The Orbital Debris Quarterly News

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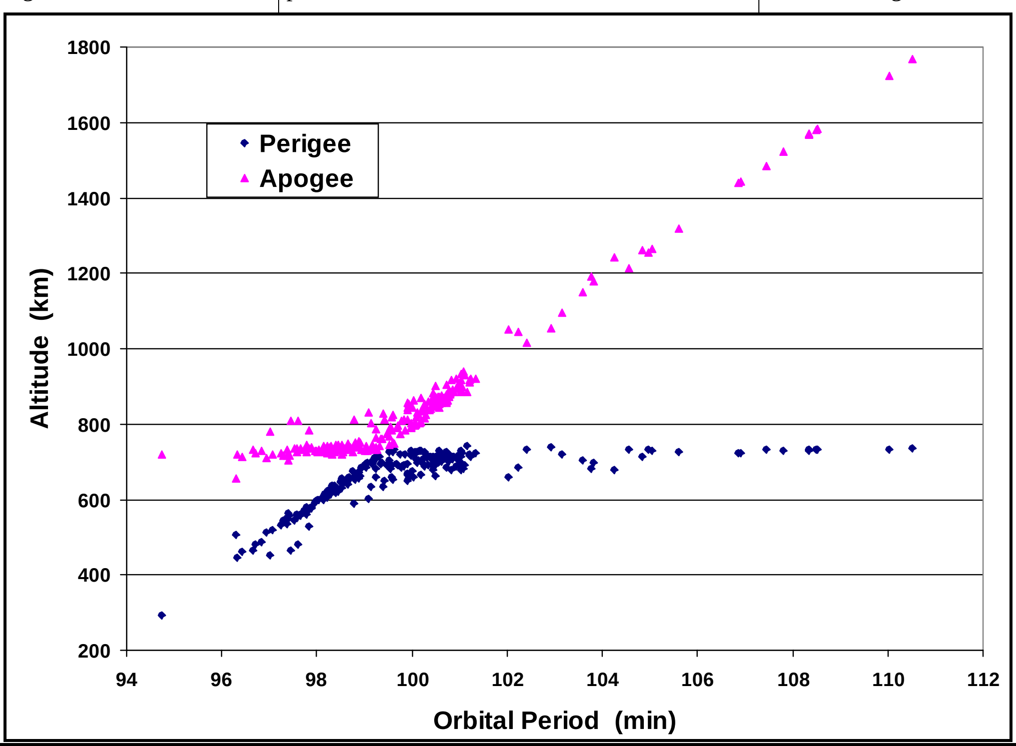
NEWS

The First Satellite Breakup of 2000

The most significant satellite breakup in nearly four years occurred on 11 March 2000 when a 5-month old upper stage disintegrated into more than 300 fragments large enough to be tracked by the U.S. Space Surveillance Network (SSN). The vehicle (International Designator 1999-057C; U.S. Satellite Number 25942) was the third stage of the Chinese Long March 4 booster which had successfully deployed the China-Brazil Earth Resources Satellite (CBERS 1) and the Brazilian Satellite Cientifico (SACI 1) spacecraft on 14 October 1999. Independent U.S. and Russian assessments determined the breakup time to have been between 1301 and 1304 UTC, while the vehicle was passing near the southern-most portion of South America.



The ~1,000-kg upper stage was in an orbit of 725 km by 745 km with an inclination of 98.5 degrees at the time of the event. A Gabbard diagram of 280 tracked debris on 6 April (accompanying figure) indicated a large altitude dispersion of the debris. A majority (60%) of the debris was found in higher orbits than the parent, but this may be due to the rapid decay of some debris thrown in retrograde directions. Interestingly, the number of debris with inclinations lower than the parent was exactly the same: 60%. However, due to the far southern latitude of the event, all inclination changes were small: +/- 1 degree.

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Inside...

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The First Satellite Breakup of 2000, Continued

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This mission was only the fourth for this version of the Long March launch vehicle family. The first two missions were flown in 1988 and 1990, and flights did not resume until 1999. The second mission in September 1990 was followed by a breakup of the third stage, this time after only a month on orbit. This earlier fragmentation, which took place at a higher altitude of 895 km, produced substantially fewer large debris. Less than 90 debris had been cataloged by the beginning of this year. Cataloging of the debris from 1999-057C did not begin in earnest until April.

Chinese analyses following the 1990 breakup determined that the most likely cause of the fragmentation was the residual hypergolic propellants. Plans to passivate the Long March 4 upper stage apparently were not implemented for the two flights in 1999. ❖

1999 Leonid Meteor Observations at the Johnson Space Center

J. Pawlowski

The November 1999 Leonids Meteor Storm was videotaped on the grounds of the NASA Johnson Space Center (JSC) in Houston, Texas and at the JSC observatory in Cloudcroft, New Mexico. Low light level video cameras were used in both locations and our Liquid Mirror Telescope (LMT) was used at Cloudcroft.

The low light level videotapes were analyzed using a meteor analysis system developed at JSC. The results were compared to the Leonid Mass Distribution Model derived at JSC and used in conjunction with orbital debris models to compute risk assessments before each Space Shuttle mission.

The observed data compared favorably to the model in the .01 to.2 gram range but differed for the smaller masses. The difference can be attributed to the limitations of the low light level video equipment. This equipment is unable to detect the faint meteors (those of small mass), however these meteors can be detected by the LMT.

A modification of the software used to analyze orbital debris detected by the LMT has recently enabled analysis of the Leonid Meteors also detected by that instrument. This will result in a sizable sample of faint Leonid Meteors for a complete comparison to the model. ❖

HAPS Debris Separation Velocity Distribution

P. Anz-Meador

The separation velocities of debris produced by a fragmentation event, hereafter referred to as the delta-v distribution, is of interest because the magnitude and directional (angular) distribution governs the initial deposition of a debris cloud throughout space and provides information as to the severity or energetics of the event. The latter may be evidenced by the isotropy or anisotropy of the directional distribution. We have examined the Hydrazine Auxiliary Propulsion Stage (HAPS) rocket body debris cloud associated with the STEP II launch (1994-029B) to characterize the cloud [Ref.1]; in this paper we examine the delta-v distribution in particular.

Two methods were examined. The first utilized US Space Command SGP4 v. 3.01 software and the pseudo-ballistic coefficient B*, averaged over two solar rotations, to propagate the first cataloged element set of each piece back in time to the time of the fragmentation event. Delta-v was then calculated by vector subtraction of the state vector velocity components. This technique provided poor results, as indicated by extreme scatter in the delta-v calculated. The second technique utilized the Orbital Debris Program Office's THALES program and the median estimated area-to-mass (AOM) ratio to propagate the debris elements to the event time. Delta-v was calculated using the equations of Meirovitch [Ref.2]. This technique is judged to provide a superior mean of calculating delta-v, based upon (a) the in-plane delta-v components are similar to the cloud's Gabbard diagram, (b) the magnitude of the delta-v vector is comparable with the Gabbard diagram's 450-500 m/s maximum, and (c) there is a correlation between delta-v and AOM, as should be expected if more massive objects are associated with low-AOM debris and less massive objects are associated with high-AOM debris. Figures 1 and 2 illustrate conditions (b) and (c); figure 1 categorizes the magnitude of the delta-v vector for each object into 50 m/s bins.

