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GROWTH IN THE NUMBER OF SSN TRACKED ORBITAL OBJECTS

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ABSTRACT

The number of objects in earth orbit tracked by the US Space Surveillance Network (SSN) has experienced unprecedented growth since March, 2003. Approximately 2000 orbiting objects have been added to the "Analyst list" of tracked objects. This growth is primarily due to the resumption of full power/full time operation of the AN/FPS-108 Cobra Dane radar located on Shemya Island, AK. Cobra Dane is an L-band (23-cm wavelength) phased array radar which first became operational in 1977. Cobra Dane was a "Collateral Sensor" in the SSN until 1994 when its communication link with the Space Control Center (SCC) was closed. NASA and the Air Force conducted tests in 1999 using Cobra Dane to detect and track small debris. These tests confirmed that the radar was capable of detecting and maintaining orbits on objects as small as 5-cm diameter. Subsequently, Cobra Dane was reconnected to the SSN and resumed full power/full time space surveillance operations on March 4, 2003. This paper will examine the new data and its implications to the understanding of the orbital debris environment and orbital safety.

Introduction

The US Space Surveillance Network provides collision avoidance screening for manned spaceflight, including the International Space Station, against all tracked orbiting objects. For many years, the nominal sensitivity of the network for low earth orbit objects was 10 cm. However, spacecraft are vulnerable to severe or catastrophic damage from collisions with debris much smaller. Shielding techniques can protect spacecraft from the smallest debris pieces, but there is a large gap between what can be shielded against and 10 cm. In recent years, the US has begun making efforts to improve the sensitivity of the SSN.

Catalog Growth

Tracked objects are maintained in two lists. Objects in the official catalog are given, along with their international designator, a sequential number starting with satellite number 1, the Sputnik 1 rocket body. Currently there are over 28,000 objects in the regular catalog including close to 19,000 objects which have reentered the earth's atmosphere or have left earth orbit. Objects must meet certain criteria to be included in the catalog. One criteria is that the object must be associated with its original launch. There are many objects which are tracked by the SSN which have not yet been identified by mission. This includes many small debris fragments. These objects are maintained in an "Analyst" list using numbers from 80,000 to 89,999. Objects in the analyst catalog are often transient in that they are discovered, tracked, identified, and then transferred to the regular catalog. The number in the analyst catalog is then reused. Many objects in the analyst list reenter or are administratively removed prior to them entering the regular catalog. Objects in both the regular and analyst catalogs are screened for collision avoidance with manned space flights.

Breakups

Figure 1 shows the growth in the regular and analyst catalogs of on-orbit objects since 1990. Sharp jumps in the regular catalog are usually associated with on-orbit fragmentation events. The largest single jump shown comes from the fragmentation of object 1994-029B, the Pegasus HAPS (Hydrazine Auxiliary Propulsion System) stage from the STEP II launch which broke up in June, 1996. Over 700 objects were eventually cataloged from this event[1]. The transient nature of the analyst list can be seen in the rapid rise in number of analyst satellites tracked immediately after the event and the subsequent reduction a few months later as the objects were transferred to the regular catalog. Other breakups which produced more than 100 (regular) cataloged fragments and which show visible sharp jumps in Figure 1 are listed in Table 1.

