Visit the NASA Orbital Debris Program Office Website

at

www.orbitaldebris. jsc.nasa.gov

Modeling and Monitoring the Decay of NASA Satellites

D. WHITLOCK

In February 2002, NASA Headquarters directed that greater attention be given to the reentry of orbiting NASA spacecraft and rocket bodies. NASA Policy Directive 8710.3B[1] charges the Orbital Debris Program Office, in support of the Director of the NASA Johnson Space Center, to maintain a list of predicted reentry dates for all NASA spacecraft and their associated orbital stages and to advise appropriate NASA personnel during the final stages of orbital decay. A process, which begins before launch and which includes cooperation with the U.S. Space Surveillance Network (SSN), has been developed to model and to monitor the orbital decay of NASA space objects. NASA's PROP3D orbit propagator is the principal tool used to predict orbital lifetimes in the period prior to 60 days before reentry. PROP3D accounts for complex factors such as the Sun and Moon's gravitational effects, solar activity, J_2/J_4 effects, atmospheric drag, and solar radiation pressure. One of the most difficult and often most important parameters to estimate accurately is an object's ballistic coefficient. In the final 60 days before reentry, emphasis is placed on the more accurate numerical tools of the SSN. During a satellite's final four days in space, specific reentry time and location predictions are made by the SSN and distributed by the NASA Orbital Debris Program Office to relevant NASA offices.

PROP3D uses an initial element set and ballistic coefficient as primary inputs and then propagates these orbital elements forward (in one-day steps) until object reentry (perigee altitude less than 95 km). The object's area-to-mass ratio (A/M) directly affects the ballistic coefficient and may either be defined by the user or estimated using software developed specifically for this task by NASA. This software uses a curve-fit of the semi-major axis history (using a least squares filter) to derive an observed A/M for any Earth-orbiting object.

The assessment of object decay begins during the design phase for each NASA sponsored project. NSS 1740.14[2] requires every project to provide a preliminary Orbital Debris Assessment report at the time of the preliminary design review, with a final report submitted no later than 45 days prior to the critical design review. It is during this assessment that the project is required to demonstrate that the spacecraft, rocket body, and any mission-related debris stay in orbit no longer than 25 years after completion of mission. Each project also provides an A/M for each object for the purpose of determining its lifetime. NASA provides Debris Assessment Software to the project for assistance in lifetime calculation.

After launch, a reentry date can be estimated using the latest available ephemeris from the SSN with PROP3D and an A/M taken from the assessment report or from an internal database. Once multiple element sets are available after launch, the A/M
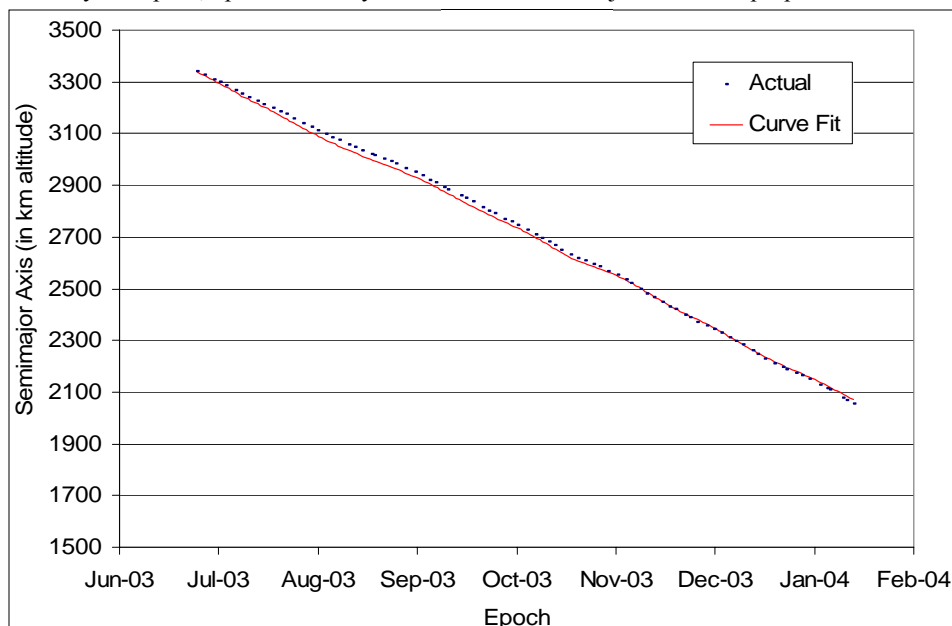

Figure 1. Least squares curve-fit of semi-major axis for the MER-B, Delta 2 rocket body (27851, estimated A/M = 9.29E-3 m^2/kg).

Decay of NASA Satellites

(and consequently the ballistic coefficient) can be better estimated. Twice per year, the Orbital Debris Program Office estimates reentry for all of the near 200 NASA space objects. Figure 1 displays a semi-major axis curve-fit for a Delta 2 rocket body associated with the Mars Exploration Rover (B) launched in July 2003. For this example, the curve-fit included ephemeris data through 30 January 2003. The curve-fit estimates an A/M of 0.00929 m^2/kg. Propagating the last ephemeredes forward (using this A/M) a reentry prediction of 28 July 2004 is shown in Figure 2. Actual reentry was 26 July 2004.

For some mission profiles, the rocket body may reenter within 60 days of launch. While PROP3D can assist in determining whether or not this is the case, other numerical tools from the SSN are used to determine the most accurate reentry epoch for all objects within 60 days of reentry. These tools are also used during the final four days, when the SSN provides NASA a predicted reentry epoch and location based upon the latest observations. These predictions are continuously updated until final atmospheric reentry.
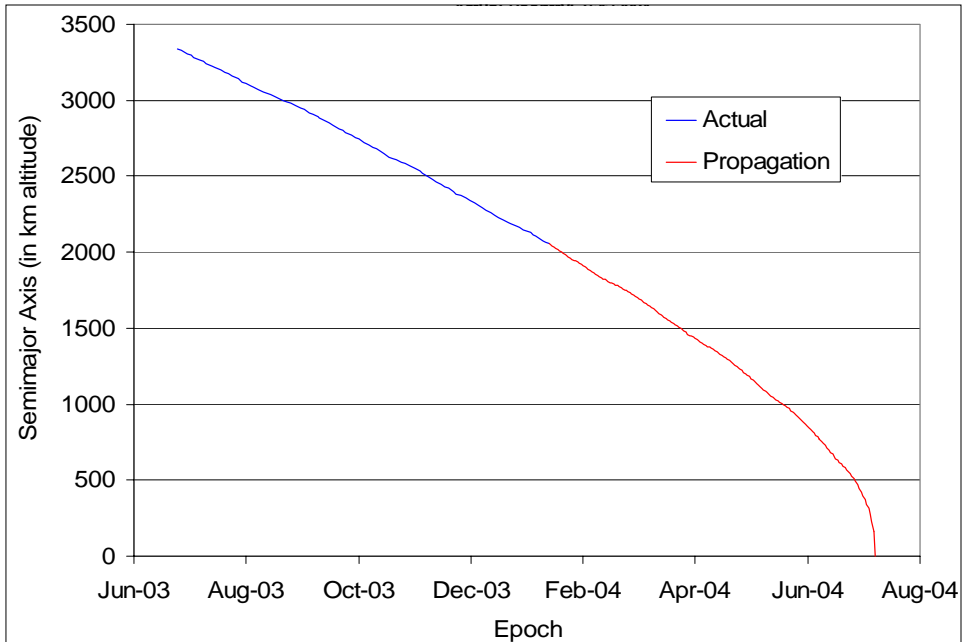

