The Orbital Debris Quarterly News

A publication of

The Orbital Debris Program Office
NASA Johnson Space Center
Houston, Texas 77058

January 2000 **Volume 5, Issue 1**

Project Reviews

EVOLVE 4.0 Sensitivity Study Results

P. Krisko

Sensitivity studies of the EVOLVE 4.0 results pertaining to the breakup and traffic models within EVOLVE, orbital debris mitigation measures, and the GEO debris environment are underway. The purpose of these studies is two-fold. First, the EVOLVE results themselves are tested by varying certain input parameters. These include such quantities as the energy threshold for catastrophic collisions, the allowed variability of size distributions of fragments, and the most probable impact velocity as a function of altitude. Second, parameters that would potentially influence the projected environment are varied to study their effect on those projections. For example, changes in launch traffic and in imposed mitigation measures such as collection and disposal orbits and explosion suppression are tested to determine which cause significant changes in the long-term debris environment.

Preliminary analyses of the breakup and traffic models and of mitigation practices in LEO have been completed. Study of the GEOEVOLVE model is slated for early this year. Highlights of the three completed studies are presented here. Each study test parameter set is compared to the ‘standard’ EVOLVE run, which is defined under the following assumptions:

- the launch traffic is that of the last eight years (1991 through 1998) cycled over the 100 year projection period;
- the energy threshold resulting in catastrophic collision is set to 40 J/g;
- impact velocity is randomly selected based on present-day population in LEO;
- the mean of 30 Monte Carlo iterations is used to represent the environment;
- the standard deviation of the 30 Monte Carlo iterations is used to represent the error of the projection.

Figure 1 displays one result of the breakup model study, the variation of the future population of 10 cm and larger objects in LEO over time due to variations in the energy threshold, $Q^*=(\frac{1}{2} m_{proj} v^2_{impact})/m_{targ}$, for catastrophic collisions.[1] The values of 30 to 60 J/g are chosen because this is the published range of the energy threshold associated with a catastrophic collision. Very little difference in the outcome of the EVOLVE runs is associated with a variation of this magnitude. In fact all cases reside within the error bars of each of the others. This is an indication that the choice of threshold impact strength within the above range is not a critical modeling issue.

Specified variations in the launch traffic in LEO and their effect on the future LEO debris environment are shown in Figure 2.[2] The two test cases show the projected 10 cm and larger population resulting from changes of $\pm$25% in the cycled launch traffic. As expected, launch traffic varied in this way has a major effect on the projected population. The varied population is not simply a result of launch traffic but also of changes in the explosion and collision activity wrought by that traffic. Hence, the lower traffic rate yields a population of 38% below the nominal case, while the higher rate leads to a 46% increase in population.

Finally, an analysis of the effects of NASA Safety Standard inspired mitigation measures on the future environment is shown.[3] Figure 3 again displays the variation of the future population of 10 cm and larger

(Continued on page 2)

Project Reviews

EVOLVE 4.0 Sensitivity Study Results, Continued

(Continued from page 1)
objects in LEO over time. Here, explosion suppression results in a minor decrease in the debris population over time. Ninety-five percent of explosions that could possibly occur during the projection time are explicitly disallowed after the tenth projection year (excluding Russian photo-reconnaissance satellites). Further reduction in population is accomplished through the adoption of post-mission disposal rules. In these cases, all intact spacecraft and rocket bodies launched after the fifth projection year are required, at the end of mission, to move to orbits that will allow them to decay out of orbit within 50, 25, and 10 years. As compared to the standard EVOLVE run and the explosion suppression results, these re-orbit cases result in a dramatic reduction in the population by the end of the 100 year projection period.

It must be re-iterated that the above results are preliminary and based on an initial small set of sensitivity testing criteria. These studies have been instrumental, however, in identifying directions for future work. Extensions of the preceding studies will be performed later this year.

References

1. Liou, J.-C., P. Anz-Meador, D. Kessler, P. Krisko, and J. Opiela, EVOLVE breakup model sensitivity study, Technical Memorandum, December 3, 1999..
2. Opiela, J.N., P. Anz-Meador, D. Kessler, P. Krisko, and J.-C. Liou, EVOLVE launch traffic sensitivity study, Technical Memorandum, December 17, 1999.
3. Krisko, P., D. Kessler, P. Anz-Meador , J.-C. Liou, and J. Opiela, EVOLVE mitigation sensitivity study, Technical Memorandum, December 3, 1999. ❖

