CURRENT CAPABILITIES AND FUTURE REQUIREMENTS OF THE AIR FORCE SPACE SURVEILLANCE NETWORK

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Prepared for Presentation at the
Tenth Air University Aerospace Power Symposium
"The Impace of Space on Aerospace Doctrine"
Air War College
Maxwell Air Force Base, Alabama
10-12 March 1986

When the Soviet Union launched Sputnik 1 on 4 October 1957 it was a complete surprise to the US. It was immediately realized that the US had almost no means of detecting, tracking or identifying man-made objects in space. As a result a crash program was initiated to develop and deploy a system of sensors capable of maintaining surveillance on man-made earth orbiting objects.

The first network of spacetrack sensors consisted of the Naval Space Surveillance (NAVSPASUR) system, developed by the Advanced Research Projects Agency and the Baker-Nunn cameras which had been developed by the Smithsonian for the purpose of tracking Vanguard, initially scheduled for launch in 1957. These sensors were combined to form the Space Data and Tracking System (SPADATS) and assigned operationally to NORAD on 7 November 1960, by the Joint Chiefs of Staff.

This system, now known as the Space Surveillance Network (SSN), has expanded rapidly over the past 25 years. The evolution can be divided into three phases. Phase one which began in 1960 lasted until the end of 1963. During this time the existing sensors were supplemented by radars of the Ballistic Missile Early Warning System (BMEWS). These radars, although designed to warn of missile attack, had space surveillance capabilities. By the end of 1963 the SSN was tracking about 400 man-made space objects.

Phase two began in 1964 and lasted through 1971. There were two driving factors during this phase. The first was a need to increase the accuracy of positional data from the SSN to support an anti-satellite (ASAT) system the Air Force had been directed to deploy. The second was the need to determine the reentry and impact points of decaying satellites. This requirement was formalized in the 1967 Outer Space Treaty which made States responsible for damage caused by reentering objects. These new requirements lead to two significant improvements. One was the Space Defense Center (SDC) which was established in the NORAD Cheyenne Mountain Complex in 1966. With the powerful software developed for the SDC, the SDC was providing data to users on almost 1900 orbiting satellites.

The second upgrade during this phase was the addition of the FPS-85 radar at Eglin AFB, Florida. This was the first radar designed exclusively for satellite surveillance. Because of its location it was capable of tracking most satellites, especially low inclination satellites. Many "unknown" satellites were added to the catalog after the FPS-85 became operational.

Phase three which began in 1971 is continuing today. Figure 1 shows the SSN as it now exists. The total number of sensors is 23 with two more PAVE PAWS, phased array radars scheduled to be added, one in Texas, one in Georgia. The 23 sensors function in one of three modes, dedicated, collateral or contributing.

The dedicated sensors are those sensors controlled by NORAD with a primary mission of spacetrack support. The dedicated sensors consist of three optical and two radar systems. The optical sensors are the Baker-Nunn cameras, the Ground-Based Electro-Optical Deep-Space Surveillance (GEODSS) system, and the Maui Optical Tracking and Identification Facility (MOTIF). Radar components of the dedicated network are NAVSPASUR and the Global Positioning System-10 (GPS-10) located at San Miguel, Republic of the Phillipines.

Collateral sensors are those sensors controlled by NORAD, but with a primary mission other then spacetrack, usually missile warning. These sensor types include the FPS-85; Cobra Dane at Shemya, Alaska; three BMEWS at Alaska, Greenland and England; The Perimeter Attack Radar Characterization System (PARCS) in North Dakota; the FPS-79 at Pirinclik, Turkey; and the PAVE PAWS, phased arrays in California and Massachusetts.

Finally, there are the contributing sensors. These sensors are not controlled by NORAD. Instead, they are under contract to provide information when requested. The sensor names and locations include Kaena Point, Hawaii; ALTAIR and ALCOR at the Kwajaln Altoll; Millstone and Haystack in Massachusetts; and Ascension and Antigua Islands.