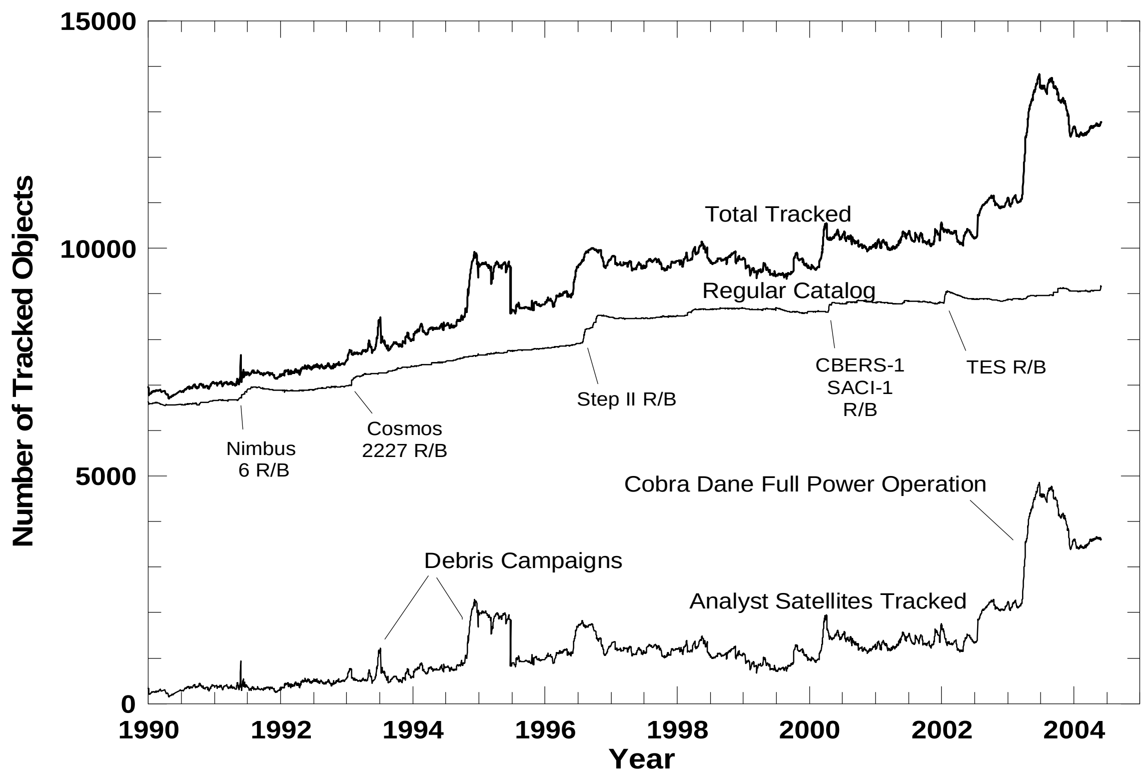

Fig. 1: Number of orbiting objects tracked by the SSN.

Common Name	International Designator	Event Date	No. of Catalogued Objects
Nimbus 6 R/B	1975-052B	1-May-91	268
Cosmos 2227 R/B	1992-093B	26-Dec-92	225
Step II R/B	1994-029B	3-Jun-96	709
CBERS-1/SACI-1 R/B	1999-057C	11-Mar-00	316
TES R/B	2001-049B	19-Dec-01	326

Table 1. Fragmentation events since 1990 with >100 cataloged objects.

Debris Campaigns

There are several sharp increases in the analyst satellites list which are not associated with fragmentation events. In 1993 and 1994, the Air Force conducted two debris campaigns using existing sensors in the SSN. The 1994 campaign was conducted from October 11 – November 8, 1994[2]. The campaign was conducted in two phases. The first phase concentrated on detecting new objects while the second phase emphasized follow up tracking (although many additional objects were detected during Phase 2). Over 1100 element sets were added to the analyst list during the campaign although 350 of these were later identified as duplicates or as previously known objects. This left about 800 unique new objects tracked during the campaign. The campaign required special, manpower intensive, operating procedures to maintain the orbits of these objects. For instance, more than 40% of the new objects detected in the campaign were in high eccentricity orbits (> 0.1). Orbits for these objects are more difficult to maintain than circular orbits because there are fewer sensor viewing opportunities. Additionally, the campaign specifically looked for low inclination orbits where normal SSN coverage is sparse. When the campaign ended and the SSN returned to its normal operational procedures, the large majority of the 800 new objects were lost. Hence, about six months after the end of the campaign, most of the campaign objects were administratively removed from the analyst list of tracked objects[3].

Cobra Dane

The largest rapid increase in the number of tracked objects occurs starting in March, 2003. This timing correlates to the resumption of full power/full time operation of the AN/FPS-108 Cobra Dane radar located on Shemya Island, AK (52.7° N latitude, 174.1° E longitude). In contrast to the 1994 debris campaign where the gains were the result of temporary operating procedures, the addition of Cobra Dane to the SSN will provide long-term improvement to the total tracked population.