Angular Distributions

A coordinate frame was defined such that X (denoted by dv_T) points in the direction of the tangential velocity, Y (denoted by dv_L) points in the direction of the positive orbit angular momentum vector, and Z (denoted by dv_R) points in the radial or zenith velocity direction. The most convenient angles in this coordinate system are pitch and yaw; pitch is defined to be positive for positive Z delta-v components. Yaw is defined to be positive when measured in a counter-clockwise direction about the +Z axis, *i.e.* as in a standard right-handed coordinate system. Figure 3 depicts the distribution in yaw-pitch space.

To further examine the angular distribution, the debris delta-v components were mapped into the relevant planes. The X-Y plane represents the local horizontal plane. The X-Z plane represents the in-orbit plane components, and the Y-Z plane represents velocity components perpendicular to the tangential velocity (approximately the on-orbit velocity of the HAPS stage). Figures 4A, 4B, and 4C depict these mappings, respectively.

The X-Z plane is also the local horizontal plane. Figure 4A indicates that the event distributed debris symmetrically about the orbit plane and, apparently , asymmetrically along the dv_T axis. As seen in Figure 4B, the in-orbit plane components mimics the Gabbard diagram as should be expected since only these components affect the change in semimajor axis, and hence orbital period, of each debris object. Figure 4C again indicates an event symmetric about the orbit plane. The apparent anisotropy evident in these figures, with the majority of the debris delta-v vector components oriented towards the velocity vector, may be attributable to atmospheric removal of a portion of the original debris cloud rather than being representative of a true asymmetry. The time scale for atmospheric removal due to object reentry ranges from immediately after the fragmentation event to a relatively long life, based upon perigee height. However, coupled with current US Space

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HAPS Debris Separation Velocity Distribution, Continued

(Continued from page 2)
Command cataloging criteria, the initial perigee height distribution can significantly alter the apparent directionality of the debris cloud.

Discussion

The apparent symmetry of the debris cloud indicates a fairly anisotropic directional distribution, given the limits imposed by cataloging and the breakup altitude. However, low pitch angles are not apparent in either Figure 3 or 4B, perhaps indicative of the explosion occurring in the rear portion of the HAPS stage, *i.e.* that portion of the stage oriented away from the velocity vector.

Of more interest is the magnitude distribution of the velocity vectors. The frequency of higher velocities in the HAPS debris cloud differs significantly from similar distributions computed for the SPOT-1/Viking Ariane H8 rocket body, the P78G-1 (SOLWIND) collision, and various Cosmos-series fragmentations. Only in the case of the Delta rocket body historical fragmentations do we encounter velocities of a similar magnitude, although the relative frequency of HAPS debris exceeds that of the Delta debris. This is probably indicative of the initial fragmentation impulse and the combination of small sizes and low masses of the HAPS debris, which may be similar to the production of high-AOM/low mass objects in the Delta debris ensembles. However, the frequency distribution is a further indicator of the unique nature of the HAPS rocket body fragmentation.

References

[Ref.1] Settecerri, T., P. Anz-Meador, and N. Johnson, "Characterization of the Pegasus-Haps Breakup." Presented at the 50th IAF Congress, Amsterdam, the Netherlands, October 1999.

[Ref.2] Meirovitch, L. Methods of Analytical Dynamics. McGraw Hill, 1970. In R. Kling, "Postmortem of a Hypervelocity Impact: Summary", Teledyne Brown Engineering report CS86-LKD-001, September 1986. ❖

