National Aeronautics and Space Administration

Orbital Debris Quarterly News

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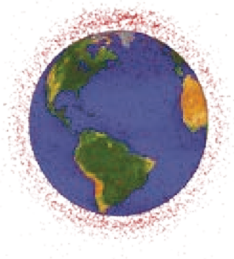
Inside...



A publication of
the NASA Orbital
Debris Program Office

NASA and DARPA Sponsor International Debris Removal Conference

NASA and DARPA (Defense Advanced Research Projects Agency) jointly sponsored the first-of-its-kind International Conference on Orbital Debris Removal; held in Chantilly, VA, 8-10 December 2009.

In 2005, NASA conducted an analysis using its long-term debris environment evolutionary model, LEGEND, which clearly showed that the number of debris larger than 10 cm would continue to increase due to collisions between existing resident space objects, even if no new satellites were launched (ODQN, April 2006, pp 1-2). This result was reinforced by the first accidental collision between two large intact satellites, Iridium 33 and Cosmos 2251, in February 2009 (ODQN, April 2009, pp 1-2). These events, along with the Chinese Fengyun-1C anti-satellite (ASAT) test in 2007, have significantly increased the number of 10 cm and larger objects in orbit and provided the impetus for the debris removal conference (see Figure 1).

Although one of the primary goals of the conference was to exchange ideas for technical

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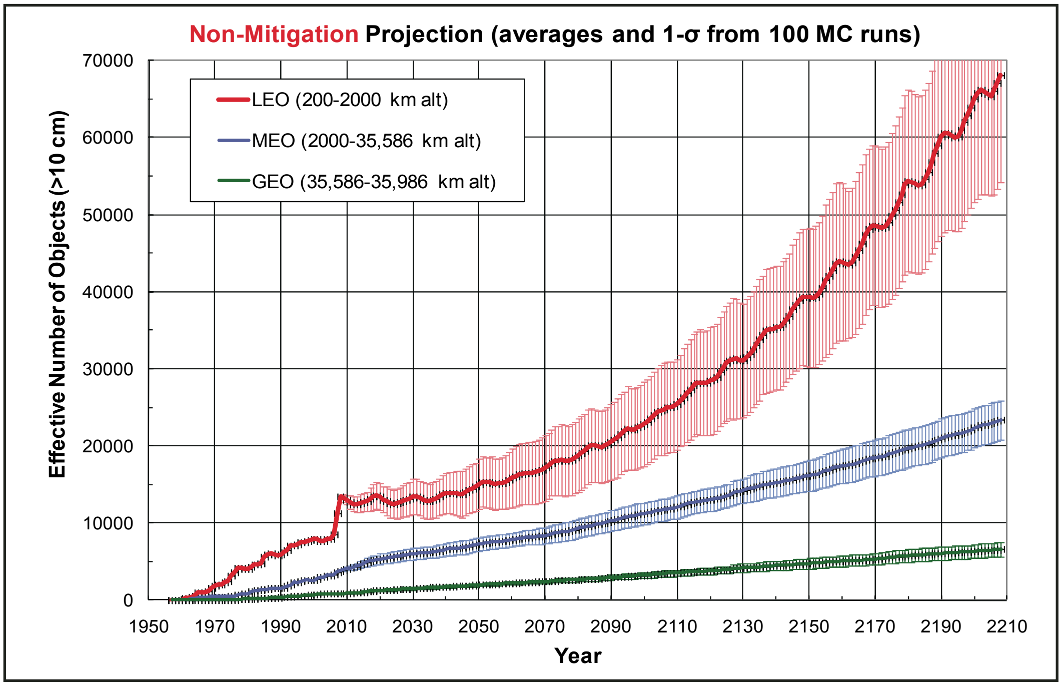

Figure 1. Updated (includes Fengyun-1C ASAT and Iridium/Cosmos collisions) projection of the runaway growth of >10 cm resident space objects if postmission disposal measures are not implemented. Figure includes 1 σ uncertainties.

NASA-DARPA Conference

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solutions to debris removal, the conference also covered areas including economic factors and incentives, international legal issues, and identifying stakeholders and building support for debris removal.

The conference was well attended by about 275 participants from 9 foreign countries and the U.S. More than 50 presentations were grouped into 10 sessions: Understanding the Problem, A Solution Framework, Legal and Economic Issues/Incentives, Operation Concepts, Using Environmental Forces, Capturing Objects, Orbital Transfer Solutions, Technical Requirements, In Situ vs. Remote Solutions, and Laser Systems.

In addition to the technical presentations, four keynote addresses also were given. Bryan O'Connor, Chief for Safety and Mission Assurance at NASA HQ, gave the first keynote address on "Space Operations Safety." Don Kessler, former NASA Senior Scientist for Orbital Debris, presented "The Kessler Syndrome: Implications to Future Space Operations" during a working lunch address. On day 2 of the conference, Dr. Heiner Klinkrad gave the noon keynote talk on "Space Debris Environment Remediation Concepts." The final keynote speaker was Col. Chris Moss from the 14th Air Force's Joint Space Operations Center (JSpOC), who discussed Space Situational Awareness.

No evident consensus or conclusions were reached at the conference. Removing existing, non-cooperative objects from Earth orbit is an extremely difficult and likely expensive task. Although some of the techniques for removal discussed at the Conference have the potential of being developed into technically feasible systems, each concept seems to currently suffer from either a lack of development and testing or economic viability. ♦

Avoiding Satellite Collisions in 2009

All NASA programs and projects operating maneuverable spacecraft in low Earth orbits (LEO) or in geosynchronous orbits (GEO) are required to have periodic conjunction assessments performed for the purpose of avoiding collisions with other known resident space objects. These conjunction assessments are conducted by the Joint Space Operations Center (JSpOC) of the U.S. Strategic Command at Vandenberg Air Force Base in California. For the International Space Station and the Space Shuttle, these assessments are typically updated three times per day. For robotic satellites, which normally operate at higher altitudes where atmospheric drag effects are less pronounced, the assessments are updated daily, on average.

The conjunction assessment alert messages from JSpOC identify the object which is expected to come near the NASA spacecraft along with information on the predicted time and distance of closest approach, as well as the uncertainty associated with the prediction. Typically, alert messages are issued if the calculated miss-distance is within a few kilometers of the NASA spacecraft. While the sensors of the U.S. Space Surveillance Network are tasked to collect additional tracking data to refine the close approach prediction, NASA specialists compute the actual probability of collision. In the case of human space flight, collision avoidance maneuvers are normally conducted if the risk of collision is greater than 1 in 10,000. In general, robotic spacecraft accept higher levels of risk, i.e., on the order of 1 in 1,000.

Most alert messages do not result in collision avoidance maneuvers. Often, a recomputation of the conjunction assessment with updated tracking data and a shorter propagation period (i.e., time to the encounter) will reveal a more distant miss-distance and a lower risk of collision. It is not uncommon for collision avoidance maneuvers to be planned but canceled when new assessments are completed. For example, the International Space Station was prepared to conduct a collision avoidance maneuver on 17 March to evade a piece of debris from a former Soviet satellite which exploded in 1981. A later conjunction assessment revealed that the maneuver was not necessary. The debris reentered the Earth's atmosphere on 4 April, no longer posing a threat to the International Space Station or other satellites.