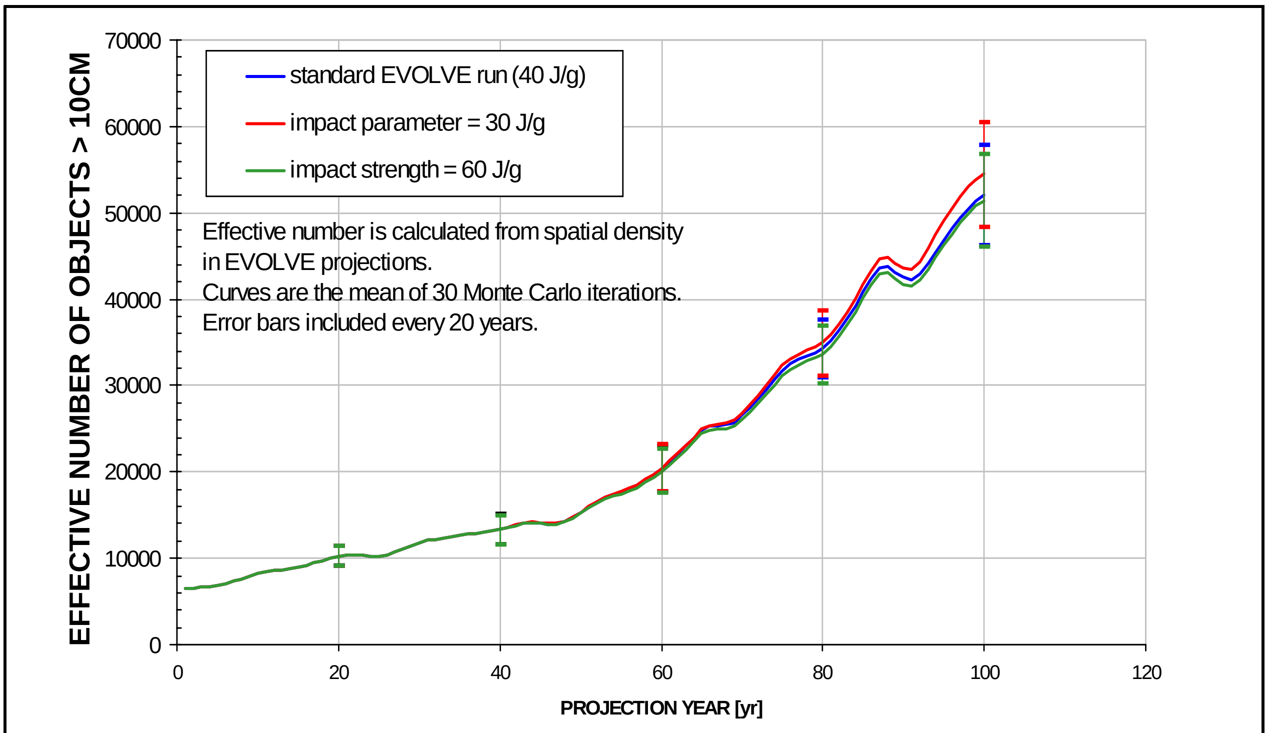


Figure 1. Results of the initial breakup model sensitivity study with energy thresholds for catastrophic collisions of 30 J/g, 40 J/g, and 60 J/g.

(Continued on page 3)

Visit the New NASA Johnson Space Center Orbital Debris Website

http://www.orbitaldebris.jsc.nasa.gov

Project Reviews

EVOLVE 4.0 Sensitivity Study Results, Continued

(Continued from page 2)

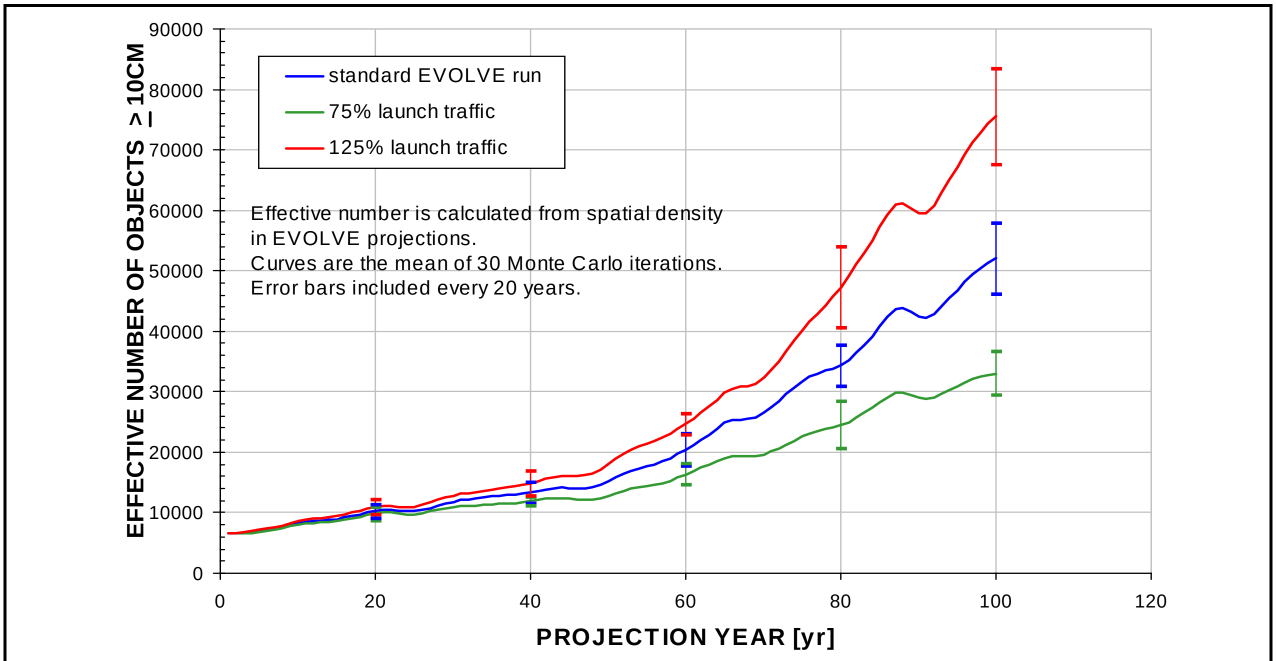


Figure 2. Results of the initial launch traffic sensitivity study with launch traffic varied by ±25% for the entire projection period.

