The Orbital Debris Quarterly News

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The Orbital Debris Program Office
NASA Johnson Space Center
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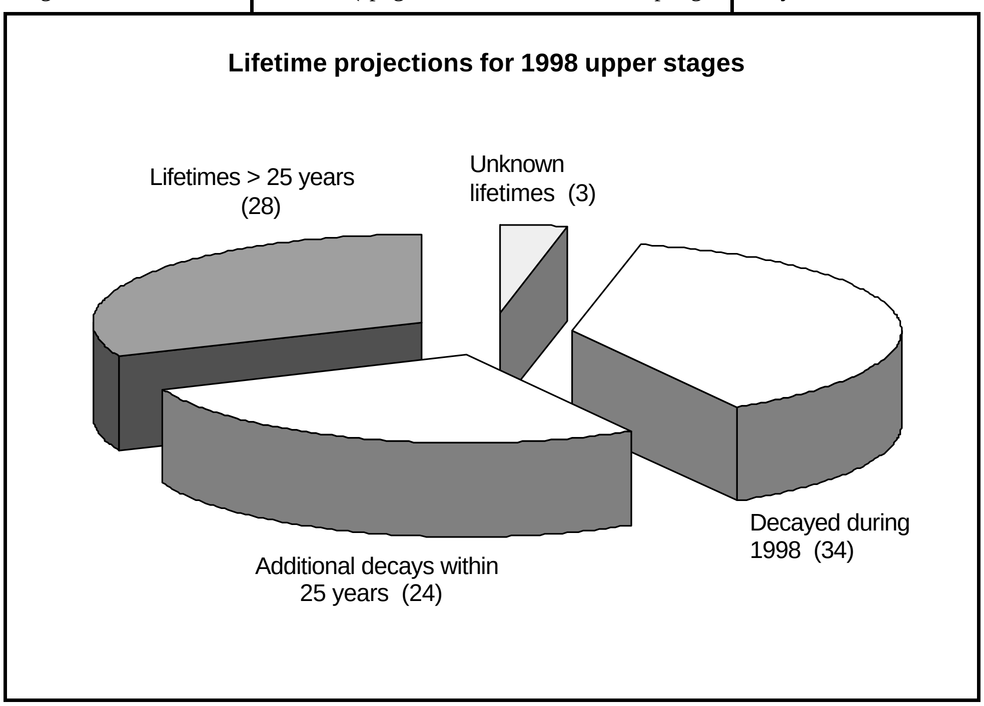
Project Reviews

The Fate of Upper Stages Placed in Earth Orbit in 1998

N. Johnson

Since orbital debris mitigation guidelines in the U.S. and several other space-faring nations recommend limiting the orbital lifetime of most upper stages, an analysis was recently performed at NASA JSC to determine how well operators are complying with the guidelines. During the past ten years (1989-1998), upper stage mass has been increasing in Earth orbit at the rate of 73 metric tons per year.

A total of 77 space missions were conducted world-wide in 1998, placing 89 upper stages in Earth orbit, and approximately one out of every three will remain in space for more than 25 years. Of the 89 upper stages, two (believed to be in GTO) could not be analyzed due to lack of sufficient orbital information and another was inserted into an orbit with an uncertain evolution (apogee near 600,000 km and perigee near 2,000 km). The orbits of the remaining 86 upper stages were studied to determine their longevity.



Due to a combination of normal natural decay and deliberate orbital lifetime reduction maneuvers, 34 upper stages (40%) were no longer in orbit by the end of 1998. An additional ten stages are expected to decay during 1999, for a total of 44 (51%). For example, 10 Iridium missions in 1998 placed 14 upper stages in LEO, all of which decayed within one year of launch. This record was achieved by intentionally reducing the perigees of 11 of the upper stages following spacecraft deployment.

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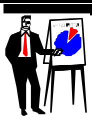

Project Reviews

The Fate of Upper Stages Placed in Earth Orbit in 1998, Continued

(Continued from page 1)
An estimated two-thirds of the 1998 upper stages will have decayed within 25 years of launch. The remaining 28 upper stages will be evenly divided between LEO and higher altitude orbits. In LEO 11 of 14 upper stages will likely remain in orbit longer than 100 years, while 10 of the 14 higher altitude upper stages will also probably exceed the century mark. Of the higher altitude upper stages, 9 with perigees in LEO reside in orbits of more than 25 years lifetime.

The study has demonstrated that most launch vehicles are being flown in accordance with the recommended orbital debris mitigation guidelines. However, one in three upper stages were found to be in orbits with lifetimes greater than 25 years. GEO missions, which may leave upper stages in LEO and/or GTO, represent the largest category of long-lived upper stages. Many GEO mission flight profiles could be brought into compliance with the 25-year rule with only modest payload capacity impacts. ❖

New Safety Standard Tracking System

R. O'Hara

In an effort to control and minimize future development of orbital debris resulting from space operations, each NASA program or project is required to perform orbital debris assessments in accordance with NASA Safety Standard 1740.14. To better monitor compliance, the JSC Orbital Debris Program Office has developed a new tracking system and database of existing and proposed NASA programs. The database currently consists of 82 programs, including some international projects in which NASA participates. Information, such as dates for the Preliminary and Critical Design Reviews, the orbital debris assessment status for both, the launch date, and the spacecraft and upper stage disposal options, are included in the database. Each program office is contacted to verify data entries and to facilitate the submission of the required orbital debris assessment reports.