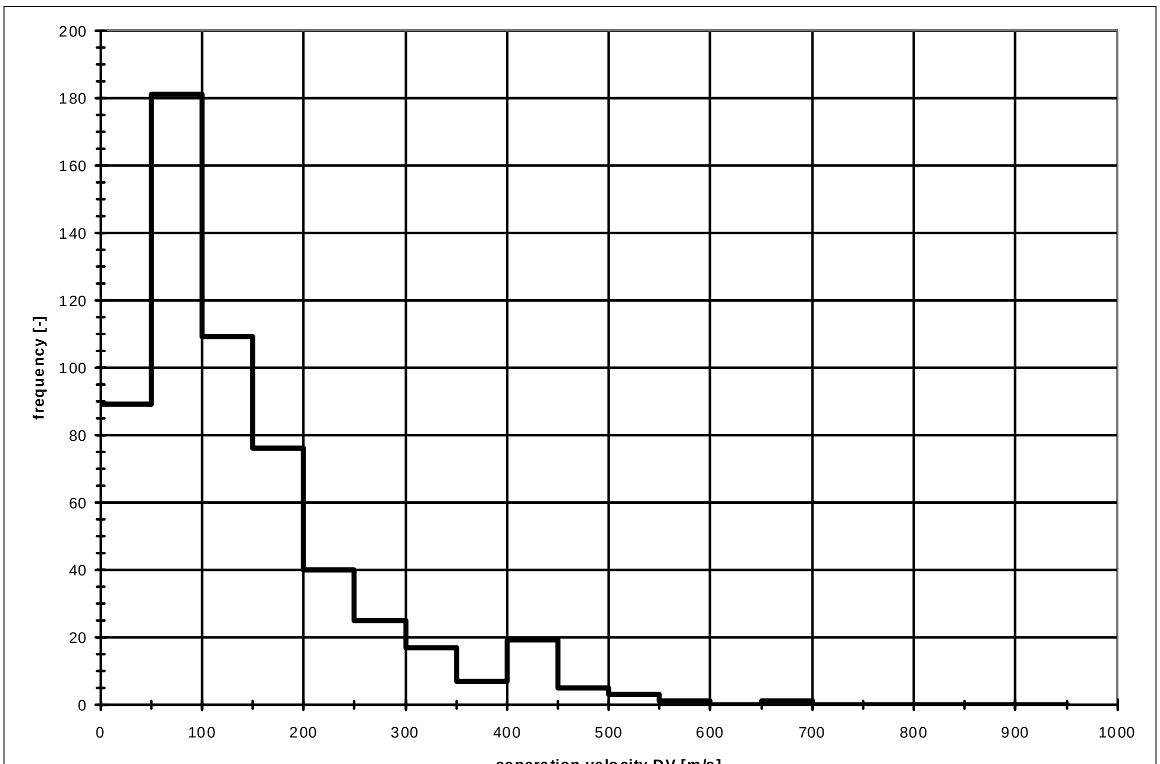

Figure 1. Delta-V Magnitude Frequency Distribution

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NEWS

HAPS Debris Separation Velocity Distribution, Continued

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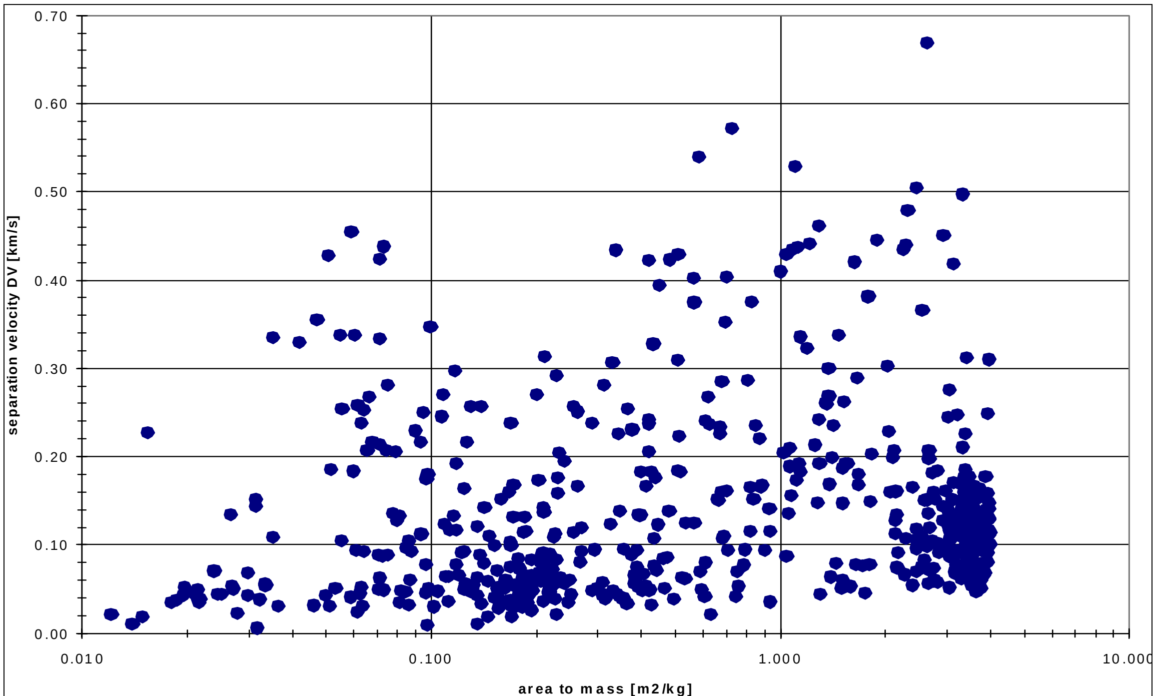

Figure 2. Delta-V Magnitude as a function of AOM

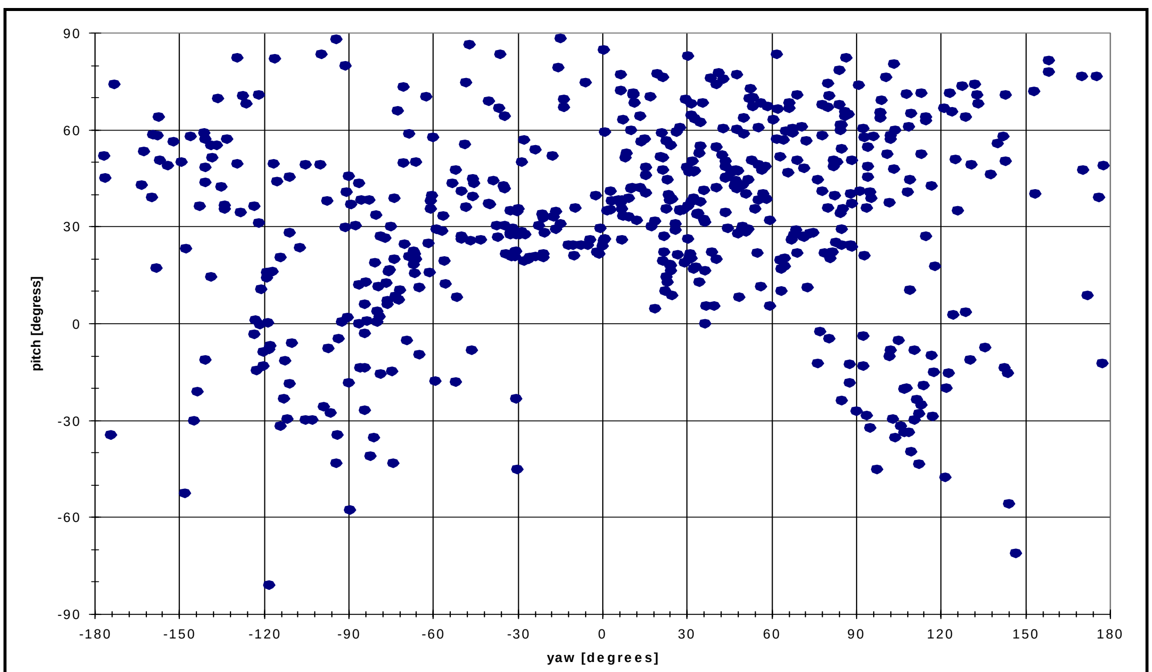

Figure 3. Debris Angular Distribution in (Yaw, Pitch) Space

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NEWS

HAPS Debris Separation Velocity Distribution, Continued

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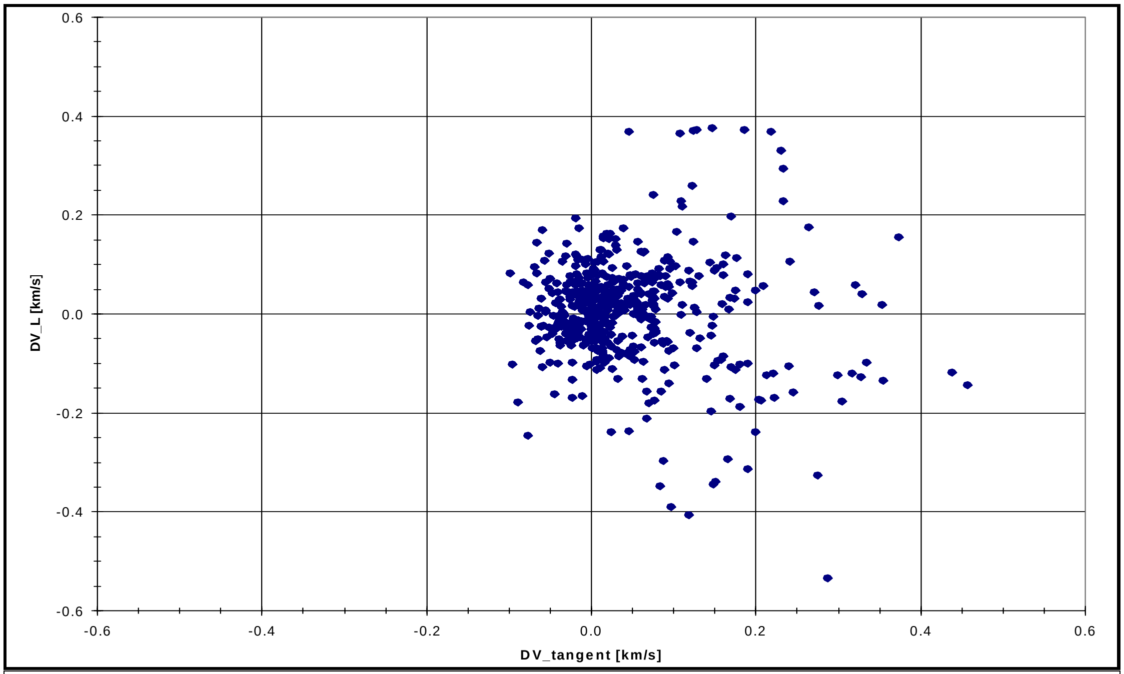

