at Los Angeles, California on 8-11 September 1986. Subcontractor participation in IMIP programs at present is primarily through the prime contractors. There were questions raised as to whether this is the most desirable arrangement. Flow down of benefits to the subtier levels may not be equitable. There are those subcontractors who do not want the exposure and examination necessary by the customer (prime). Some program offices stated they prefer conducting IMIP programs with subcontractors though primes because they get a finished product as an end item and want the prime heavily involved and committed. other program offices stated preferences to having a third party (such as a Task Order contractor) manage the IMIP programs directly with the subcontractors since they do not have the manpower within their organization to do this.

It is evident that subcontractor participation in IMIP is very desirable and can have high pay-off. Publicizing IMIP to the sub-tier contractor group is being expanded. This Space Sector Industry Analysis discussed MANTECH and IMIP with the contractors that participated and 73% requested further information on these programs.

MANTECH and its related cousin, MANSCIENCE, are being stressed at the subcontractor level. There will be a continuing requirement to make these contractors aware through the Manufacturing Technology Advisory Group (MTAG), Manufacturing Technology Information Analysis Center (MTIAC), IMIP Workshops and Industry Reviews. Publicity and awareness efforts for IMIP and MANTECH will continue throughout AFSC. Space Division will continue to look for subtier IMIP/MANTECH candidates through normal business activities. This finding is now classified as closed in view of these developments.

Problem of Aging Aerospace Workforce

Several of the contractors indicated concern over the aging workforce in the Aerospace Industry. Statistical data shows the average age of the space related industries workforce is 41+ years of age.

It was stated by one of the contractors interviewed that 22% of their workforce will be eligible for retirement in five years and 40% will be at retirement age in ten years. Since the space industry has unusually long on-the-job training problems coupled with the very high degree of skill requirements, this could be a major issue.

HQ USAF/RDCM has included this for investigation in their defense manpower studies. This finding is now classified as closed by virtue of the RDCM action.

Improve Testing Capabilities to Enhance Surge Capability

A significant finding from the 1986 PBA interview process was derived from replies to the questions on test and surge capabilities. The ability to surge in many cases is test limited.

Test is an area that many contractors believe has changed the most since the beginning of the space age. One company estimated that just twenty years ago, four out of 100 engineers were involved in test, while today it may be approaching 50 of every 100 engineers working in space programs.

Manufacturing management personnel stated in many cases the test equipment required on space projects is more sophisticated and of higher technology than the equipment it is designed to test. Emphasis is toward fully automated testers, using multi-cycle, self-analysis, self-adjusting, one-of-a-kind units that utilize the latest state-of-the-art AI techniques.

Primarily due to funding profiles and low unit quantity production runs, together with extremely high technology requirements, the concept has evolved toward building very expensive, one-of-a-kind testers that can test at the system level. These full system testers are designed around contract delivery needs and sometimes are in use three shifts a day to meet environmental and schedule commitments. They easily become saturated for trouble shooting and tweaking when test problems occur.

This complex test equipment requires very specialized software. On the average, for ever $1M spent on test hardware, $1M plus must be spent on developing and updating software to use that equipment.

The general lack of standardized (when possible) test criteria was also a concern. Some contractors stated that certain testing required to be performed in accordance with Government specifications is excessive and redundant; that it actually becomes non-productive.

Test Philosophy: Several of the responses suggested that the Government participate in a program to encourage industry to return to a test component building block process that couples into an overall system test. More focus should be given toward lower level testing, using less costly, less dedicated equipment. A blending of functional together with systems/process viewpoints should be a major goal of future test philosophy.

Test Specification: Many of the contractors would like the Government to allow those companies that are developing leading edge technology, a large input to specification and testing policies. They would like to help develop a parameter of standardization where-ever possible between programs and services.

Testing is an area that will require continuous monitoring by the Government. The current Space Sector Industry Study included topic of investigation. Further investigation in this area is planned. An action plan is being developed.

