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Space debris


**Towards Long-term Sustainability of Space Activities:
Overcoming the Challenges of Space Debris**

**A Report of the International Interdisciplinary Congress on Space
Debris**

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Towards Long-term Sustainability of Space Activities: Overcoming the Challenges of Space Debris

*** A Report of the International Interdisciplinary Congress on Space Debris ***

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Executive Summary

The near-Earth outer space environment is an important part of the global commons of outer space that is used to improve our human condition. Space-based applications such as weather and climate monitoring, position-navigation-timing (global positioning service) remote sensing, and telecommunications positively impact our lives on Earth. But the long-term sustainability of human utilization of the near-Earth space environment is seriously threatened by space debris.

Space debris is comprised of non-functioning man-made objects that result from human space activities like launch vehicle operations, spacecraft operations, and other experiments. They pose a threat because typical debris in the outer space environment does not easily degrade or rapidly re-enter the Earth's atmosphere. Instead, travelling at high velocity, space debris remains in the environment and creates a collision threat to functioning spacecraft in various orbits. The space debris population will continue to grow, even without any new launches. Such growth in the amount of space debris likely will result in more collisions. This indicates looming danger and a sense of urgency in finding viable solution(s) to the space debris problem.

Central to the successful mitigation, and eventually remediation, of space debris is international harmonization and coordination. Outer space is a "commons" environment that requires all space actors to participate in space debris mitigation. The leading international arrangement to mitigate space debris is the 2007 UN COPUOS Space Debris Mitigation Guidelines. The Guidelines are legally non-binding and their implementation is voluntary. States that choose to adopt these Guidelines do so through their respective domestic policies, laws and regulations. They are operational in nature and apply only to mission planning and operation of newly designed spacecraft and orbital stages.

The UN COPUOS Guidelines are a first and important step towards long-term sustainable use of the near-Earth outer space environment, but the Guidelines have limitations. Furthermore, international space law does not establish a sufficient and appropriate legal regime to internationally regulate the challenges created by space debris. It is therefore imperative that States and other stakeholders consider additional initiatives to combat space debris.

The goal of this Report is to contribute to the public discourse on the issue of space debris and the sustainability of use of space. The UN COPUOS Guidelines are assessed to determine their effectiveness within the context of current implementation. Limitations are identified and thereafter additional legal, policy, and technical initiatives for dealing with matters related to space debris are discussed and recommended. Also included in this Report are action items for States and other stakeholders to consider for further research and development.

Preface

Although the space age has brought about many technological, societal, and economic benefits for all humankind, these benefits have not been achieved without negative consequences. As a result of past activities in space and the rapidly increasing rate of usage of space in present times, space-faring nations are causing environmental damage that could have lasting negative effects on long-term sustainability of use of outer space by all States. The most immediate and serious of these is space debris; e.g. the non-functional satellites, used launch vehicles, and related objects that orbit the Earth uncontrolled.

Orbiting the Earth are more than 21,000 human-made objects larger than ten centimetres in diameter. It is estimated that there are an additional 600,000 objects in Earth orbit measuring between one and ten centimetres in diameter, and many hundreds of millions between one centimetre and one millimetre. A total of 15,800 objects larger than ten centimetres are catalogued, meaning they can be identified with a specific launch or release event. Of these, only six to seven percent are operational satellites; this means that, as a minimum, more than 90 per cent of space objects in Earth orbit are uncontrolled. As these objects orbit at speeds of between 3 km/sec and 7.7 km/sec, a collision between one uncontrolled object of any size and another space object can have serious consequences. Although they are spread out over a vast area, most of this space debris is concentrated in those areas of space that provide the greatest utility and benefit to humankind.

The risks posed by space debris are a global problem requiring both national and international solutions. This can be best achieved through a concerted effort by space technologists and policy and law makers, in concert with spacecraft manufacturers, operators, and insurers, to establish regulatory solutions and assure a sustainable space environment for future generations.

Recognizing a generally shared common concern that space debris presents a global risk to humanity in general and to space activities of all space-faring nations in particular, the Institute of Air and Space Law of McGill University, Montreal, Canada, planned in 2008 to organize an International Interdisciplinary Congress on Space Debris in order to begin a process that would result in specific and viable policy and regulatory options, as well as technical mechanisms, that may be considered by States and other stakeholders to monitor and reduce the challenges posed by space debris. For this purpose, the McGill Institute invited the Cologne University Institute of Air and Space Law, Germany, and the International Association for the Advancement of Space Safety to be collaborators, and the United Nations Office for Outer Space Affairs in Vienna as a co-sponsor of this event. The Congress was convened in two sessions with the financial support from Erin J. C. Arsenault Trust Fund at McGill Faculty of Law and the German Aerospace Center.

The Congress had set four specific functions to perform; i.e. to:

- (a) Assess the value of the 2007 United Nations Committee on Peaceful Uses of Outer Space's Space Debris Mitigation Guidelines;
- (b) Assess current efforts to implement these Guidelines;

(c) Examine further legal, organizational, and technical mechanisms and endeavours for possible national, regional, and international implementation and assess whether they could be complementary to these Guidelines; and

(d) Put forward specific and viable policy and regulatory steps (options) that may be considered by States and other stakeholders to monitor and reduce the risks posed by space debris.

The first Session of the Space Debris Congress, which was held on 8 and 9 May, 2009, at the McGill Institute of Air and Space Law in Montreal, concentrated on a comprehensive analysis and assessment of the causes, trends, and implications of space debris in order to provide a full and precise understanding and appreciation of the seriousness of the problem. The second Session of the Congress, held in Cologne on 29 and 30 April, 2010, was an intensive workshop. The purpose of this Session was to critically analyse the draft Report of the Montreal Session in order to put forward viable and concrete policy and regulatory options, both at the international and national levels.

Each Session was comprised of a group of about thirty-five invited experts. These experts were experienced in various fields, including natural sciences, engineering, physics, astrophysics, industry, defence, public service, political science, and law; and came from Canada, Colombia, Czech Republic, China, France, Germany, Ghana, India, Italy, Japan, the Netherlands, Romania, the Russian Federation, Sweden, the United Kingdom, the United States of America, and several space agencies and international organizations. Following the *Chatham House Rules*, the discussions were open, frank and at a high-level. The participants shared ideas, presented papers and presentations, and spoke freely on the subject. In conformity with *Chatham House Rules*, this Report does not provide attribution or citation to any particular participant nor to any particular paper and/or presentation. The limitations of adopting such a methodology without direct citation of attribution authority are recognized. Nonetheless, it is hoped that the reader will understand that significant effort has been made to maintain the highest standards of objectivity and accuracy. The authority for the Report is primarily derived from the expertise of the congressional body as a whole.

This Report seeks to: (a) objectively demonstrate the current status of space debris, (b) assess the effectiveness of current debris mitigation measures, and (c) offer recommendations to improve current and future space debris mitigation and/or remediation efforts. This Report also serves as background and basis for the *McGill-Cologne Declaration on Space Debris* (see Appendix 2) that was adopted with consensus by the Congress at the end of the Cologne Session.

Finally, before one can speak of possible solutions to a problem, it is imperative that the problem should become widely known. Thus, there is a need for widespread awareness of the risks posed by increasing space debris. Therefore, the Report is intended to contribute to the international debate on the challenges posed by space debris. The Report has been written in such format and style so that both the general public and experts in the field can read the Report and benefit. This Report is being made available to the public and submitted to various international institutions, private companies as well as government entities, with a view to raise such awareness, to highlight the challenges ahead, and to promote technical exchange and international cooperation focused on preserving the space

environment and enhancing the sustainability of use of space by all nations as well as their public and private entities.