Figure 2. Propagation of semi-major axis for MER-B, Delta 2 rocket body (27851). Predicted reentry: 7/28/2004, Actual reentry: 7/26/2004.

1. *Policy to Limit Orbital Debris Generation*, NASA Program Directive 8710.3B, 29 May 1997, revised 28 April 2004.

2. *Guidelines and Assessment Procedures for Limiting Orbital Debris*, NASA Safety Standard 1740.14, 1 August 1995. ♦

Recent Satellite Breakups

Another Proton Block DM auxiliary motor experienced a fragmentation on 29 October 2004. The auxiliary motor was one of two used for the Cosmos 2392 mission which was launched in 2002. The International Designator of the parent object is 2002-37F, with corresponding U.S. Satellite Number 27475. This is the 31st event for this class, and the second such event in 2004. The 55 kg motor was in an orbit of approximately 235 km by 840 km, with an inclination of 63.6°. No debris were officially cataloged from the breakup, although more than 60 fragments were detected by the U.S. Space Surveillance Network. This was the first auxiliary motor launched after 1996 to have experienced a fragmentation.

There have been three recent fragmentation events during the final stages of atmospheric decay from highly elliptical orbits. In mid-August, the Cosmos 1030 spacecraft (1978-83A, U.S. Satellite Number 11015) experienced a breakup when its perigee decayed below 100 km. There was one piece of cataloged debris (U.S. Satellite Number 28401) from this event. Both the parent object and the cataloged debris object decayed within a week of the breakup. A second aerody-

namic event occurred in early October, when the Molniya 1-82 (1991-53A, U.S. Satellite Number 21630) spacecraft experienced a similar fragmentation. At the time of the event, the perigee of the satellite was approximately 80 km. The parent and all debris decayed within days, and there were no cataloged debris as a result of this event.

Finally, on 11 December an Atlas V R/B (2003-20B, U.S. Satellite Number 27812) experienced an aerodynamic breakup during final atmospheric reentry. Perigee at the time of the event was near 90 km with a very high apogee, over 10,000 km. Although no piece count was available, any debris would have been very short lived. ♦

NASA Orbital Debris Program Office Hosting IADC Website

The NASA Orbital Debris Program Office became the host sponsor of the Inter-Agency Space Debris Coordination Committee (IADC) website, www.iadc-online.org, in December 2004.

The IADC is an international government-level forum for the worldwide coordination of activities related to the issues of man-made and natural debris in space. The members of IADC are the space agencies from 10 countries (China, France, Germany, India, Italy, Japan, Russian Federation, Ukraine, United Kingdom, and the United States), as well as the European Space Agency.

The primary purpose of the IADC is to exchange information on space debris re-

search activities between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities and to identify debris mitigation options.

The IADC comprises a Steering Group and four specified Working Groups. Topics addressed by these four groups include measurements (WG1), environment and database (WG2), protection (WG3) and mitigation (WG4).

This site provides information to the public about the IADC, its member agencies and past and current debris related activities. Furthermore, it provides links for communication between the IADC member agencies and the associated organizations. ♦

Haystack Orbital Debris Radar Measurements Update

E. STANSBERY, J. FOSTER, & C. STOKELY

Haystack Process Improvements

The Haystack radar began collecting orbital debris data for NASA in August 1990. Haystack and the Haystack Auxiliary (HAX) radar (which became operational in 1994) have been NASA's primary source of statistical data on the orbital debris population as small as a few millimeters in diameter. The radar and the associated data processing have evolved during the 14 years that NASA has been collecting debris data. NASA's ambitious plan in 1990 called for collecting more than 1000 hours of data per year for at least a complete solar cycle. Haystack data is collected at a 1 MHz sample rate for each of four receive channels (Principal and Orthogonal Polarizations for the Sum channel and Azimuth and Elevation monopulse channels) resulting in tens of terabytes of data each year. Storing that volume of data would be challenging even today. In 1990, it was inconceivable. It was imperative at the time to perform real-time processing of the data in order to extract a more manageable data stream for post-processing and archival.