Clean Room Technology

The majority of space systems and subsystems integration of assemblies, wiring harnesses, structures, and skin coverings are done in controlled clean room environment. These rooms vary from a 100,000 all the way up to a Class-100 rating. In recent years the demand is for larger sized (25,000 sq feet and above) and more controlled clean rooms.

Clean rooms are costly to build and maintain and therefore are not generally oversized. Increases in production through surge or other requirements would cause the contractor to be facility-limited until expansion could take place.

Certain contractors stated that they need more direction as to what assemblies must be fabricated in a given clean room level. They further stated that if no direction is given, then the safest procedure is to build everything in the highest level clean room available. This is not cost effective and in many cases unnecessary.

Future programs such as SDI and Space Station must address the critical issue of clean room environments early and establish standards and procedures for industry to follow.

It was found that while most contractors visited had 20 to 30% surplus plant capacity overall, nearly all were at or near capacity in their clean rooms. Their ability to surge and produce any new major programs will be clean room limited in many cases.

This potential problem area requires more definition. It is only related to the space industry or is it common to other industry clean room applications? It is not cost effective to build everything in higher class clean rooms, yet this is the procedure many contractors follow.

SUMMARY AND CONCLUSION

The Aerospace Industrial Modernization Office, AFSC/PLMI, and Space Division Directorate of Product Assurance, SD/PD will continue assessing the defense industrial base health and recommending improvements. This paper summarized some of the findings and recommendations found in the Space industry.

Future PBA efforts will focus on making and implementing action plans for solving already identified problems. There will also be a continued focus on future issues facing the space sector industrial base, as well as continuing to expand the analysis to subtier groups: suppliers, subcontractors, and vendors.

The health of the space industrial base is good, but the demand being placed on space industries is growing quickly. Certain technical and capacity limitations are emerging such as capacity of clean rooms, testing capabilities and precision instruments bearings production. The problems are critical since as General Thurman stated at the opening of the Consolidated Space Operations Center, "It is space where our destiny lies." For our destiny to be realized, the Air Force must constantly analyze the space industrial base to understand the capability and capacity to produce the space systems necessary.

Any questions related to the above Space Sector Production Base Analysis, or requests for copies of the Analysis may be addressed to:

HQ AFSC/PLMI (Capt Phillips)
WPAFB OH 45433-6503

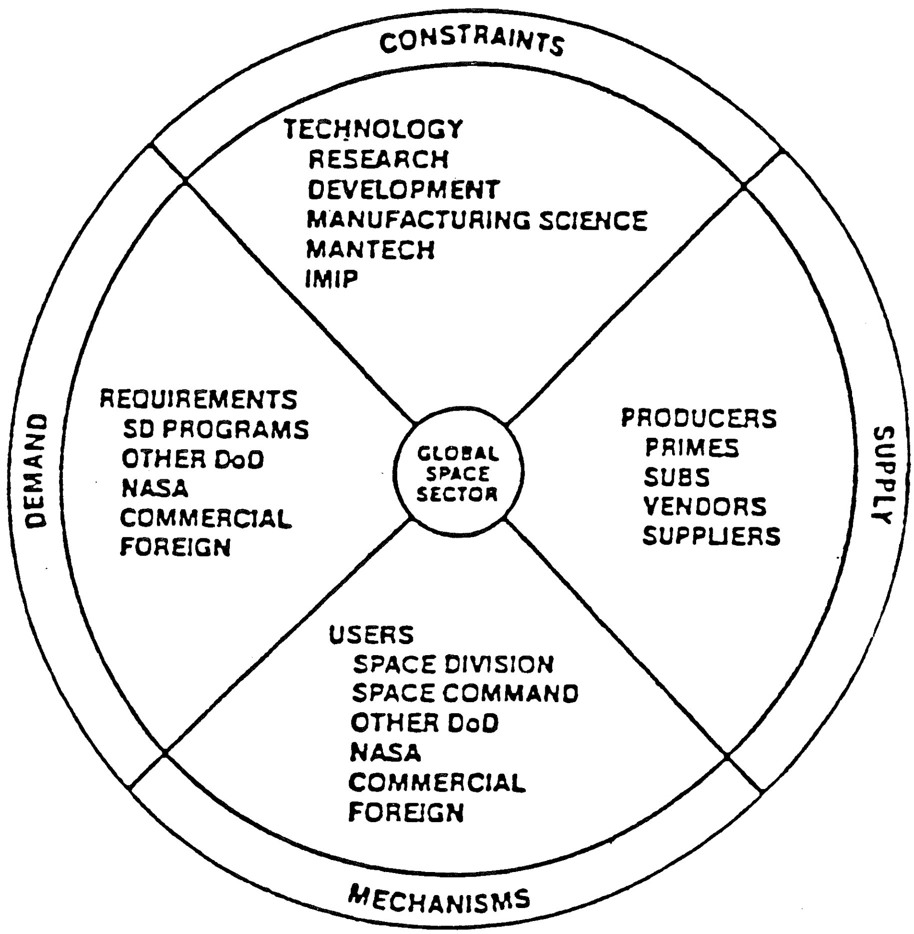


FIGURE 1

Space Sector: Top-Down Structured Analysis Model

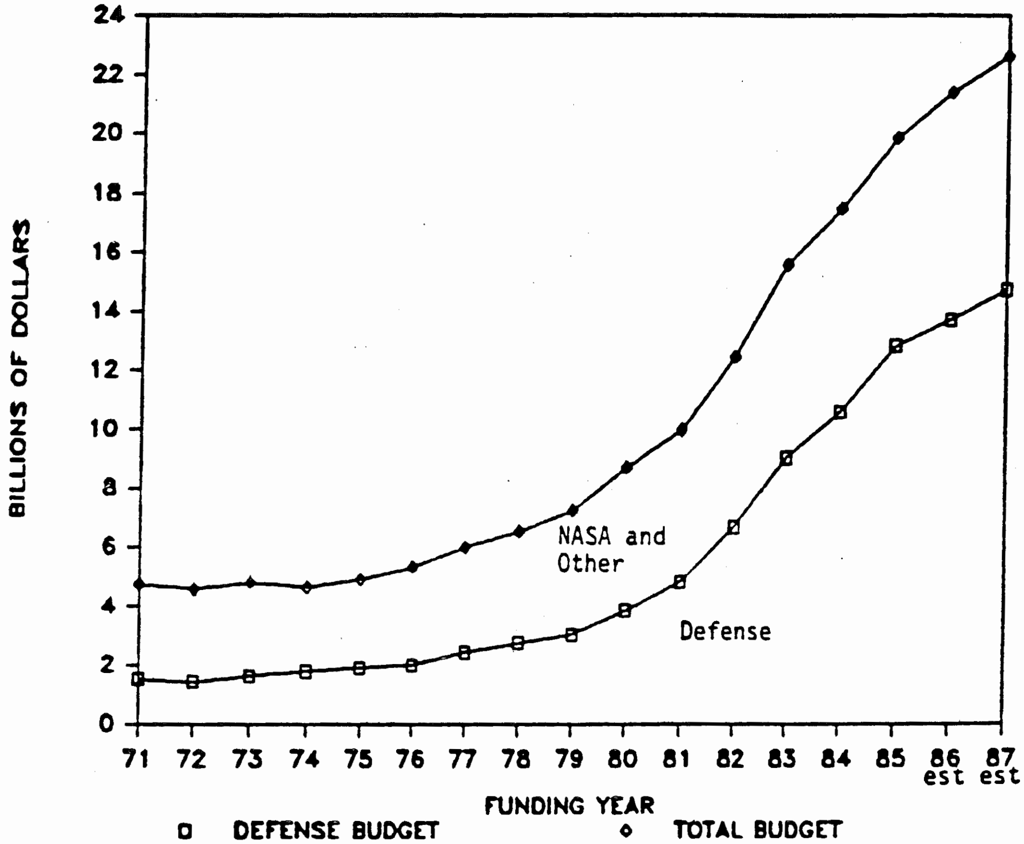


FIGURE 2

U.S. Space Budget

(Source: Department of Commerce)