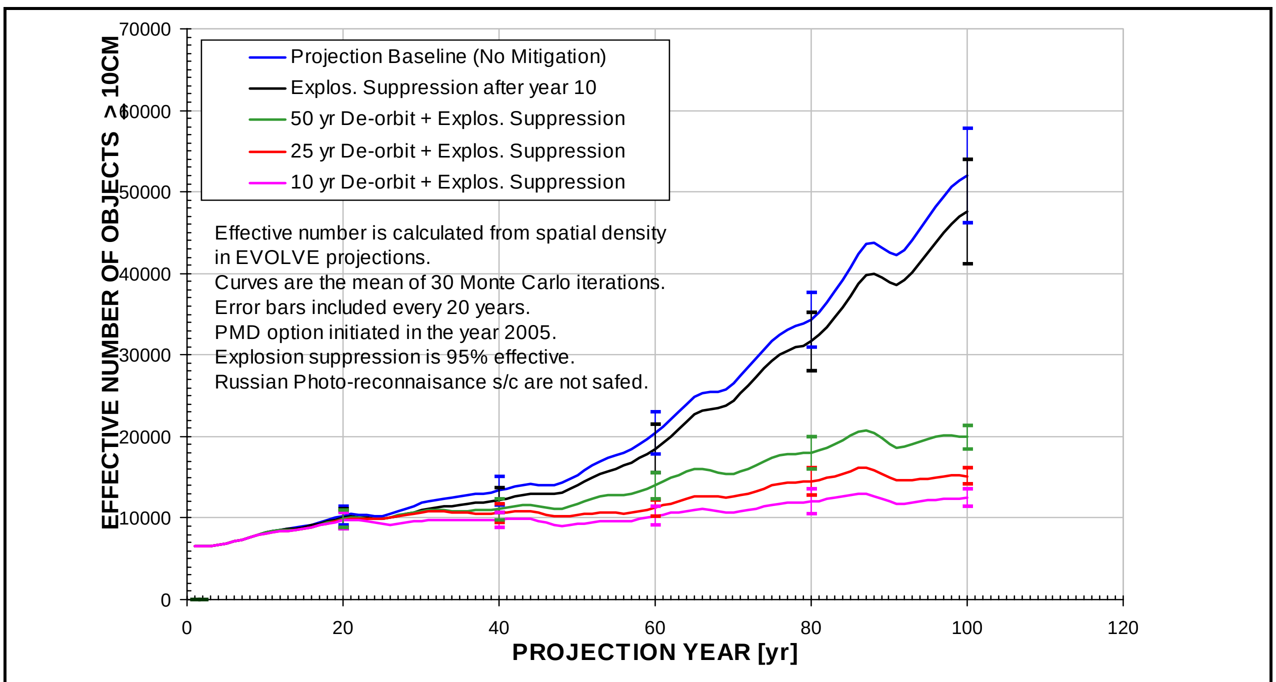


Figure 3. Results of the initial LEO mitigation sensitivity study with explosion suppression and various post-mission option exercised.

Project Reviews

Liquid Mirror Telescope Observations of the Orbital Debris Environment: October 1997 - January 1999

J. Africano

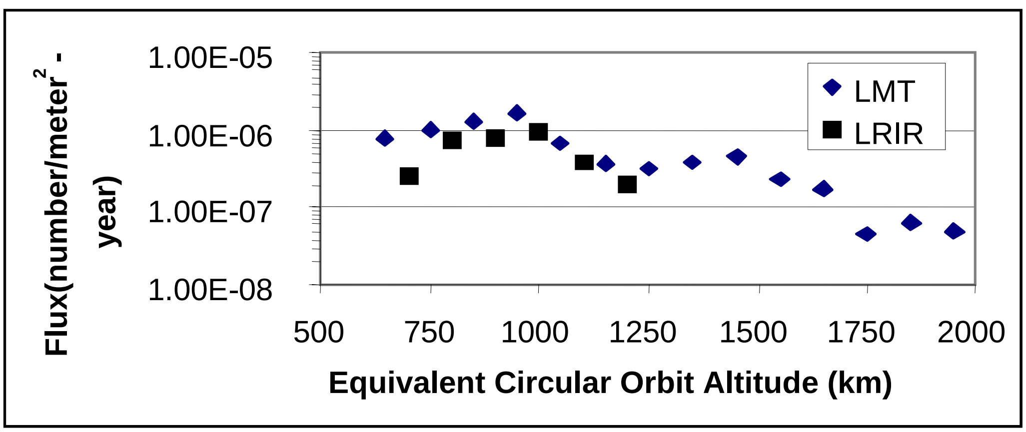
The first NASA Liquid Mirror Telescope (LMT) report (JSC-28826) has been recently published. This report provides results of optical measurements using LMT located at Cloudcroft, NM (33° N. Latitude). The results are based upon 401 hours of LMT video data collected between October 1997 and January 1999.