MIT Lincoln Laboratory developed the Processing and Control System (PACS) for near real-time processing of its primary task, range/Doppler imaging of satellites. Augmentation of the PACS allowed it to process debris data in real time, detect debris in the radar beam, and save buffered data associated with the detection to memory for later processing. The heart of the PACS in 1990 was a state-of-the-art array processor which performed Fourier transforms, non-coherent integration, and threshold comparisons. All of these steps had to be performed during one inter-pulse period. This requirement forced compromises in pulse width, pulse repetition frequency (prf), and receive range extent. Parameters for the Haystack debris measurements in 1990 are provided in
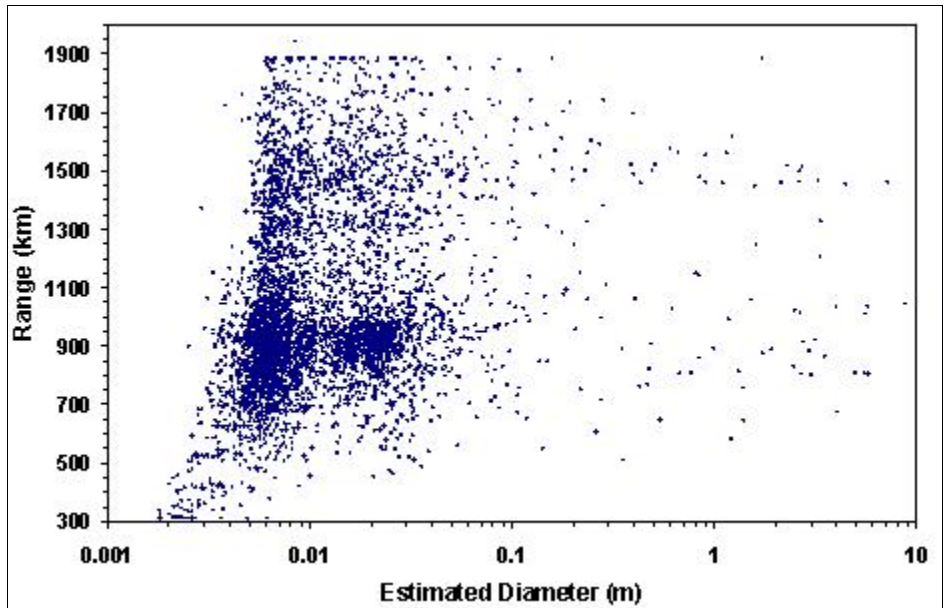
Figure 1. Altitude vs. estimated diameter for all objects detected by Haystack during FY2003.
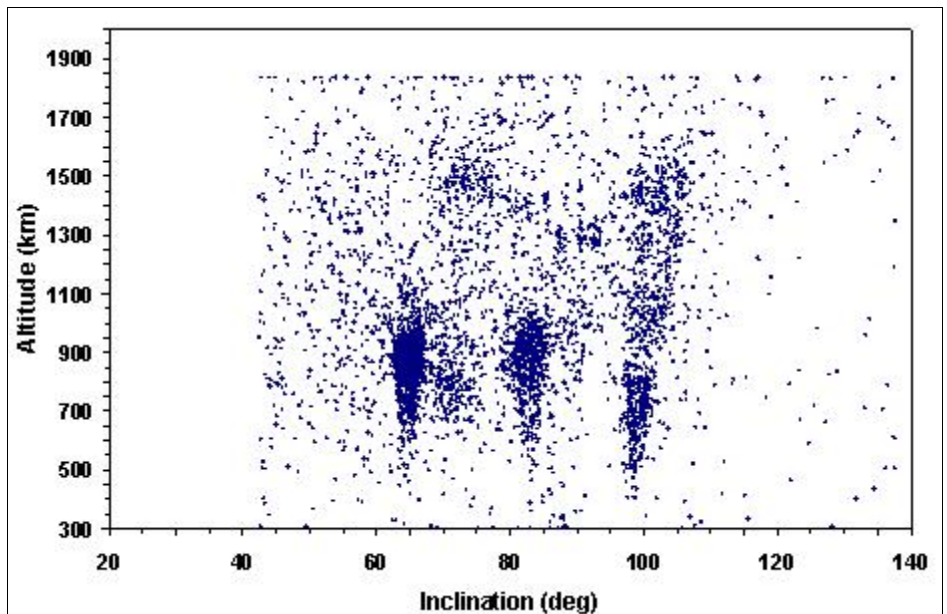
Figure 2. Altitude vs. Doppler inclination. Doppler inclination is calculated from the range rate (Doppler) of the object assuming a circular orbit.

	1990	2003
Peak Power (KW)	400	400
Pulse Width (msec)	1.023	1.64
Pulse Repetition Frequency (Hz)	40	65
Single Pulse SNR on 1-cm diameter (-41 dBsm) target at 500 km Range (dB)	27.8	29.8
Number of Non-Coherent Integrated Pulses Used for detection	12	12
Average Power (kW)	16.4	42.6

Table 1. Selected radar parameters.

Varying Solar Flux Models and their Effect on the Future Debris Environment Projection

M. HORSTMAN

Solar flux drastically affects the dynamics of an orbiting object below about 600 km altitude and the ability to forecast its future orbit. Historic solar data are very precise due to meticulous, long-term observations of the Sun. Accurately predicting solar activity is unfortunately not as easy. Due to the large variations in solar activity over time, empirically determining future activity is not reliable except in the near term. Many of the solar flux prediction models rely on theoretical solar physics and historic assessments of flux. Prediction of the solar cycle becomes less accurate as it is modeled farther into the future, and, because the prediction of the orbital debris environment is largely based on decay rates of objects over time, the long-term prediction of orbital debris is heavily linked to future solar activity modeling. Because so many different models exist and none is perfect, there can be discrepancies between environment projections from different parts of the orbital debris community. The purpose of this article is to demonstrate how different solar flux models affect the projection of the orbital debris environment.

Numerous solar flux models have been designed, all with differing results in long-term environment prediction. Three models were examined in this study: the model developed by the NASA Orbital Debris Program Office (referred to as JSC), the Marshall Space Flight Center's long-term model (referred to as MSFC), and the European Space Agency's long-term solar flux model developed by H. Klinkrad (referred to as ESA). The JSC model projects a single 11-year cycle based upon the last 5 historic cycles. The MSFC and ESA models each are based on all solar cycles from 0 to present, and are interpreted using each agency's modified algorithms based on the McNish-Lincoln linear regression method. Because the JSC and MSFC models only project to a few decades in the future, the last cycle for each model was intentionally repeated until the end of the intended envi-

ronment projection (2103). All three models were used in the NASA environment projection software LEGEND, and the results are based on averages from 30 Monte Carlo simulations. For comparison purposes, the conversion from F10.7 solar flux to exospheric temperature for all models was the same, and taken from the JSC model. Though this inaccurately represents the ESA and MSFC exospheric temperatures, this allows for ease of comparison of the effects

of differing solar flux models in orbital debris environment projection.