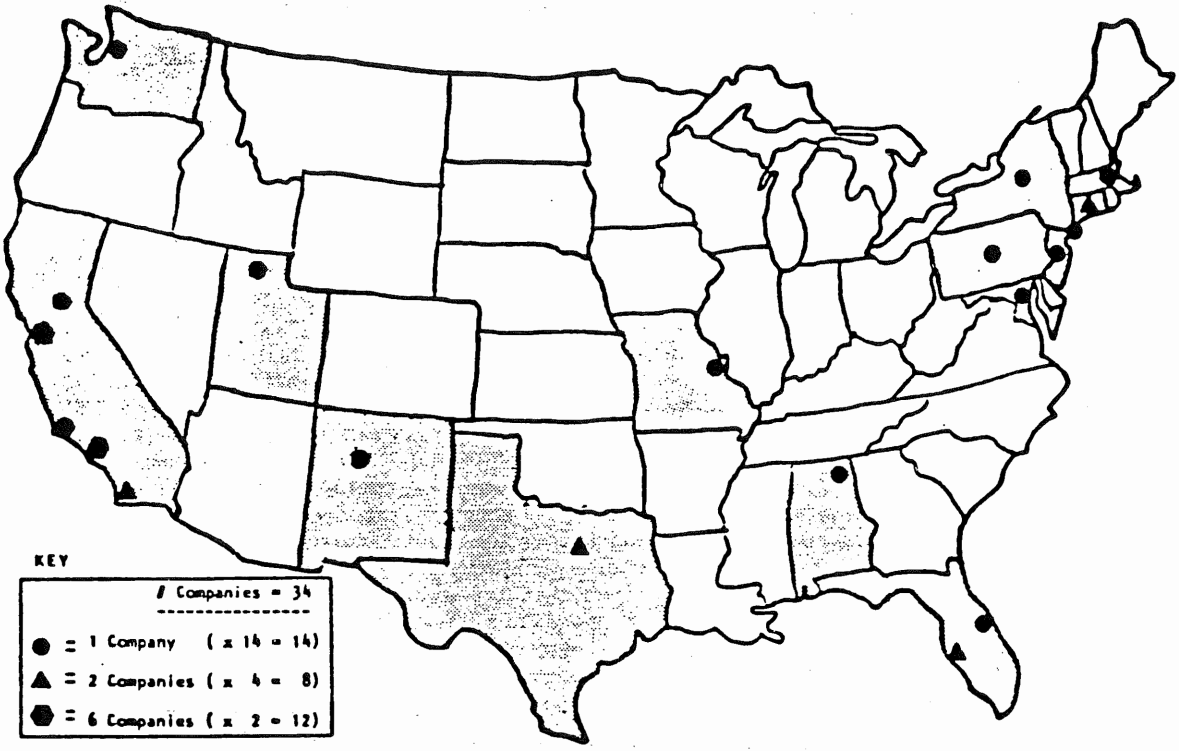
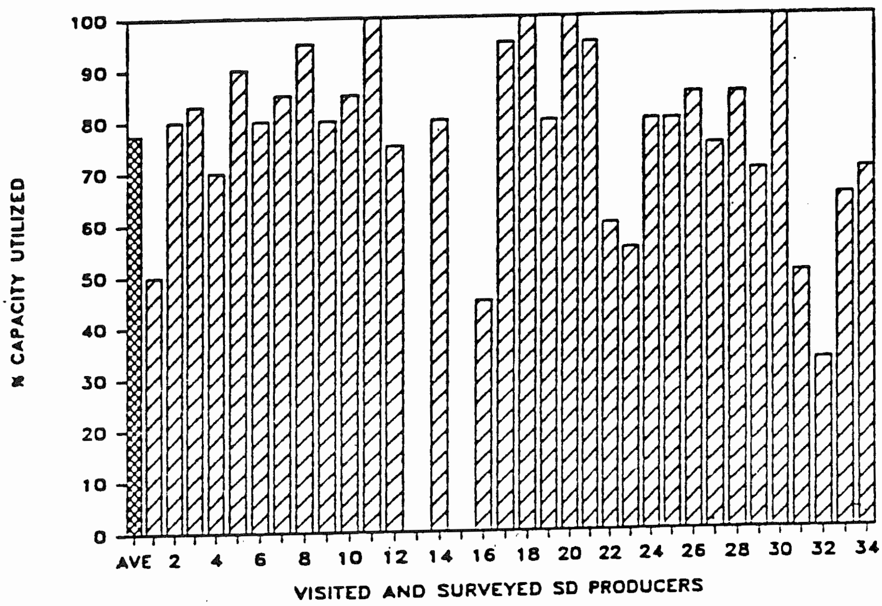