Cobra Dane (Figure 2) is an L-band (23-cm wavelength) phased array radar which first became operational in 1977. The radar generates approximately 15.4 MW of peak RF power (0.92 MW average) from 96 Traveling Wave Tube (TWT) amplifiers arranged in 12 groups of 8. This power is radiated through 15,360 active array elements. Cobra Dane actually was part of the SSN, as a "Collateral Sensor," until 1994, but operational procedures limited the size object it was able to detect and report to the Space Surveillance Center (SSC) which processes observations from the entire SSN. In 1994, the communication link from the radar to the SSC was closed and Cobra Dane was limited to its primary intelligence role.

Fig. 2: AN/FPS-108 Cobra Dane L-band phased array radar.

In an effort to explore methods of improving the sensitivity of the SSN, NASA and the Air Force conducted tests in August and September, 1999 using Cobra Dane to detect and track small debris[4]. These tests paid special attention to the region below 600 km altitude utilizing a broad "debris fence" and operating the radar at full power. Again, special operating procedures were employed to create element sets from the Cobra Dane radar since the normal communications link between the radar and the SSC no longer existed. Despite this fact, element sets for over 560 objects were created, of which more than 500 could be tracked on a regular basis. This test confirmed that the radar was capable of detecting and maintaining orbits on objects as small as 5-cm diameter. Nearly one-fourth of the routinely tracked objects crossed human space flight altitudes.

Subsequently, Cobra Dane was used in international debris measurement campaigns coordinated by the Inter–Agency Space Debris Coordination Committee (IADC). These campaigns confirmed the capacity and sensitivity demonstrated during the August-September, 1999 tests.

The communications link between Cobra Dane and the SSC was restored in October 1999. However, the radar was only operating at ¼ power and was not specifically tasked by the SSC to search for debris. Full power, full time operation began at Cobra Dane on March 4, 2003. Full power operation allowed the radar to allocate radar resources not only to its primary mission, but also to a debris search fence. On January 1, 2003, the SSN was routinely tracking ~11,000 objects including over 2000 objects in the analyst list. The number peaked in late June, 2003 with over 13,500 total objects including close to 5000 analyst satellites. Many of these objects are below the sensitivity of other sensors and can only be tracked by Cobra Dane. The additional radar resources needed to maintain the orbits of these objects has slowed the addition of new objects to the analyst list.

With over 5000 objects in the analyst list, new procedures were implemented to purge objects which had not been tracked for a specified time period. This procedure was applied to all objects in the analyst catalog. When implemented in late 2003, the number of analyst satellite orbits maintained dropped by over 1000. By the end of May, 2004 the total number of tracked objects was again approaching 13,000.

Satellite Distributions

In order to assess the effects of the increased SSN sensitivity, catalogs (including analyst satellites) from three dates were chosen. The first data set was from April, 2002, prior to full power operation of Cobra Dane. The second dataset was from September, 2003, near the peak in the satellite count. And finally, the most recent catalog available at the time of this writing, August, 2004.

Figure 3, shows the distribution in inclination for the three catalogs over the inclination range visible to Cobra Dane. Because of the high latitude location of the radar and its orientation, Cobra Dane can only detect objects with inclinations from 55° - 125°. Also, only objects with perigee altitudes below 6000 km are plotted. Figures 4 and 5 show the eccentricity and perigee altitude distributions using the same limitations and datasets shown in Figure 3.

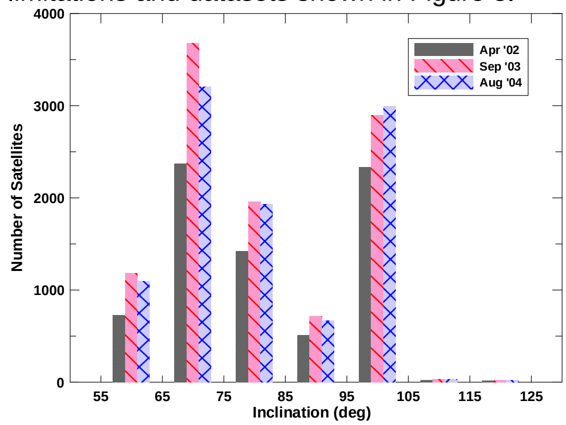

Fig. 3: Inclination distribution.