Figure 4A. X-Z Plane (local horizontal) Delta-V

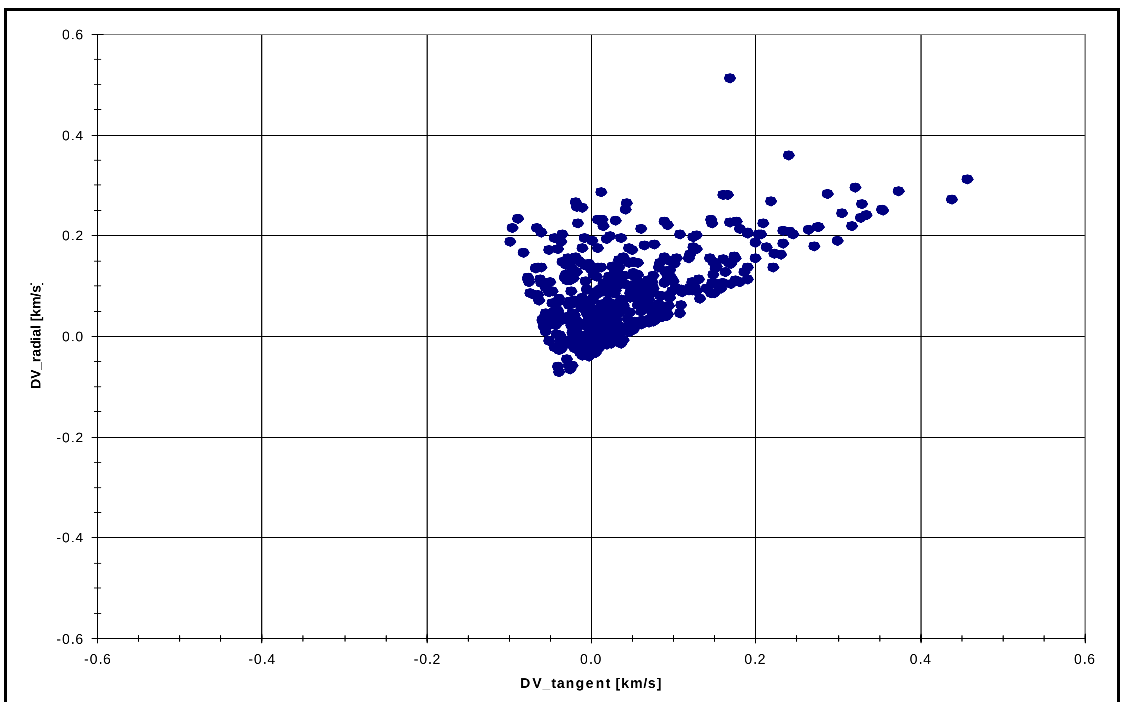

Figure 4B. X-Z Plane (orbit plane) Delta-V

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NEWS

HAPS Debris Separation Velocity Distribution, Continued

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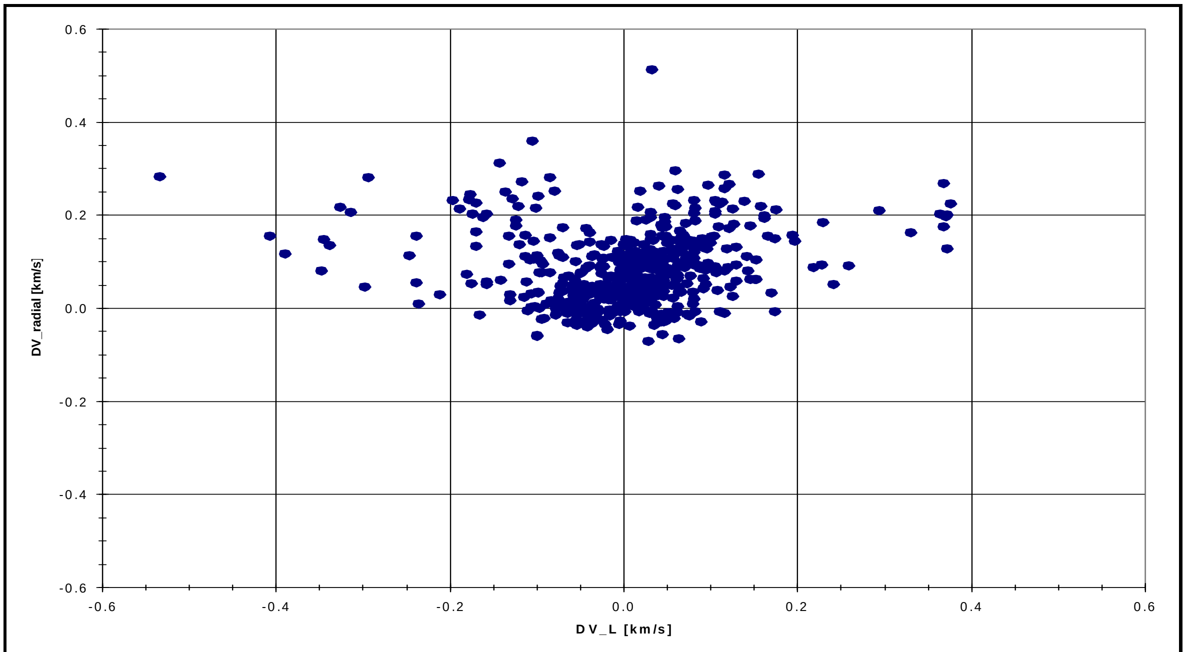

Figure 4C. Y-Z Plane (perpendicular to velocity vector) Delta-V

Compton Gamma Ray Observatory to be Deorbited

In March NASA announced the decision to deorbit the 9-year-old Compton Gamma Ray Observatory (CGRO) as early as June of this year. The second of NASA's Great Observatories, CGRO completed its primary mission in the mid-1990's and has continued to provide scientific data which has revolutionized our understanding of the nature of the Universe. The spacecraft suffered a failure of one of its three gyroscopes on 3 December 1999, precipitating a review to consider implementing a disposal plan which had been drafted in the mid-1980's during the design and construction of the spacecraft. Full control of the spacecraft has been retained with the remaining two gyros.