The debris assessments will be evaluated using two checklists, one for the Preliminary Design Review (PDR) and one for the Critical Design Review (CDR). Both checklists directly follow, in outline form, the NSS 1740.14 guidelines for producing the PDR and CDR assessments. The checklists are each split into 7 sections: Brief Background on Program and Program Management, Description of Design and Operations Factors, Assessment of Debris Released During Normal Operations, Assessment of Orbital Debris Generated by Explosions and Intentional Breakups, Assessment of Debris Generated by On-Orbit Collisions, Description of Postmission Disposal Procedures and Systems, and Assessment of Survival of Debris from the Postmission Disposal Atmospheric Reentry Option. The last section only exists in the assessment report if atmospheric reentry is the chosen option for spacecraft and upper stage disposal. These checklists ensure that the assessments made by each program are thorough and compliant with each standard specfied in NSS 1740.14.

The JSC Orbital Debris Program Office has also produced debris assessment software (DAS) to aid programs in completing their debris assessment. Both NSS 1740.14 and DAS can be downloaded from the NASA orbital debris website at www.orbitaldebris.jsc.nasa.gov. It is critical for every program to perform the assessment and ensure compliance with NASA's safety standards for the safety of that mission and missions to come. ❖

JSC Team Visits KSC for Exchange on Space Shuttle Post-Flight Inspections

J. Theall

In late April a team from the NASA Orbital Debris Program Office at JSC traveled to the Kennedy Space Center (KSC) for a technical exchange on the hazards of orbital debris to Space Shuttles and the benefit of Orbiter post-flight inspections. The Orbiter Processing Facility (OPF) staff escorted the JSC team on a walk-around of a Space Shuttle being prepared for another flight. The techniques used when inspecting the windows, the reinforced carbon-carbon (RCC) coating of the leading edge of the wing, the flexible reusable surface insulation (FRSI) on the exterior of the payload bay doors, and the radiators were demonstrated.

Of particular interest was the tool designed and developed at KSC to illuminate the window thermal panes for identification of even tiny impact features. On average one of the thermal panes on the eight main windows in the crew cabin must be replaced after each flight due to impacts by tiny orbital debris and meteoroids. The JSC team also was able to view the process for upgrading the insulation behind the leading edge of the wing to minimize the possible adverse effects during reentry from a small particle penetration in the RCC.

In return, the JSC team made presentations to two different shifts of KSC personnel, providing an overview of the NASA Orbital Debris Program, methods used to define and to monitor the orbital debris environment, and engineering and operational steps taken to reduce the threat of orbital debris and meteoroids to the Space Shuttle. ❖

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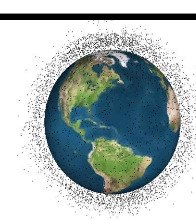
Visit the New NASA Johnson Space Center Orbital Debris Website

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



Project Reviews

JSC Team Visits KSC for Exchange on Space Shuttle Post-Flight Inspections, Continued

(Continued from page 2)

Figure 1. A probe and adhesive tape are used to retrieve residue inside a crater in the FRSI caused by an orbital debris or meteoroid impact.

Figure 2. A magnifier with light source is used to examine small impact regions on a thermal pane of the Space Shuttle.

Project Reviews

Post-Flight Examination of the STS-95 Orbiter

J. Kerr

During October-November 1998, the Space Shuttle Discovery spent nearly 9 days in a low altitude (574 km), low inclination (28.5 deg) orbit for the research in life sciences and John Glenn's return to space. In April 1999 a report sponsored by the NASA Orbital Debris Program Office summarized the orbital debris and micrometeoroid damage discovered during post-flight inspections (STS-95 Meteoroid/Orbital Debris Impact Damage Analysis, JSC-28497, 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 (40m^2), and the radiator panels (117 m^2). In all, 45 impact sites were examined by tape pull, dental mold, or wooden probe extraction techniques. Damage regions ranged from 0.02 mm to 4.8 mm in equivalent diameter.

A total of 73 window impacts were identified with the help of a new optical micrometer and fiber optic light source. Five windows required replacement following this mission — 4 windows due to craters which exceeded their replacement criteria and 1 due to cumulative damage over a number of missions. The largest window impactor was due to a paint flake estimated to have been 0.07 mm in diameter and 0.07 mm in thickness. Scanning electron microscopy with energy dispersive X-ray spectrometers permitted the characterization of 15 of the impactors: 7 orbital debris and 8 meteoroid. Of the orbital debris impactors, 43% were aluminum, 43% were paint, and 14% were stainless steel.

Examination of the radiators led to the discovery of three impact features with a minimum 1.0 mm damage diameter. All three sites yielded sufficient residue to determine the nature of the impactor. Two of the impactors were orbital debris (0.1 mm diameter stainless steel and a 0.4 mm diameter paint flake) and one impactor was a 0.5 mm diameter meteorite. Two of the three impacts created face sheet perforations including a rare perforation of the rear surface of a deployed radiator.

Inspections of the FRSI found two new impact sites greater than 1 mm in extent: one meteoroid (1.6 mm in diameter) and one orbital debris (1.8 mm diameter aluminum). No damage was identified on the RCC surfaces.