The three solar flux projections through the end of 2103 are shown in Figure 1. The JSC model has the largest amplitude while the MSFC model's amplitude is slightly higher than that of the ESA model. All three models have small, yet noticeable differences in phase. The amplitude has a direct impact on the long-term debris environment
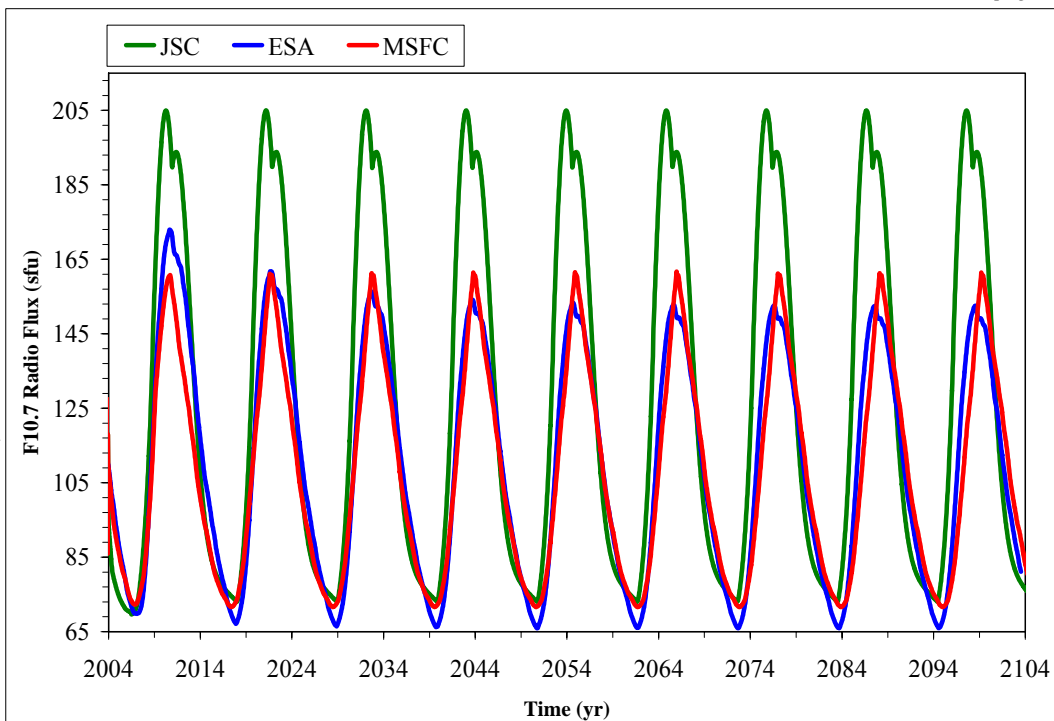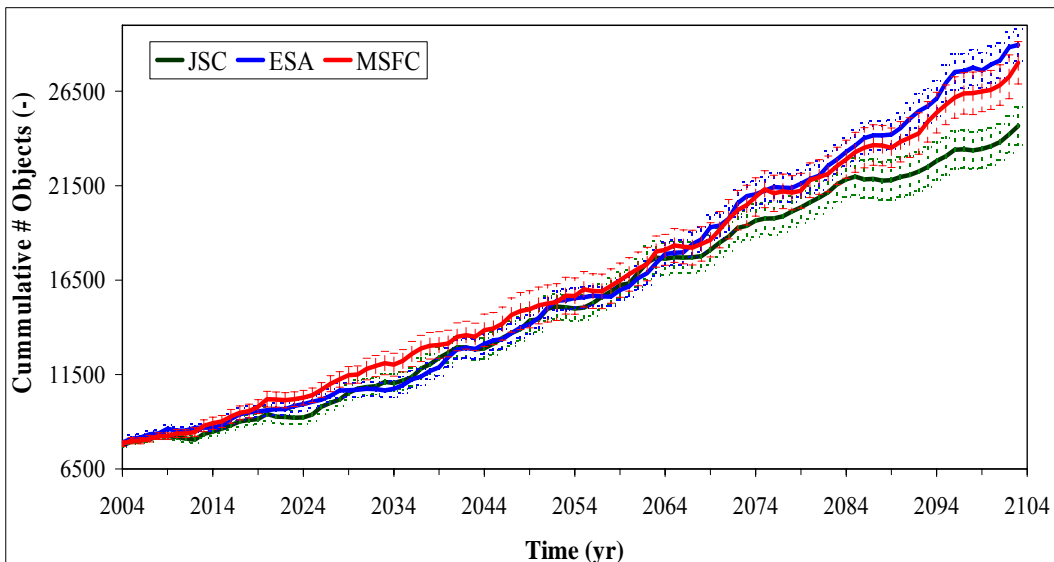
Figure 1. Three Solar Flux Models (100 Year Projections)

Figure 2. LEO Environment 100 Year Projection

Solar Flux Models

projection. With higher solar flux, drag increases on an orbiting object. This in turn increases the rate of its orbital decay. The out of phase factor can yield differences in the environment projection as well. In the long run such effects seem to cancel out but this can be an issue in the short-term examination of population projections.

Figure 2 shows the debris environment projections based on the three different solar flux models. Each curve represents the effective number of objects, 10 cm and larger, passing through the low Earth orbit (LEO) region. The effective number is defined as the fractional time, per orbital period, an object spends between 200 and 2,000 km altitude. The error bars represent the error-in-the-mean for each projection, based on 30 Monte Carlo simulations. By the end of the 100 year projection, there is a clear correlation between the solar flux amplitude and the on-orbit debris population.   ♦

Haystack Update

Table 1. These parameters provide a duty cycle (percentage of time that the radar can transmit its radar energy) of 4%, although the transmitter itself is capable of much more.

Improvements in the PACS have occurred over the years since 1990 as processing speeds and capacities have increased. In 2001-2002 most of the remaining analog components of the processing system were removed and their steps are now done digitally. This change forced major revision of the processing algorithms both at the radar and post-processing of the data at the Johnson Space Center. The real-time processing now had excess capacity which allowed improvements in critical parameters. Pulse width has been increased from 1 msec to 1.64 msec and the prf was increased to 65 Hz. This improves the duty cycle to 10.4%. The higher duty cycle puts more average energy on the target improving overall sensitivity of the radar. In addition, the receive range extent has been increased from 1000 km to 1570 km. The increased range extent allows us to measure from 300 - 1800 km altitude during one interval using the 75° elevation/90° azimuth staring angle.

The new real-time system also allows simultaneous operation of both Haystack and HAX, although this feature is rarely utilized due to the increased workload it places on personnel operating the radars.

Latest Measurement Results

The most recent Haystack data that has been fully analyzed is from fiscal year 2003. Over 630 hours of data was collected by Haystack from 1 October 2002 – 30 September 2003. HAX also collected close to 600 hours, but HAX results will not be presented here. All of the data was collected at a staring angle of 75° elevation and 90° azimuth and the 1.64 msec waveform described above. Figure 1 shows altitude vs. estimated diameter for all detections. It is evident that Haystack is detecting objects as small as 2 mm diameter at the lowest altitudes. Figure 2 shows altitude vs. inclination. As in previous years the data shows distinct groupings at ~65°, ~82°, and ~100°. Smaller groups are evident including one at 90° inclination and 1300 km altitude. This well known grouping is from the SNAP 10A payload which has been known to shed pieces over the years. Other plots which indicate right ascension show an identifiable group of detections related to the CBERS-1/ SACI-1 Long March 4 rocket body breakup which occurred in March 2000.