The primary mirror of the LMT is a three-meter parabolic dish of mercury spinning at a rate of ten revolutions per minute. As the dish spins, the mercury spreads over the dish to form a reflective surface with a focal ratio of 1.7. Liquid mirror technology is an extremely cost-effective way of providing a large aperture primary mirror and a relatively large field-of-view. Its major limitation of zenith staring does not hinder it from statistically sampling the LEO orbital debris environment.

Automated data processing has been developed which identifies meteors, satellites, and orbital debris in the recorded digital video data without human intervention. The automated processing outperformed trained, careful, and dedicated human screeners (i.e. the authors of this report). By eliminating the human factor, detection of objects in the video data is inherently more reliable, repeatable, and economical.

After an object has been detected, newly developed analysis algorithms extract estimates of the object's inclination and altitude. In order to estimate altitude, a circular orbit must be assumed. Comparison of extracted estimates with known values for SSN cataloged objects show that for satellites with altitudes less than 2000 km and nearly circular orbits: 1) the inclination estimate has a bias of about 2°, and 2) the altitude estimate has a bias of about 26 km. These biases are most likely due to a slight error in the determination of the plate scale for the LMT and will be studied further. Comparison of radar-derived sizes with optical magnitudes shows that the cataloged objects have a median albedo of 0.10, although a large amount of scatter is present. This albedo has been used to estimate the size of all detected objects.

The data was recorded on a commercial grade digital video camera equipped with a 40-mm light intensifying multi-channel plate (MCP). This combination was able to detect orbital debris objects as dim as 16^{th} magnitude and stars down to 17^{th} magnitude. Assuming an albedo of 0.10, this corresponds to debris sizes as small as 3 cm in diameter. After removing identifiable meteors, the distributions in altitude and inclination of the detected objects are presented. The flux for detected objects is also presented after correcting for effects of earth shadow height on time of collection. The following figure shows the flux of objects 10-cm in diameter and larger as a function of altitude compared to similar measurements made over a similar time period by the Haystack LRIR. Overall, the data are in fairly good agreement. The LMT flux appears to be slightly higher than the radar flux for altitudes less than 1000 km. The two sensors could be detecting slightly different populations. Or, if the albedo used for the size estimation was increased from the median value of 0.10 to the average value of about 0.17, all of the sizes would decrease, which would lower the flux and bring the two data sets into better agreement. More work is needed to better quantify the distribution of the albedo of small debris objects. ❖



Haystack/HAX 1999 Report

T. Settecerri

The Haystack Observatory located in Tyngsboro, MA operates the Long Range Imaging Radar (LRIR, nominally called Haystack), which has been NASA's primary tool for collecting 1 – 10 cm, orbital debris data since October 1990. Beginning in 1994, the Haystack Auxiliary (HAX) Radar became operational and started collecting debris data. This report summarizes NASA/Johnson Space Center's orbital debris radar measurements program from October 1990 to October 1998. It also serves as a comprehensive document describing the steps used to collect, process, analyze, and characterize the orbital debris environment. The main body of this report includes a description of the measurements, data processing, and results. Appendix A summarizes the previous reports. Appendix B contains a description of the various plots generated from the Haystack and HAX data. In addition, it contains all plots from Fiscal Year 1991 through Fiscal Year 1998.

This report is a compendium of the Haystack and HAX radar measures of the

(Continued on page 5)

Project Reviews

Haystack/HAX 1999 Report, Continued

(Continued from page 4)
orbital debris environment. The data shown in the appendix was collected between October 1990 and October 1998 (FY91 through FY98). The primary objective of the radar measurements has been to characterize the debris environment in the size-range from 1 to 10 cm. During that time-period Haystack had 51,740 hits, 16,462 valid detections, during 4,718 hours; HAX had 9,701 hits, 2,377 valid detections, during 2,690 hours. The addition of the HAX radar in FY94 has improved the counting statistics at the larger sizes and provided an additional confidence factor in the NASA Size Estimation Model. The HAX detection rate is higher than LRIR at space station altitudes due to its wider beamwidth. This improves the confidence limits on the population estimate at shuttle and space station altitudes. Data collected for different radars around the world have shown excellent agreement in regard to inclination, altitude, and size distributions.

The data have provided a wealth of knowledge regarding fragmentation debris, non-fragmentation debris, inclination and altitude distributions, population estimates, and cumulative size distributions that are invaluable to modeling. The radars have collected data on breakups soon after they occurred. Examination of these events provides a benchmark for explosion models. The temporal changes in the environment are readily observed in the data. Examination of debris families is the first step toward understanding the mechanisms responsible for debris creation and may lead to proactive actions in controlling the orbital debris population.

Figure 1 shows the flux observed for objects that are 1 cm or larger versus altitude. One centimeter was selected for two reasons. First, the International Space Station shielding provides protection against debris objects approximately one centimeter in diameter or smaller. Second, the Haystack radar detection sensitivity is such that for objects detected below 1000-km altitude, the probability of detection is nearly 99 percent.