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 preliminary results anticipated in 1999. ❖

Figure 1. SEM image of a radiator impact and through face sheet penetration (sample 50).

International Debris Measurement Campaign

E. Stansberry

Two 24-hour debris measurement campaigns to statistically sample the debris environment were held this year. The effort was coordinated through the Inter-Agency Space Debris Coordination Committee's (IADC) Working Group 1 (Measurements). The first campaign occurred in early February. During this session, ESA provided the use of the FGAN/TIRA radar located in Germany while the U.S. operated the Haystack radar (NASA's primary source for statistics on centimeter-sized orbital debris).

The second campaign, conducted in April, was more ambitious. The suite of sensors used was unprecedented. U.S. participation included the Haystack radar, the Goldstone radar (for an 8-hour observation period), the TRADEX radar (located near the equator and the only sensor in the test capable of detecting low inclination debris), the Cobra Dane radar (a phased-array radar), and NASA's Liquid Mirror Telescope (5 hours of data collected during twilight). ESA again provided the FGAN/TIRA. Preliminary results indicate that the test was outstandingly successful. All sensors obtained results although the Goldstone radar reported some signal interference and the LMT was delayed several days due to cloud cover.

The star of the campaign appears to have been the Cobra Dane radar. Although Cobra Dane only detected objects larger than about 5 cm. diameter, it was the only phased-array radar in the campaign. As such, it was able to set up a 60-deg. wide detection fence. Using this large detection area, the radar saw approximately 1100 unique, uncorrelated targets, which are not in the Space Command catalog of orbiting objects. The data are very valuable in determining inclination and altitude distributions in the 5-10 cm. diameter debris size regime. ❖

NEWS

International Reentry Prediction Exercise

In June the Inter-Agency Space Debris Coordination Committee (IADC) conducted the second exercise of its Risk Object Reentry notification system. In 1998 the IADC developed a Reentry Database and a communications network to facilitate the exchange of orbital data and predictions of reentry time and location for objects posing unusual risks to people and property on Earth. Risk objects include vehicles with a mass of more than five metric tons or containing hazardous, e.g., radioactive, materials.

The IADC's inaugural exercise was conducted in October-November 1998 using the Inspektor spacecraft as a target of opportunity. The latest exercise officially commenced on 10 June and concluded with the reentry of the GFZ-1 satellite (1986-017JE, Satellite No. 23558) on 23 June. During this period, IADC members submitted current tracking data in the U.S. two-line element set format as well as predicted reentry time windows (opening, center, closing) and nominal reentry coordinates. The data were stored in the Risk Object Reentry Database maintained by ESA in Darmstadt, Germany, for access by all IADC members.

The NASA Orbital Debris Program Office at JSC served as the U.S. interface with the IADC during the exercise, forwarding the latest orbital parameters and reentry predictions developed by the U.S. Space Surveillance Network on a 24-hour basis. The successful exercise again confirmed the ability of the IADC to react promptly and effectively should an actual risk object threaten to fall back to Earth in an uncontrolled manner. ❖

Titan 2 Modified to Reduce Debris Potential

The launch of NASA's QuikSCAT spacecraft on 20 June 1999 employed a Titan 2 rocket with a second stage modification to reduce the likelihood of post-mission breakup. The Titan 2 second stage normally does not enter orbit, instead falling back to Earth after a brief ballistic flight. However, in support of the Clementine mission in January 1994, a Titan 2 second stage was left in a very low orbit of approximately 245 km by 300 km. Two weeks after launch, the vehicle unexpectedly fragmented into more than 350 detectable debris (an equal number of debris thrown in a retrograde direction probably reentered the atmosphere before being detected). Although no failure mechanism was ever confidently identified, the stage had not been passivated, leaving the residual, hypergolic propellants as the most likely source of energy for the severe breakup.

With the QuikSCAT mission plan calling for the Titan 2 second stage to remain in LEO for up to two years, NASA and U.S. Air Force officials investigated methods for passivating the vehicle, in accordance with NASA Safety Standard 1740.14. Unfortunately, the design of the second stage allowed for neither restarting the main engine for a depletion burn nor venting the residual propellants. A decision was finally made to modify the upper stage to permit venting of the fuel and oxydizer. QuikSCAT's Titan 2 second stage was ultimately left in an orbit of 279 km by 807 km and should now experience no fragmentation until its fiery fall back to Earth. ❖

New and Proposed Orbital Debris Mitigation Regulations

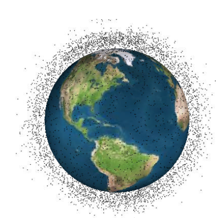
Whereas orbital debris mitigation guidelines for U.S. Government space missions are primarily covered by NASA and Department of Defense policies, regulations for the U.S. commercial space sector have largely been absent. Now, the three principal U.S. agencies with licensing authority over commercial space missions are examining the rationale and benefits of selected rules pertaining to orbital debris mitigation.

The Department of Transportation's Federal Aviation Administration (FAA), which licenses commercial launch operations, released a Notice of Proposed Rulemaking (NPRM) 19 March 1997, which in part would promote the practice of passivation of all orbital stages at the conclusion of payload delivery operations. This rule was formally adopted in 1999 with an effective date of 21 June and calls for stored energy to "be removed by depleting residual fuel and leaving all fuel line valves open, venting any pressurized system, leaving all batteries in a permanent discharge state, and removing any remaining source of stored energy."