The large size of CGRO, nearly 14 metric tons dry mass, and the nature of some of the very dense gamma ray instruments, mean that several components of the spacecraft are expected to survive reentry and reach the surface of the Earth. Although CGRO was launched before the release of NASA Safety Standard 1740.14, which recommends the deorbiting of such large spacecraft into broad ocean areas, the potential risk to people and property on the Earth was recognized early in the CGRO program. The CGRO contractor, TRW, published a draft disposal plan in July 1985, and this was followed by a NASA-generated plan in December 1989. Based upon the low inclination of CGRO, both documents recommended reentry over a region in the eastern Pacific Ocean. Consequently, the spacecraft was designed to carry sufficient propellant for this operation.

In the 24 March announcement, Dr. Ed Weiler, Associate Administrator for the Office of Space Science, NASA Headquarters, said that "NASA must have a controlled reentry to direct Compton towards an uninhabited area in the Pacific Ocean. NASA decided before Compton was launched that due to its size, it would be returned to Earth by controlled reentry when the mission was over. This was always NASA's plan."

Following the gyro failure last December, the JSC Orbital Debris Program Office was tasked to reevaluate the risk of an uncontrolled reentry using the more sophisticated analytical tools now available. After a careful review of original CGRO design documents, the NASA-Lockheed Martin Orbit Reentry Survivability Analysis Tool (ORSAT) 5.0 was employed to determine which parts of the spacecraft would probably survive and what the total casualty area might be. The results of this study, summarized in *Reentry Survivability Analysis of Compton Gamma Ray Observatory (CGRO)*, JSC-28929, confirmed that the risk of an uncontrolled reentry would exceed NASA and U.S. Government standards. Furthermore, in accordance with NASA Policy Directive 8710.3 and in support of the NASA Headquarters Office of Space Flight, the Orbital Debris Program Office reviewed the overall CGRO disposal plan prepared by a Goddard Space Flight Center-led team.

The spacecraft will be brought down from its operational orbit near 500 km with a series of maneuvers beginning less than a week before the directed reentry. "NASA will work closely with aviation and maritime authorities to ensure the impact zone is free from traffic during reentry," said Preston Burch, Deputy Program Manager for Space Science Operations at Goddard Space Flight Center. ❖

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NEWS

Compton Gamma Ray Observatory to be Deorbited, Continued

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The Compton Gamma Ray Observatory is scheduled to be de-orbited as early as June.

Kessler Receives Losey Award

Don Kessler, NASA Senior Scientist (Retired) for Orbital Debris, was named as the 2000 recipient of the AIAA Losey Atmospheric Sciences Award, "in recognition for pioneering work in the discovery and definition of the orbital debris component of the atmospheric environment."

Don's interest in orbital debris was an extension of his work with meteoroids. In the late 60's, Don began to consider whether colliding satellites might be a source of man-made debris in earth orbit, just as colliding asteroids were sources of natural debris in solar orbit.

In 1978, with co-author and long-time collaborator Burt Cour-Palais, Don published "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt" in the Journal of Geophysical Research. The conclusions of this paper were briefed to the US Senate Subcommittee on Science, Technology and Space by NASA Administrator Dr. Robert Frosch and Dr. William Brown of the Hudson Institute. This publication proved to be the seminal work in orbital debris research and forced NASA, the US Government and the scientific community at large to seriously consider the long-term technical ramifications of an orbital debris population.

Since then, Don has been one of the field's leading researchers and advocates, and has at last count published 97 technical articles or extended abstracts on meteoroids and orbital debris.

The award was presented on January 11, 2000 during the 38th Aerospace Sciences Meeting and Exhibit at the Reno Hilton, Reno, Nevada. The Robert M. Losey Award was established in memory of Captain Robert M. Losey, a meteorological officer who was killed while serving as an observer for the U.S. Army. The award is presented in recognition of outstanding contributions to the atmospheric sciences as applied to the advancement of aeronautics and astronautics. ❖

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Project Reviews

A Look from the LMT at Debris from Molniya Orbits

M. Matney, T. Hebert

The Molniya orbit is a specialized orbit developed by the former Soviet Union in the early 1960s to meet their communication needs. These objects are placed into orbits with a 12-hour period, an eccentricity of about 0.7, and a critical inclination near 63.4 degrees so that the argument of perigee remains nearly constant in the southern hemisphere. The apogee is thus fixed high over northern latitudes. Although there have been several observed breakups in Molniya-type orbits, orbital debris populations associated with these orbits are difficult to measure and are not well-characterized. The LMT observations can be used to help benchmark orbital debris in and around Molniya orbits, as well as provide a tool for quantifying the proportion of catalogued objects within this debris population. This is because optical sensors are in general more sensitive for measurements at long range than comparable radar systems because optical sensitivity falls off as the square of the range while radar sensitivity falls off as the fourth power of the range.

Figure 1 shows a number of deep-space objects detected by LMT in or near Molniya orbits. Note that there are several uncorrelated objects detected, but they do not dominate the population. Figure 2 shows that many of these uncorrelated objects are dimmer and probably smaller than the correlated objects. These objects probably represent a modest population of uncatalogued debris in Molniya-like orbits. ❖

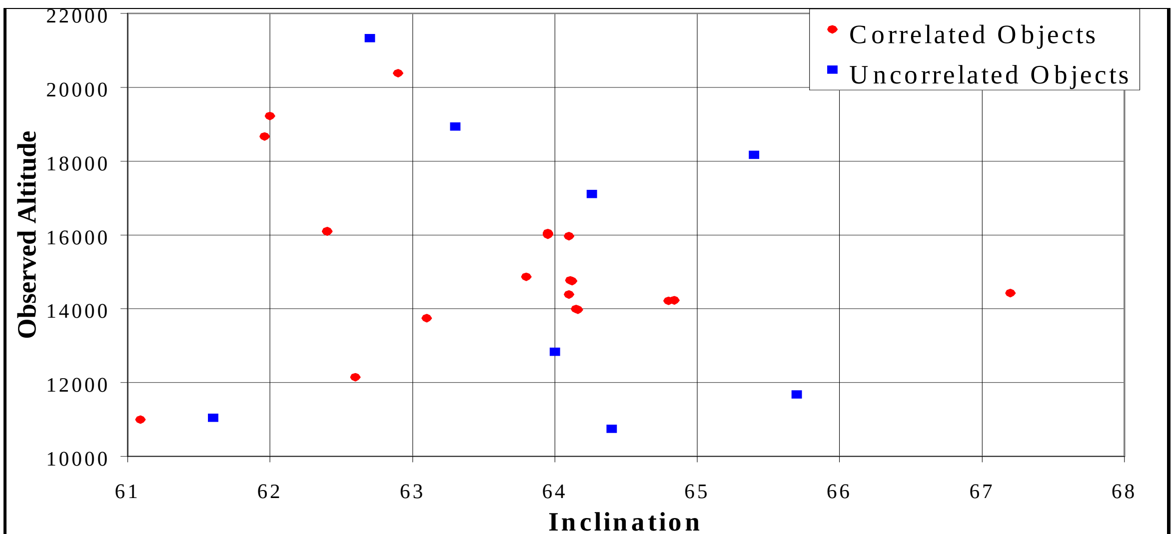


Figure 1. Observed Altitude vs. Inclination: Correlated and Uncorrelated Debris in and around the Molniya Orbit