All of the data obtained from the SSN, over 30,000 observations daily, is fed to the NORAD Space Surveillance Center (NSSC) located in NORADs Cheyenne Mountain Complex. The NSSC mission is to detect, track, identify, and maintain surveillance on all man-made objects in earth orbit. The data received by the NSSC is also used for foreign satellite identification, satellite maneuver processing, collision avoidance, decay/impact prediction, targeting for the US Anti-satellite (ASAT) system, and attack assessment for both the US and Soviet ASAT systems. The NSSC maintains an accurate, current catalog of all space objects and provides this data to numerous cooperating agencies, including the Johnson Space Center, Goddard Space Flight Center, and the Air Force Satellite Control Facility.

FUTURE REQUIREMENTS

Future requirements to support the space surveillance mission will be dependent upon many factors. Perhaps the most significant of these factors are the projected growth of the satellite population, and the need for surveillance on smaller objects. An analysis of these requirements reveals future deficiencies in the SSN capability to support the surveillance mission, especially in the areas of collision avoidance and Deep-Space (DS) satellite (period > 225 min) tracking.

To understand the future requirements of the SSN both the US and the USSR space programs must be examined. It is necessary to appreciate the extent of reliance by both nations militaries to accomplish communications, navigation, reconnaissance, early warning, nuclear explosion detection, weather forecasting and geodetics. Satellites allow for these functions to be accomplished in an economical, technically superior manner.

The Soviet Union normally maintains 110-120 satellites in an operational status. The USSR spent approximately $35 billion on space activities in 1984. The USSR conducted 97 space launches, of which about 70 percent were military related.

The robust nature of the Soviet space program indicates a quest for military superiority. The USSR is developing several new space vehicles. These vehicles include a heavy-lift launch vehicle, equivalent to the Saturn 5; a medium lift vehicle, evidently designed for high launch rates; and a Space Transportation System (STS) which closely resembles the US shuttle.

The US military space program is also expanding. Recognizing the importance of space, the Air Force established the Space Command in 1982. The Navy quickly followed by forming a Naval Space Command. This year a Unified US Space Command was created with a headquarters in Colorado Springs, Colorado. The FY 1984 military space budget was $10.5 billion. A Consolidated Space Operations Center (CSOC) is presently under construction and due to be activated in 1986. From the CSOC, [redacted] STS and military satellite missions will be controlled. In conjunction with the expanding role of the military in space, a launch complex for the STS is being completed at Vandenberg AFB, California. From this location it will be possible to launch the STS on polar orbit missions. Finally, the Strategic Defense Initiative is bringing the military into space. The total cost of this program if pursued to completion could exceed $400 billion.

COLLISION AVOIDANCE

As our dependence on satellites, the STS, and possible future manned platforms becomes even greater, the credibility of collision avoidance data becomes critical. There is substantial evidence that at least two satellite breakups have been the result of collision with space debris.

To date there have been at least 70 known explosions of orbiting objects. At least 11 other breakups resulting in a large number for fragments have also occurred. Almost 50 percent of the objects cataloged originated from these events.

Orbiting debris are beginning to pose an increasingly significant hazard to active payloads. The degree of hazard is dependent upon the payload size, the number of debris fragments operating in the same environment, and the length of time on orbit. The NSSC presently maintains data on over 6000 objects. Most are larger than 10 cm in diameter. The probability of collision, of a payload, with these objects is small. For the STS it is approximately 4x10-6 for a seven day flight.

There is a second, more significant threat to spacecraft. This threat is from the untracked satellite population. The number of these objects must be much higher than that of the trackable objects. Based upon the number of objects 4 cm and larger which are newly detected just prior to decay, the probabilities of collision are increased substantially. When these smaller, uncataloged objects are taken into account the estimate for collision of a large satellite in one year is 0.016 in an 850 km orbit (figure 2). The danger is substantial from even smaller particles. Studies have shown that particles as small as 1 cm could, in a collision, penetrate a 5 cm thickness of aluminum.