Communications satellites, licensed by the Federal Communications Commission (FCC), may also be required to adopt specific orbital debris mitigation procedures. In its NPRM for Mobile Satellite Service in the 2 GHz band (25 March 1999), the FCC requested comments from industry on the wide range of orbital debris mitigation standard practices proposed by the U.S. Government in January 1998 (these practices were published in their entirety in the April 1998 issue of *The Orbital Debris Quarterly News*). If the FCC decides in this case to regulate actions which might otherwise have a deleterious effect on the orbital debris environment, the agency could expand such rules to include other classes of communications satellites.

The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) also issued in 1997 an NPRM which included a section concerning the disposal of remote sensing spacecraft at the end of mission. If the rule is adopted, an applicant would be required to submit a disposal plan which "minimizes orbital debris and does not endanger public safety." The latter includes hazards to the public from components which survive an uncontrolled reentry. After receiving several industry comments on the NPRM, NOAA has decided to release a new, expanded NPRM for further comment.

The U.S. Government continues to strongly encourage all space-faring organizations and spacecraft operators to voluntarily adopt effective measures which will constrain the growth of the orbital debris population, and, thereby, preserve near-Earth space for current and future generations. ❖



NEWS

Update to History of On-Orbit Satellite Fragmentations

E. Cizek

The latest update to the *History of On-Orbit Satellite Fragmentations* (JSC-28383) has recently been completed. The update includes the two-page format for the five breakups that occurred between 1 August 1998 and 1 July 1999. The first page consists of information pertinent to the breakup: parent identity, satellite number, event date/time, breakup orbital parameters, the number of pieces detected and other relevant information, as available. The second page includes a Gabbard diagram of the debris cloud if sufficient orbital data were collected. Table 2.1 History of Satellite Breakups by Launch Date and Table 2.2 History of Satellite Breakups by Event Date have also been updated to include these recent events.

The five new events included a Tsyklon upper stage (see article below) and four breakups of Russian Proton fourth stage ullage motors. These ullage motors were discarded during the deployment of GLONASS navigation spacecraft; see "Abandoned Proton Ullage Motors Continue to Create Debris" in the April issue of this publication.

The new change pages will be sent to recipients of the original document. The update will be available by 31 July 99 from the NASA orbital debris website at www.orbitaldebris.jsc.nasa.gov. If you did not receive the original document and would like to request one, please send a request to marie.e.cizek1@jsc.nasa.gov. ❖

New Report on Constellations and Orbital Debris

The American Institute of Aeronautics and Astronautics (AIAA) released in June a new report on orbital debris entitled *MEO/LEO Constellations: U.S. Laws, Policies, and Regulations on Orbital Debris Mitigation* (AIAA SP-016-2-1999). Prepared by the Orbital Debris Committee on Standards, the report presents an "overview of the emerging U.S. legal regime for orbital debris mitigation. The overview addresses current U.S. laws, policies, and regulations that impose orbital debris mitigation requirements on U.S. government and commercial space operations. The particular focus is on debris mitigation for commercial space operations, Medium Earth Orbit and Low Earth Orbit (MEO/LEO) satellite constellations."

The report reviews Congressional legislation, national space policy, U.S. government Interagency coordination, as well as the developing policies of NASA, the Department of Defense, the Department of Transportation, the Department of Commerce, and the Federal Communications Commission. According to the report, the Interagency process "has created a focus for action and prompted debris mitigation initiatives across government and commercial space sectors. The process also has served to ensure some measure of coordination and uniformity of debris mitigation standards."

The 28-page report is available from the AIAA, 1801 Alexander Bell Drive, Suite 500, Reston, VA, 20191-4344; website: www.aiaa.org. ❖

Third Tsyklon Upper Stage Breaks Up

The breakup of a Tsyklon upper stage on 18 April 1999 marked the third such occurrence and raised concerns about the more than 100 similar stages still in orbit. The subject of the latest satellite fragmentation was the Cosmos 2053 rocket body (International Designator 1989-100B, Satellite Number 20390) in an orbit of 470 km by 485 km at an inclination of 73.5 degrees. The 1360-kg vehicle has a basic diameter of 2.1 m and a length of 2.4 m.

The breakup, which occurred over the South Pacific, generated more than 60 detectable debris. Twenty-five of these debris were cataloged within 10 days of the event (Satellite Numbers 25696-25720) with nine decaying from orbit by the end of June. The maximum altitude excursion (in this case, apogee) observed was 200 km. Thus, all the debris remain in relatively low altitudes and should decay within the next few years.

Most of the cataloged debris are small with radar cross-sections less than 0.25 m^2. An optical observation of the principal remnant of the Cosmos 2053 upper stage was made by Paul Maley on 3 June. At that time, the object appeared to be tumbling rapidly with flashes at the rate of 4-5 per second.

One common denominator among the three Tsyklon upper stage breakups (including the Cosmos 1045 and Meteor 2-16 upper stages) has been their age. Each vehicle had been in orbit approximately 10 years at the time of the event. Nearly two-thirds of the 106 Tsyklon upper stages still intact are more than 10 years old. To date, more than 40 debris have been associated and cataloged with the Cosmos 1045 upper stage, while the piece count from the Meteor 2-16 breakup (see *Orbital Debris News Quarterly*, April 1998, p. 1) is nearly 80.

