Recent Developments in Space Debris Mitigation Policy and Practices

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Since the American Institute of Aeronautics and Astronautics (AIAA) issued the first position paper on space debris 25 years ago, recognition of the threats posed by debris in Earth orbit and the need to act now to protect the future space environment have become wide-spread. This new awareness has been matched with positive actions by spacecraft and launch vehicle designers, manufacturers, and operators. As a result, a common set of space debris mitigation policies and practices has been forming at both the national and international levels.

Following the establishment in 1995 of detailed space debris mitigation guidelines for all NASA space projects and programs, several additional space debris mitigation policies were developed, including by the space agencies of Japan, France, and Russia, as well as the European Space Agency. After several years of coordination with U.S. industry, the U.S. Government Orbital Debris Mitigation Standard Practices were formally adopted in February 2001 and are referenced in the latest U.S. National Space Policy signed by President Bush on 31 August 2006.

In recent years, emphasis has shifted from national efforts to control the space debris population to international ones. Here, too, great progress has been made, most notably by the Inter-Agency Space Debris Coordination Committee (IADC) and the Committee on the Peaceful Uses of Outer Space (COPUOS) of the United Nations. Today, a firm international consensus is rapidly building on the principal space debris mitigation measures.

The IADC is an association of the space agencies of ten countries (China, France, Germany, India, Italy, Japan, Russia, Ukraine, the United Kingdom, and the United States) and the European Space Agency, representing 17 countries of which four (France, Germany, Italy, and the United Kingdom) are also full IADC members. At the 17th meeting of the IADC in October 1999, a new Action Item (AI 17.2) was adopted to develop a set of consensus space debris mitigation guidelines. The purpose of the activity was to identify the most valuable space debris mitigation measures and to reach an international agreement on common directives. The *IADC Space Debris Mitigation Guidelines* (www.iadc-online.org/index.cgi?item=docs_pub) were formally adopted in October 2002 during the Second World Space Congress in Houston, Texas. Two years later a companion document, entitled *Support to the IADC Space Debris Mitigation Guidelines*, was completed to provide background and clarification for the guidelines.

The *IADC Space Debris Mitigation Guidelines* emphasizes four major areas which require the attention of the aerospace community:

(1) limitation of debris released during normal operations;
(2) minimization of the potential for on-orbit break-ups during and after space operations;
(3) post-mission disposal recommendations for vehicles in low Earth orbit (LEO; below 2000 km altitude), geosynchronous orbit (GEO), and other orbital regimes; and
(4) prevention of on-orbit collisions.

The first area concentrates on avoiding the creation of unnecessary orbital debris during the deployment and operational phases of a space mission. For example, the release of payload attachment devices, sensor covers, explosive bolt fragments, and straps and wires should be avoided whenever possible. During the past 25 years, approximately 15% of all cataloged objects in Earth orbit have fallen into this category, although since the turn of the century the absolute number of mission-related debris in Earth orbit has declined due to increasing adoption of design modifications.

By far the greatest source of debris now in orbit about the planet has been the often violent break-up of spacecraft and rocket bodies. At the beginning of 2006 these debris accounted for 37% of all cataloged objects still in orbit. Moreover, typically only a small fraction of these debris arose from deliberate fragmentations, such as actions associated with national security operations. Faulty propulsion systems are by far the most prevalent source of break-up debris. In fact, the vast majority of these propellant- or pressurant-induced break-ups occur after a spacecraft or launch vehicle orbital stage has successfully completed its mission.

Fortunately, simple end-of-mission passivation, especially the release or burning of residual propellants and pressurants, of a spacecraft or orbital stage can eliminate the potential for future explosions. Such post-mission action is now routine for virtually all space launch vehicles of the world, and, consequently, the rate of creation of long-lived debris has fallen. Spacecraft operators, particularly those responsible for GEO spacecraft, are also following suit.

The third area of interest is the disposal of spacecraft and orbital stages after their useful lives have ended. The ultimate objective, whether in LEO or in GEO, is to limit the probability of derelict objects colliding with other space objects (operational or not), which can result in the creation large numbers of additional debris. Spacecraft and orbital stages operating in LEO should be left in orbits which will reenter the atmosphere within 25 years of their end of mission. Vehicles operating in or near GEO should be placed in disposal orbits above GEO which prevent their drifting back within 200 km above GEO, typically for at least 100 years.

The fourth topic of space debris mitigation is active collision avoidance. Although one cannot avoid the vast majority of potentially damaging debris, *i.e.*, those numerous objects which are too small to be tracked by national space surveillance networks, some operators of high-valued spacecraft rely on predictive conjunction assessments to avoid even small chances of colliding with members of the tracked space object population. Risk thresholds of 1 in 10,000 for human space flight and 1 in 1,000 for robotic spacecraft can be effectively managed with the existing levels of accidental collision probability. Some space launch operators also rely on conjunction assessments to avoid colliding with a resident space object during the initial few hours of orbital insertion and deployment of new missions.