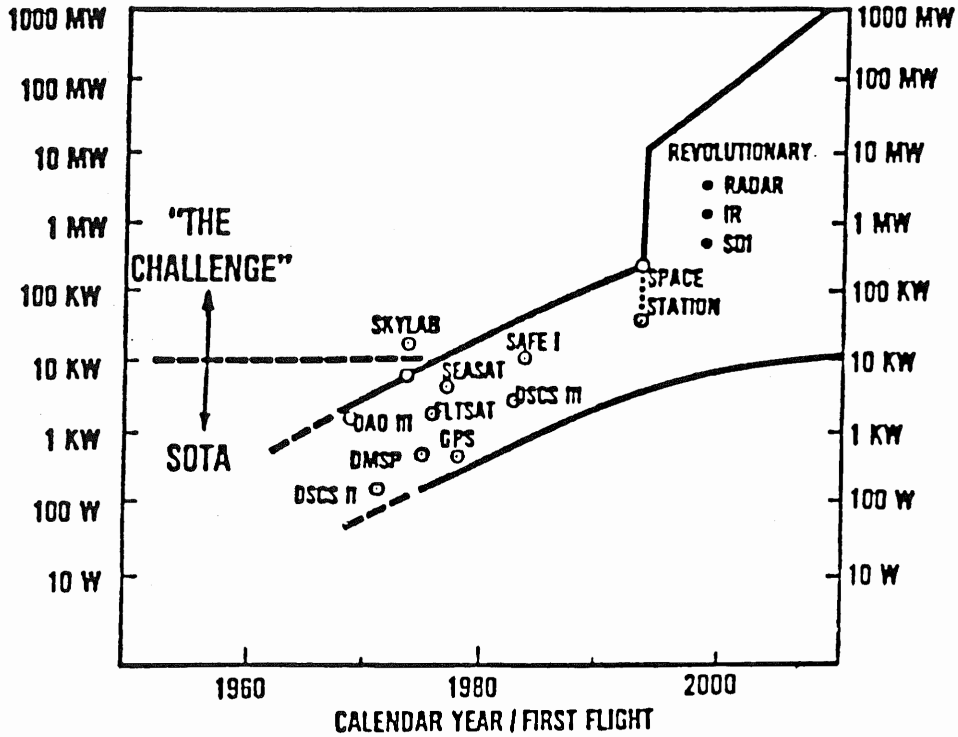
FIGURE 3

Geographic Distribution of Visited/Surveyed SD Producers



Plant Capacity Utilization

FIGURE 4



Electrical Power Trends - Spacecraft

FIGURE 5