The Ukrainian designer and manufacturer of the Tsyklon upper stage has been asked to provide information on the vehicle and its operation to determine a probable cause of the breakups and to implement corrective measures. ❖

Visit the New NASA Johnson Space Center Orbital Debris Website

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

NEWS

Underwater Testing of Space Station Impact Repair Kit Begins

EVA training of a kit designed to patch holes on the International Space Station (ISS) caused by orbital debris and meteoroid impacts began at JSC's Neutral Buoyancy Laboratory (NBL) in June. Classroom training and tool familiarization were followed by underwater testing on an ISS module mock-up. Designated KERMIt (Kit for External Repair of Module Impacts), the system was developed by the Mission Operations Laboratory at the Marshall Space Flight Center to permit crew members on EVA to seal penetrations in pressurized, habitable compartments of ISS.

The KERMIt patches would be installed after the damaged compartment had become fully depressurized. It can seal holes up to four inches in diameter with associated cracks measuring as much as eight inches long. The kit also includes surface preparation tools and an adhesive injector system. A more complete description of KERMIt will be included in a forthcoming issue of *The Orbital Debris Quarterly News*. ❖

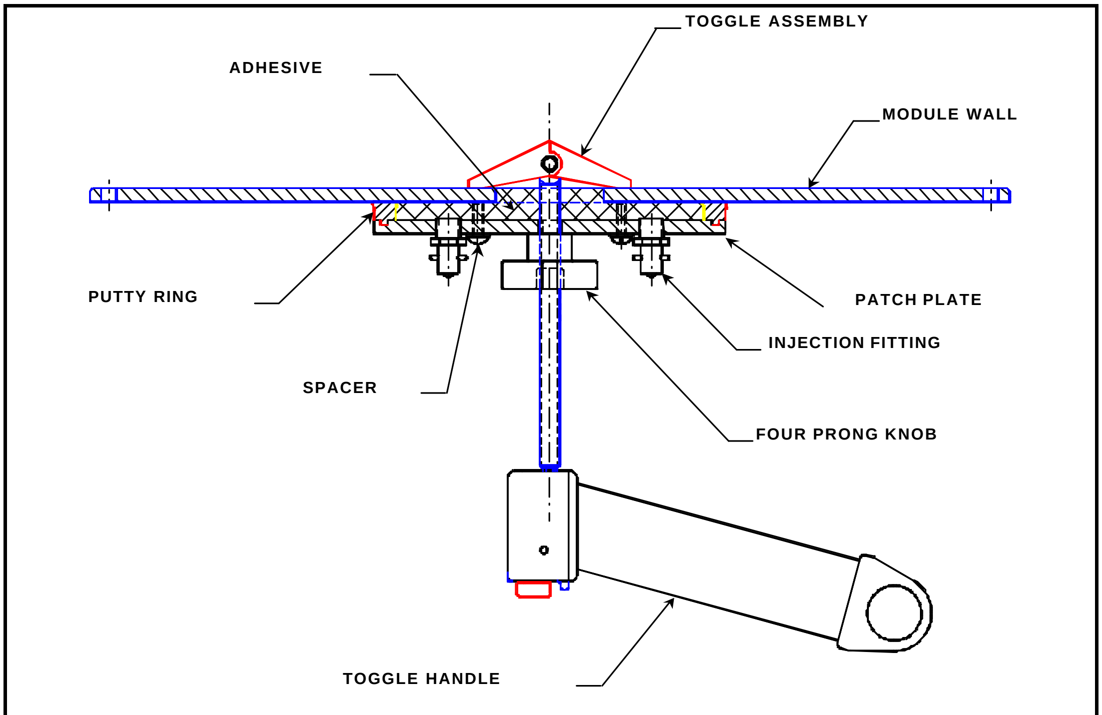


Figure 1. Type 1 (small) patch equipment.

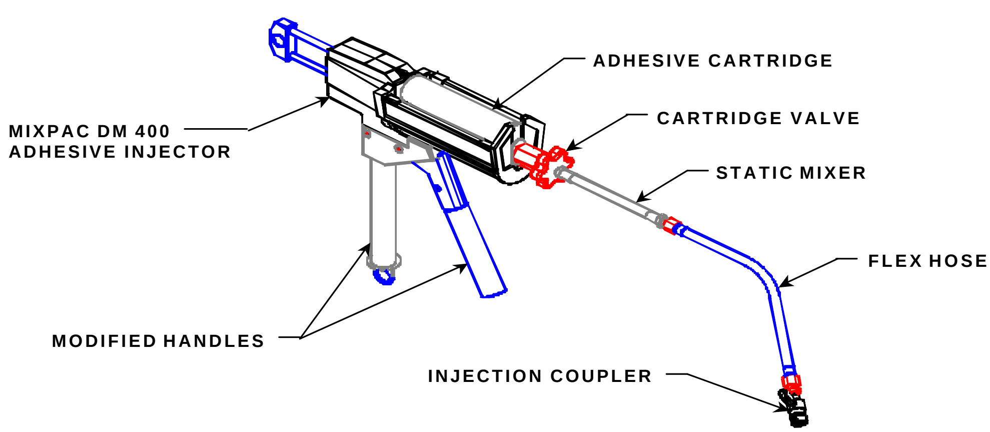


Figure 2. Adhesive injector system.