Acronyms

ASAT:	Anti-Satellite
ASTM:	The American Society for Testing and Materials
CFE:	Commercial and Foreign Entities Program of the U.S. Department of Defense
COPUOS:	United Nations Committee on the Peaceful Uses of Outer Space
CSSI:	Center for Space Standards and Innovation, Colorado Springs (the United States)
CNES:	<i>Centre National d'Etudes Spatiales</i> (France)
DOD:	Department of Defense (the United States)
ECSS:	European Cooperation for Space Standardization
ESA:	European Space Agency
GEO:	Geostationary (Geosynchronous) Earth Orbit
IAA:	International Academy of Astronautics
IAASS:	International Association for the Advancement of Space Safety
IADC:	Inter-Agency Space Debris Coordination Committee
ISO:	International Organization for Standardization
ISON:	International Scientific Optical Network (the Russian Federation)
ISOC:	International Space Operations Clearinghouse
ISSAA:	Information System Security Assurance Architecture
ISTI:	<i>Istituto di Scienza e Technologie dell'Informazione</i>
JSpOC:	Joint Space Operations Center (the United States)
LSC:	Legal Sub-committee of the UN COPUOS
LEO:	Low Earth Orbit
MEO:	Medium Earth Orbit
NASA:	National Aeronautics and Space Administration (the United States)
PMD:	Post-Mission Disposal
SDA:	Space Data Association
SDM:	Space Debris Mitigation software
SSA:	Space Situational Awareness
STM:	Space Traffic Management
STSC:	Scientific and Technical Sub-committee of the UN COPUOS
TVM:	Testing, Validation, and Modelling

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I. Space Debris Capstone

The objective of this Section is to provide the necessary background for a better understanding of the space (orbital) debris problem. Towards that end, this Section defines space debris, explains how space debris is detected and observed, illustrates the current space debris environment, and describes international legal considerations related to space debris.

A. Definition of Space Debris

The Inter-Agency Space Debris Coordination Committee (IADC)¹ defined space debris as “all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional.”² The UN COPUOS Space Debris Mitigation Guidelines³ also adopted this IADC definition.

In accordance with the 1975 Registration Convention, a Launching State is obliged to notify the Secretary General of the United Nations should the status of the space object on that State’s registry change, or if the State’s space object is no longer in orbit.⁴ Thus, under international law, there is some ambiguity as to when a space object becomes space debris. This is an important issue that has serious implications concerning State jurisdiction and control over the space object in question, as well as State liability for damage suffered by others. In the event of remediation or salvage of space debris, these legal ambiguities will surface. However, for the time being, the definitions in the IADC and UN COPUOS Space Debris Mitigation Guidelines seem to be sufficient.

¹ The Inter-Agency Space Debris Coordination Committee (IADC) is an international forum of governmental bodies for the coordination of activities related to space debris. Its membership is limited to governmental space agencies, which currently are: Agenzia Spaziale Italiana (ASI), Centre National d’Etudes Spatiales (CNES), China National Space Administration (CNSA), German Aerospace Center (DLR), European Space Agency (ESA), Indian Space Research Organisation (ISRO), Japan Aerospace Exploration Agency (JAXA), National Aeronautics and Space Administration (NASA), National Space Agency of Ukraine (NSAU), Russian Federal Space Agency (ROSCOSMOS), UK Space Agency (UKSpace). Online at www.iadc-online.org/index.cgi?item=members. Recently the Canadian Space Agency (CSA) joined as a full member of the IADC Online <http://news.gc.ca/web/article-eng.do?crtr.sj1D=&mthd=tp&crtr.mnthndVl=&nid=575749&crtr.dpt1D=&crtr.tp1D=1&crtr.lc1D=&crtr.yrStrtVl=&crtr.kw=&crtr.dyStrtVl=&crtr.aud1D=&crtr.mnthStrtVl=&crtr.yrmdVl=&crtr.dyndVl=>.

² “IADC Space Debris Mitigation Guidelines”, IADC 02-01, 15 October 2002, online at http://stage.tksk.jaxa.jp/spacelaw/kokusai_utyu/space_debris/iadc.pdf.

³ See Appendix 1 of this Report.

⁴ Article IV of the Convention on Registration of Objects Launched into Outer Space (hereinafter referred to as the “Registration Convention”), adopted by the General Assembly in its resolution 3235 (XXIX), opened for signature on 14 January 1975, entered into force on 15 September 1976; 55 ratifications, 4 signatures, and 2 declaration of acceptance of rights and obligations acceptances.

B. Sources of Space Debris

Approximately 60 per cent of the catalogued objects are generated from break-ups or fragmentation of spacecraft and rocket bodies. Often fragmentation is the result of the explosion of leftover fuel or other reactive chemicals, trapped within used rocket engines. This is the primary source of fragmentation space debris. Collisions between large objects (usually spacecraft or rocket bodies) and other pieces of space debris provide an additional source of fragmentation debris.

Another significant source of space debris is the act of placing satellites in orbit. Explosive bolts, lens covers, or nozzle covers can all separate from the satellite and end up in uncontrolled orbit. Such mission-related debris and the rocket bodies that remain in orbit account for 18 per cent of the total catalogued debris. Inoperable satellites account for another 15 per cent. There have also been cases of deliberate destruction of satellites which have contributed significantly to the space debris population. In brief, the primary sources of space debris are:

- Satellites that have reached their end-of-life and been left in orbit;
- Upper stages of launchers which had been used to place satellites in orbit;
- Operational debris, which are objects intentionally released during a mission. These include casings needed to protect instruments during the launch phase, mounting systems for solar panels or antennas before their deployment in orbit, and release mechanisms;
- The result of fragmentation, either by a collision between two objects in orbit or from a space object accidentally or intentionally exploding;
- Propellant residues from solid propellant motors that are used to carry out orbit transfers, particularly between a transfer orbit and geostationary orbit, which release small aluminium particles during and immediately following thrust; and
- Ageing of materials in space due to the extremely hostile environment that leads to production of large quantities of debris (e.g. heat shield covers flaking, paintwork peeling off, etc.).

C. How Space Debris is Observed and Detected

In Low-Earth Orbit (LEO, typically defined as below 2000 kilometres), phased array radars are best suited to detect and track space debris. At altitudes below 600 kilometres, objects which are up to ten centimetres in diameter can be tracked, but as altitude increases up to 5000 kilometres, the size threshold where radar can detect objects decreases to greater than one meter. Detection and tracking of space objects and/or debris in Geostationary Earth Orbit (GEO, approximately 36,000 kilometres) and higher orbits is usually done with optical telescopes and very powerful mechanical radars.

A sensor that is tracking a space object records the position of the object relative to that sensor at a specific time, known as an observation. Usually, a sensor records a series of observations during a short time frame called a track. Multiple tracks of the same object, usually from different sensors and taken at different times, are

combined using a mathematical process to produce an element set that represents the object's orbit in space. An element set can be used to calculate the object's past or future position in orbit to varying degrees of accuracy. A satellite catalogue is a database containing element sets for multiple objects.⁵

The U.S. military maintains a world-wide network of radars and telescopes called the Space Surveillance Network (SSN) to survey objects in the sky which are larger than about ten centimetres in LEO and about one meter in GEO.⁶ Certain sensors in the network can track even smaller objects. However, since a single sensor is not sufficient to maintain an accurate orbit on an object, objects smaller than ten centimetres are currently not routinely tracked by the SSN or maintained in the satellite catalogue. Observations from the SSN and other sources of data are collected by the Joint Space Operations Center (JSpOC) at Vandenberg Air Force Base, California, USA. The JSpOC uses this data to maintain a number of satellite catalogues used for space situational awareness (SSA). Some of these data are also available publicly through the SSA Sharing Program on the Space Track website (www.space-track.org) in the form of Two-Line Elements (TLEs) and other data products.

The Russian Federation also operates a significant network of radars and telescopes and a satellite catalogue; however, it does not make public any of this data. The Russian organization International Scientific Optical Network (ISON) maintains a network of twenty-five scientific and research telescopes distributed around the world, used mainly to observe satellites and debris in high Earth orbit.

Some States in Europe also operate powerful radars (e.g. the German TIRA, the French Graves, Scandinavian/multinational EISCAT, the UK's Fylingdales) and optical telescopes to characterize the space environment. In 2008, ESA initiated a 3-year SSA Preparatory Programme to develop a European SSA capability to serve both civil and military users.⁷ An eventual system is likely to combine data from existing national sensors and potentially to develop new European sensors.

In 2009, a group of commercial satellite operators formed the Space Data Association (SDA), an international non-profit organization to increase the sharing of SSA data and cooperation between satellite operators. In 2010, the SDA's Space Data Center began initial operations to provide conjunction assessment and collision warning services to participating satellite operators, and in 2011 it is expected to add radio frequency interference mitigation services as well.⁸

⁵ A detailed treatment of this process can be found in the article entitled "The Numbers Game" by Brian Weeden in *Space Review*, 13 July 2009, online at www.thespacereview.com/article/1417/1.