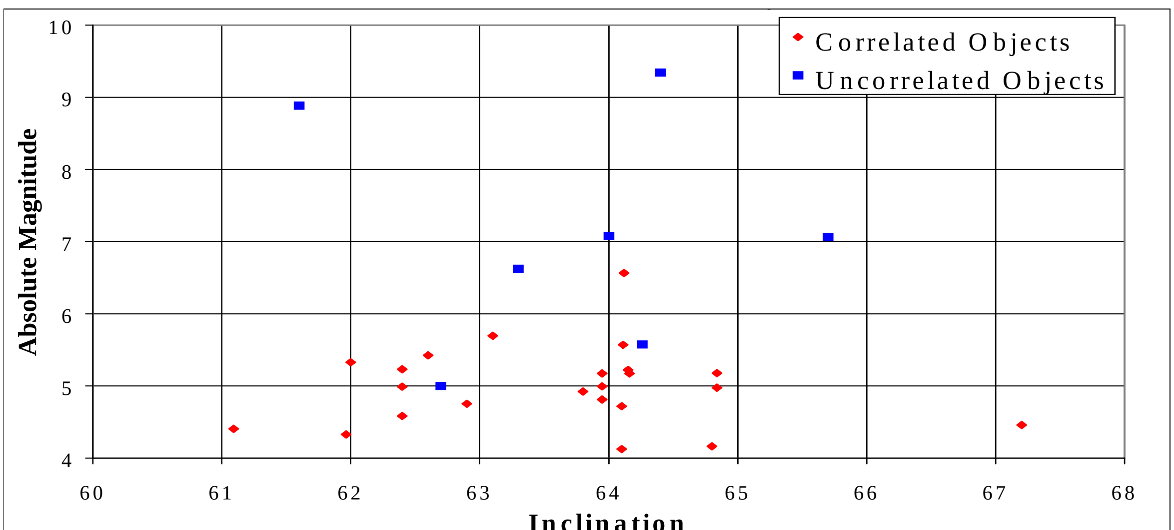


Figure 2. Absolute Magnitude vs. Inclination: Correlated and Uncorrelated Debris in and around the Molniya Orbit

Project Reviews

Reentry Assessment for Taurus Upper Stage Performed

The 28 February scheduled lift-off of the Multispectral Thermal Imager (MTI) spacecraft by a booster from Vandenberg AFB was postponed only two days before launch due to concerns about the risks to residents in French Polynesia. The ballistic reentry of the third stage of the Taurus launch vehicle was targeted for a remote area of the Pacific Ocean previously believed to have been uninhabited. The 11th-hour revocation of permission by the Tahitian government to use the region for a drop zone prompted U.S. Government officials to reexamine the threat posed by the small stage.

Revising the flight profile might require destacking the launch vehicle and introducing at least a two-month delay in the mission. With the flight on an indefinite hold, the JSC Orbital Debris Program Office was contacted on Thursday, 2 March, by the Department of Energy (owner of the spacecraft), the Department of Defense (operator of the launch site), and Orbital Sciences Corporation (provider of the launch vehicle) with a request to conduct a rapid evaluation of the reentry hazard of the Taurus third stage (known as Stage Two, since the initial stage was designated Stage Zero).

Using the NASA-Lockheed Martin Object Reentry Survival Analysis Tool (ORSAT), Version 5.0, and the appropriate trajectory parameters, the nearly 500 kg dry mass rocket body with a width of 1.6 m and a length of 4.4 m was modeled and its behavior during reentry studied. The vehicle presented a modeling challenge due to unusual materials used in the construction of the stage. A verification of the debris footprint region, if any, was also requested. Special efforts by Dr. Bill Rochelle and Mr. Ries Smith, both of Lockheed Martin, permitted a preliminary assessment to be made in less than 36 hours from receipt of the request. This was followed-up with a more definitive and confident answer by Monday, 6 March.

The analysis confirmed that a large portion of the upper stage was likely to survive reentry. Fortunately, the launch was permitted when a reevaluation of the impact zone indicated that the Island of Maria was not in danger. The mission was successfully flown on 12 March. ❖

Abstracts from Papers

A New Approach to Applying Interplanetary Meteoroid Flux Models to Spacecraft in Gravitational Fields
IAU Colloquium 181 and COSPAR Colloquium 11

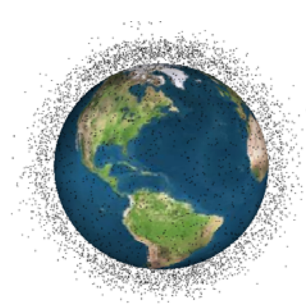
M. Matney

Neil Divine in his "Five Populations of Interplanetary Meteoroids" [JGR, Vol. 98, E9, pp. 17,029-17,048, 1993] introduced a method of defining the interplanetary meteoroid environment in terms of orbit families. For this work, a new method is introduced to apply orbit populations to compute meteoroid fluxes on spacecraft in interplanetary space and within the gravitational field of a planet or moon. The flux on the target is defined per unit solid angle per unit speed. This differential flux can be related to that outside the gravitational field by use of Liouville's theorem. Integration is performed over bins in solid angle (defining the direction of the meteoroids) and in meteoroid speed. This formulation computes the directional gravitational lensing while avoiding the numerical problems in Divine's method. It is also relatively easy to account for the shadowing of the planet body. This method is even applicable to complex multi-body systems. ❖

The New NASA Space Debris Breakup Model
IAU Colloquium 181 and COSPAR Colloquium 11

J.-C. Liou, N. Johnson, P. Krisko, and P. Anz-Meador

To model the past, current, and future space debris environment, the Orbital Debris Program Office at the NASA Johnson Space Center has developed a numerical program, EVOLVE, to perform the task. The model has been constantly modified/upgraded to make use of new data from observations and laboratory experiments. A key element in EVOLVE is the breakup model that simulates fragmentation outcomes of historical as well as future explosions and collisions. A new breakup model has been recently developed and implemented into the latest version of EVOLVE 4.0. For explosions, the model uses a single power law to describe the size distribution of breakup fragments. It is based primarily on the observed fragment distributions of 7 on-orbit rocket body explosions. For collisions, the model uses a power law that depends on the mass of the target object to describe the fragment distribution. It is based on several laboratory hypervelocity impact tests and one on-orbit collisional event. The simulated debris populations those with diameters equal or greater than 10 cm) between 200 and 2000 km altitudes, between 1957 and 1998, compare well with those derived from the catalogue objects tracked by the US Space Surveillance Network. Details of the new model and the comparisons are presented. ❖