During 2009 conjunction assessments led to eight collision avoidance maneuvers by NASA spacecraft, in addition to a collision avoidance maneuver of a French satellite operating in concert with NASA Earth observation satellites (Table 1). Only two of the maneuvers involved close approaches by intact vehicles (one a spacecraft and one a rocket body). The other maneuvers were needed to avoid collisions with smaller debris, including twice with debris from the Chinese anti-satellite test of 2007 and once with debris from the collision of the Iridium 33 and the Cosmos 2251 satellites in February of 2009.

On a separate occasion in March 2009, the crew of the International Space Station had to retreat temporarily into their Soyuz return spacecraft when debris from a U.S. upper stage were projected to make a close approach (ODQN, Vol. 13, Issue 2, p. 3). The elliptical nature of the debris' orbit (about 145 km by 4230 km) contributed to a late notification of the conjunction, leaving too little time to prepare for a collision avoidance maneuver. ♦

Table 1. Collision Avoidance Maneuvers in 2009

Spacecraft	Maneuver Date	Object Avoided
TDRS 3	27 Janaury	Proton rocket body
ISS	22 March	CZ-4 rocket body debris
Cloudsat	23 April	Cosmos 2251 debris
EO-1	11 May	Zenit rocket body debris
ISS	17 July	Proton rocket body debris
Space Shuttle	10 September	ISS debris
PARASOL (France)*	29 September	Fengyun-1C debris
Aqua	25 November	Fengyun-1C debris
Landsat 7	11 December	Formosat 3D

* Operating in NASA-led Earth observation network

MMOD Inspection of the HST Wide Field Planetary Camera 2 Radiator Update

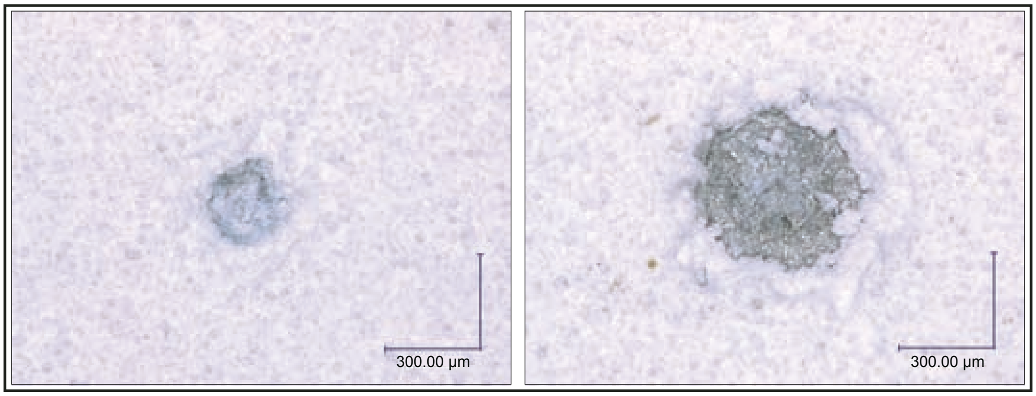

Figure 1. A typical impact crater on the WFPC2 radiator where the impacting particle did not penetrate the paint layer (left) and a typical crater where the impacting particle went through the paint and damaged the metal part of the radiator (right).

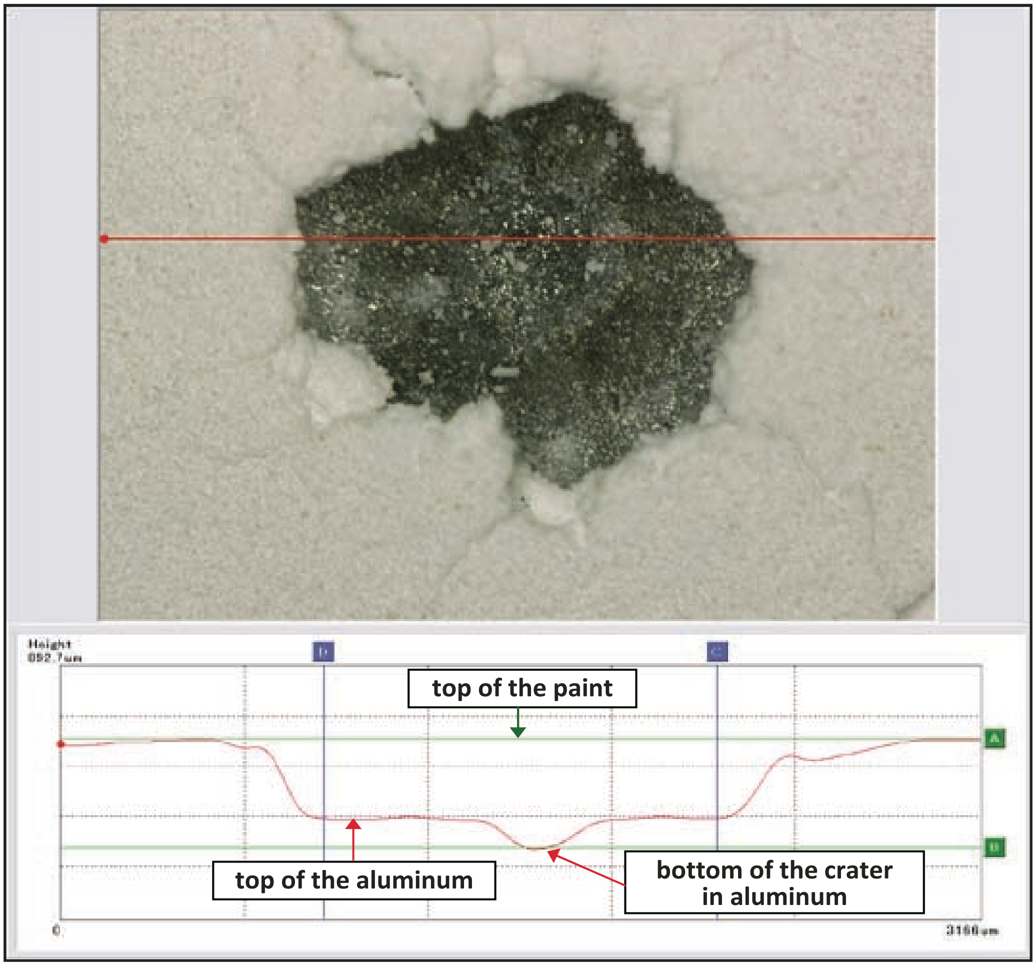

Figure 2. The image and measurements of one of the MMOD impact craters on the WFPC2 radiator.

The initial micrometeoroid and orbital debris (MMOD) impact inspection of the Hubble Space Telescope (HST) Wide Field Planetary Camera 2 (WFPC2) radiator was completed in September 2009. The task was led by the NASA Orbital Debris Program Office, with full support from the HST Program at GSFC, NASA Curation Office at JSC, NASA Hypervelocity Impact Technology Facility at JSC, and NASA Meteoroid Environment Office at MSFC. The objective of the inspection is to document and analyze the MMOD impact damage on the radiator, and then apply the data to validate or improve the near-Earth MMOD environment definition.