⁶ A more detailed examination of various SSA tracking networks around the world can be found in the paper by B. Weeden, P. Cefola, and J. Sankaran entitled "Global SSA Sensors", presented at the 2010 Advanced Maui Optical and Space Surveillance Conference, Maui, Hawaii, September 15-17, 2010, online at < www.amostech.com/TechnicalPapers/2010/Integrating_Diverse_Data/Weeden.pdf.

⁷ In December 2010 a report was issued on a satellite tracking campaign to test European capability. The activity is part of the ongoing ESA SSA activity. www.esa.int/esaMI/SSA/SEMALXFMTGG_0.html.

⁸ See Space Data Association home page, www.space-data.org/sda/.

In addition to the actual tracking of objects in Earth orbit, sophisticated software models are also used to statistically represent the space debris population which cannot currently be tracked, generally those objects smaller than 10 centimetres in size. Attempts are made to calibrate and validate the models using specific tracking events, such as beam park experiments,⁹ and through analysis of recovered space hardware.

The European Space Agency has procured the development of a high-fidelity space debris and meteoroid model called MASTER. The model includes all known launched objects as well as:

- Simulated pieces of more than 200 explosions;
- Dust and slag released by more than 1000 solid rocket motor firings in space;
- Paint flakes and ejecta released from spacecraft surfaces during their aging process in space;
- Sodium-potassium droplets which were released from cooling systems of Russian RORSATs; and
- Clusters of copper needles released in the US Westford Needles Experiment in the early 1960's.

The MASTER model has been upgraded to include the fragments from the Fengyun 1C breakup in January 2007 and from the collision of Iridium 33 with Cosmos 2251 in February 2009. In order to be able to assess the effectiveness of space debris mitigation measures, a long-term simulation tool called DELTA is forecasting the evolution of the MASTER population. A similar tool called SDM has been developed by ISTI (Pisa, Italy). These simulation tools demonstrate the effects of explosion prevention and, of the de-orbiting of satellites and rocket bodies in LEO.

NASA has also developed its own software tool to model the space environment called LEGEND.¹⁰ It shares many of the same techniques and functions as MASTER and DELTA including the ability to model changes in the space debris population over long stretches of time, typically 100 years into the future.

D. Current Space Debris Environment

As noted earlier, space debris is defined as human-generated, non-functional objects in Earth orbit or re-entering the atmosphere. The space environment also includes micrometeoroids, which do pose a threat to spacecraft in orbit but are not generally tracked or included in catalogues of space objects.

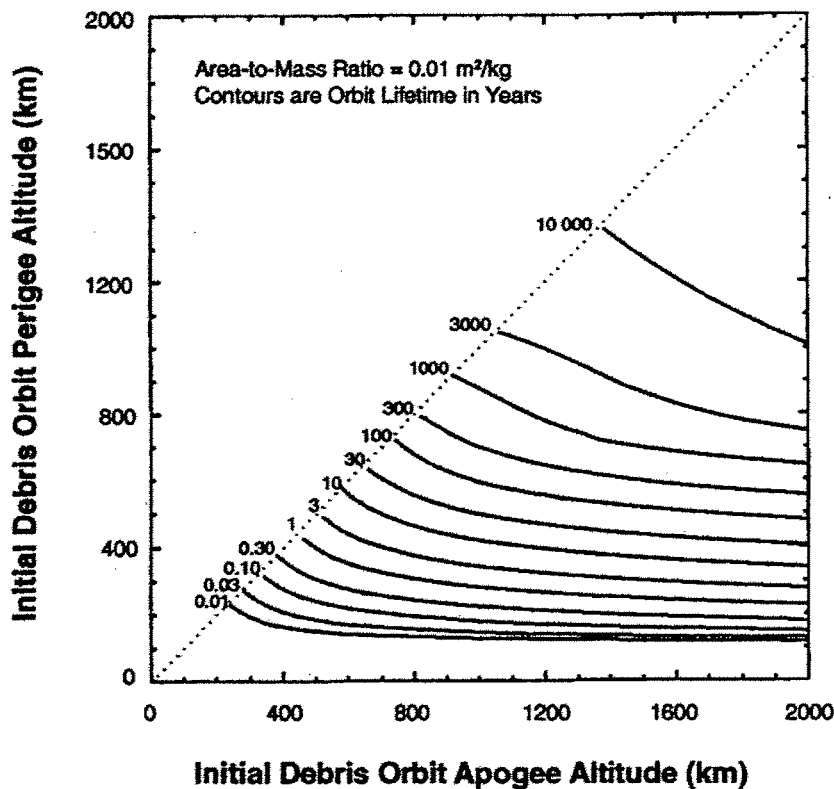
⁹ A beam-park experiment is a method by which a radar beam that is set in a fixed position on Earth is utilized to detect space debris in inertial space. The radar beam is left in place, and as the Earth rotates, a 360 degree area is scanned. "Backscattering" of the radar beam enables some information to be gleaned about debris, including orbital parameters of the debris. Such experiments can be performed by installations around the world, such as FGAN in Germany, or at Haystack and Goldstone in the United States.

¹⁰ An explanation of LEGEND is available online at NASA's website:
<http://orbitaldebris.jsc.nasa.gov/model/evolmodel.html>.

Since the launch of Sputnik in 1957, more than 4700 launches have occurred which placed objects in Earth orbit. In order to achieve orbit, an object must be boosted to the desired orbital altitude above the Earth and given a forward velocity required to stay in orbit. As Earth's gravitational field extends into space, objects must continuously move forward to avoid being pulled back into the Earth's atmosphere. The velocity required to stay in orbit depends on the altitude: the higher in altitude, the lower the Earth's gravitational pull, and thus the slower an object needs to move to stay in orbit.

The Earth's upper atmosphere extends into space and creates significant drag effects on space objects below approximately 1000 kilometres. This drag effect dissipates their orbital energy, reduces their altitude, and eventually causes them to re-enter the atmosphere through a process known as natural decay. Thus, the lifetime of an object on orbit is a function of its altitude and area-to-mass ratio, as shown in Figure 1.

Figure 1
Orbital Lifetime as a Function of Altitude¹¹



Currently, there are about 21,000 human-generated objects measuring over ten centimetres in diameter being tracked in Earth orbit, of which about 15,800 are in

¹¹ NASA Safety Standard 1740.14 (August 1995).

the public satellite catalogue maintained by the U.S. military.¹² In addition, there are at least 600,000 untracked objects between one and ten centimetres and more than 100,000,000 untracked objects between 0.1 and one centimetre. Particles measuring less than 0.1 centimetres are even more abundant.