Abstracts from Papers

Long-Term Orbital Debris Projections Using EVOLVE 4.0
38th AIAA Aerospace Sciences Meeting and Exhibit

P. Krisko and J. Theall

EVOLVE 4.0 is the latest version of the NASA long-term, space debris, environment evolution code. Analysis and validation of results of this model are ongoing. This paper discusses EVOLVE 4.0 calculations of the low Earth orbit (LEO) debris environment during both the historical and projection periods. The study of the historical period includes comparisons with data from various sources: the USAF Space Surveillance Network (SSN) catalog, the Haystack radar, and the Liquid Mirror Telescope (LMT). Projection period validation relies on reference to the historical period as well as on sensitivity and parametric studies. ❖

Meeting Report

Meeting of the NASA-DoD Orbital Debris Working Group
25-26 January 2000 NASA Johnson Space Center, Houston, TX, USA

The third annual meeting of the NASA-DoD Orbital Debris Working Group was held at the NASA Johnson Space Center during 25-26 January 2000. Thirty-five orbital debris and space surveillance specialists gathered together to review the joint orbital debris work plan and to exchange information on new surveillance and modeling capabilities.

Following a review of the status of 17 current work plan tasks, NASA and support contractors, including Lockheed Martin, Boeing, and Viking Science and Technology, Incorporated, made a series of presentations on radar and optical small debris observations in LEO and optical observations in GEO. An update on NASA's effort to revise the Orbital Debris Engineering Model, ORDEM96, with a more comprehensive and capable program was described. NASA also shared with its DoD colleagues the substantial upgrades incorporated into Version 4.0 of the EVOLVE long-term satellite environment model, including details of the new breakup model distribution functions. NASA offered to hold a special workshop on the EVOLVE model for DoD personnel in the Spring.

Air Force Space Command reciprocated by reviewing planned upgrades to the operation of the Cobra Dane radar in Alaska and the hardware and software changes anticipated in the GEODSS Modification Program. Army Space Command briefly reviewed the capabilities of the new GBR-P X-band radar in the Kwajelin Atoll. The radar has the potential for providing valuable data on small orbital debris, especially in low inclination and Molniya-type orbits. NASA and U.S. Army plan to conduct the first small debris observations with GBR-P later this year. ❖

Scientific and Technical Subcommittee of the United Nations' COPUOS
14-18 February 2000 Vienna, Austria

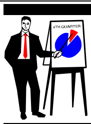
During 14-18 February the Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) resumed discussions on orbital debris at its annual meeting in Vienna, Austria. Orbital debris has been on the agenda of the STSC since 1994. A multi-year work plan was completed in 1999 with the publication of *Technical Report on Space Debris*, A/AC.105/720, which summarized international research and knowledge of orbital debris with emphasis on measurements, modeling, and mitigation.

The February 2000 session of the STSC focused on orbital debris issues associated with the geosynchronous (GEO) regime, including geosynchronous transfer orbits, operational orbits, and disposal orbits. Presentations on this topic were made by representatives of ESA, France, the Russian Federation, and the United States. The last was given by a member of the JSC Orbital Debris Program Office. In addition, a representative of the Inter-Agency Space Debris Coordination Committee (IADC) provided that organization's consensus view on these issues and described the IADC's activity to quantify better the GEO debris population.

In general, all agreed that the unique nature of the GEO environment and the persistence of debris generated there dictated close attention be paid to GEO debris, including derelict spacecraft and upper stages, operational debris, and fragmentation debris. The official session report noted

> *Most satellite operators were aware of the seriousness of the space debris situation near the geostationary orbit and had acknowledged the wisdom of undertaking some mitigation measures. However, the Subcommittee noted that, because of technical and managerial problems, even self-imposed guidelines were not being followed in some cases. It also noted that more research would be needed to understand fully the space debris environment near the geostationary orbit.*

After reviewing several proposals for future STSC discussions on orbital debris, the Subcommittee decided that the passivation and limitation of mission-related space debris for launch vehicles would be a suitable subject for the February 2001 session. Member States were also invited to examine the question of the costs and benefits of debris mitigation measures. ❖



Meeting Report

IAU Colloquium 181 and COSPAR Colloquium 11
10-14 April 2000 University of Kent at Canterbury, UK

J.-C. Liou

The joint International Astronomical Union (IAU) Colloquium 181 and COSPAR Colloquium 11 "Dust in the Solar System and Other Planetary Systems" was held at University of Kent at Canterbury, UK, April 10-14, 2000. Two sessions were devoted to space debris modeling and measurements. In total, 11 orbital debris research papers were presented (including posters). Two of the papers were presented by NASA Orbital Debris Program Office contract scientists: (1) A new approach to applying interplanetary meteoroid flux models to spacecraft in gravitational fields (by Mark Matney) and (2) The new NASA space debris breakup model (by J.-C. Liou). Other space debris papers included in-situ debris measurements in low Earth orbit (LEO) by the Japanese Space Flyer Unit and in geosynchronous orbit by ESA's GORID detector, a proposed CNES-funded project to measure 0.1 mm to 1 cm debris in LEO (LIBRIS), and the updated ESA debris model MASTER. There were also discussions of detectors to be flown in upcoming missions that are capable of measuring and distinguishing small orbital debris and meteoroids. The papers will be peer-reviewed and published in the colloquium proceedings later this year.

Mark Matney also attended a meeting with the orbital debris group at DERA in Farnborough, England on April 17. There were informal discussions about ongoing joint orbital debris projects between NASA and DERA (primarily under the framework of the IADC), as well as future research and measurement plans for each group. ❖

18th AIAA International Communications Satellite Systems Conference
10-14 April 2000 Oakland, CA, USA

D. T. Hall

The American Institute of Aeronautics and Astronautics convened the 18th International Communications Satellite Systems Conference (ICSSC) April 10 – 14 Oakland California. The meeting focused on satellite communications services, and was attended by representatives from European, Asian and American organizations. Much of the conference addressed interoperability between terrestrial and satellite communications systems. For instance, at least a dozen presentations addressed the potential and difficulties of using of internet protocols in satellite communications. Space debris issues were discussed by several authors, and for the first time, the ICSSC devoted an entire session to orbits and space environments.