Two instruments were used during the 6-week inspection at GSFC – a laser scanner for a quick map of the distribution of impact features on the surface and a digital microscope for detailed two- and three-dimensional imagery of individual impacts. In addition, a laser template projector was designed and set up to record the coordinates of individual impact features. The inspection was limited to features larger than about 300 µm across, because this is approximately the threshold for the smallest MMOD particles that are important for satellite impact risk assessments.

By the end of the inspection, a total of 685 MMOD impact features were identified and documented. The largest one has a crater diameter of 1.6 mm with a surrounding spall zone about 1.4 cm across (on the painted radiator surface). The outermost layer of the radiator is a 4-mm thick aluminum plate coated with thermal control paint. The majority of the documented impacts did not penetrate the paint layer. The crater on the left in Figure 1 is a typical example, whereas the crater on the right shows a different type of impact where the projectiles went through the paint and damaged the metal part of the radiator. An additional 200 or so non-impact features, such as surface contamination and tool marks, were also observed and documented.

The processing and analysis of the crater images are currently underway. Figure 2 shows the image (top) and the two-dimensional cross-section profile (bottom) of one of the largest impacts. The damage shown is ~1.4 mm across

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MMOD Inspection

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(distance between "C" and "D") with a spall zone about twice as big. The green line labeled by "A" defines the top surface of the paint while the green line labeled by "B" indicates the bottom of the crater in aluminum. The distance from "A" to "B" is about 0.38 mm. The thickness of the paint at this particular location can also be estimated from the image to be about 0.28 mm. Once all the images are processed, various feature distributions, such as diameter and depth, will be analyzed. The first series of hypervelocity impact tests on targets made of materials identical to the radiator has been tentatively scheduled for February 2010. The test results will be used to convert the observed feature dimensions to the characteristics of the impacting particles and to estimate the impact condition. An effort to use the HST attitude-time history to model the observed impacts has been initiated. A plan to core samples from the radiator for composition analysis is under review. More results will be reported in future Orbital Debris Quarterly News. ♦

PROJECT REVIEWS

Shielding Against Micrometeoroid and Orbital Debris Impact with Metallic Foams

S. RYAN, E. L. CHRISTIANSEN,
D. M. LEAR

For the past 50 years the protection of manned spacecraft against micrometeoroids and orbital debris (MMOD) has, for the most part, been performed by the Whipple shield (or derivatives thereof). Although highly capable, the installation of Whipple-based shielding configurations requires a significant amount of non-ballistic mass for installation (e.g., stiffeners, fasteners, etc.), that can consume up to 35% of the total shielding mass. As NASA's vehicle design focus shifts from large pressurized modules operating for extended durations in relatively debris-polluted, low Earth orbits to small volume, lower duration craft, new protective concepts are being designed and evaluated to address the new threats.

One possible solution involves using structural components that have intrinsic shielding capability. Traditional primary structures such as honeycomb sandwich panels are unsuited for use in manned vehicles due to their poor shielding performance. Metallic foams, however, are a relatively new material with low density and novel physical, thermal, electrical, and acoustic properties that offer a promising alternative for MMOD protective systems.

There are two competing types of metallic foam: open cell and closed cell. Although closed cell foams can retain some residual atmosphere, which may aid in the deceleration of penetrating fragments via drag, open cell foams are considered the more promising technology due to their lower weight and higher degree of homogeneity. Preliminary investigations have demonstrated the potential of open cell-foam core structures, as shown in Figure 1 (compared to a traditional, honeycomb core, sandwich structure).

Three experimental investigations have recently been performed by the NASA JSC Hypervelocity Impact Technology Facility (HITF) to comprehensively evaluate the performance of open-cell foams during hypervelocity impact: a fundamental study to investigate penetration and failure mechanisms in open-cell, metallic foam structures; an application study evaluating the performance effect of modifying ISS-representative shields with open-cell, metallic foams; and a study comparing the performance of open-cell foams of varying materials with alternate MMOD-shielding materials and structures.[3,4,5]

1. Hypervelocity impact performance of open-cell foams

An advantageous property of open-cell, metallic foams, in terms of MMOD shielding, is their periodic structure of small diameter, low mass pores. During a hypervelocity impact event, the isentropic shock and non-isentropic release process acts to raise the thermal state (internal energy) of the impacting particle. As a projectile penetrates through an open-cell foam structure, repeated impacts upon individual foam cell ligaments induce multiple shock and release events, resulting in the fragmentation, melt, and vaporization of meteoroid or debris particles at impact velocities significantly lower than with traditional shields.

The multi-shock shield used a similar concept, demonstrating potential weight savings of 30-40% over traditional Whipple shields for equal levels of protection.[1] Although enhanced fragmentation and melting was clearly observed in experiments on foam core sandwich panels, rear facesheet failure was almost exclusively caused by the penetration of individual solid (or molten) fragments, even at impact velocities above 7 km/s. Given the non-homogeneity of the foam structure on a micro scale, it is considered that these individual fragments have propagated through the foam core with minimal secondary impacts. Subsequently, the degree of experimental scatter for these structure types may be greater than that of traditional configurations.

The number and size of foam ligaments is a function of material pore density (i.e., PPI or pores per linear inch), which is specified in the manufacturing process. Additionally, the relative density of the foam (also adjustable during manufacturing) controls both the panel weight and the cross-sectional form of the foam ligaments (see Figure 2). It was found that increased pore density led to minor improvements in protective capability, for instance 40 PPI foam-core sandwich panels were found to be ~5% more capable than 10 PPI configurations. The effect of ligament shape was found to be minimal, with 6-8% (nominal) relative density cores providing a small improvement in protection over lighter 3-5% (nominal) panels. However, this is expected to result from the higher core weight rather than ligament shape.

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Shielding with Metallic Foams

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2. Improved shielding performance through utilization of metallic foam

Metallic open-cell foams provide comparable mechanical and thermal performance to honeycomb structures, without the MMOD shielding, detrimental, through-thickness channeling cells. A double-layer, honeycomb-sandwich, panel shield, with a mesh outer layer and monolithic aluminum rear wall was modified to include aluminum open-cell foam, and thus evaluate the effect on shielding performance. The aluminum, honeycomb core of the outer sandwich panel was replaced with 10 PPI foam, while the second honeycomb sandwich panel was replaced with an equal thickness-foam panel (no facesheets), maintaining approximate totals for shield standoff and weight. The foam-modified shield was found to provide a 3-15% increase in critical diameter for impacts normal to the target surface (0°). For oblique impacts, the performance gain was more substantial, particularly at low velocities. A comparison between impact damages induced by 0.833 cm-diameter, Al2017-T4 spheres at ~6.9 km/s with normal incidence is shown in Figure 3. In addition to reduced rear wall damage, clear evidence of enhanced fragment melting is visible on the foam-modified target.