Figure 2
Historical Growth of Catalogued Objects¹³

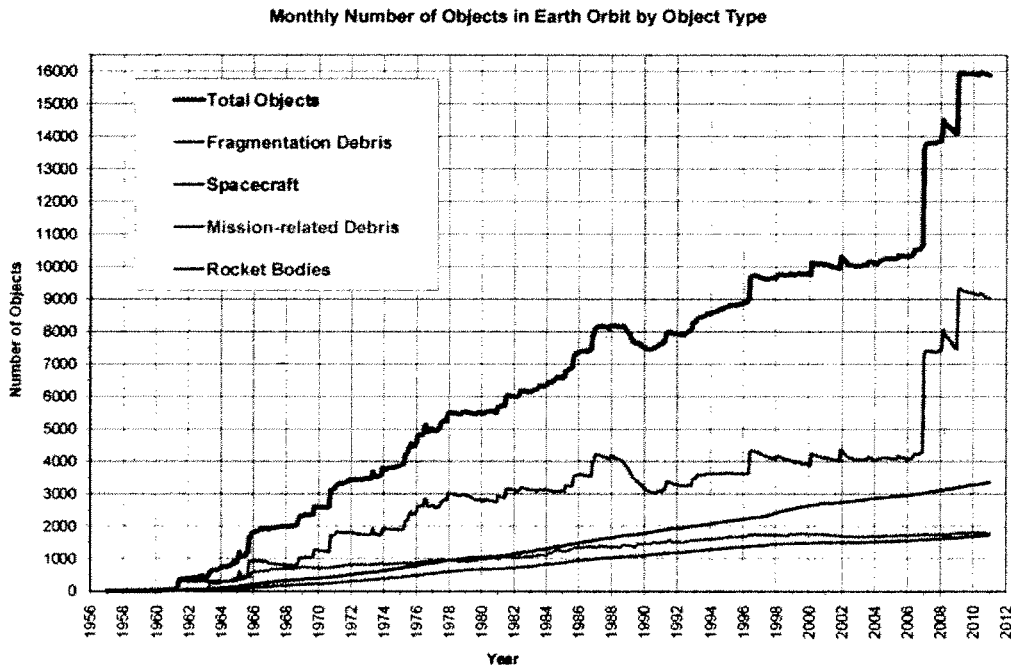
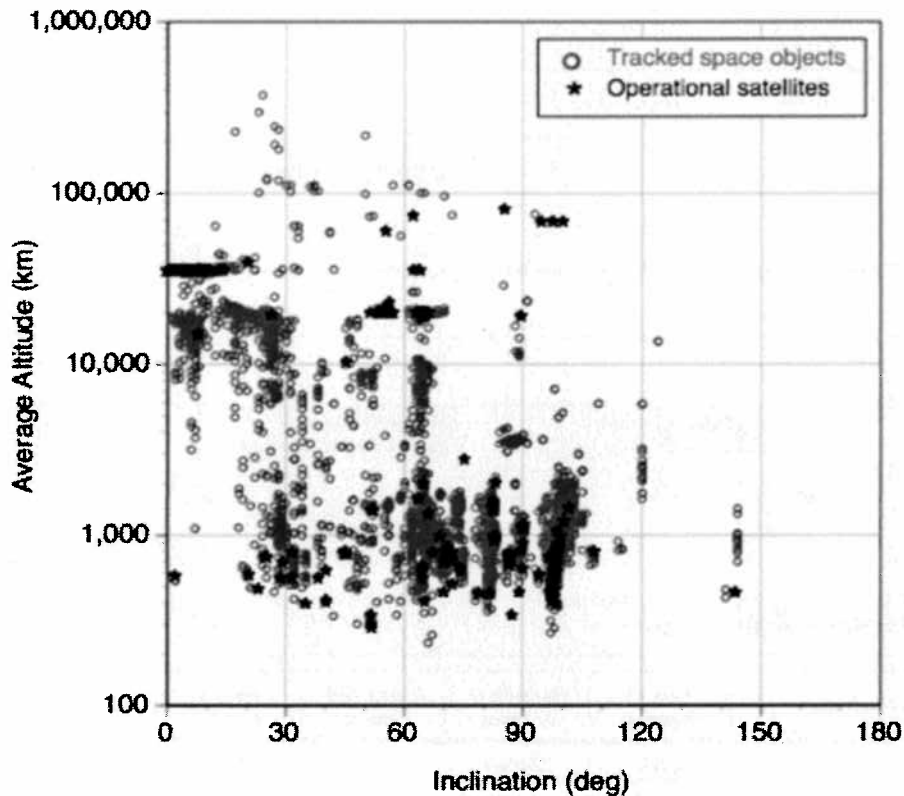


Figure 2 shows the historical growth in the public satellite catalogue over time. The periodic downward trends correspond to periods of high solar activity which in turn expands the Earth’s atmosphere and accelerates the natural decay process. However, in general, the amount of debris has grown at a faster rate than the number of active spacecraft, and what little gains were achieved by debris mitigation measures or natural decay were cancelled out by major events which added large amounts of debris.

¹² Data retrieved from the public satellite catalogue, which can be accessed at: www.space-track.org.

¹³ *Orbital Debris Quarterly*, (January 2011) at 10, online: NASA Orbital Debris Program Office <http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv15i1.pdf>.

Figure 3
Distribution of Debris and Operational Satellites¹⁴



The distribution of debris in space is not uniform since it is a function of human activities in space. Most space debris is concentrated in 'useful' orbits where human activity is greatest, particularly in LEO between 600 and 1,500 kilometres, where many Earth observation satellites are located, and in GEO at 36,000 kilometres, where most of the telecommunications satellites are placed.

Figure 4 below shows the debris flux on a typical satellite in a Sun-synchronous orbit, a portion of LEO that is one of the most crowded regions, and the potential negative effects from a collision with various sizes of debris.

¹⁴ "Space Traffic Management", Space Studies Program Student Report, International Space University, August 2007, online at www.isunet.edu/index.php?option=com_docman&task=doc_download&gid=371.

Figure 4
Debris Flux in Sun-synchronous Orbit and Potential Impact on Spacecraft¹⁵

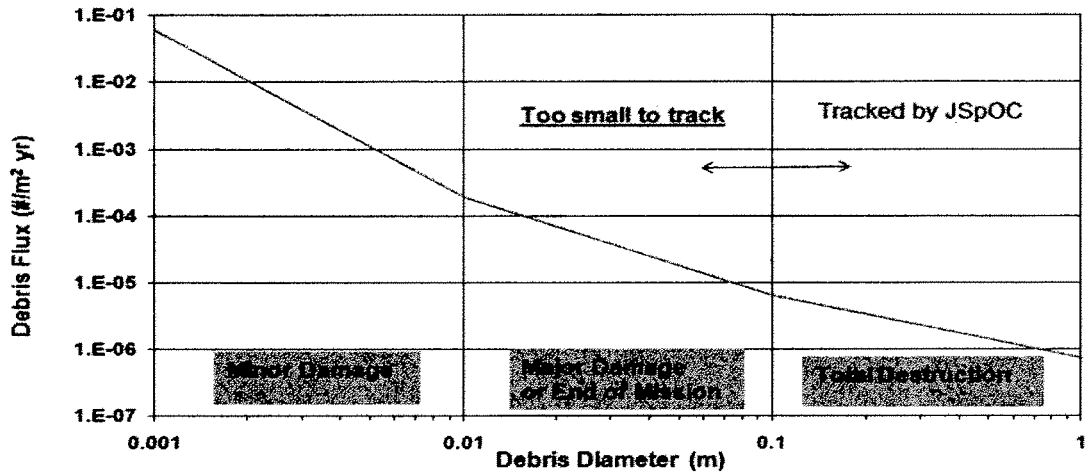


Figure 5
Top Ten Satellite Breakups¹⁶

Common Name	Year of Breakup	Altitude of Breakup	Cataloged Debris ^a	Debris in Orbit ^b	Cause of Breakup
Fengyun-1C	2007	850 km	2841	2756	Intentional Collision
Cosmos 2251	2009	790 km	1267	1215	Accidental Collision
STEP 2 Rocket Body	1996	625 km	713	63	Accidental Explosion
Iridium 33	2009	790 km	521	498	Accidental Collision
Cosmos 2421	2008	410 km	509	18	Unknown
SPOT 1 Rocket Body	1986	805 km	492	33	Accidental Explosion
OV 2-1 / LCS 2 Rocket Body	1965	740 km	473	36	Accidental Explosion
Nimbus 4 Rocket Body	1970	1075 km	374	248	Accidental Explosion
TES Rocket Body	2001	670 km	370	116	Accidental Explosion
CBERS 1 Rocket Body	2000	740 km	343	189	Accidental Explosion
			Total: 7903	Total: 5172	

* As of May 2010

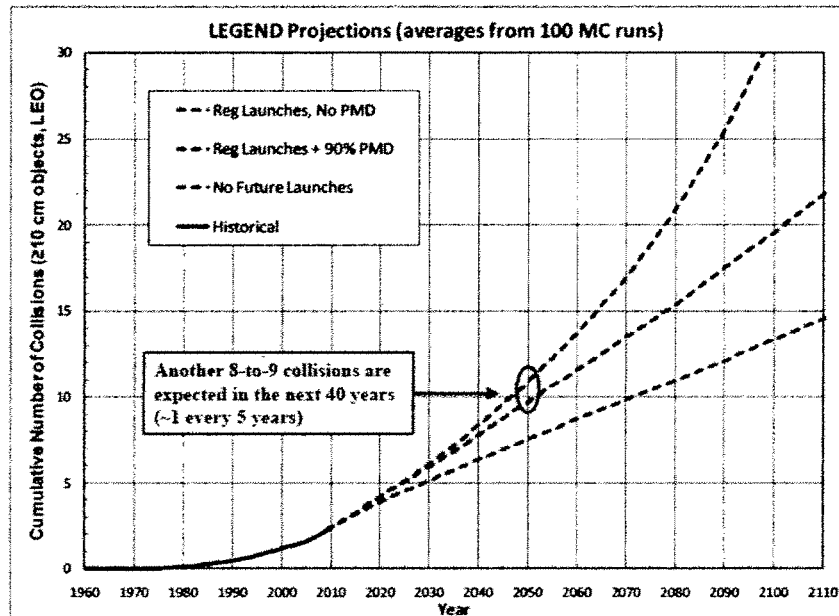
¹⁵ Scott Hull, "Orbital Debris Prevention and Protection", 31 March 2010, online at http://ses.gsfc.nasa.gov/ses_data_2010/100202_Hull.ppt.