Figure 2 below compares the 10-cm flux with the catalog population. The spatial density from each mid-Fiscal Year catalog (~DOY 90) was used to calculate flux for this plot. Note in most cases the Haystack data flux is slightly higher than the catalog. This shows the catalog is not totally complete down to 10 cm. ❖

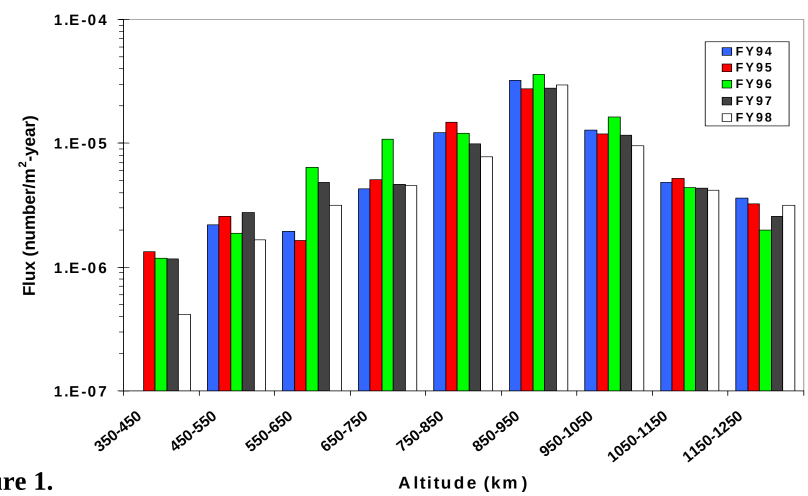


Figure 1.

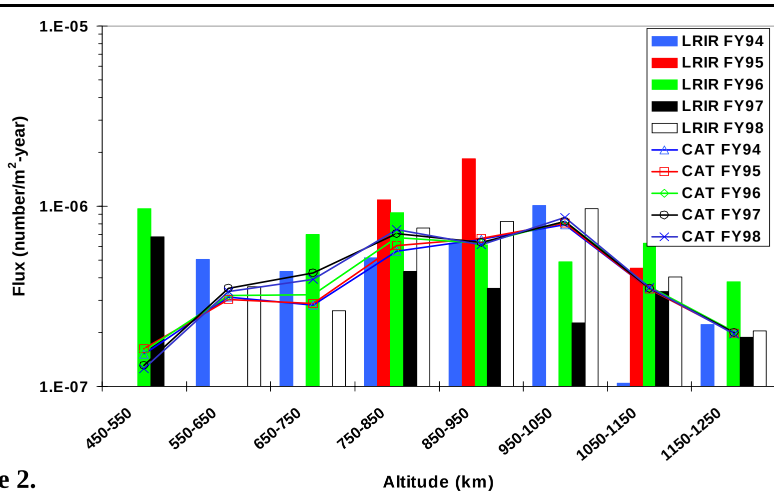


Figure 2.

Project Reviews

Post-flight Examination of the STS-96 Orbiter

J. Kerr

During June 1999, the Space Shuttle Discovery spent nearly 10 days in a low altitude (390 km), high inclination (51.6 degree) orbit for the first docking with the International Space Station. In December 1999 a report sponsored by the NASA Orbital Debris Program Office summarized the orbital debris and micrometeoroid damage discovered during post-flight inspections (STS-96 Meteoroid/ Orbital Debris Impact Damage Analysis, JSC-28642, Justin Kerr and Ronald Bernhard).

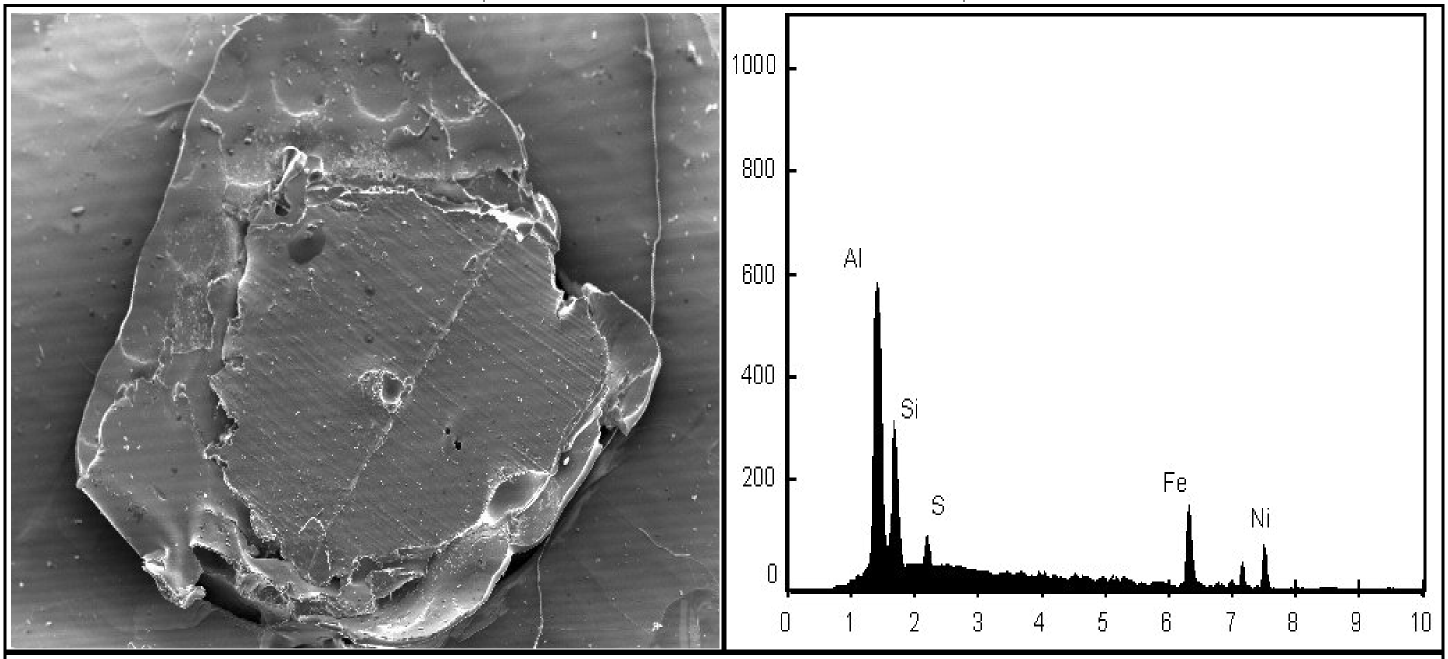
The primary orbiter surface areas examined included the crew compartment windows (3.6 m^2), the reinforced carbon-carbon (RCC) leading edge of the wings (41 m^2), the flexible reusable surface insulation (FRSI) on the exterior of the payload bay doors (40 m^2), and radiator panels (117 m^2). In all, 64 impact sites were examined by tape pull, dental mold, or wooden probe extraction techniques. Damage regions ranged from 0.125 mm to 4.0 mm in equivalent diameter.