On Tuesday April 11 Roger Rusch (TelAstra, Inc.) delivered a compelling talk entitled "Estimating the Demand for Launch Vehicle Services." The NASA-sponsored analysis he and his collaborators performed indicates that there is a tendency for industry to overestimate the need for launch services. The reasons for this are multifold. First, not all proposed satellites actually make it to launch because funding may be cut or customer needs may change. Second, satellites have been getting more capable and living longer, leading to fewer numbers launched initially and as replacements. Finally, over the next 10–20 years in particular, it is unclear how many of the low Earth orbit (LEO) communications satellite constellations will survive in the rapidly changing telecommunications market: orbiting systems may be deactivated, obviating the need for replacements; planned constellations may be eliminated or reduced in number. Using these and other considerations, TelAstra has developed a 20-year future launch traffic model that projects significantly fewer launches than

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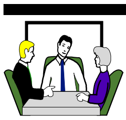

Upcoming Meetings

13-16 June 2000: *The 18th Inter-Agency Space Debris Coordination Committee (IADC) Meeting*, Colorado Springs, Colorado, USA. Over 120 delegates from the eleven member agencies will convene for three full days of discussions and presentations concerning space debris measurements, modeling, protection and mitigation.

30 July-4 August 2000: *The International Symposium on Optical Science and Technology (SPIE's 45th annual meeting)*, San Diego, California, USA. The technical emphasis of the International Symposium on Optical Science and Technology confirms SPIE's commitment to a long-standing societal goal to create global forums that provide interaction for members of the optics and photonics communities, who gather to discuss the practical science, engineering, materials, and applications of optics, electro-optics, optoelectronics, and photonics technologies. The Annual Meeting also serves as an industry focal point, offering excellent interaction with the vendor community, who will be exhibiting their newest product developments. More information can be found at: http://www.spie.org/web/meetings/programs/am00/am00_home.html.

16-23 July 2000: ***33rd Scientific Assembly of COSPAR,*** Warsaw, Poland. Four sessions on orbital debris are being jointly organized by Commission B and the Panel on Potentially Environmentally Detrimental Activities in Space to include such topics as techniques to measure orbital debris, methods of orbital debris modeling, hypervelocity impact phenomenology, and debris mitigation practices. For further information contact Prof. Walter Flury, wflury@esoc.esa.de

2-6 October 2000: *The 51st International Astronautical Congress (IAF),* Rio de Janeiro, Brazil. The theme for the congress is "Space: A Tool for the Environment and Development." The 51st International Astronautical Congress will offer a great opportunity for interactions and knowledge on innovative applications, new concepts and ideas, new scientific results and discussions. The Congress is open to participants of all nations. More information can be found at: http://www.iafastro.com/congress/con_fra.htm.

INTERNATIONAL SPACE MISSIONS

January - March 2000

International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2000-001A	USA 148	USA	ELEMENTS UNAVAILABLE			2	0
2000-002A	GALAXY 10R	USA	35782	35788	0.1	1	0
2000-003A	ZHONGXING-22	CHINA	35782	35789	0.7	1	0
2000-004A	JAWSAT	USA	751	803	100.2	1	2
2000-004B	OCSE	USA	748	797	100.2		
2000-004C	OPAL	USA	751	805	100.2		
2000-004D	FALCONSAT	USA	751	807	100.2		
2000-004E	ASUSAT	USA	751	806	100.2		
2000-004H	PICOSAT (MEMS) 1 & 2	USA	749	800	100.2		
2000-004J	PICOSAT 3 (THELMA)	USA	752	804	100.2		
2000-004K	PICOSAT 4 (LOUISE)	USA	749	805	100.2		
2000-004L	PICOSAT 5 (JAK)	USA	750	805	100.2		
2000-004M	PICOSAT 6 (STENSAT)	USA	750	805	100.2		
2000-005A	PROGRESS M-1	RUSSIA	344	350	51.7	1	0
2000-006A	COSMOS 2369	RUSSIA	844	857	71.0	1	6
2000-007A	HISPASAT 1C	SPAIN	35770	35802	0.1	1	0
2000-008A	GLOBALSTAR A	USA	EN ROUTE TO OP. ORBIT			1	0
2000-008B	GLOBALSTAR B	USA	1413	1414	52.0		
2000-008C	GLOBALSTAR C	USA	EN ROUTE TO OP. ORBIT				
2000-008D	GLOBALSTAR D	USA	EN ROUTE TO OP. ORBIT				
2000-009A	DUMSAT	RUSSIA	581	606	64.9	1	0
2000-010A	STS-99	USA	226	234	57.0	0	0
2000-011A	GARUDA-1	INDONESIA	35776	35800	3.0	1	0
2000-012A	SUPERBIRD 4	JAPAN	35757	35777	0.0	1	0

Correspondence concerning the ODQN can be sent to:

Sara A. Portman
Managing Editor
NASA Johnson Space Center
The Orbital Debris Program Office
SN3
Houston, Texas 77058

sara.a.portman1@jsc.nasa.gov

18th AIAA Meeting Report, Continued

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competing models.

On Thursday April 13 Walter Flury (ESA) and Tetsuo Yasaka (Kyushu Univ.) chaired the first-ever ICSSC session devoted to "Orbits and Space Environments." Xiaolong Li (IFSST) presented an outline of a software tool that compares the ESA MASTER and the NASA ORDEM96 debris models, revealing some interesting differences - especially in small particle populations. Michael Fudge (ITT Industries) presented an analysis of orbital debris threats posed by the deployment of LEO communications satellite constellations, concluding that deployment of such constellations is unlikely to change the debris threat to other satellites significantly. Finally, Walter Flury (ESA) outlined the pertinent space debris issues in the geostationary ring, including ESA's successful ongoing effort to observe GEO space debris from groundbased telescopes. He concluded by emphasizing that a code of conduct (or a UN regulation) addressing collision-avoidance concerns would help ensure the safety of operational geosynchronous satellites. ❖

ORBITAL BOX SCORE

(as of 5 April 2000, as catalogued by US SPACE COMMAND)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	27	102	129
CIS	1334	2572	3906
ESA	24	236	260
INDIA	20	4	24
JAPAN	66	47	113
US	914	2932	3846
OTHER	284	25	304
TOTAL	2669	5918	8587

Orbital Debris and the Internet

Orbital Debris Information

NASA Johnson Space Center:
http://www.orbitaldebris.jsc.nasa.gov

NASA White Sands Test Facility:
http://www.wstf.nasa.gov/hypervl/debris.htm

NASA Marshall Space Flight Center:
http://see.msfc.nasa.gov/see/mod/srl.html

NASA Langley Research Center:
http://setas-www.larc.nasa.gov/index.html

University of Colorado:
http://www-ccar.colorado.edu/research/debris/html/ccar_debris.html

European Space Agency:
http://www.esoc.esa.de/external/mso/debris.html

Italy: http://apollo.cnuce.cnr.it/debris.html

United Nations: http://www.un.or.at/OOSA/spdeb

NASA Hypervelocity Impact Technology Facility:
http://hitf.jsc.nasa.gov

Orbital Debris Documents

National Research Council, "Orbital Debris – A Technical Assessment":
http://www.nas.edu/cets/aseb/debris1.html

National Research Council, "Protecting the Space Station from Meteoroids and Orbital Debris":
http://www.nas.edu/cets/aseb/statdeb1.html

National Research Council, "Protecting the Space Shuttle from Meteoroids and Orbital Debris":
http://www.nas.edu/cets/aseb/shutdeb1.html