Figure 3 shows the altitude distribution of 1 cm objects from 350 – 1750 km in 100 km bins. Due to the increased range extent at Haystack, this is the first time that this entire altitude range has been covered using one data set. In the past, two data sets collected over different time intervals had to be combined in order to cover the entire altitude span. Since the number of hours at Haystack available for debris observations is limited, this always meant that each of the two data sets was smaller than the combined, thus increasing the uncertainty of the results.

The Orbital Debris Program Office will publish a more comprehensive analysis of this data set in the near future.   ♦

Figure 3. Altitude distribution of debris 1-cm diameter and larger.
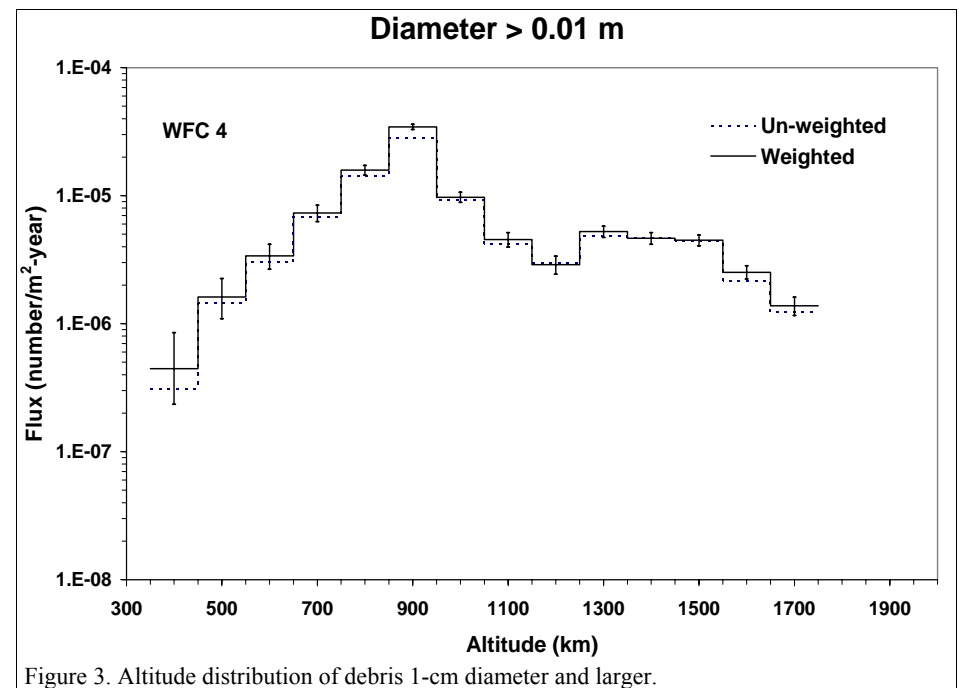
Visit the NASA Orbital Debris Program Office Website

www.orbitaldebris.jsc.nasa.gov
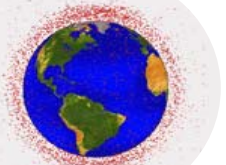
ST9 Solar Sail - A Potential Meteoroid and Orbital Debris Sensor

J.-C. LIOU, E. CHRISTIANSEN, R. CORSARO, F. GIOVANE, & E. STANSBERY

It is a well-known fact that meteoroid and orbital debris (MOD) impacts represent a threat to space vehicles, instruments, and extravehicular activity. Depending on the impact location, particles 100 µm and larger can produce significant damage to a vehicle and lead to serious consequences. To have a reliable MOD impact risk assessment and to design appropriate shielding, a good MOD environment definition is needed. Required information includes flux, size, spatial density, and velocity distributions as functions of altitude and latitude. Ground-based radars and optical telescopes as well as space-based in situ measurements have been utilized to characterize the MOD environment. While radars and telescopes have the capability of detecting debris a few millimeters in size below 500 km altitude (the sensitivity limits decrease rapidly with increasing altitude), space-based in situ measurements represent the only means by which to characterize millimeter-sized and smaller debris. Although the meteoroid environment does not change on a yearly basis, the orbital debris environment has grown dramatically since the beginning of the space age. There is a need to monitor and update the orbital debris environment on a regular basis.

One of the best designed MOD in situ measurements was the Long Duration Exposure Facility (LDEF). It was launched in April 1984 (near circular orbit at an altitude of 476 km) and retrieved in January 1990. With a long mission duration (5.8 years) and large detection areas (> 30 m^2 from several MOD experiments), the data LDEF collected have been widely used to improve our understanding of the MOD populations. However, since the return of LDEF, there is a lack of in situ experiments with sufficiently large surface areas to update the small debris environment.

The recent NASA Research Announcement (NRA) for a planned solar sail mission provides a great opportunity to sample and update the near Earth MOD environment. This New Millennium Program (NMP) solicits proposals for its Space Technology-9 (ST9) system flight validation for solar sail technologies. One of the objectives cited in the NRA is to use the sail as a sensing instrument for the detection of dust and micrometeoroid impacts. The

Figure 1. One of the configurations of the test. The target film (to the left) had an exposure area of 30 × 30 cm^2. Two PVDF sensors were attached to the film while a third one was attached to the frame.

minimum requirements for the mission include a 40 × 40 m^2 sail on a modified geosynchronous transfer orbit (GTO) with perigee altitude above 1500 km and a mission duration of at least 4 months. The combined area-time product of more than 500 m^2-year makes the sail a unique in situ detector to sample small MOD from 1500 km altitude to near geosynchronous orbit region.

A major challenge to utilize the sail as an MOD detector lies in the development of

Figure 2. The left picture shows another configuration of the test. A second, round-shaped, panel was hanging loosely behind the first one. Preliminary signal analysis is shown to the right. PVDF provided the clearest indication of initial projectile impact, while the fiber optic sensor more clearly responded to the excitation of the modes of the film, initiated by the particle impact.