A total of 50 window impacts were identified with the help of a optical micrometer and fiber optic light source. Two windows required replacement following this mission due to craters that exceeded their replacement criteria. The largest window impactor was aluminum orbital debris and is estimated to have been 0.05 mm in diameter. Scanning electron microscopy with energy dispersive X-ray spectrometers permitted the characterization of 24 of the impactors: 10 orbital debris and 14 meteoroid. Of the orbital debris impactors, 50% were paint, 40% were aluminum, and 10% were stainless steel.

Examination of the radiators led to the discovery of six impact features with a minimum 1.0 mm damage diameter. All six sites yielded sufficient residue to determine the nature of the impactor. Two of the impactors were orbital debris and the remaining four impactors were meteoroids. Only one of the impactors, a 0.4 mm diameter meteoroid, was sufficient to create a hole (1.0 mm diameter) in the radiator facesheet.

Inspections of the FRSI found six new impact sites greater than 1 mm in extent: two unknown, two meteoroids (1.2 and 1.3 mm in diameter) and two orbital debris (1.1 and 1.3 mm diameter paint and aluminum, respectively). In addition, two new impact sites were located on the RCC surfaces. The damage was caused by a 0.4 mm diameter aluminum orbital debris and an unknown impactor.

Post-flight inspections of Space Shuttle orbiters continue to produce valuable data on the natural and artificial particulate environment in low Earth orbit. A new, more comprehensive assessment of these mission data has been recently initiated at JSC with results to be published in early 2000. ❖



SEM Image and EDX spectra of a radiator tape impact from the through penetration impact.

Visit the New NASA Johnson Space Center Orbital Debris Website

http://www.orbitaldebris.jsc.nasa.gov

NEWS

Satellite Breakups Increase in Last Quarter of 1999

After witnessing only three breakups during the first nine months, the year ended with four additional breakups from three satellites, all traversing low Earth orbit. Whereas the environmental consequences of three of the events were or will be short-lived, the effects of one breakup will be more enduring.

On 9 October a Tsyklon third stage (1991-068G, U.S. Satellite Number 21734), which inserted six Cosmos spacecraft into orbit eight years earlier, brokeup into more than 30 trackable fragments. The orbit of the third stage at the time of the event was 1410 km by 1485 km with an inclination of 82.6 degrees. The known debris cloud was spread over more than 600 km in altitude, approximately 300 km above and below the breakup altitude of 1460 km. The debris is centered near the 1414 km operational altitude of the new Globalstar commercial communications satellite constellation with 48 spacecraft.

In a very rare occurrence, a perturbation of the Tsyklon third stage's orbit was detected by U.S. Space Surveillance Network (SSN) personnel about five days prior to the breakup, permitting greater scrutiny of the satellite just before the fragmentation. This stage is the fourth such object known to have broken-up on-orbit, with three of these explosions occurring during 1998-1999. (The others were upper stages for the Cosmos 1045, Cosmos 2053, and Meteor 2-16 missions.) Each stage had been in space between 8 and 10.5 years.

To date these Ukrainian-manufactured upper stages, of which more than 100 remain in orbit, have not been purged of residual propellants or in other ways passivated at the end of their missions. Coincidentally, a Ukrainian observer delegation briefed the Inter-Agency Space Debris Coordination Committee (IADC) about Tsyklon third stage fragmentations on 11 October, as a result of an IADC request following the 18 April 1999 breakup of the Cosmos 2053 third stage (see *Orbital Debris Quarterly News*, July 1999).