¹⁶ "Orbital Debris Quarterly Newsletter", NASA Orbital Debris Program Office, Vol 14 Issue 3, July 2010, online at www.orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv14i3.pdf.

Figure 5 lists the top ten breakups that generated space debris. Note that the most recent breakups have added a proportionally significant amount of debris that will remain in orbit for an extended period of time.

Figure 6

Future Prediction of Collisions in LEO using NASA LEGEND Model¹⁷



Multiple models and simulations done by major space agencies have all shown that the orbital debris population will continue to grow, even without additional launches. Figure 6 shows the results of one such simulation done by NASA using their LEGEND model under three scenarios: no future space launches, future launches continue at historical rates but there is no post-mission disposal (PMD) of space objects, and future launches at historical rates with 90 per cent PMD compliance. The projections show that even without any new launches, the growth in the amount of space debris will result in eight to nine more collisions in LEO by 2050, with half of those being of the same catastrophic nature as the Iridium-Cosmos collision in 2009.

¹⁷ J.-C. Liou and N.L. Johnson, "Controlling the growth of future LEO debris populations with active debris removal", *Acta Astronautica*, Volume 66, Issues 5-6, 648-653 (March-April 2010).

Figure 7
Future Growth in the Number of Space Objects under Various Scenarios

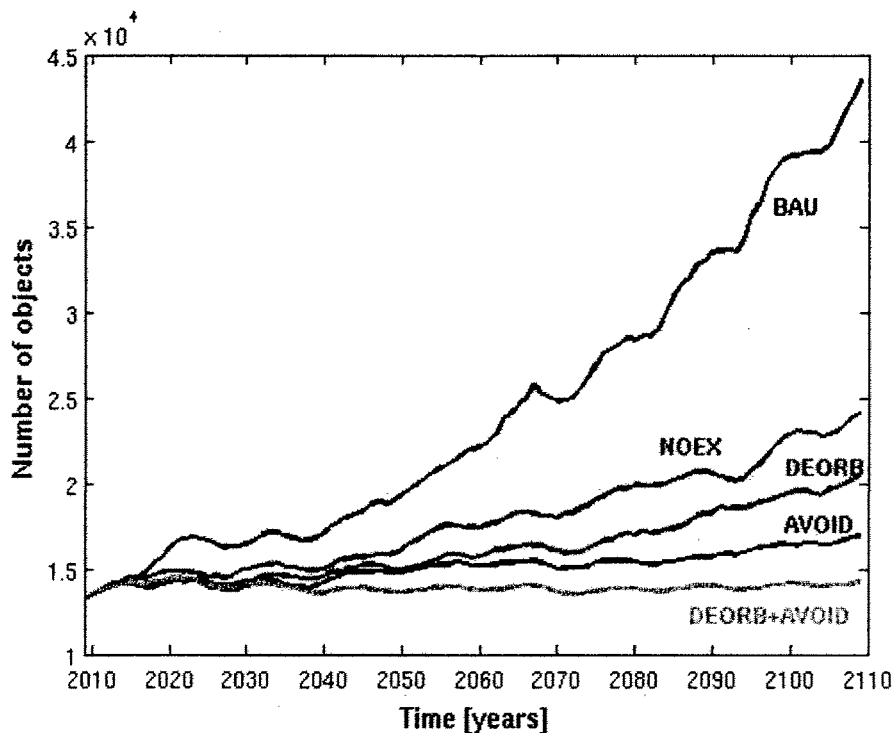


Figure 7 shows additional simulations with the ISTI Space Debris Mitigation (SDM) software which demonstrates the effects of various strategies on the number of space objects. If no steps are taken, the Business-As-Usual (BAU) line shows a rapid growth in the number of objects. Stopping all explosions (NOEX) helps dramatically, as does de-orbiting four large pieces of debris each year (DEORB) and implementing collision avoidance manoeuvres for all controlled objects (AVOID). The growth can almost entirely be stopped, if and when possible active debris removal and collision avoidance are done (DEORB+AVOID).

E. Impact of Space Debris

Space debris poses a risk in two major ways. First, it is a navigation hazard to operational satellites of all space-faring nations. A collision between a piece of debris and a satellite poses the risk of damage to, or even loss of, the satellite. In the event of a collision in outer space, even particles as small as a few millimetres can damage a critical component and end the mission of an operational satellite, due to their very high relative velocities. Satellite owner-operators are faced with a tough choice — do they invest resources into the ability to detect and determine whether or not their satellite will conjunct with another object? Or do they simply let it be and hope that they are not involved in the unlikely collision? And even if they do have the resources to determine that there will be a close approach, satellite owner-operators must weigh the fuel and opportunity costs of any avoidance manoeuvre against the risk of collision and possibility of losing the entire satellite. These are

not theoretical debates: in November, 2010, the U.S. military announced that its conjunction assessment screening of all operational satellites produced on average 190 close encounters per week.¹⁸ Based on these warnings, satellite operators around the world performed an average of three collision avoidance manoeuvres a week throughout 2010.

The second major risk from space debris is to humans on the surface of the Earth. All but the highest altitude pieces of space debris eventually will re-enter the Earth's atmosphere. On average, one catalogued space object (greater than ten centimetres in size) re-enters the Earth's atmosphere every day. And, on average, a piece larger than one meter in size re-enters the atmosphere each week. Many of these objects survive their trip through the atmosphere in some form and impact the surface of the Earth. While so far there have not been any confirmed reports of human fatalities caused by this, the possibility exists. In late December 2007, the United States determined that there was enough of a risk to human life from the re-entry of a failed satellite that it destroyed the satellite with a missile in February 2008 just before re-entry.¹⁹ This assessed risk was due to the large amount of hydrazine, an extremely toxic rocket fuel, which was left on board the satellite after it malfunctioned shortly after launch. Similar concerns were voiced over the re-entry of the Russian Mir and American Skylab, both large space stations, and great effort was put into managing their re-entry so as to avoid any human casualties or property damage.

There is also the risk of re-entering space objects creating environmental pollution, as was the case of the Soviet satellite COSMOS 954 which disintegrated in 1978 and scattered radioactive debris over a large area of Northern Canada.²⁰ Re-entering orbital debris could also pose additional risks to aircraft in flight, although there have been no reported cases of actual or near collisions.

F. Regulatory Efforts to Control Space Debris

Growing awareness of the impact of space debris has encouraged space actors to take steps to mitigate the production of new debris through the development and implementation of national and international debris mitigation measures. Several space-faring nations support the mitigation of space debris production, though there are some differences between their respective debris mitigation efforts. In 2002, five European space agencies (ASI, BNSC, CNES, DLR and ESA) issued the European Space Debris Safety and Mitigation Standard, which became in 2004 the European Code of Conduct on Space Debris. Later in 2009 CNES prepared the Technical Regulations which are now applicable through the French Space Operations Act. The U.S. National Space Policy of 2010 reiterated the American policy to minimize space debris and preserve the space environment for the responsible, peaceful, and safe use of all users. In 2006, China released a white paper entitled "China's Space Activities in 2006," in which it reported that it was actively participating in debris mitigation mechanisms and policy efforts at the international level. In 2010, China

¹⁸ Comments made by Lieutenant General Larry James at the 2010 U.S. Strategic Command Strategic Space Symposium.