Perhaps that most important aspect of the debris problem is its self-propigating nature. Hundreds of objects can result from a single collision. Each of these new objects, in turn, increases the probabilities of other collisions. It is predicted that the number of objects tracked will increase by three the eight times over the next 20 years. Figure 3 shows that by the 1990s the chances of orbital collision will be significant.

Long-term solutions to the problem of space debris have not yet been formed. For the near-term, however, the credibility of collision avoidance information for operational payloads must be improved. This will necessitate improvements to the SSN. The capability to track smaller objects must be added. To support these new objects more powerful computing systems are necessary at the NSSC. Only with this new data available will collision avoidance for payloads remain viable.

DEEP-SPACE SURVEILLANCE

A second critical area of concern also exists for the SSN. This is the capability to support the future DS surveillance requirements. The DS satellite population, satellites with periods great than 225 mins, is expected to grow dramatically, increasing by 200 percent in the next 15 years (Figure 4).

There are presently nine sensors tasked to maintain observational data on these satellites. These sensors are the FPS-85; the FPS-79 at Pirinclik, Turkey; Millstone; ALTAIR; GEODSS; and the Baker-Nunn cameras. The FPS-85, which provides 40 percent of the total number of DS observations, and the Baker-Nunn cameras are scheduled to be closed before 1990. There are three operational GEODSS located in New Mexico, Hawaii, and Korea. Two additional GEODSS should be operational in 1987. When capabilities of the GEODSS, the FPS-79, Millstone and ALCOR are examined, it is evident that the DS surveillance network can support only a finite number of objects per day. Figure 5 shows a hypothetical tasking-response curve for a GEODSS site. Due to equipment and weather limitations a given site can support only a finite number of satellites tasked before the response curve flattens. A radar site shows similiar limitations due to the time require to obtain observations on DS satellites. If the DS population continues to grow at the expected rate, this finite number will eventually be exceeded perhaps before additional operational sensors are available.

SOLUTIONS

The problem of tracking, small objects will be especially acute after closure of the FPS-85. The FPS-85 and PARCS with augmentation from NAVSPASUR provide most data on smaller objects.

The two new PAVE PAWS will probably not alleviate the problem. Because of software limitations associated with this system, which was primarily designed as a missile warning radar, correcting the inherent spacetrack problems is considered unacceptable.

Consideration should be given to the deployment of an additional sensor to alleviate the debris problem, A C-Band radar located with Southeast PAVE PAWS would be of great assistance because of the accuracy of the tracking data. The addition of a PACBAR III at Guam or Saipan would help, especially with low inclination objects.

The best near-earth solution would be to retain the FPS-85 in a solely spacetrack role. Perhaps as a contract sensor. If this should occur the problems of equipment and maintenance for this old system should be addressed. Also, as a near-earth solution one of the two new PAVE PAWS could be extensively modified to support satellite surveillance. This would create a unique system however with its inherent problems. Finally, the NSSC must be upgraded to accomodate the increased number of observations a more powerful SSN would provide.

Probably the most viable alternative to the DS problem is accelerated development of the Space Based Surveillance System (SBSS). A NASA symposium on debris concluded that a SBSS would be capable of detecting particles as small as 1mm. Most advantages of all it would not be subject to the weather constraints inherent in the GEODSS system. Once SBSS is deployed the DS surveillance problem should be solved.

Military satellites are crucial to the security of the US. In many cases the terrestrial equivalent of the services these satellite provide has atrophied or no longer exists. The SSN must be improved to allow for the protection and defense of our national space assets. The cornerstone is complete and accurate space surveillance.