The second breakup of the quarter occurred on 22 November 1999 when the Russian spacecraft Cosmos 2347 (1997-079A, U.S. Satellite Number 25088) brokeup at an altitude of 370 km. This national security spacecraft had been operating in an orbit of approximately 405 km by 420 km with an inclination of 65 degrees for nearly two years when it performed an end-of-mission maneuver on 19 November, moving into an elliptical orbit of 230 km by 410 km. More than 130 debris were detected by the SSN shortly after the event.

This was the 19th spacecraft of this class known to have suffered a fragmentation, normally (all but one) after the vehicle had completed its primary mission. Although these breakups were frequent in the 1970's and 1980's, this was only the third such event in the 1990's. The cause of the breakups remains unknown.

A second breakup of Cosmos 2347 was discovered on 10 December when the spacecraft's orbit had decayed to 175 km by 250 km. Three dozen new debris were detected after the second event, but the very low altitude made it difficult to assess accurately the number of large debris. Prior spacecraft (especially Cosmos 1220, 1260, and 1306) also experienced multiple fragmentations.

The last breakup of the year occurred on 13 December when an ullage motor (1996-034F, U.S. Satellite Number 23887) from a Proton fourth stage brokeup in an orbit of 145 km by 5605 km with an inclination of 46.5 degrees. This was the 21st breakup of this type since 1984 and the sixth in the past two years. The cause of the breakups is assessed to be related to residual hypergolic propellants. Newer versions of this stage have been redesigned to reduce this explosion potential.

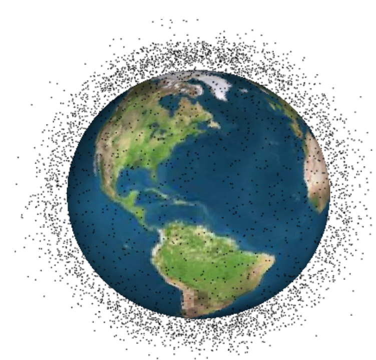
Three of the four breakups of the quarter occurred in orbits which intersect with Space Shuttle and International Space Station altitudes. Consequently, after each event the Orbital Debris Program Office performed rapid risk assessments of potential hazards to human space flight operations. In the case of the first breakup of Cosmos 2347, the fragmentation took place at 370 km, the same altitude as the International Space Station. Fortunately, in all cases, the threat posed by the new debris cloud to human space flight was found to be very slight. ❖

ISS Performs First Collision Avoidance Maneuver

The International Space Station (ISS) conducted its first collision avoidance maneuver on 26 October to ensure no possible contact with a derelict Pegasus upper stage (1998-046K, U.S. Satellite Number 25422). JSC mission operations personnel were informed late on 24 October by U.S. Space Command analysts of an anticipated conjunction between the two objects on 27 October. Further tracking and orbital analysis confirmed a probability of collision of only ~0.3%, but this value exceeded ISS flight rules and called for maneuver preparations. Consequently, plans were drawn up for executing a posigrade maneuver of 1 m/s, thereby raising the orbit of ISS and effectively employing the 30 kg of propellant which would be required.

Close cooperation between the Houston and Moscow mission control centers led to a reorientation of the ISS complex and a 5-second burn of the Zarya module's propulsion system 18 hours before the conjunction would occur. Instead of a miss distance of less than one kilometer, ISS and the Pegasus stage passed at a safe separation of more than 140 km.

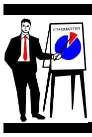
The Pegasus vehicle had been used on 2 August 1998 to place eight Orbcomm spacecraft into an orbit of approximately 820 km altitude. The final stage, a Hydrazine Auxiliary Propulsion System (HAPS), later performed a propellant depletion maneuver (in part to prevent a recurrence of an abandoned HAPS explosion on 3 June 1996), significantly lowering the vehicle's perigee and ensuring its natural orbital decay within the NASA and U.S. Government 25-year guidelines. The ISS collision avoidance maneuver demonstrated how the safety of human space flight can be enhanced while also curtailing the growth of the orbital debris population. ❖



NEWS

Professor Hanada on Sabbatical at JSC

The Orbital Debris Program Office is pleased to welcome Kyushu University associate professor Dr. Toshiya Hanada for a one-year sabbatical at NASA Johnson Space Center to conduct orbital debris research. An instructor for several years in Kyushu University's Department of Aeronautics and Astronautics, Dr. Hanada has conducted original research in the phenomenology of high speed impacts and modeling of the geosynchronous environment. Dr. Hanada is the author or co-author of several orbital debris papers with emphasis on modeling the satellite population growth in GEO, the consequences of GEO satellite fragmentations, and GEO satellite disposal options. Dr. Hanada arrived at JSC in early November and is accompanied in Houston by his wife Michiko. ❖



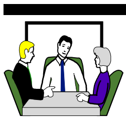
Meeting Report

17th Meeting of the IADC

The Inter-Agency Space Debris Coordination Committee (IADC) met at the European Space Operations Center (ESOC) in Darmstadt, Germany, during 11-13 October. The meeting followed the 50th International Astronautical Congress which was held the previous week in Amsterdam, the Netherlands, and where more than 30 papers on orbital debris were presented. The 10 members of IADC represent the space agencies of China, France, Germany, India, Italy, Japan, Russia, the United Kingdom, and the United States, as well as the European Space Agency. Joining the IADC meeting for the first time, as an official observer, was the National Space Agency of Ukraine.