¹⁹ T. Shanker, "Missile Strikes a Spy Satellite Falling from Its Orbit", *The New York Times*, February 21, 2008, online at www.nytimes.com/2008/02/21/us/21satellite.html.

²⁰ "The COSMOS 954 Accident", Health Canada, June 24, 2008, online at www.hc-sc.gc.ca/hc-pps/ed-ud/fedplan/cosmos_954-eng.php.

finalized national regulations implementing space debris mitigation measures similar to UN COPUOS and IADC Guidelines.

Efforts to control space debris at the international level have essentially been limited to technical discussions at the IADC and the Scientific and Technical Subcommittee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) which adopted their respective guidelines.²¹ It may be noted that the UN COPUOS Space Debris Mitigation Guidelines are voluntary and based on, and consistent with, the IADC Guidelines. They are expected to increase mutual understanding on acceptable activities in space and decrease the likelihood of friction and conflict. It should be kept in mind that the UN COPUOS and IADC Guidelines are only technical in origin and nature.

G. International Legal Considerations Related to Space Debris

The international legal framework governing space activities must be considered both with regard to legal obligations and rights to take preventive measures that address the risks posed by space debris, as well as to the legal consequences should such a risk materialize. The former clause addresses prevention and/or minimization of the risk to damage spacecraft and/or damage on the ground. This entails a broad spectrum of legal questions ranging from:

- The (il)legality of generating space debris;
- Obligations to mitigate and remediate the space debris environment;
- Obligations to participation in collision avoidance schemes and exchange of data;
- Active removal and possibly recycling of space debris; and
- Allocation of the financial burden and technology transfer.

The latter clause primarily raises questions of responsibility and liability for space debris and the allocation of risks.

- (1) **How does space law address the question of space debris?** The existing international treaties do not include a definition of space debris. The question is whether they apply to aspects of space debris generation. Arguably, the international nature of outer space will ultimately require international coordination, and hence, international agreement on the control, mitigation, and remediation of space debris. To date, efforts to confront the production of space debris have only been in the form of international non-binding guidelines (such as the IADC and UN COPUOS Guidelines) or national regulations and procedural rules (such as NASA's Procedural Requirements for Limiting Orbital Debris—NPR 1785 006A).
- (2) **What is the (il)legality of space debris generation?** The generation of space debris is not per se illegal. According to Article I of the Outer Space Treaty,²²

²¹ For more historical explanation of the STSC efforts, see below, Chapter II, Sub-chapter B entitled "Historical Development of UN COPUOS Guidelines".

²² The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (hereinafter referred to as the "Outer Space Treaty"), adopted by the General Assembly in its resolution 2222 (XXI), opened for

all States have the right to access outer space, peacefully use and explore it. However, creation of space debris can be illegal in certain contexts (e.g. extreme environmental modification, purposeful debris generation intended to interfere with the peaceful use and exploration of space). If State practice and *opinio juris* move towards some legally binding mitigation measures, the legality of space debris generation might also evolve towards more stringent standards.

- (3) **Is there an international legal obligation to mitigate risks associated with space debris?** There is no explicit international legal obligation to mitigate risks associated with space debris. The international legal principle of due regard, articulated in varying forms under the existing international space law treaties, may impose obligations to mitigate space debris generation depending on the factual context. Under Article IX of the Outer Space Treaty, States are obligated to “avoid harmful contamination” of the outer space environment and to undertake “appropriate international consultations” when there is reason to believe that a planned space activity would cause potentially harmful interference to another State.

There is an international obligation upon space-faring nations to take appropriate measures to prevent harm to other States and areas beyond their national jurisdiction and control, or at least minimize the risk thereof, when conducting activities in outer space. Though they are not legally binding, the UN COPUOS Guidelines may serve as a point of reference for the exercise of due diligence. However, a fully operational legal framework that addresses the complex space debris issue in a comprehensive way necessitates binding and clear-cut rules. Only the rule of law can capitalize on preventive and authoritative effects to the maximum extent and protect the community interest in outer space.

- (4) **Is there an international legal obligation to exchange information for the purposes of collision avoidance?** While there is a general duty of due regard, there is no clear legal obligation to exchange information with other space actors for the purposes of collision avoidance. However, under Article IX of the Outer Space Treaty, ratifying States have a duty to consult with regard to potentially harmful interference with other States Parties’ peaceful use or exploration of outer space if a State knows that its space objects will, or are likely to, collide with the space object of another State.
- (5) **Materialization of risk and allocation of financial burden?** Numerous mitigation and remediation measures (ranging from techniques for protection of space objects, specific design and operation, manoeuvring for collision avoidance or subsequent disposal, through space surveillance to active removal of space debris) are associated with costs and technological know-how. Space debris has been recognized by the international community as a hazard with the potential to cause damage to other spacecraft and on the ground. Under the current international legal regime, States bear international responsibility for “national activities in outer space”, and are liable for damage caused in space as a result of their negligence. In addition, the “polluter-pays”

signature on 27 January 1967, entered into force on 10 October 1967, 100 ratifications and 26 signatures.

principle emerges as one of the pillars of general international environmental law, arguably being of relevance for outer space activities.

Each State is individually burdened with the costs for measures related to “its” space debris. This allocation of costs does not, however, reflect the community interest in preserving the outer space environment, especially in cases where space debris can no longer be attributed to a certain source. The principle of “common but differentiated responsibility”²³ may guide the fair allocation here as well. In the absence of schemes that address the distinct degrees of economic or scientific development, efforts to preserve the outer space environment might face the dilemma of being objectively in need of certain minimum measures, but be left with a subjectively defined obligation of due diligence that factors in financial and technological resources. While some financial uncertainty will remain in human endeavours in space for the foreseeable future, States actions towards one another in terms of responsibility for damage to one another’s space objects are not without a measure of guidance. Indeed, the 1972 Convention for International Liability for Damage Caused by Space Objects²⁴ provides for liability to be assigned via a two-tiered system — fault based liability for damage caused in space, and absolute liability for damage caused on Earth. The difficulty would be in proving both fault and causation where two space objects collide.

One major distinction is to be made between cases where a State (or another subject of international law) complies with its international obligations and the risks related to space debris materialize nonetheless, and cases where the State in question is in breach of its international obligations. The former case may give rise to international liability, whereas the latter case may additionally entail responsibility for internationally wrongful acts. It is important to note that international responsibility under Article VI Outer Space Treaty is born for “national activities in outer space” while the matter of international liability is tied to ‘space objects.’ Arguably, only the latter may raise the definitional issue of whether space debris is or is not a ‘space object’.

²³ As stated in *The Principle of Common But Differentiated Responsibilities: Origins and Scope* (online at: www.cisd.org/pdf/brief_common.pdf), “The principle of ‘common but differentiated responsibility’ evolved from the notion of the ‘common heritage of mankind’ and is a manifestation of general principles of equity in international law. The principle recognises historical differences in the contributions of developed and developing States to global environmental problems, and differences in their respective economic and technical capacity to tackle these problems. Despite their common responsibilities, important differences exist between the stated responsibilities of developed and developing countries. The principle of common but differentiated responsibility includes two fundamental elements. The first concerns the common responsibility of States for the protection of the environment, or parts of it, at the national, regional and global levels. The second concerns the need to take into account the different circumstances, particularly each State’s contribution to the evolution of a particular problem and its ability to prevent, reduce and control the threat.” For a detailed analysis of this principle, see Tuula Honkonen, *The Common but Differentiated Responsibility Principle Multilateral Environmental Agreements: Regulatory and Policy Aspects*, (Wolters Kluwers, August 2009).

²⁴ The Convention on International Liability for Damage Caused by Space Objects (hereinafter referred to as the “Liability Convention”), adopted by the General Assembly in its resolution 2777 (XXVI), opened for signature on 29 March 1972, entered into force on 1 September 1972, 88 ratifications, 23 signatures, and 3 acceptances.

- (6) **Does space law need clarification and further development to become a fully operational rule-based framework?** In view of the above-mentioned points, the answer to this question would be in the affirmative.

II. UN COPUOS Guidelines: Analysis and Current Implementation

The objectives of this Section are: (a) to provide a legal and technical analysis of the UN COPUOS Space Debris Mitigation Guidelines and to discuss their long-term effectiveness; (b) to describe the activities of some nations that are currently implementing these Guidelines; and (c) to briefly point out the perspectives of various actors in order to enlarge international coordination to more nations and other actors.