3. Evaluation of advanced-shielding materials and structures

The performance of aluminum, titanium, copper, stainless steel, nickel, nickel/chromium, reticulated vitreous carbon (RVC), silver, and ceramic open-cell foams was evaluated in an extensive experimental impact campaign. Configured in single-, double-, and triple-bumper shields, their protective capability was assessed against metal plates, meshes, and various flexible fabrics via a figure-of-merit based on cratering and impulsive failure modes. Further ballistic limit-based evaluations were performed, in which the advanced shield configurations were compared against equivalent weight, all-aluminum shields. The top performing configurations were found to generally include monolithic aluminum outer bumper plates, with metallic foam and/or Kevlar fabric inner bumper plates. Of the various foam types investigated, copper was found to provide the best protection, with RVC the worst.

The generation of ejecta during MMOD impact on a shield outer bumper is of concern due to the danger of secondary impacts, and the general pollution of the orbital environment. For impact on common shielding materials

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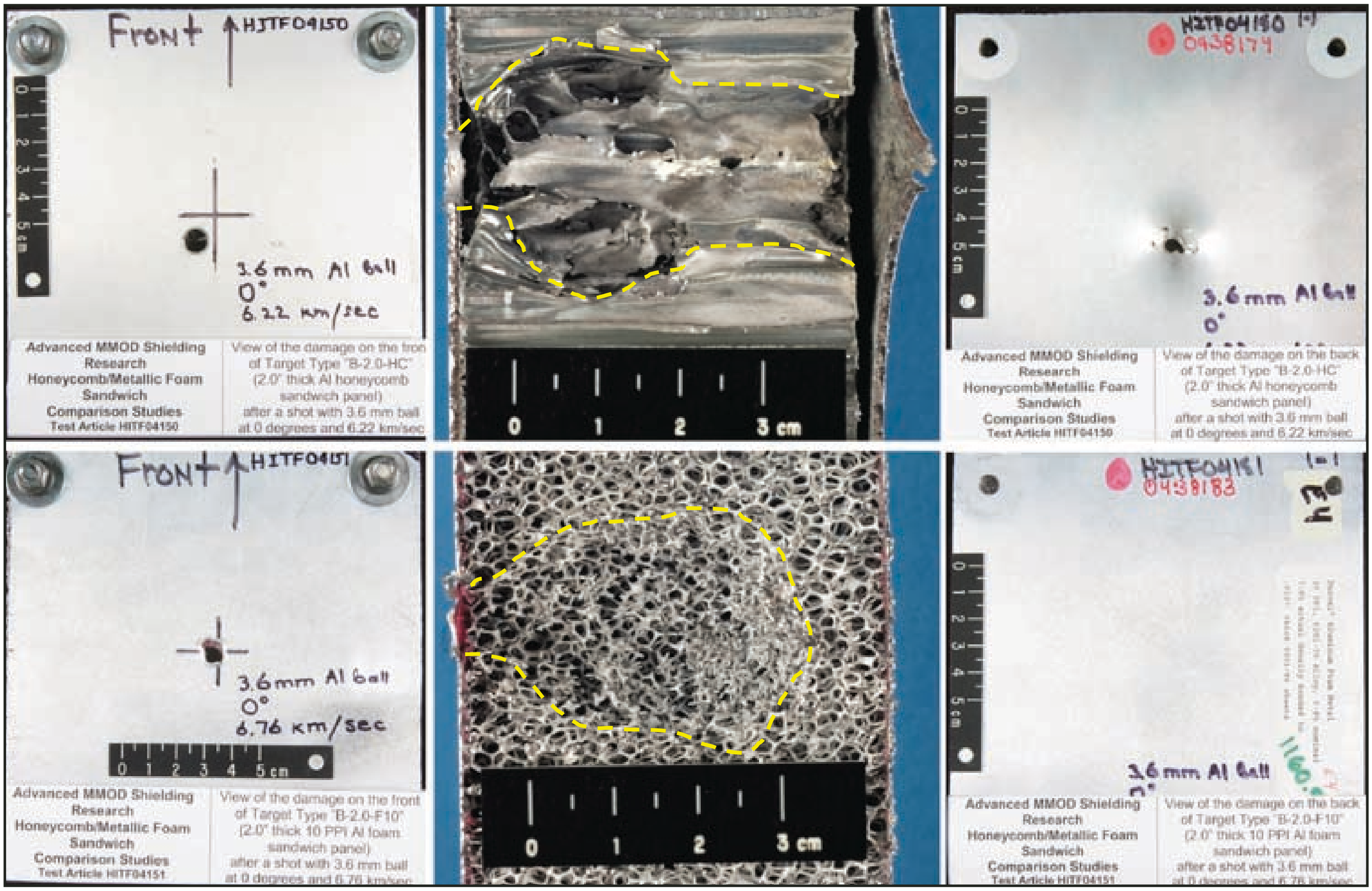

Figure 1. Comparison of damages in a honeycomb core (top) and open-cell foam core (bottom) sandwich panel impacted by 3.6 mm diameter Al-spheres at 6.22 km/s (honeycomb) and 6.76 km/s (foam) with normal incidence (0°). From left to right: bumper (front view), core cross-section (emphasis added), rear wall (rear view).

Shielding with Metallic Foams

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(i.e., aluminum, CFRP), ejecta can constitute up to 30% of the total expelled mass (ejecta + fragment cloud).[2] Impact on foams, meshes, and fabrics was found to generate almost no ejecta of any significance, providing a substantial reduction in ejecta mass over monolithic structures (shown in Figure 4).

1. Cour-Palais, B. G. and Crews, J. L. A multi-shock concept for spacecraft shielding, *International Journal of Impact Engineering* **10**, 135-146 (1990).

2. Christiansen, E. L. Evaluation of Space Station meteoroid/debris shielding materials, *NASA JSC CR-185627*, (1987).

3. Ryan, S. and Christiansen, E. L. Hypervelocity Impact Testing of Advanced Materials and Structures for Micrometeoroid and Orbital Debris Shielding, *NASA JSC-64933* (2009).

4. Ryan, S., Ordonez, E. and Christiansen, E. L. Hypervelocity Impact Performance of Open Cell Foam Core Sandwich Panel Structures (submitted for publication 2009).

5. Ryan, S., Hedman, T. and Christiansen, E. L. Honeycomb vs. Foam: Evaluating a Potential Upgrade to ISS Module Shielding for Micrometeoroids and Orbital Debris, *NASA JSC TM-2009-214793* (2009). ♦

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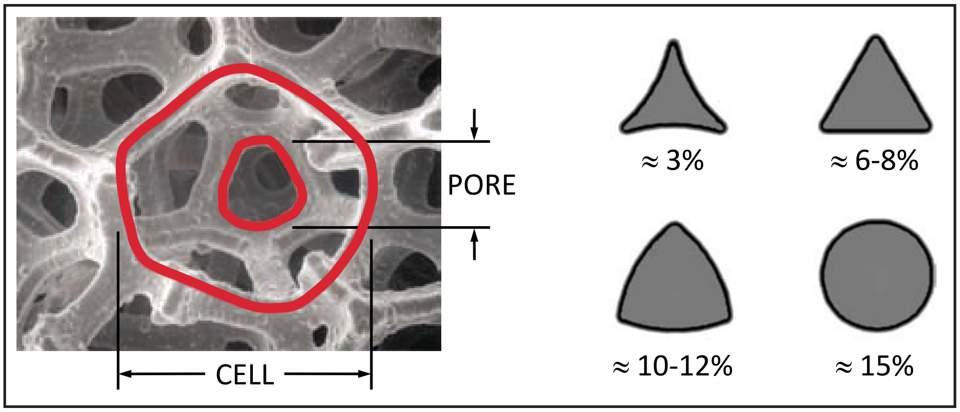

Figure 2. Foam pore size, cell size, and ligament cross-section (variation with relative density) (© ERG Aerospace).