NEWS

New Orbital Debris Website Address

The NASA orbital debris website, developed and maintained by the JSC Orbital Debris Program Office, has a new, easier-to-remember internet address: www.orbitaldebris.jsc.nasa.gov. The website contains considerable information on orbital measurements, modeling, protection, and mitigation and permits visitors to download important orbital debris documents and software. During the first five months of 1999, more than 7,600 distinct users visited the website, some many times. In addition to U.S. Government, commercial, and educational organizations, the site serves users from all over the world, including Europe (second largest user domain), Asia, Australia, Africa, South America, the South Pacific, and the Caribbean.

By far the most popular section of the website is the *Orbital Debris Quarterly News*, with more than 12,000 accesses since the first of the year. All issues since January 1997 are available for viewing. Those who have not visited the site recently will also find a list of frequently asked questions (with answers!) on a wide variety of orbital debris topics. ❖

Abstracts From Papers

Results from the CoBeam Experiment: Simultaneous Orbital Debris Measures from Haystack, FGAN, and TRADEX 1999 Space Control Conference at MIT/Lincoln Laboratory

T. Settecerri, E. Stansbery

In order to foster international understanding of the space debris environment, NASA initiated the formation of an international agency-level organization (the Inter-Agency Space Debris Coordination Committee, IADC) to facilitate the exchange of technical information on space debris. The U.S., Russia, Japan, European Space Agency (ESA), France, Germany, United Kingdom, Italy, China and India have representation on the committee. The IADC is chartered to report on four major areas related to orbital debris: measurements, modeling, risk assessment, and mitigation. The measurements group reports on data collected by ground-based radar and optical systems and returned surfaces from satellites. In addition, they coordinate international measurements campaigns to further the knowledge of space debris.

An IADC action item requested joint orbital measurement to foster inter-agency cooperation and to compare measurements from different radar sensors. Both the United States and Germany agreed to participate. NASA used some of its Haystack time to participate and funded TRADEX time. Germany's Research Establishment for Applied Science (FGAN), under ESA/ESOC contract, used FGAN's Tracking and Imaging Radar (TIRA) and the Max-Planck-Institute for Radio Astronomy's Effelsberg radio telescope in a bistatic configuration. Haystack (42.6 deg N.) and the TIRA/Effelsberg (50.6 deg N.) radars are located at relatively high latitudes. The operational configuration of both of these radars during the 24-hour campaign limited the debris orbits sampled to inclinations greater than or equal to the radar's latitude. NASA supplemented the Haystack and TIRA/Effelsberg measurements by sampling the orbital debris environment at a low latitude site using the TRADEX (Target Resolution and Discrimination Experiment) radar which is part of the Kiernan ReEntry Measurement Site suite of sensors of the Kwajalein Missile Range. The radar is located at 9.4 deg North latitude on the island of Roi-Namur in the Kwajalein Atoll. ❖

NASA/JSC Optical Orbital Debris Program: Results from the Liquid Mirror Telescope (LMT) and the CCD Debris Telescope (CDT) 1999 Space Control Conference at MIT/Lincoln Laboratory

J. Africano, T. Settecerri, J. Lambert, E. Stansbery

The NASA Johnson Space Center is conducting an active, on-going program to characterize the orbital debris environment using both optical and radar sensors. To gain a better understanding of the LEO and MEO (low and medium Earth orbits) orbital debris environments especially in the important, but difficult to track, one to ten centimeter size range, NASA Johnson Space Center has built a zenith staring Liquid Mirror Telescope (LMT) near Cloudcroft, NM. The primary mirror of the LMT consists of a three-meter diameter parabolic dish that contains several gallons of mercury that is spun at a rate of ten revolutions per minute. Centrifugal force and surface tension causes the mercury to spread out in a thin layer over the dish creating a parabolic reflective surface accurate to within a fraction of the wavelength of light. The greatest advantage of a liquid mirror over a glass mirror is cost. The LMT was built for a cost of about 1 million dollars, about one tenth the cost of a traditional telescope of similar size. A disadvantage of the LMT is its inability to point in any direction other than the zenith. However, this is not a major limitation for statistical sampling of the orbital debris population. By staring at the zenith, the LMT observes the orbital debris that passes through its field of view.