FIGURE 1

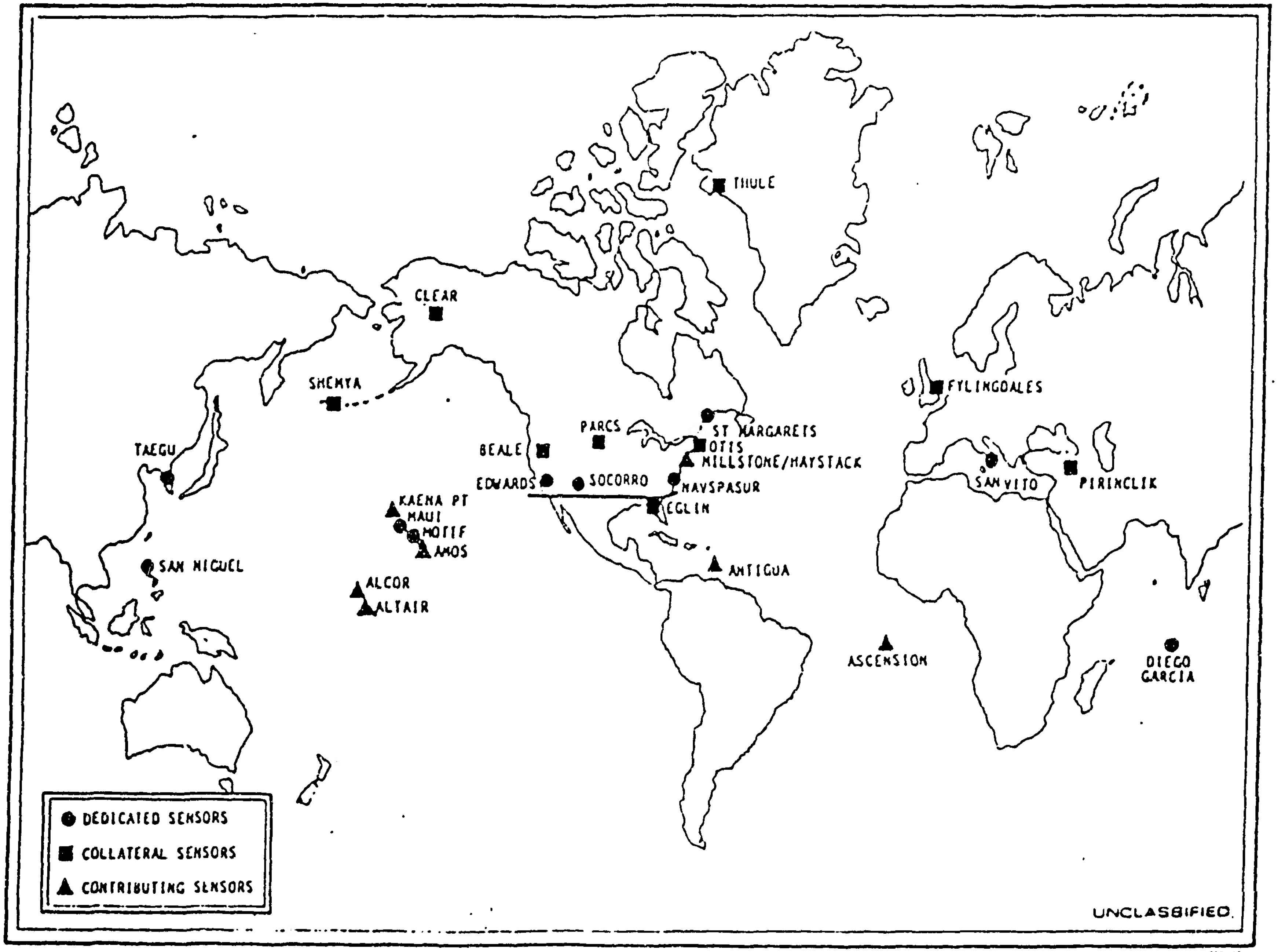