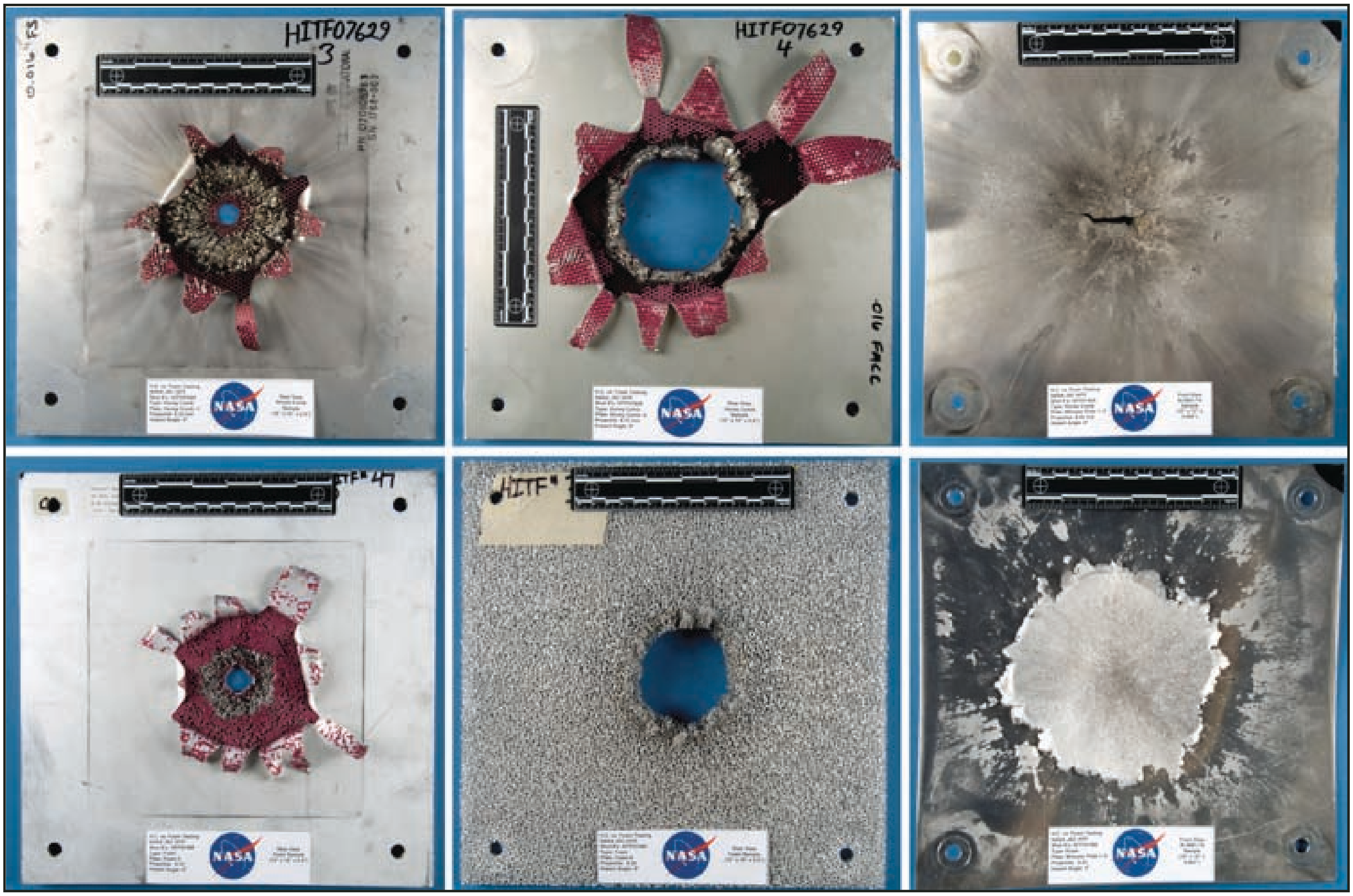

Figure 3. Comparison of damages induced by impact of 0.833 cm-diameter Al-spheres at approx. 6.9 km/s (0°) on the double-layer honeycomb (top) and foam (bottom) targets. From left to right: outer sandwich panel (rear view), second panel (rear view), rear wall (front view).

Shielding with Metallic Foams

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Figure 4. Comparison of ejecta plate damages following impact of 0.3175 cm-diameter Al-spheres on a monolithic aluminum outer bumper (left) and stainless steel foam outer bumper (right) at hypervelocity (6.8 km/s).

An Updated Assessment of the Orbital Debris Environment in LEO

J.-C. LIOU

The landscape of the near-Earth orbital debris environment changed significantly after the Fengyun-1C (FY-1C) anti-satellite test conducted by China in January 2007 and the collision between Iridium 33 and Cosmos 2251 in February 2009. These two breakups created about 5000 objects larger than 10 cm and increased the cataloged population by ~50%. This article aims to provide an updated assessment of the environment after the two events, including population instability in the low Earth orbit (LEO) region and the anticipated collision activities among the cataloged population in the near future. The discussion is limited to objects 10 cm and larger because they represent more than 99% of the on-orbit mass and are responsible for the growth of the future debris population.

A good way to characterize the instability of the LEO debris environment is to analyze the "no future launches (NFL)" scenario in future environment projection. In essence, this represents a best-case scenario by providing a bottom-line assessment of the environment. Figure 1 shows the simulation results from NASA's long-term orbital debris evolutionary model LEGEND. The solid curves are averages of 50 Monte Carlo (MC) runs. They are based on a historical component covering 1957 through 2006 and a future projection, assuming no launches beyond 2006, for 200 years.[1] This early study's main conclusion is that the future LEO population is maintained at an approximately constant level – a balance between the increasing collision fragments and decaying objects – for the next 50 years or so. Eventually, the ever-increasing collision fragments will force the total population to increase over the next 200 years. In this same figure, the dashed curves are averages from 100 MC runs of an updated simulation. The historical component covers 1957 through 2009 and the future environment, assuming no launches beyond 2009, is projected for 200 years.

The sharp increase of the new total between 2007 and 2009 (top curve in Figure 1) is primarily driven by fragments generated from the FY-1C event and the Iridium 33/Cosmos 2251 collision. However, observational data indicate that a significant amount of the FY-1C and Iridium 33 fragments have high area-to-mass ratios. These fragments appear to be pieces of multi-layer insulation, solar panel, or lightweight composite materials.[2,3] The more rapid orbital decay of these objects will decrease the total population for the next 25 years. Nevertheless, the remaining "regular" fragments from the two events will still increase the total number of objects by about 2500 over time.