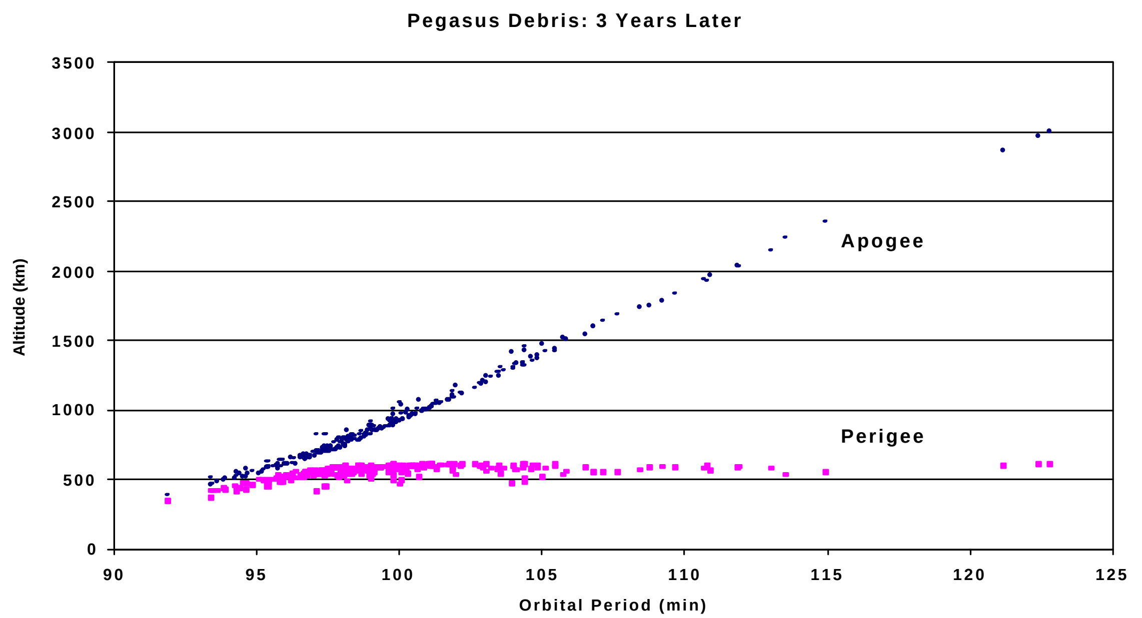
While the LMT is used for the characterization of the LEO and MEO orbital debris environments, its inability to point off zenith limits its utility for the GEO (geosynchronous Earth orbit) environment where objects are concentrated near the equator. To gain a better understanding of the GEO debris environment, NASA JSC built a CCD Debris Telescope (CDT). The CDT is a 12.5-inch aperture Schmidt portable telescope with automated pointing capability that has been used in several orbital debris measurement campaigns. The CDT is presently co-located with the LMT. With the current sensor (27 µm, 512 x 512 pixel CCD), the CDT can see down to 17.1 magnitude in a 30 second exposure and has about a 1.7 X 1.7 square degree field of view. This corresponds to a ten percent reflective, 0.8-meter diameter object at geosynchronous altitude.

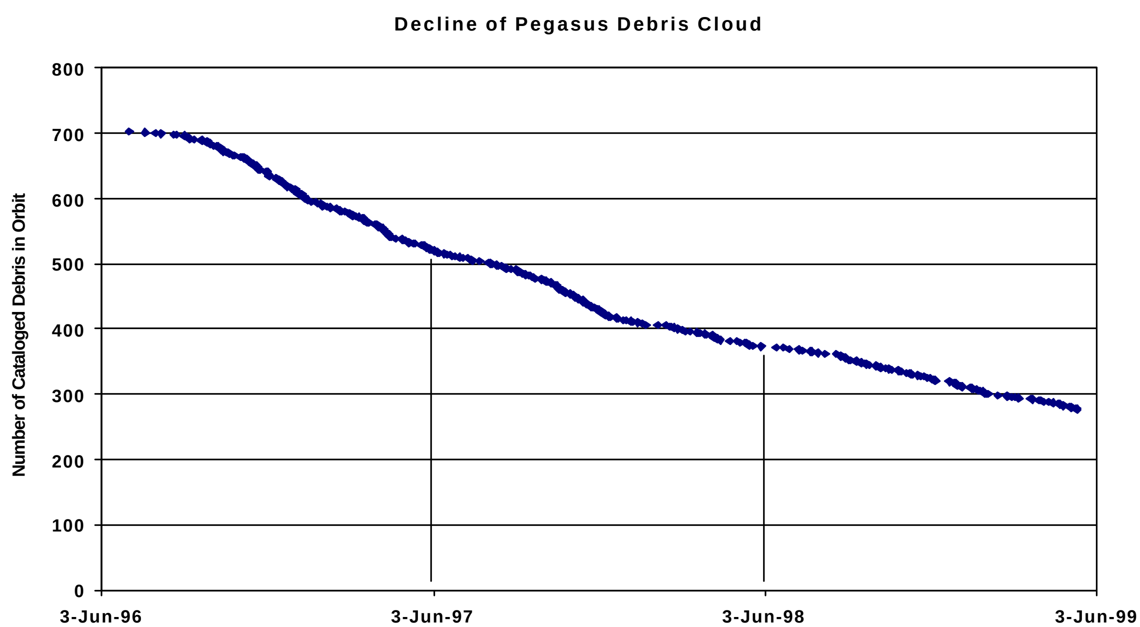
This paper presents descriptions of the telescopes and sensors, as well as the data collection and processing. ❖

NEWS

The Pegasus HAPS Debris Cloud: Three Years Later

The third anniversary of the breakup of the STEP II upper stage (1994-029B, Satellite No. 23106), a Pegasus Hydrazine Auxiliary Propulsion System (HAPS), was marked on 3 June 1999. Officially recognized as the worst satellite fragmentation in history with 702 debris cataloged, the breakup continues to draw the interest of orbital debris researchers. Figure 1 indicates the apogees and perigees of the 276 cataloged debris remaining in Earth orbit three years after the event. Fortunately, the orbits of only two debris were then crossing the orbit of the International Space Station (386 km apogee, 380 km perigee). On the other hand, the debris cloud remnant does still present a hazard to nearly every operational spacecraft in low Earth orbit. Figure 2 represents the decline in the magnitude of the debris cloud during the 36-month period. Over 60% of the cataloged debris have already dropped out of orbit, and the expected high levels of solar activity during the next two years should significantly further reduce the number of debris. A new analysis of the characteristics of the Pegasus HAPS debris by the NASA Orbital Debris Program Office at JSC will be presented at the 50th International Astronautical Congress in Amsterdam in October. ❖