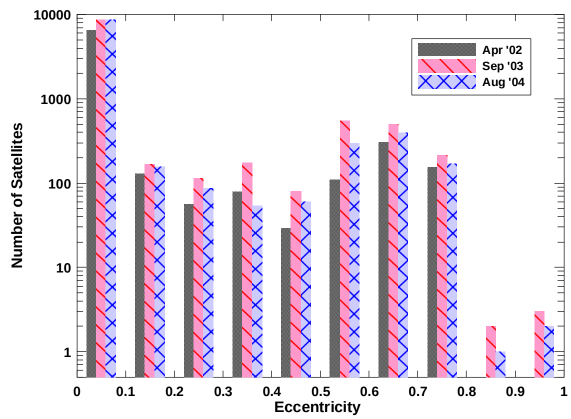

Fig. 4: Eccentricity distribution.

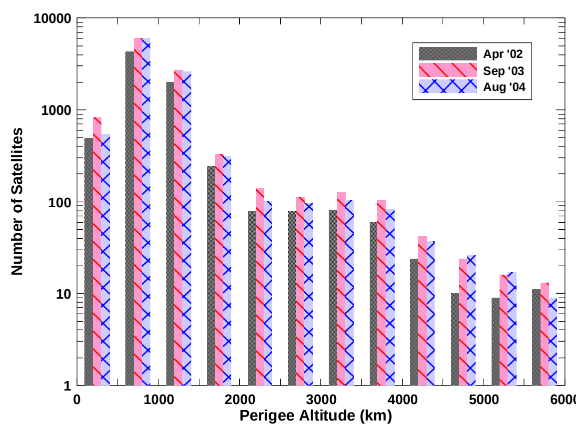

Fig. 5: Perigee altitude distribution.

One area noted in examination of the early catalog and the peak catalog is an increase in the population near 65° at mean altitudes near 9000 km. A Gabbard diagram (Figure 6) of these objects shows perigees near 300-500 km altitude with apogees in the 15,000-20,000 km range. A number of known breakups of Proton-Block DM Ullage motors have occurred with these orbital parameters. However, very few objects were cataloged from these breakups. Cobra Dane is currently maintaining orbits on about 100 of these objects.

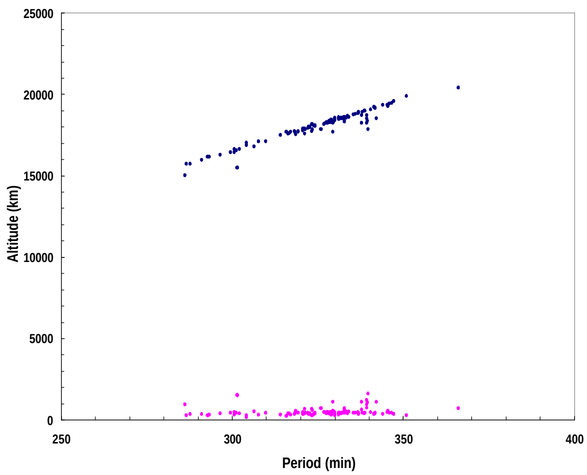

Fig. 6: Gabbard diagram of “analyst” satellites with orbital inclinations between 60° - 70° and with mean altitudes between 8,000 – 11,000 km.

Conclusions

The addition of the Cobra Dane radar to the SSN has increased the number of tracked orbiting objects by over 2000. Many of these objects are smaller than the 10-cm diameter nominal pre-Cobra Dane sensitivity of the SSN. Although this does marginally improve the safety of manned spaceflight by increasing the number of objects for which collision avoidance screening is performed, it does not fully close the gap between what can be shielded against and what can be tracked and avoided. Further, because of Cobra Dane’s high latitude location, not all inclinations are covered to Cobra Dane’s nominal sensitivity of 5-cm. Additional assets are needed to further improve the sensitivity of the SSN and to increase the number of orbiting objects tracked.

References

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