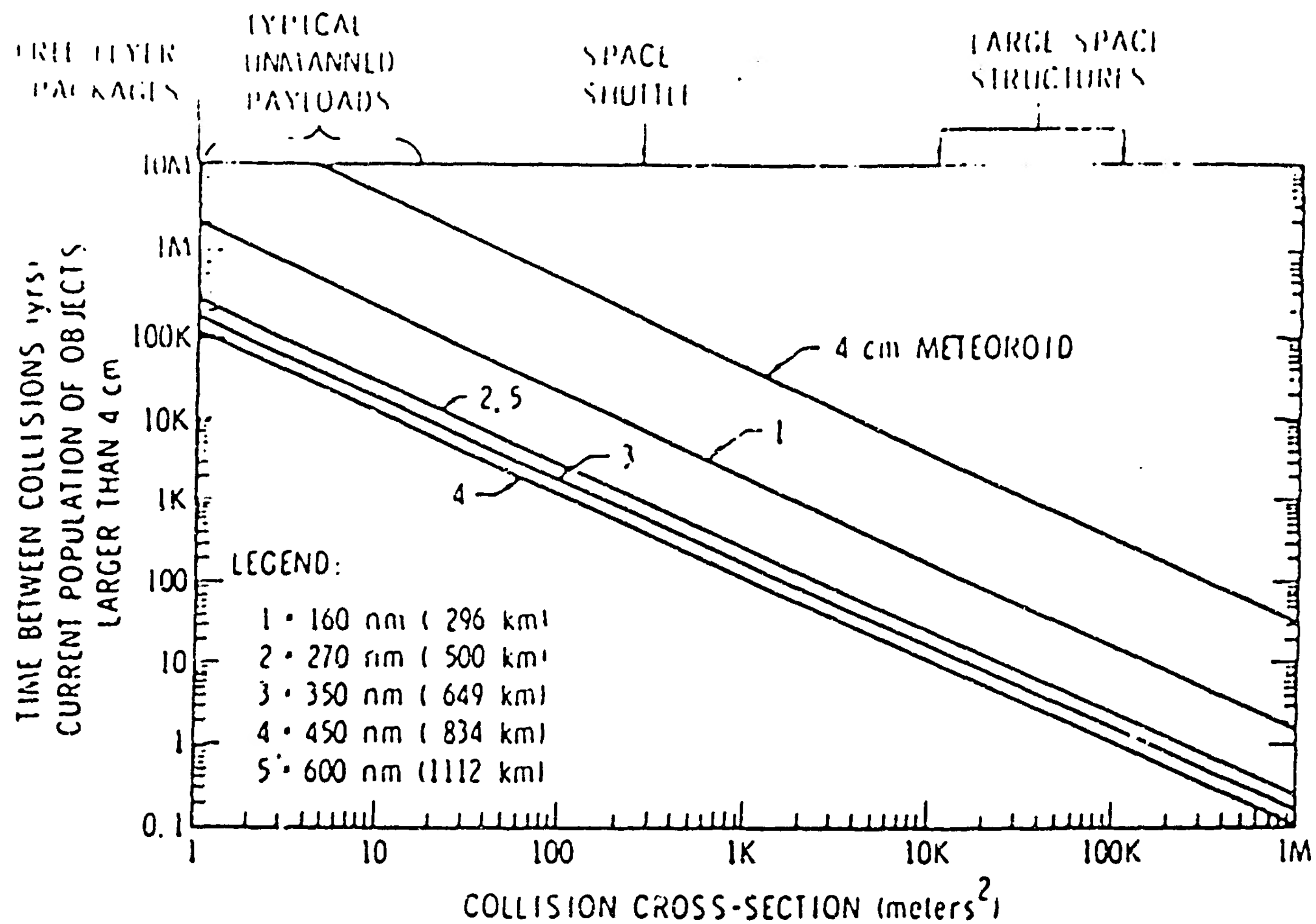