The growth of the LEO debris population will lead to more collisions among the cataloged objects. To quantify the anticipated collision activities in the environment, three special LEGEND simulations, with 100 MC runs each, have been completed. Fragments from FY-1C, Iridium 33, and Cosmos 2251 are included in the historical component. For future projection, the first simulation is based on the NFL scenario. The second one is based on a non-mitigation scenario where the 2001-to-2008 launches are repeated in the projection period but no mitigation measures are implemented. The third one is a postmission disposal scenario where

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Updated Assessment

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the 2001-to-2008 launches are repeated in the projection period with the commonly-adopted mitigation measures (passivation, the 25-year rule, etc.) implemented, at a 90% success rate, to payloads after an assumed 8-year mission lifetime and to upper stages after launch.

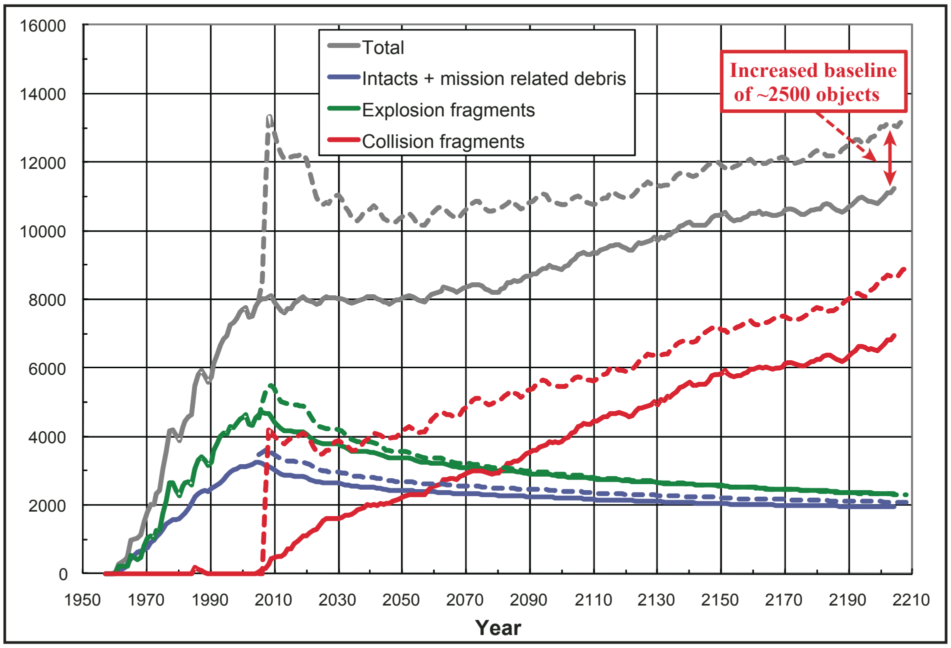

Figure 1. LEGEND-predicted growth of the LEO debris population based on the "no future launches" assumption. The solid curves are the results of a historical simulation through 2006 and a 200-year projection with no future launches beyond 2006. The dashed curves are results of a historical simulation through 2009 and a 200-year projection with no future launches beyond 2009. The FY-1C event and the Iridium 33/Cosmos 2251 collision will contribute about 2500 objects to the environment over time.

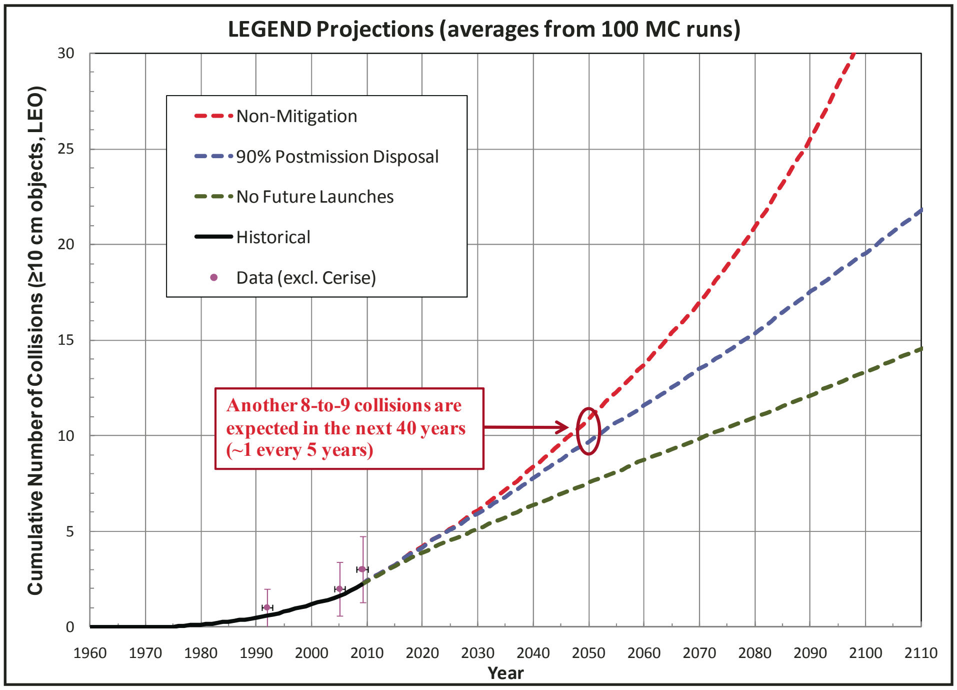

Figure 2. LEGEND-predicted accidental collision activities in LEO. An average of about one collision every 5 years is expected for the next 40 years.

Figure 2 shows the cumulative number of accidental collisions in LEO from the simulations. Three recorded on-orbit collisions and the Poisson 1-σ error bars are also included for comparison with the LEGEND-predicted collision probabilities among the cataloged objects in the historical component. The collision of Cerise is not included for comparison. The main body of Cerise was a box with dimensions of 60 cm × 30 cm × 30 cm.[4] Its 6-m long, gravity-gradient boom was severed by a small cataloged fragment in 1996. LEGEND does not model collisions on satellite appendages (e.g., booms or solar panels). Such collisions may be problematic for operational payloads, but have negligible contribution to the growth of the debris population.

The top two curves of Figure 2 indicate the difference between the non-mitigation and 90% postmission disposal scenarios is small for the next 40 years. This is understandable because upper stages and payloads can still remain in-orbit for up to 25 years after mission completion under the postmission disposal scenario. The benefit of the 25-year rule is long-term and can be seen from the gradual deviation of the two curves over time. The NFL scenario only represents an ideal best-case projection. The near-term reality of the LEO environment should lie between the top two curves. This means about 8 or 9 collisions among the cataloged objects are expected in the next 40 years (about one every 5 years). Approximately 50% of the predicted collisions are catastrophic collisions. Beyond 2050, collision activities in LEO will depend upon how well postmission disposal measures are implemented and if any active debris removal is carried out to further limit the growth of the debris population.

1. Liou, J.-C. and Johnson, N. L. Risks in space from orbiting debris, *Science* **311**, 340-341, (2006).

2. Liou, J.-C. and Johnson, N. L. Characterization of the cataloged Fengyun-1C fragments and their long-term effect on the LEO environment, *Adv. Space Res.* **43**, 1407-1415, (2009).