A. Introduction

The UN COPUOS Space Debris Mitigation Guidelines are non-binding directives. This means there is no legal obligation for States and their nationals to comply. The purpose of the UN COPUOS Guidelines is to limit the generation of space debris in the environment. While observance of the UN COPUOS Guidelines themselves is voluntary, some States have implemented domestic policies, legislations, and/or regulations that adopt and apply the UN COPUOS Guidelines to commercial, civilian, and/or military space actors. This Section contains information on the national coordination and implementation measures being carried out in countries such as Canada, China, France, Germany, India, the Russian Federation, and the United States.

The UN COPUOS Guidelines are applicable to mission planning and the design and operation of spacecraft and orbital stages that will be injected into Earth orbit. Government organizations are encouraged to use these Guidelines in identifying the standards that they will apply when establishing the mission requirements for planned space systems. Operators of space systems are encouraged to apply the UN COPUOS Guidelines to the greatest extent possible.

It is important to note that the UN COPUOS Space Debris Mitigation Guidelines and the IADC Space Debris Mitigation Guidelines are two different documents that evolved via distinct methodologies, which are described to some extent in this Section.

B. Historical Development of UN COPUOS Guidelines

The process of development of the UN COPUOS Space Debris Mitigation Guidelines began many years ago, based upon detailed technical documentation and new satellite/launcher design techniques. Space debris was first recognized as a problem in the 1970's and 1980's; studies and reports carried out by the U.S. National Security Council since the late 1980s recognized the risk posed by space debris both in space and on Earth.²⁵

²⁵ Samuel Black and Yousaf Butt, "The Growing Threat of Space Debris", online at <http://bos.sagepub.com/content/66/2/1.full>.

In 2002, the IADC published the "IADC Space Debris Mitigation Guidelines",²⁶ a technical document containing the recommendations of the group. The work for these guidelines was started in 1997 when guidelines for the GEO were published by the IADC.

The Scientific and Technical Subcommittee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) has dealt with the issue of space debris since 1994, first by adopting a technical report on space debris in 1999,²⁷ acknowledging the risk posed by space debris to spacecraft and on the ground. Beginning in 1994, the space debris mitigation guidelines had been discussed in the STSC, first moving through the work plan of the STSC as a technical report, then tasked to working groups, and eventually transformed into the Space Debris Mitigation Guidelines as adopted. These Guidelines were endorsed by COPUOS at its fiftieth session in 2007, as Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, reflecting the consensus of major space faring and non-space faring States. These Guidelines subsequently were endorsed by the UN General Assembly in its resolution 62/217 of 22 December 2007,²⁸ (which are hereinafter referred to as UN COPUOS Guidelines, and are also attached herewith as Appendix 1 to this Report).

It should be kept in mind that the 1999 STSC Report as well as the UN COPUOS and IADC Guidelines are all technical in origin and nature. The UN COPUOS Guidelines constitute a higher level document based on the IADC Guidelines. The UN COPUOS Guidelines are couched in the form of seven guidelines containing general recommendations to be implemented by States primarily through national legislation, regulations, and/or policy directives. Nonetheless, humankind recently witnessed two intentional destructions of satellites and one unintentional collision, which further emphasized the seriousness and urgency of the space debris problem.

C. Applicability, Scope and Status of the UN COPUOS Guidelines

Applicability: UN COPUOS Guidelines apply only to mission planning and operation of newly designed spacecraft and orbital stages and, if possible, to existing ones. They are future-oriented, not retroactive, and operational, as opposed to regulatory. This can include manufacturers of launchers as well as spacecraft; however, the requirements for launchers are different.²⁹ The UN COPUOS Guidelines are executed during the certification processes at the design and manufacturing stage, exerting a substantive influence for these spacecraft to operate within the UN COPUOS Guidelines. They are not legally binding under

²⁶ Online at www.spacelaw.olemiss.edu/library/space/IntOrg/IADC/IADC-%202002-01%20-%20IADC%20Space%20Debris%20Mitigation%20Guidelines.pdf.

²⁷ *Technical Report On Space Debris*, Text of the Report adopted by Scientific and Technical Subcommittee of the United Nations Committee of on the Peaceful Uses of Outer Space, UN Document No. A/AC.105/720 (New York, 1999).

²⁸ UN Doc. A/62/20 (2007). The Guidelines have also been published by the United Nations Office for Outer Space Affairs as *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*, United Nations, Vienna, 2010.

²⁹ For instance, ESA requires rules for disposal of both launchers and spacecraft, but, as yet, there are no launchers with stages that degrade in less than twenty-five years. For spacecraft, this is an internal mandatory rule. ESA has signed waivers for Russian launchers but not for spacecraft.

international law. It is also recognized that exceptions to the implementation of individual Guidelines or elements thereof may be justified, for example by provisions of the “United Nations Treaties and Principles on Outer Space”.

The UN COPUOS agreed that its approval of the voluntary Guidelines for debris mitigation would increase mutual understanding on acceptable activities in space and, thus, enhance stability in space-related matters and decrease the likelihood of friction and conflict.

It is imperative to differentiate between the different sets of guidelines when discussing implementation, making very clear precisely which are to be implemented. For instance, although a State may say that it is implementing UN COPUOS Guidelines, it might actually be implementing its own guidelines (or ESA’s or IADC’s) which, de facto, implement the UN COPUOS Guidelines as a minimum standard.

Scope: UN COPUOS Guidelines do not outlaw a certain type of space activity. The Guidelines provide guidance on how to conduct space activities in principle in order to prevent, or at least to minimize, harmful by-products of space activities.

- Guideline 1 seeks to limit the debris released during normal operations. Design of space activity should prevent generation of space debris. If this is not feasible, the effect should at least be minimized.
- The UN COPUOS Guidelines are not designed as a comprehensive approach and cure for the space debris issue.
- The UN COPUOS Guidelines cannot stabilize the space debris environment and do not give guidance to liability and insurance.
- Guideline 3 attempts to avoid collision. Lack of regulatory guidance has prompted some operators to set up their own data exchange centre. There is no guidance regarding sharing data about the space environment.
- Safety and security considerations, particularly visible under Guideline 4, imply the attempt to avoid intentional destruction of space objects but do not ban ASAT tests.

Legal status of the UN COPUOS Guidelines: The UN COPUOS Guidelines are non-binding. First, they make their status clear by use of the word “declare”. The UN COPUOS Guidelines were not developed by the Legal Subcommittee of UN COPUOS, which seems to indicate the fact that they are primarily technical, and not fully legal in nature and content. They constitute fundamental guiding principles, recognizing the problem of space debris, and expressing political commitment to address and mitigate the problem. The UN COPUOS Guidelines define policy, implementation is recommended and States may voluntarily take measures to implement the Guidelines.

Currently, the UN COPUOS handles space debris issues through its two subsidiary bodies; i.e. (a) the Legal Sub-committee (LSC), which now incorporates an agenda item on general exchange of information on national mechanisms relating to space debris mitigation measures; and (b) the Scientific and Technical Sub-committee (STSC), where the technical report and UN COPUOS Guidelines were drafted. The STSC has a long-standing regular agenda item on space debris and now also includes on its agenda an item under work-plan on long-term sustainability of outer

space activities. At its 2010 Session, the STSC agreed that Member States, in particular space-faring nations, should pay greater attention to the problem of collisions of space objects and that Member States and space agencies should once again be invited to provide reports on research on space debris. This call is regularly made in the annual General Assembly resolution on international cooperation in the peaceful uses of outer space. Current consensus is to report and share information, while views regarding new regulatory frameworks and/or treaties remain divergent.

D. Effectiveness of UN COPUOS Guidelines

Based on catalogued space objects, it is concluded that from the 1960s to the mid-1990s there was linear growth in the amount of debris, found primarily in LEO and GEO, as described in Section 1. In the mid-90s, NASA was the first space agency in the world to issue comprehensive orbital debris mitigation guidelines, culminating in the development of the U.S. Orbital Debris Mitigation Standard Practices in 1997. From the mid-90s until 2006, there was a gradual decline in the growth rate of the space debris population, suggesting a possible relationship between mitigation efforts and slowing growth rates. Unfortunately, a series of significant debris-creating events involving both the intentional and unintentional breakup of large space objects have occurred since 2006. These events reveal the importance of preventing the breakup of massive objects. With the inclusion of these recent events, there has been no reduction in the growth rate of space debris: these intentional and accidental fragmentations have effectively reversed any debris population reductions achieved by the UN COPUOS Guidelines.