THULE
CLEAR
SHEMYA
FYLINGDALES
PARCS
ST MARGARETS
OTIS
MILLSTONE/HAYSTACK
BEALE
TAEGU
EDWARDS
SOCORRO
NAVSPASUR
SAN VITO
PIRINCLIK
EGLIN
KAENA PT
MAUI
MOTIF
AMOS
SAN MIGUEL
ANTIGUA
ALCOR
ALTAIR
ASCENSION
DIEGO GARCIA
DEDICATED SENSORS
COLLATERAL SENSORS
CONTRIBUTING SENSORS
UNCLASSIFIED

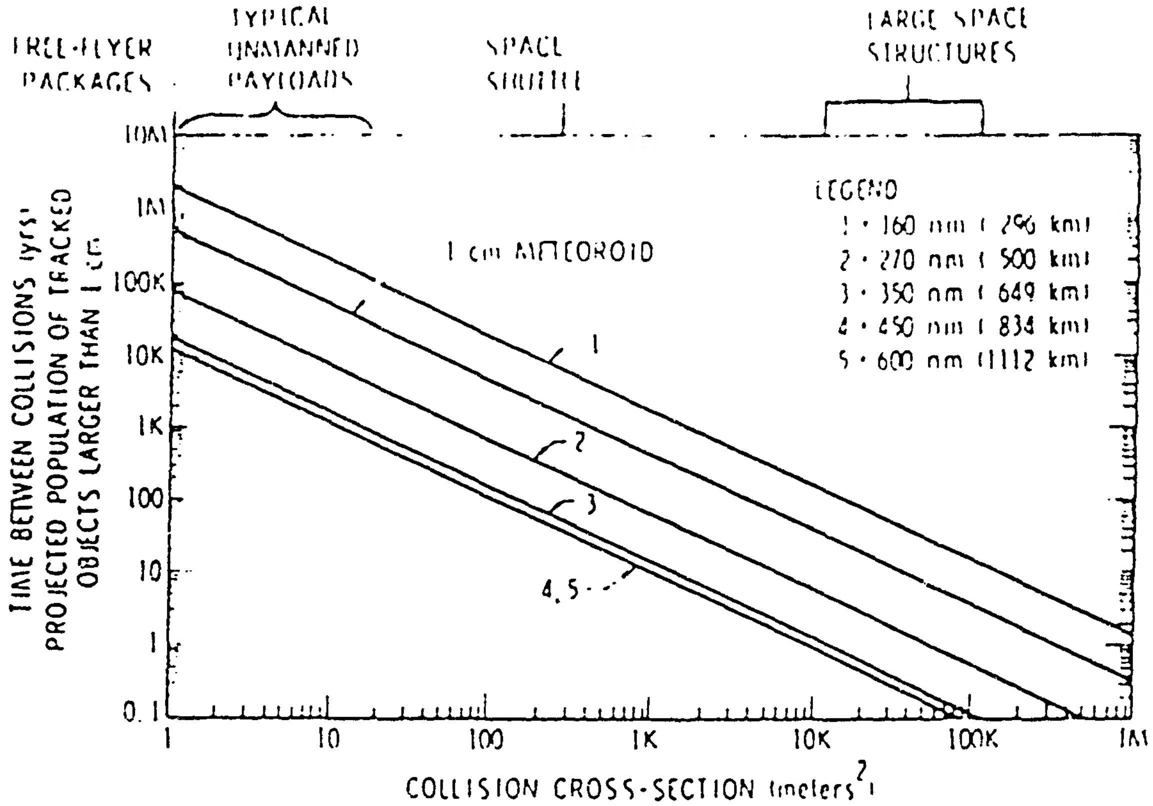
FIGURE 2



Source: Kessler, D. J., "Sources of Orbital Debris and the Projected Environment for Future Spacecraft," Presented at AIAA International Meeting and Technology Display, AIAA-80-0855, 6-8 May 1980

Time Between Collisions as a Function of Collision Cross-Section and Altitude for the Current Background Debris Population Larger than 4 cm

FIGURE 3



Source: Based on Data From: Kessler, D. J. and B. G. Cour-Palais, "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt," J. Geophysical Res., Vol. 83, No. A6, 1 June 1978, and Kessler, D. J., "Sources of Orbital Debris and the Projected Environment for Future Spacecraft," Presented at AIAA International Meeting and Technology Display, AIAA-80-0855, 6-8 May 1980

Time Between Collisions as a Function of Collision Cross-Section and Altitude for the Projected Debris Populations Larger than 1 cm in the Year 1995.