3. Liou, J.-C. An update on recent major breakup fragments, *ODQN Vol 13, Issue 3, 5-6,* (2009).

4. Johnson, N. L., Stansbery, E., Whitlock, D. O., Abercromby, K. J., and Shoots, D. History of On-orbit Satellite Fragmentations, 14th Edition, *NASA/TM-2008-214779*, (2008). ♦

ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

International Conference on Orbital Debris Removal
8-10 December 2009, Chantilly, VA

Space Debris Environment Remediation Concepts

H. KLINKRAD AND N. L. JOHNSON

Long-term projections of the space debris environment indicate that even drastic measures, such as an immediate, complete halt of launch and release activities, will not result in a stable environment of man-made space objects. Collision events between already existing space hardware will, within a few decades, start to dominate the debris population and result in a net increase of the space debris population, also in size regimes which may cause further catastrophic collisions. Such a collisional cascading will ultimately lead to a run-away situation ("Kessler syndrome"), with no further possibility of human intervention.

The International Academy of Astronautics (IAA) has been investigating the status and the stability of the space debris environment in several studies by first looking into space traffic management possibilities, and then investigating means of mitigating the creation of space debris. In an on-going activity, an IAA study group looks at ways of active space debris environment remediation. In contrast to the former mitigation study, the current activity concentrates on the active removal of large objects, such as defunct spacecraft, orbital stages, and mission-related objects, which serve as a latent mass reservoir that fuels initial castastrophic collisions and later collisional cascading. The paper will outline different mass removal concepts, e.g., based on directed energy, tethers (momentum exchange or electro-dynamic), aerodynamic drag augmentation, solar sails, auxiliary propulsion units, retarding surfaces, or on-orbit capture. Apart from physical principles of the proposed concepts, their applicability to different orbital regimes and their effectiveness concerning mass removal efficiency will be analysed.

The IAA activity on space debris environment remediation is a truly international project which involves more than 23 contributing authors from 9 different nations. ♦

A Review of the Recent NASA Long-Term Orbital Debris Environment Projection and Active Debris Removal Modeling Activities

J.-C. LIOU

The NASA Orbital Debris Program Office (ODPO) developed a high fidelity debris evolutionary model, LEGEND (a LEO-to-GEO Environment Debris model), in 2004 to enhance its capability to better model the near-Earth environment. LEGEND can mimic the growth of the historical debris population and project it into the future based on user-defined scenarios. The first major LEGEND study in 2006 concluded that even without any future launches, the LEO population would continue to increase due to mutual collisions among existing objects. In reality, the increase will be worse than this prediction because of ongoing satellite launches and unexpected major breakups. Even with a full implementation of the commonly-adopted mitigation measures, the LEO population growth is inevitable. To preserve the near-Earth environment for future generations, active debris removal (ADR) must be considered.

A follow-up LEGEND ADR study was completed recently. The main results indicate that (1) the mass and collision probability of each object can be used to establish an effective removal selection criterion and (2) a removal rate of approximately five objects per year is sufficient to stabilize the LEO environment. Due to the limitation of removal techniques, however, different target selection criteria (in size, altitude, inclination, etc.) may be more practical. A careful evaluation of the effectiveness of different proposed techniques must be carried out to maximize the long-term benefit to the environment. ♦

MEETING REPORT

60th International Astronautical Congress (IAC)
12-16 October 2009, Daejeon, Republic of Korea

The 60th International Astronautical Congress (IAC) 2009 was held in Daejeon, Republic of Korea, from 12-16 October 2009. The theme of the Congress, "Space Sustainability for Peace and Progress," resulted in orbital debris being included in a plenary session and as a Late Breaking News session, both presented by N. Johnson (NASA). The discussions included descriptions of the near-Earth debris environment and a brief history of the development of government mitigation standards. The Iridium 33/Cosmos 2251 accidental collision was highlighted as a 'shape of things to come'.

The Space Debris Symposium was coordinated by C. Bonnal (CNES) and N. Johnson (NASA). It spanned two and one-half days with five paper sessions (37 papers presented) – Measurements and Space Surveillance; Modeling and Risk Analysis; Hypervelocity Impacts and Protection; Mitigation and Standards; and a new session, Space Surveillance, Legal Aspects, and Space Debris Modeling. Recent research was reported and included survey measurements of the near GEO environment from optical systems, results of debris environment modeling, debris clouds produced by hypervelocity impacts on different materials, debris environment mitigation policy, active debris reduction techniques, and collision avoidance. Again the Iridium/Cosmos collision was highlighted in several papers in terms of long-term consequences and collision avoidance strategies. Also of interest were presentations on techniques for active debris removal including brush-contact robotic arm capture and laser and tether de-orbiting systems. ♦

UPCOMING MEETINGS

5-10 February 2010: The 33rd Annual AAS Guidance and Control Conference, Breckenridge, Colorado

The annual Guidance and Control Conference of the American Astronautical Society will feature a special lead-off session on the topic of orbital debris. The session will feature seven papers, four of which will be presented by members of the NASA Orbital Debris Program Office. The topics to be discussed include an overview on the growing threat of orbital debris to space operations, the U.S. Space Surveillance Network, current and near-term future measurements of the orbital debris environment, NASA's orbital debris environment model, NASA satellite conjunction assessment and collision avoidance strategy, the Kessler syndrome, and the sustainable use of space through orbital debris control. Additional information for the conference is available at <http://aas-rocky-mountain-section.org/conf_info.htm>.

19-21 May 2010: The 4th IAASS Conference, Huntsville, Alabama

The theme of the fourth conference of the International Association for the Advancement of Space Safety will be "Making Safety Matter." The IAASS conference will address several issues associated with orbital debris, including space traffic management, safety risk management, probabilistic risk assessment, regulations and standards for safety, and spacecraft reentry safety. The IAASS, legally established 16 April 2004 in the Netherlands, is a non-profit organization dedicated to furthering international cooperation and scientific advancement in the field of space systems safety. The IAASS membership is open to anyone having a professional interest in space safety. Additional information is available at <http://www.congrex.nl/10a06/>.

18 - 25 July 2010: The 38th COSPAR Scientific Assembly, Bremen, Germany

Three debris sessions are planned during the Assembly. They will cover topics in ground-based and in-situ measurement techniques, debris and meteoroid environment modeling, collision risks for space missions, on-orbit collision avoidance, reentry risk assessments, debris mitigation measures and their effectiveness for long-term environment stability, national and international debris mitigation standards and guidelines, hypervelocity impact testing, and shielding designs. A joint session with the Space Weather Panel, "Space Situational Awareness and its Relationship with Science," is also planned. The abstract submission deadline is 19 February, 2010. Additional information for the Assembly is available at <http://www.cospar-assembly.org>.

27 September - 1 October 2010: The 61st International Astronautical Congress (IAC), Prague, Czech Republic

The theme for the 2010 IAC is "Space for Human Benefit and Exploration." A Space Debris Symposium is planned during the Congress. It will include five sessions on (1) measurements, (2) modeling and risk analysis, (3) hypervelocity impacts and protection, (4) mitigations, standards, and legal issues, and (5) space surveillance and space situation awareness. The deadline for abstract submission is 5 March 2010. Additional information for the Congress is available at <http://www.iac2010.cz>.

(Photo credit: JCL)

A snapshot of the southern skies from the Cerro Tololo Inter-American Observatory, Chile. The Southern Cross is visible in the middle. The dome to the lower right is the 1.5 meter Ritchey-Chretien Telescope and the streak to the left is the overpass of the International Space Station.