ST9 Solar Sail

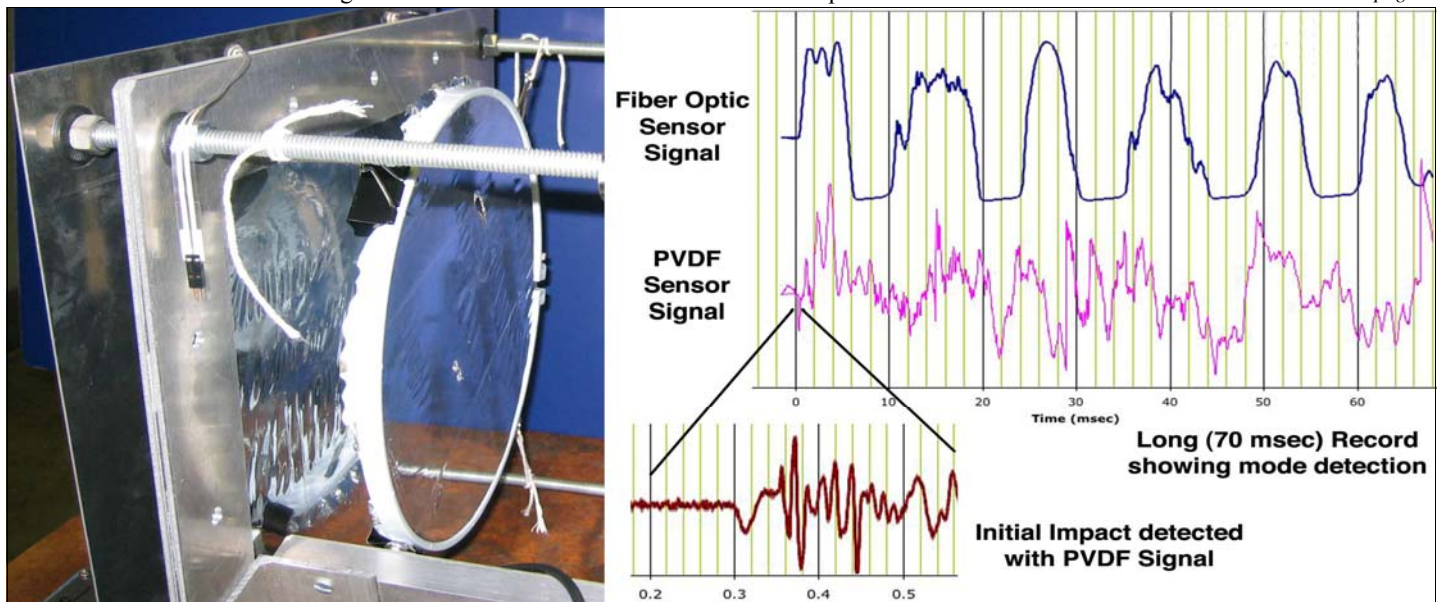instruments within the allocated ST9 mass and power budget (≤ 1 kg and ≤ 1 W, respectively). A team of scientists and engineers with different disciplines has been assembled to come up with an innovative design to meet the challenge. The proposed project is led by the Naval Research Laboratory with collaboration from the NASA Orbital Debris Program Office and the Hypervelocity Impact Test Facility at the Johnson Space Center (JSC). The system is called Acoustic Impact Meteoroid Sensor (AIMS). It is based on a low mass/power/ cost acoustic sensor developed by the team for a different experiment[1]. The principal detection mechanism relies on the sensitive nature of thin poly-vanylidene fluoride (PVDF) films as they respond to sudden changes in strain when an impact occurs.

To demonstrate the feasibility of AIMS, several hypervelocity impact tests have been conducted using the JSC 0.17 caliber two-stage light gas gun located at Rice University. The targets were thin films of Mylar® coated with aluminum with a total thickness of 25 μm, similar in nature to the proposed solar sail material. The projectiles were 1 mm diameter aluminum spheres with a typical impact speed around 7.2 km/sec. Figure 1 shows one of the configurations for the test. The target panel was a 30×30 cm^2 film mounted on an aluminum frame. The entire set was mounted on a rail inside the target chamber during the test. Two PVDF acoustic sensors, also 25 μm thick, were attached to the Mylar® film and a third one was attached to the frame. Each sensor was connected to high-frequency and wideband amplifiers. Figure 2 shows another configuration where a fiber-optic displacement sensor was installed as a potential addition for AIMS and a second panel (with one PVDF sensor attached) was hanging loosely behind the first one. Data from all channels were analyzed after each shot. Preliminary results indicate that both the PVDF acoustic sensor and the fiber-optic

sensor could detect clear signals generated by the impact of the projectile on the film. This demonstrates that the sensing capability and the low mass and power requirements of AIMS make it a potentially good sensor for the planned ST9 solar sail to detect MOD impacts. Additional tests will be needed to better correlate the detected signals to other impact characteristics (e.g., projectile size and impact speed).

Large detection area (> 1 m^2) and long mission duration are the keys for future MOD in situ measurements. New and innovative instruments need to be developed to meet the goals and to keep the mass, power, and cost requirements within the practical constraints at the same time. Our proposed AIMS package to utilize the ST9 GTO solar sail represents a step forward in this direction.

1. Corsaro, R. *et al. PINDROP - An Acoustic Particle Impact Detector*, ODQN Vol. 8, Iss. 3, 2004. ♦

ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

55th International Astronautical Congress
4-8 October 2004, Vancouver, Canada

Modeling the Sodium Potassium Droplet Interactions with the LEO Space Debris Environment

P. KRISKO, J. FOSTER

The NASA sodium potassium (NaK) RORSAT coolant source and propagation model has been extended down to 1 mm in diameter via a debris/meteoroid size distribution, which is an inverse power law fit that has been modified to damp out in the large size regime. This function matches the observed Haystack NaK population down to diameters of about 6 mm. The extrapolated function takes the population to arbitrarily small sizes all the while retaining the mass dominance of the 2 cm to 3 cm droplets that is observed in the Haystack data. Only about 2% of the total droplet mass exists below 5 mm according to this fit. This result is physically satisfying since the mechanism of NaK ejection appears to be a nonviolent release at low relative velocities. A violent ejection such as a boiling off of heated coolant would result in a large number of small droplets and a mass dominated by them. In this vein we contend that a population of NaK droplets has a natural lower size limit in the sub-millimeter range. Any smaller NaK particles that exist would

not be part of the NaK source mechanism. Instead, we show that such a population could be the result of subsequent collisions of NaK droplets (> 1 cm) with larger intact resident space objects or the micrometeoroid population.

In modeling the historical LEO orbital debris environment including NaK release events we perform a Monte Carlo process to estimate collision probabilities. We determine that collisional activity between objects of sizes 1-cm and larger is statistically probable based on the spatial distribution of the LEO population. Not only do NaK droplets possess a reasonable probability of collision with large resident space objects, but also other small objects (e.g., fragments of historical explosion and collision events) are shown to be likely to participate in similar events.