In all, more than 110 specialists attended the meeting, hosted by ESA, to exchange information on the latest research in orbital measurements, modeling, protection, and mitigation. (see January 1998 issue of *Orbital Debris Quarterly News* for scope and organization of IADC.) One of the actions adopted at this most recent meeting was the initiation of an effort to develop a consensus set of orbital debris mitigation standards. Most IADC members already have or are preparing their own mitigation standard practices.

The expertise and reputation of the IADC continues to grow. In February 2000, at the invitation of the Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on the Peaceful Uses of Outer Space, the IADC will present an overview of orbital debris issues in the geosynchronous regime. This will mark the fourth consecutive year that IADC has made a presentation before the STSC. With the assistance of the German space agency, DLR, an IADC website is being developed to make information about orbital debris more accessible and to enhance communications within the IADC. The implementation of the IADC website is anticipated in early 2000. Its internet address will be identified in a future issue of *the Orbital Debris Quarterly News*. ❖



Upcoming Meetings

11-13 April 2000: ***Space Control Conference 2000,*** Lexington, Massachusetts, USA. The conference is the 18th annual meeting hosted by MIT Lincoln Laboratory on space control issues, surveillance technology (including orbital debris), and monitoring and identification. For further information contact Susan Andrews at scc@ll.mit.edu

12-14 June 2000: ***Space and Air Survivability Workshop 2000***, Colorado Springs, Colorado, USA. The purpose of this workshop, which is jointly sponsored by the AIAA and the DoD Joint Technical Coordinating Group on Aerospace Survivability, is to (1) summarize environment hazards and directed threats to commercial and military spacecraft performance (including orbital debris), (2) discuss spacecraft survivability analysis methods, tools, and test techniques, and (3) explore how aircraft survivability methodologies and enhancement techniques might be applied to improve spacecraft survivability. For further information contact Mr. Joel Williamsen, jowillia@du.edu

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 ❖

Visit the New NASA Johnson Space Center Orbital Debris Website

http://www.orbitaldebris.jsc.nasa.gov

INTERNATIONAL SPACE MISSIONS

October - December 1999

International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
1999-055A	NAVSTAR 46 (USA 145)	USA	20088	20277	53.0	2	0
1999-056A	DIRECTV 1-R	USA	35779	35796	0.0	1	0
1999-057A	CBERS 1	CHINA/ BRAZIL	773	775	98.6	1	0
1999-057B	SACI 1	BRAZIL	732	745	98.6		
1999-058A	GLOBALSTAR 31	USA	1413	1414	52.0	2	0
1999-058B	GLOBALSTAR 56	USA	1413	1414	52.0		
1999-058C	GLOBALSTAR 57	USA	1415	1412	52.0		
1999-058D	GLOBALSTAR 59	USA	1414	1413	52.0		
1999-059A	ORION 2	USA	35780	35794	0.1	1	0
1999-060A	GE 4	USA	35760	35800	0.0	1	0
1999-061A	SZ1	CHINA	195	315	42.6	1	3
1999-062A	GLOBALSTAR M029	USA	EN ROUTE TO OP. ORBIT			2	0
1999-062B	GLOBALSTAR M034	USA	1411	1416	52.0		
1999-062C	GLOBALSTAR M039	USA	EN ROUTE TO OP. ORBIT				
1999-062D	GLOBALSTAR M061	USA	1413	1414	52.0		
1999-063A	UFO 10 (USA 146)	USA	34945	36627	6.0	1	0
1999-064A	HELIOS 1B	FRANCE	679	682	98.1	1	0
1999-064B	CLEMENTINE	FRANCE	646	665	98.1		
1999-065A	ORBCOMM A	USA	825	834	45.0	2	0
1999-065B	ORBCOMM B	USA	825	834	45.0		
1999-065C	ORBCOMM C	USA	825	833	45.0		
1999-065D	ORBCOMM D	USA	825	833	45.0		
1999-065E	ORBCOMM E	USA	824	831	45.0		
1999-065F	ORBCOMM F	USA	824	830	45.0		
1999-065G	ORBCOMM G	USA	824	830	45.0		
1999-066A	XMM	ESA	7396	113699	38.7	1	0
1999-067A	DMSP F15 (USA 147)	USA	838	850	98.9	0	2
1999-068A	TERRA	USA	654	685	98.2	1	0
1999-069A	STS 103	USA	563	609	28.5	0	0
1999-070A	KOMPSAT	KOREA	690	722	98.3	1	1
1999-070B	ACRIMSAT	USA	684	725	98.3		
1999-071A	GALAXY 11	USA	EN ROUTE TO OP. ORBIT			1	0
1999-072A	COSMOS 2361	RUSSIA	404	418	65.0	1	0
1999-073A	COSMOS 2368	RUSSIA	551	39136	62.9	2	1

Correspondence concerning the ODQN can be sent to:

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

sara.robertson1@jsc.nasa.gov

ORBITAL BOX SCORE

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

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	26	102	128
CIS	1334	2579	3913
ESA	24	234	258
INDIA	19	4	23
JAPAN	65	49	114
US	898	2959	3857
OTHER	281	23	304
TOTAL	2647	5950	8597

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