This photo was taken during the fall campaign of the NASA GEO debris observations in 2009. It was captured using a point-and-shoot digital camera with 15 second exposure time and no tracking.

INTERNATIONAL SPACE MISSIONS
01 October – 31 December 2009

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2009-054A	AMAZONAS-2	SPAIN	35767	35805	0.0	1	1
2009-054B	COMSATBW-1	GERMANY	35773	35800	0.1		
2009-055A	WORLDVIEW 2	USA	767	768	98.6	1	0
2009-056A	PROGRESS-M 03M	RUSSIA	333	344	51.6	1	0
2009-057A	DMSP 5D-3 F18 (USA 210)	USA	842	859	98.9	0	4
2009-058A	NSS 12	NETHERLANDS	35768	35803	0.0	1	1
2009-058B	THOR 6	NORWAY	35779	35794	0.0		
2009-059A	SMOS	ESA	759	760	98.4	1	1
2009-059B	PROBA 2	ESA	709	729	98.3		
2009-060A	POISK	RUSSIA	333	344	51.6	1	0
2009-061A	SJ-11-01	CHINA	688	705	98.3	1	4
2009-062A	STS 129	USA	336	348	51.6	0	0
2009-063A	COSMOS 2455	RUSSIA	902	909	67.2	1	0
2009-064A	INTELSAT 14	INTELSAT	35780	35795	0.0	1	0
2009-065A	EUTELSAT W7	EUTELSAT	35784	35787	0.1	1	1
2009-066A	IGS 5A	JAPAN	NO ELEMS. AVAILABLE			1	0
2009-067A	INTELSAT 15	INTELSAT	35680	35785	0.0	1	0
2009-068A	WGS F3 (USA 211)	USA	NO ELEMS. AVAILABLE			1	0
2009-069A	YAOGAN 7	CHINA	623	659	97.8	0	0
2009-070A	COSMOS 2456 (GLONASS)	RUSSIA	19131	19421	64.8	2	6
2009-070B	COSMOS 2457 (GLONASS)	RUSSIA	18864	19130	64.8		
2009-070C	COSMOS 2458 (GLONASS)	RUSSIA	19124	19136	64.8		
2009-071A	WISE	USA	526	532	97.5	1	1
2009-072A	YAOGAN 8	CHINA	1193	1204	100.5	1	0
2009-072B	XIWANG-1 (HOPE-1)	CHINA	1193	1205	100.5		
2009-073A	HELIOS 2B	FRANCE	NO ELEMS. AVAILABLE			1	0
2009-074A	SOYUZ-TMA 17	RUSSIA	333	344	51.6	1	0
2009-075A	DIRECTV 12	USA	EN ROUTE TO GEO			1	1

SATELLITE BOX SCORE

(as of 06 January 2010, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	82	3062	3144
CIS	1395	4258	5653
ESA	41	44	85
FRANCE	48	421	469
INDIA	39	132	171
JAPAN	114	73	187
USA	1126	3686	4812
OTHER	454	115	569
TOTAL	3299	11791	15090

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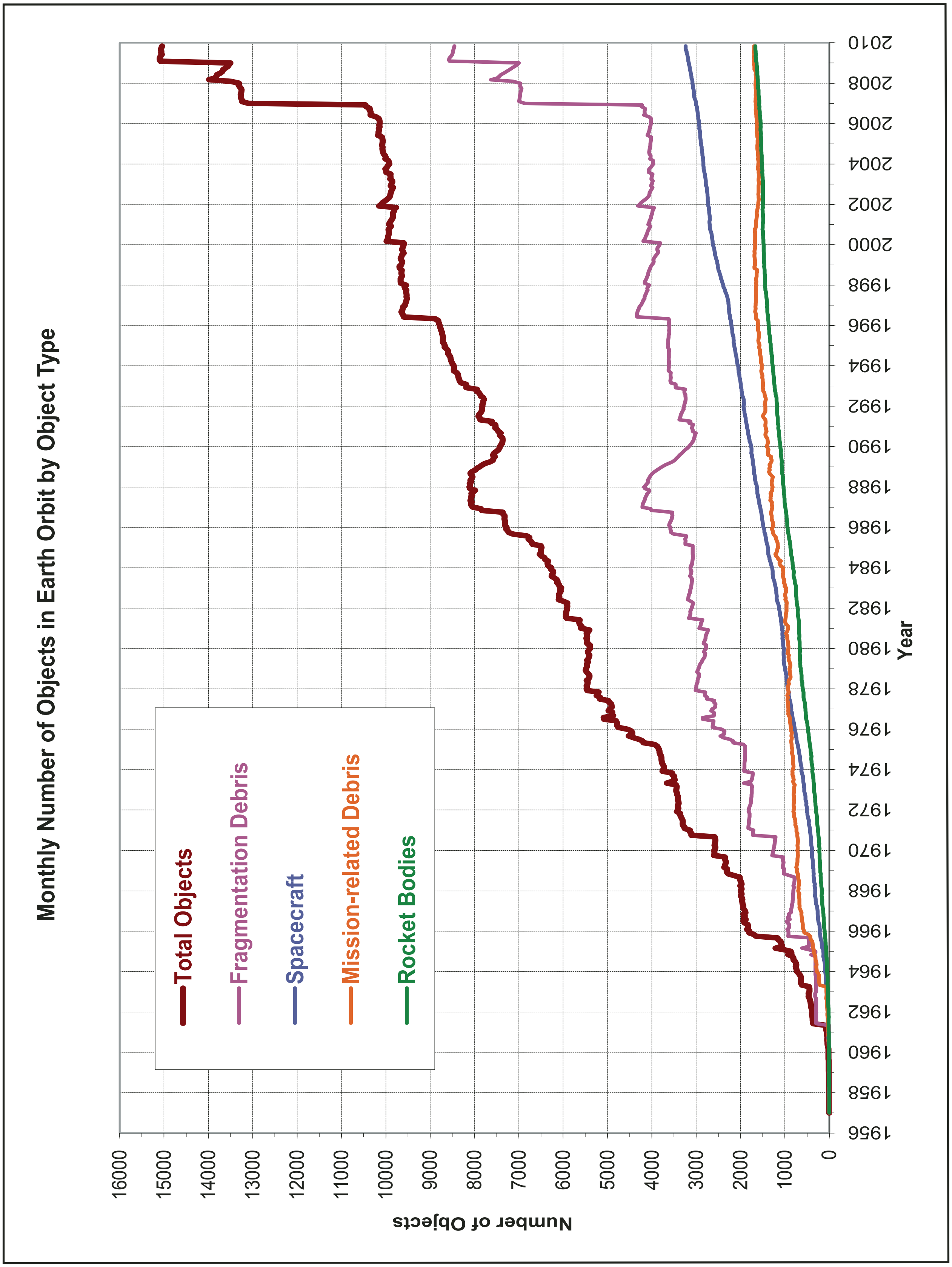

Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. “Fragmentation debris” include satellite breakup debris and anomalous event debris, while “mission-related debris” include all objects dispensed, separated, or released as part of the planned mission.

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