The characteristics of this historical collisional activity are consistent with observation, or lack thereof; 1) the collisions are dominated by those between very small objects (i.e., those untracked by USSTRATCOM) and large resident space

objects, 2) the most active collisional regime is between 800 km and 1000 km in altitude, and 3) due to the size differences between the impactor pairs, the collisions are generally non-catastrophic (i.e., small projectiles are destroyed, but large target resident space objects remain intact). All these characteristics point to the fact that it is likely that such events would remain undetected by current measurement techniques.

By the same type of Monte Carlo analysis we investigate the collisional activity between the high micrometeoroid flux in LEO and NaK droplets. Preliminary analysis shows that collisions between these two populations are likely. Though the result of such collisions involving NaK droplets with large resident space objects and the numerous meteoroid population are generally unknown there remains the possibility that ejecta of NaK enters the LEO environment as a result. ♦

A LEO Satellite Postmission Disposal Study Using LEGEND

J.-C. LIOU, N. JOHNSON

Postmission disposal has been recognized as the most effective way to limit the growth of future orbital debris populations. The 1995 NASA Safety Standard (NSS 1740.14) recommends placing a spacecraft or upper stage passing through LEO in an orbit in which atmospheric drag will limit its lifetime to less than 25 years after completion of mission. This postmission disposal practice has been known as the 25-year decay rule. However, a prolonged satellite mission lifetime will certainly decrease the effectiveness of the 25-year decay rule. In this paper we present an analysis to quantify how the future debris environment responds to the 25-year decay rule with different spacecraft mission lifetimes. The analysis was based on a parametric study using the NASA orbital debris evolutionary model, LEGEND.

The parametric study included a reference scenario, where the mission lifetimes of all spacecraft were set to 5 years, and three test scenarios, where the mission lifetimes of spacecraft were set to 10, 20, and 30 years, respectively. At the end of mission lifetimes, spacecraft were moved to either the 25-year decay orbits or the LEO storage orbits (above 2000 km altitude) depending on which option required the lowest delta velocity for the maneuvers. All future upper stages were move to the 25-year decay orbits after launch. The analysis for each scenario was based on 30 Monte Carlo simulations for a projection period of 100 years. Future launch traffic was simulated by repeating the 1995 to 2002 launch cycle.

Our analysis showed that at the end of the 100-year projection, the number of 10 cm and larger objects in LEO would increase with increasing spacecraft mission lifetime. We have also completed an additional test scenario in which no postmission disposals were applied to spacecraft and upper stages. A quantitative summary of the differences between different scenarios is included in this paper. ♦

Dynamic Orbital Debris Collision Risk Mitigation

M. MATNEY

Historically, calculations of orbital debris risks have used the debris flux time-averaged over the spacecraft orbit to assess hazard and to design shielding. This method gives the average flux as a function of debris size, direction, and impact speed, and works well for spacecraft that maintain orientation to the velocity vector.

However, the debris flux is not constant, either in magnitude or in direction, over the progress of the spacecraft through its orbit. For instance, as the spacecraft crosses the equator going north, typically there is an enhanced flux on the port side (relative to the local horizontal). The opposite holds true on southbound transits of the equator, with maximum flux typically coming from the starboard side. This behavior opens up the possibility of designing missions to dynamically mitigate debris, by turning "dumb" structure or shielding toward the varying direction of maximum flux at different points along the spacecraft orbit.

This paper will examine this effect using NASA's Orbital Debris Engineering model ORDEM2000 and show how such knowledge could be used in potential mitigation strategies. ♦

Results from the GEO Debris Survey with MODEST

P. SEITZER, K. JORGENSEN, J. AFRICANO, T. PARR-THUMM, M. MATNEY, K. JARVIS, E. STANSBERY

Beginning in February 2001, the University of Michigan's 0.6/0.9-m Curtis Schmidt telescope at Cerro Tololo Inter-American Observatory in Chile has been used in a continuing optical survey of debris at geosynchronous orbit. The system uses a scanning CCD to cover a strip of sky 1.3º high by over 100º long each clear scheduled night. The following results will be discussed:

1. The observed angular rate distribution of debris fainter than R = 15 is very different than the distribution of bright objects. The two populations cannot be distributed on the same families of orbits.
2. Since February 2001, the part of the ring of active geostationary satellites that is visible from Chile has been routinely observed, and there has been no detection of faint debris moving very slowly with respect to current station-keeping satellites.
3. Many objects show large (up to 2 magnitudes) brightness variations within a 5 minute observing window. A not surprising conclusion is that these objects are non-spherical and tumbling.
4. A summary of the derived orbital inclination and RAAN (right-ascension of the ascending node) of detected objects will be presented.

This work has been supported by NASA's Orbital Debris Program Office, Johnson Space Center, Houston, TX. ♦

Growth in the Number of SSN Tracked Orbital Objects

E. STANSBERY

The number of objects in Earth orbit tracked by the USSTRATCOM 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 4 March 2003. This paper will examine the new data and its implications to the understanding of the orbital debris environment and orbital safety. ♦

INTERNATIONAL SPACE MISSIONS
October—December 2004

International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2004-040A	SOYUZ-TMA 5	RUSSIA	351	356	51.6	1	0
2004-041A	AMC-15	USA	35783	35792	0.0	1	1
2004-042A	FENGYUN 2C	CHINA	35778	35791	0.6	1	1
2004-043A	EXPRESS AM-1	RUSSIA	35782	35793	0.1	2	6
2004-044A	JB-3 C	CHINA	479	503	97.3	1	0
2004-045A	NAVSTAR 56 (USA 180)	USA	19938	20426	54.8	2	0
2004-046A	TANSUO 2	CHINA	695	711	98.2	1	5
2004-047A	SWIFT	USA	584	604	20.6	1	0
2004-048A	AMC-16	USA	35779	35794	0.0	1	0
2004-049A	HELIOS-2A	FRANCE	679	697	98.1	1	0
2004-049B	NANOSAT-1	SPAIN	657	679	98.1		
2004-049C	ESSAIM-1	FRANCE	665	688	98.1		
2004-049D	ESSAIM-2	FRANCE	655	679	98.1		
2004-049E	ESSAIM-3	FRANCE	655	678	98.1		
2004-049F	ESSAIM-4	FRANCE	644	668	98.1		
2004-049G	PARASOL	FRANCE	652	678	98.1		
2004-050A	USA 181	USA	19035	36418	13.5	0	0
2004-051A	PROGRESS M51	RUSSIA	351	356	51.6	1	0
2004-052A	SICH-1M	UKRAINE	280	639	82.6	1	0
2004-052C	MIKRON	UKRAINE	283	639	82.6		
2004-053A	COSMOS 2411	RUSSIA	19134	19142	64.8	2	3
2004-053B	COSMOS 2412	RUSSIA	19136	19140	64.8		
2004-053C	COSMOS 2413	RUSSIA	19135	19140	64.8		