INTERNATIONAL SPACE MISSIONS

April - June 1999

International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclina-tion (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
1999-015A	PROGRESS M-41	RUSSIA	349	352	51.7	1	0
1999-015C	SPUTNIK JR. 3	RUSSIA	349	352	51.7		
1999-016A	INSAT 2E	INDIA	35744	35830	0.1	1	0
1999-017A	USA 142	USA	NOT AVAILABLE			3	2
1999-018A	EUTELSAT W3	EUTELSAT	35781	35794	0.0	1	0
1999-019A	GLOBALSTAR M045	USA	Enroute to Operational Orbit			2	0
1999-019B	GLOBALSTAR M042	USA	Enroute to Operational Orbit				
1999-019C	GLOBALSTAR M044	USA	1413	1414	52.0		
1999-019D	GLOBALSTAR M019	USA	1413	1414	52.0		
1999-020A	LANDSAT 7	USA	702	703	98.2	1	0
1999-021A	UOSAT 12	UK	644	657	64.6	1	1
1999-022A	ABRIXAS	GERMANY	553	602	48.4	1	0
1999-022B	MEGSAT	ITALY	548	602	48.4		
1999-023A	USA 143	USA	NOT AVAILABLE			1	0
1999-024A	ORION 3	USA	422	1316	29.1	1	1
1999-025A	FENGYUN 1C	PRC	849	868	98.8	1	2
1999-025B	SHI JIAN 5	PRC	844	869	98.8		
1999-026A	TERRIERS	USA	540	555	97.7	2	1
1999-026B	MUBLCOM	USA	771	778	97.7		
1999-027A	NIMIQ 1	CANADA	35778	35796	0.1	2	1
1999-028A	USA 144	USA	NOT AVAILABLE			1	9
1999-029A	KITSAT-3	S. KOREA	711	737	98.4	1	0
1999-029B	TUBSAT	GERMANY	716	737	98.4		
1999-029C	OCEANSAT	INDIA	718	739	98.4		
1999-030A	STS 96	USA	384	397	51.6	0	0
1999-030B	STARSHINE	USA	380	397	51.6		
1999-031A	GLOBALSTAR M052	USA	1413	1414	52.0	1	0
1999-031B	GLOBALSTAR M049	USA	1412	1415	52.0		
1999-031C	GLOBALSTAR M025	USA	1412	1413	52.0		
1999-031D	GLOBALSTAR M047	USA	1411	1414	52.0		
1999-032A	IRIDIUM 14A	USA	709	712	86.5	1	5
1999-032B	IRIDIUM 21A	USA	709	712	86.5		
1999-033A	ASTRA 1H	LUXEMBG.	35767	35807	0.1	2	1
1999-034A	QUIKSCAT	USA	792	821	98.6	1	0
1999-035A	FUSE 1	USA	754	770	25.0	1	0

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ORBITAL BOX SCORE

(as of 30 June 1999, as catalogued by US SPACE COMMAND)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	26	103	129
CIS	1338	2590	3928
ESA	24	228	252
INDIA	27	6	33
JAPAN	65	50	115
US	858	3081	3939
OTHER	272	27	299
TOTAL	2610	6085	8695

Upcoming Meetings

26 July 1999: ***Workshop on Space Debris***, UNISPACE III technical forum, Vienna, organized by IAA. Contact Prof. Walter Flury, email: wflury@esoc.esa.de

30 August - 3 September 1999: ***AMOS Technical Conference,*** Maui, Hawaii, USA. The technical sessions will focus on imaging and image processing, photometry and radiometry, LADAR and LIDAR, orbital debris, near-Earth objects, small portable telescopes, astronomy, and high-performance computing at the Maui Space Surveillance System (MSSS).

4-8 October 1999: ***50th International Astronautical Congress***, Amsterdam, The Netherlands. Technical program includes 29 Symposia and 111 sessions which address the latest technological, economic, legal, management, political, and environmental issues of astrodynamics and space. NASA/JSC will present seven papers in the Safety, Rescue, and Quality Symposium in session: IAA.6.4 Space Debris Measurements and Modeling, IAA.6.5 Space Debris Mitigation, IAA.6.6Satellite Constellations and Space Debris, IAA.6.7 Space Debris Modeling, Collision Risk, and Reentry Analysis. One paper will be presented in the 18th IAA/IISL Scientific-Legal Roundtable session Protection of the Space Environment.

11-13 October 1999: ***17th Inter Agency Space Debris Coordination Committee Meeting***, Darmstadt, Germany.

10-13 January 2000: ***38th AIAA Aerospace Sciences Meeting and Exhibit***, Reno, Nevada, USA. The 38th AIAA Aerospace Sciences Meeting and Exhibit will again place emphasis on fundamental science issues. Participation by the basic research community is especially encouraged. The meeting will feature both invited and contributed presentations that address the future scientific and technical challenges facing the aerospace community. All Orbital Debris papers should be submitted to Atmospheric Environment Technical Committee via:

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