At the 38th meeting of the UN COPUOS Scientific and Technical Subcommittee (STSC) in Vienna, Austria, during February 2001, a new multi-year work plan on space debris was adopted. A focal point of the work plan was the anticipated receipt of the *IADC Space Debris Mitigation Guidelines* by the February 2003 meeting of the STSC. STSC Member States would then review the guidelines during 2003 and 2004 with a potential endorsement of same at the end of the 2004 session. The IADC guidelines were well received, but a decision was made to develop a separate set of STSC Space Debris Mitigation Guidelines based in large measure upon the very valuable work of the IADC.

A special STSC working group of interested Member States was formed in 2005 to draft the proposed STSC guidelines. This work was completed in February 2006 when the draft document was submitted to the full STSC for review. The document, which will be considered for adoption in 2007, contains seven numbered guidelines:

- Guideline 1: Limit debris released during normal operations
- Guideline 2: Minimize the potential for break-ups during operational phases
- Guideline 3: Limit the probability of accidental collision in orbit
- Guideline 4: Avoid intentional destruction and other harmful activities
- Guideline 5: Minimize potential for post-mission break-ups resulting from stored energy
- Guideline 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low Earth orbit region after the end of their mission
- Guideline 7: Limit the long-term interference of spacecraft and launch vehicle orbital stages with geosynchronous region after the end of their mission

In addition to the extremely effective work of the IADC and the UN, three other international efforts have recently produced valuable contributions to space debris mitigation. Leveraging off its 1995 position paper on orbital debris and a subsequent update in 2000/2001, the International Academy of Astronautics

(IAA) undertook a challenge to produce a new position paper on space debris mitigation. Subtitled *Implementing Zero Debris Creation Zones*, this position paper was approved and released in October 2005. The report contains separate sections devoted to space debris mitigation for spacecraft and launch vehicles. In addition to general recommendations for space debris mitigation, this new position paper also addresses short term actions which could be taken by the aerospace community.

A proposed *European Code of Conduct for Space Debris Mitigation* has been prepared by the space agencies of France, Germany, Italy, and the United Kingdom in concert with the European Space Agency. Completed in June 2004, the document had been signed by all five agencies by 2006. Like the *IADC Space Debris Mitigation Guidelines*, the *European Code of Conduct for Space Debris Mitigation* was accompanied by a helpful document, *Support to Implementation of the European Code of Conduct for Space Debris Mitigation*. While many elements of the European Code of Conduct are similar to those in the IADC and UN works, the European document separates the mitigation measures into three categories: management, design, and operations.

Finally, in 2004 the International Telecommunication Union (ITU) revised its recommendation for the disposal of GEO spacecraft (ITU-R S.1003) to be consistent with the IADC recommendation for GEO spacecraft disposal, first developed in 1997 and included in the 2002 *IADC Space Debris Mitigation Guidelines*.

All of the aforementioned documents focus on debris which is created or remains in orbit. A few national space agencies also include guidelines for risks associated with objects reentering the atmosphere in either a controlled or uncontrolled manner. For example, NASA recommends limiting the risk of human casualty from reentering debris to less than 1 in 10,000 per event for uncontrolled objects. In the case of a controlled, destructive reentry, like that of the Compton Gamma Ray Observatory in June 2000, the footprint of the surviving debris should be well away from all inhabited regions of the world as well as from the permanent ice pack of Antarctica, i.e., over a broad ocean area. The IADC is also investigating possible recommendations for reentry criteria and procedures.

Adherence to the aforementioned space debris mitigation policies and guidelines is gaining momentum yearly. Many spacecraft and launch vehicle designers have reduced the amount of debris produced during normal operations. Passivation of space vehicles at end of mission is becoming more commonplace, as is the proper disposal of GEO spacecraft. Cost-effective means of limiting post-mission orbital lifetimes of LEO spacecraft and orbital stages remains a challenge for many missions, but advances are being made. Some spacecraft are being designed to propel themselves into their final orbits, leaving their launch vehicle stages in lower, shorter-lived orbits. Interest is also increasing in new ways to lower the altitudes of vehicles by drag augmentation devices or momentum exchange tethers. Some orbital stages are using their residual propellants to lower their orbits after payload release, combining recommendations for both passivation and orbital life time reduction in a truly cost-effective manner.

Overall, the prospects for controlling the near-Earth space debris environment are very bright, thanks to the dedication and energies of space debris scientists, the industrial aerospace community, and national organizations and governments. Whereas significant strides have already been made to curtail the growth of the debris population, the work is not yet finished.