ORBITAL BOX SCORE
(as of 29 DEC 2004, as catalogued by US SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	46	305	351
CIS	1355	2636	3991
ESA	32	29	61
FRANCE	42	282	324
INDIA	28	107	135
JAPAN	85	50	135
US	1000	2878	3878
OTHER	339	19	358
TOTAL	2927	6306	9233

MEETING REPORT

55th International Astronautical Congress
4-8 October 2004, Vancouver, Canada

The 55th IAC (International Astronautical Congress) meeting was held in Vancouver, Canada, 4-8 October 2004. The Space Debris and Space Traffic Management Symposium was organized by W. Flury and N. Johnson. It included 5 presentation sessions and 1 poster session. A total of 41 papers and 7 posters were presented over 3 days. Presented material included reports on optical and radar surveillance programs, near-term and long-term debris environment modeling, impact tests and models, risks in the space environment as well as during re-entry, and mitigation and space traffic management proposals. ♦

UPCOMING MEETINGS

18-20 April 2005: Fourth European Conference on Space Debris, Darmstadt, Germany.
The conference will be held at the European Space Operations Centre (ESOC). Six sessions have been planned to include measurements and modeling of debris and meteoroids, hypervelocity impacts, risk assessments and debris mitigation, and standards and regulations. For further information contact Walter.Flury@esa.int or go to http://www.esa.int/spacedebris2005.

17-21 October 2005: The 56th International Astronautical Congress, Fukuoka, Japan.
The Congress will include three sessions on space debris: B6.1 Measurements and Space Surveillance, B6.2 Risk Analysis, Hypervelocity Impact and Protection, B6.3 Mitigation and Standards. Abstract submission deadline is 1 March 2005. Additional information on the Congress is available at http://www.iac2005.org.
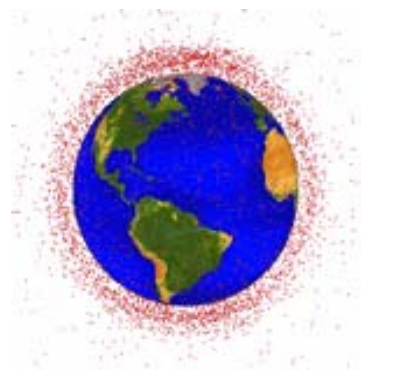
Monthly Number of Cataloged Objects in Earth Orbit by Object Type
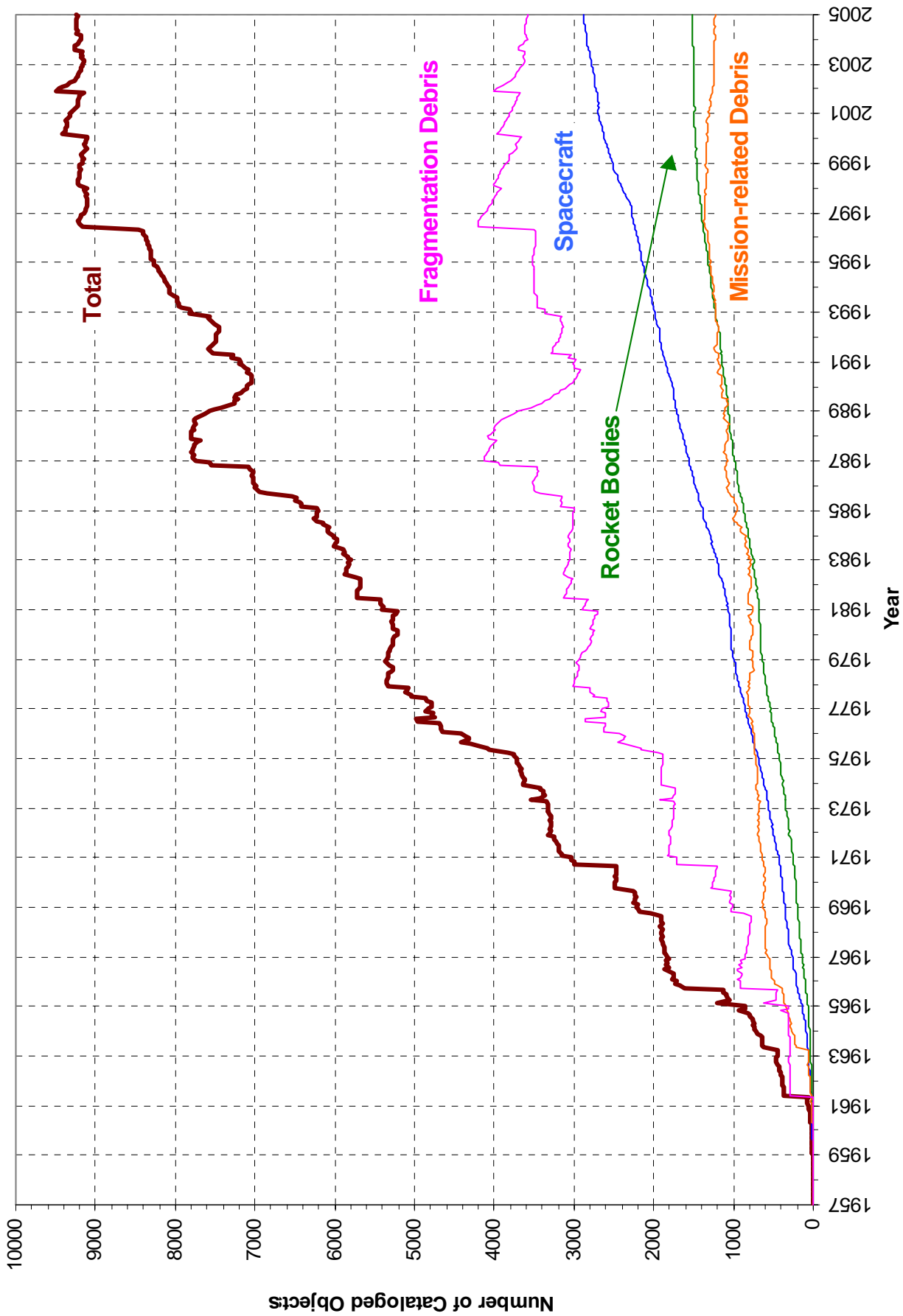
Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the US Space Surveillance Network. "Fragmentation debris" includes satellite breakup debris and anomalous event debris, while "mission-related debris" includes all objects dispensed, separated, or released as part of the planned mission.