FIGURE 4

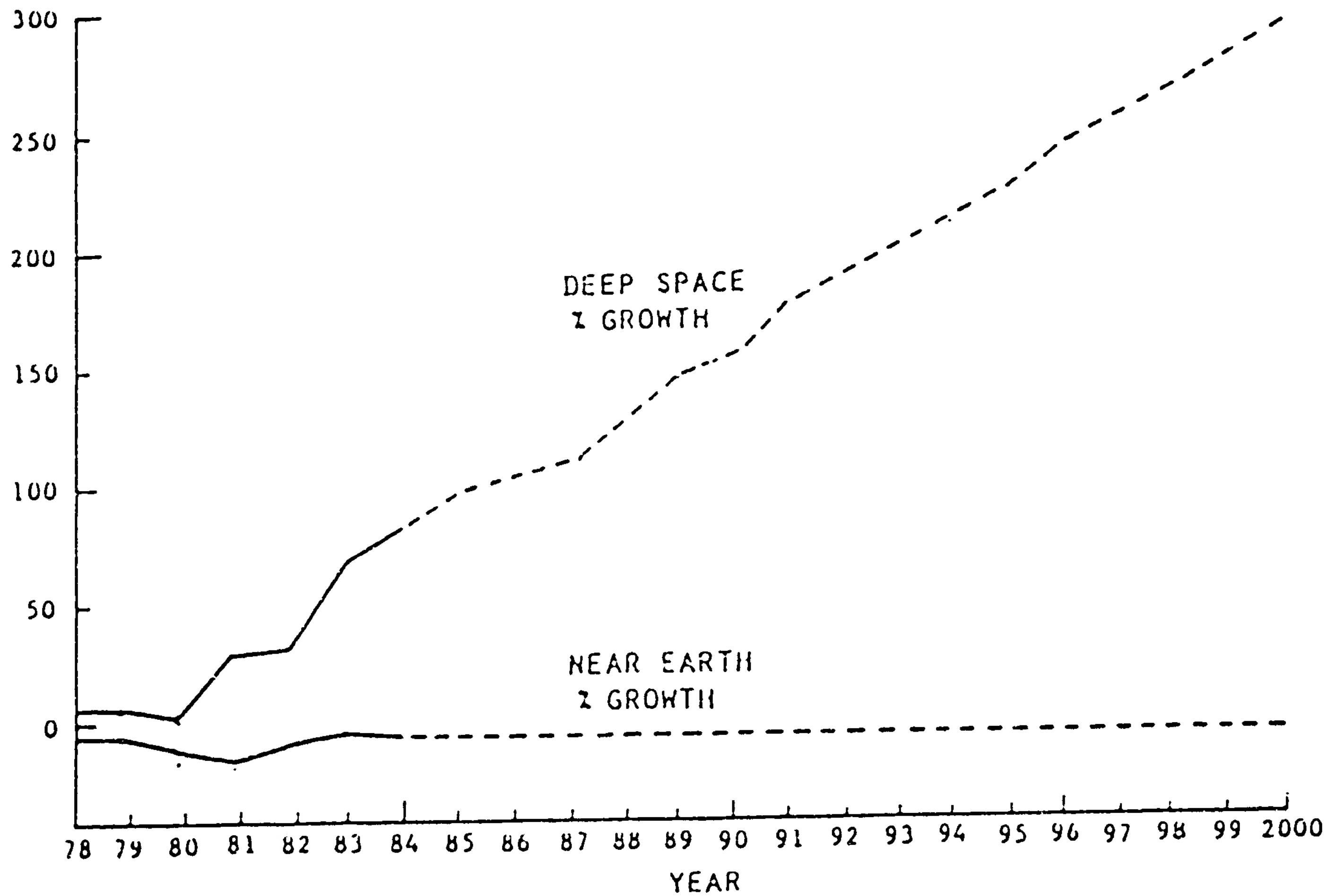
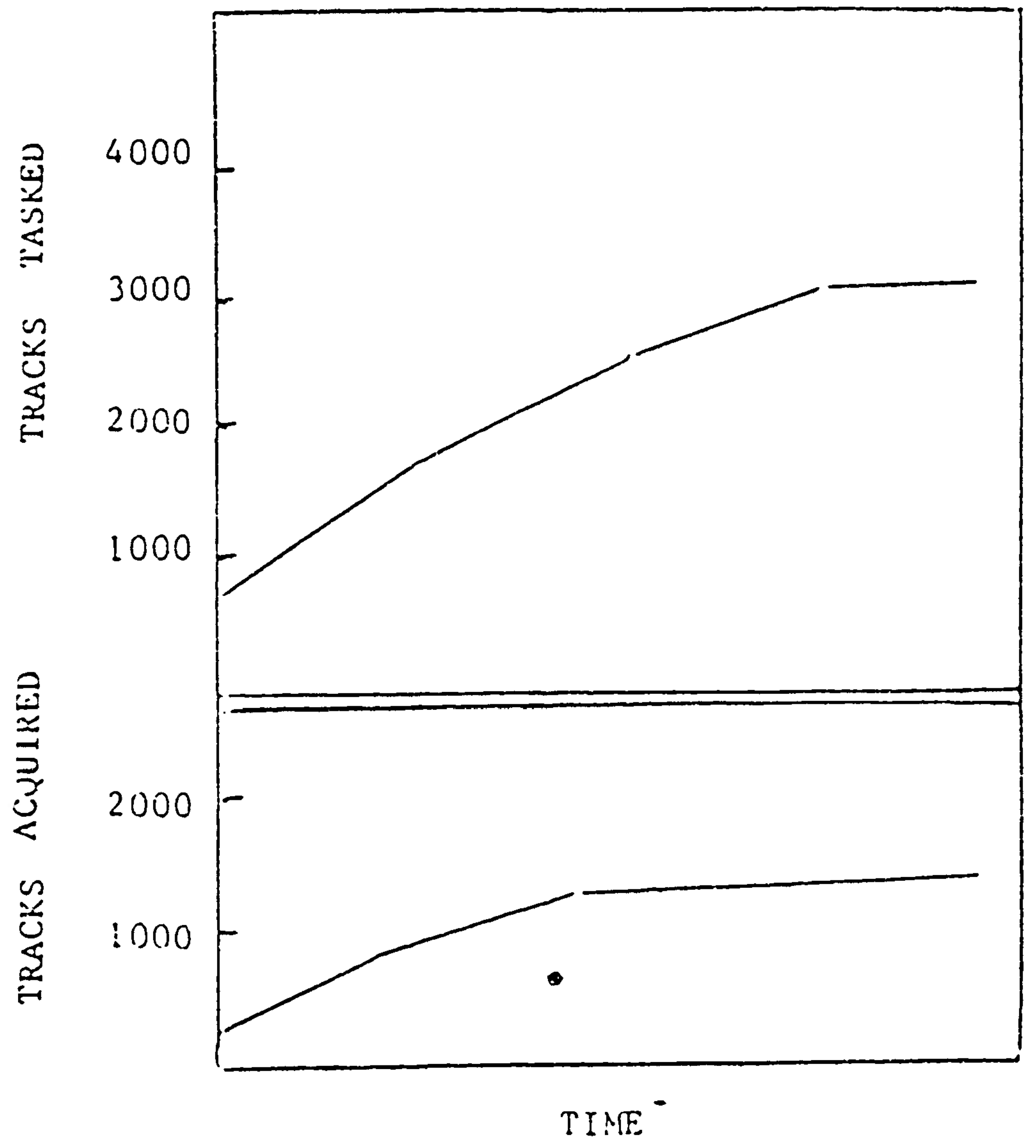

300
250
200
150
100
50
0
DEEP SPACE
% GROWTH
NEAR EARTH
% GROWTH
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 2000
YEAR

FIGURE 5

DEEP-SPACE SENSOR TASKING RESPONSE



ENVIRONMENTAL INTELLIGENCE