There are mixed signs about how well the UN COPUOS Guidelines are working in practice. There is evidence that standard practices are getting better, which is important given the level of space activity. But years of successful mitigation can be negated by a single large event. Overall, we are not doing as well as necessary. It is especially important to stop deliberate destructions, particularly at high altitudes. The International Telecommunication Union (ITU) should continue to be involved in the discussion of space debris as its coordination and assignment of spectrum and orbit is impacted by, and has impact upon, issues concerning debris.

Although ambivalence exists regarding how well the UN COPUOS Guidelines are working in practice, the intent behind the creation of the Guidelines was to promote their wide acceptance within the international community. This explains why the impact(s) of the Guidelines began appearing years before their formal adoption by the UN COPUOS. As such, the UN COPUOS Guidelines form part of a hierarchy of instruments, demonstrating their intrinsic value. The hierarchy also includes IADC Guidelines, European Guidelines, (issued and signed by members of the European Network of Centres on Space Debris consisting of ESA, ASI, BNSC, CNES and DLR), and national implementing instruments, all of which are more detailed than the UN COPUOS Guidelines.

There is a clear difference in roles between the UN COPUOS Guidelines and those first developed by the IADC. The IADC's terms of reference were to coordinate research in order to achieve agreement – the space debris catalogues maintained by the U.S. and Russia, in particular, were in very different formats and the IADC's job was to bring these differing standards together. The process leading to the adoption

of the UN COPUOS Guidelines was lengthy and compromises were necessary during that process in order to achieve consensus. The effectiveness of both sets of Guidelines lies in their technical backing. The UN COPUOS Guidelines were designed to provide more general direction than the IADC version; however, ongoing review will be necessary in order to incorporate the outcome of continuing research and to this end the IADC provides an annual report to the UN COPUOS. The UN COPUOS Guidelines should lead to new policies and regulations, most significantly on a national level where implementation can be more easily enforced. Regardless of whether the UN COPUOS Guidelines achieve more binding status at the international level, mandatory national legislation by all space-faring States concerned can attain the stated goals of the UN COPUOS Guidelines.

E. National Efforts to Implement UN COPUOS Guidelines

Although the UN COPUOS/IADC Guidelines are not legally binding, and are at best “soft law”, it is presumed that States will implement them in good faith and as appropriate to their national interests.

In assessing national efforts to implement the Guidelines, there is a need to distinguish between publicly licensed commercial and/or civil space activities on the one hand, and unlicensed government military and/or civil space activities on the other. This distinction is important because commercial/private activities are licensed by governments, and through the licensing mechanism, the government is able to impose space debris mitigation and end-of-life disposal requirements or conditions in accordance with the dictates of the Guidelines. In contrast, government sponsored military and civilian space activities are generally not subject to the licensing regime, as they are typically carried out by governmental agencies. Instead, internal government policies dictate whether and to what extent the Guidelines are to be followed. Internal government policy often deals with conflicting policy goals, including national security. Moreover, incorporation of the UN COPUOS/IADC Guidelines into domestic policy and/or regulatory procedures, mechanisms or structures varies according to each State, its level and type of space activity.

The following is very brief and specific information on the national implementation of Guidelines in Canada, China, France, Germany, India, Russia, and the United States:

» **Canada** applies space debris mitigation standards to satellites, including GEO satellites, and disposal requirements that are consistent with the UN COPUOS/IADC/ITU Guidelines:

- Canadian Remote Sensing Space Systems Act of 2005, whose implementation is led by the Department of Foreign Affairs and International Trade, requires detailed plans for end-of-life disposal of remote sensing spacecraft.
- Radiofrequency license procedures, administered by Industry Canada, impose requirements on minimizing debris and moving GEO satellites into graveyard orbits (minimum 300 kilometres) at end of life.

» **China** is undergoing a process of finalizing national regulations on space debris mitigation and management. In 2010, COSTIND (Commission for Science,

Technology, and National Defense) of SBOSTIND (State Bureau of Science, Technology and National Defense) issued a new department regulation entitled *Interim Instrument of Space Debris Mitigation and Management*. The purpose of these interim regulations is to guarantee the normal operation of spacecraft, protect the space environment, and also implement international obligations to control and mitigate space debris. These interim regulations grant SBOSTIND the authority to supervise the implementation of space debris mitigation and management and to coordinate the implementation of IADC Guidelines. Interim measures are also in place as requirements for Space Debris Mitigation³⁰ issued in 2005 as industrial standards.

- Chinese debris mitigation efforts, evolving through a series of white papers and action plans, focus on space situational awareness, spacecraft protection/survivability, and debris mitigation.
 - Registration and licensing regulations for civil space objects include debris mitigation requirements.
 - Future work includes finalizing regulations on limitation and management of space debris.
- » **France:** at a national level, regulatory activities on space debris started in 1997: this led to the publication of the CNES standard in June 1999.³¹ This document was then used as a basis to prepare the European Code of Conduct, in cooperation between the five European space agencies (ASI, BNSC, CNES, DLR and ESA). This document was published in June 2004 and signed by the high level management of the 5 agencies.
- The application of the Code of Conduct was limited to CNES projects, and did not concern French manufacturers or operators working on their own projects. However, according to international treaties, liability in case of damage caused in orbit or on the ground lies with the Launching State. This implies that the State must authorise, and have the means to control, space activities carried out by its own citizens.
 - To this end, a Space Operations Act was promulgated in June 2008, instituting a prior authorisation or licensing scheme. The technical regulations associated with this Act were published in 2010. Their objectives are the protection of populations (safeguarding), the protection of the atmospheric environment (pollution, contamination) and the protection of the outer space environment (space debris). Since December 10, 2010, the operators must demonstrate their compliance with the Technical Regulations to obtain an authorization for their operations.
- » **Germany** applies a set of national space debris mitigation safety regulations and a related implementation mechanism.
- The regulations are based on the European Code of Conduct for Space Debris Mitigation and compliant with the UN COPUOS Guidelines. They form part of

³⁰ (QJ3221-2005).

³¹ (MPM-51-00-12: "safety requirements — space debris").

the “Product Assurance & Safety Requirements” of the German Aerospace Center DLR and must be applied to the national space projects.

- Germany is currently in the process of elaborating a national space law that will set the frame for all German space activities. Compliance of these activities with the UN COPUOS Guidelines will be ensured also under the new regulatory regime.

» **India** has implemented the following space debris mitigation measures: launch vehicle final stage passivation; re-orbiting of GSO satellites; de-orbiting of LEO satellites; minimization of mission related debris through design, development of models for orbit fragmentation/close approach; and, participation in international exercises involving estimating the re-entry of de-orbiting objects. The responsibility for implementing space debris mitigation measures lies with the Department of Space (i.e. Indian Space Research Organization).

» **Russia** imposes national standards on debris mitigation consistent with both the UN COPUOS and IADC Guidelines.

- Since the early 1990s Russia actively participates in all actions concerning space debris. The official activity of the IADC was started in Moscow in 1993 when the IADC Terms of Reference had been adopted and today the IADC is the leading international technical expert on space debris. The Federal Space Agency of the Russian Federation (Roscosmos) carries out the coordinated branch policy on space debris mitigation. Roscosmos takes part in all sessions of the IADC and of the ISO space debris working group. Every year Roscosmos presents a comprehensive report about its activity on debris mitigation to the Scientific and Technical Subcommittee (STSC) of UN COPUOS.
- In 1999, the Branch Standard OST 134-1022-99, “Near-Earth Space. Model of spatial - temporary distribution of density of Space Debris”, came into force. In 2000 the second Branch Standard, OST 134-1023-2000 “Space Technology Items. General Requirements for Mitigation of Space Debris Population”, had come into force. The standard requirements are similar to best practices of other organizations and agencies - IADC members and are obligatory for all activities by the order of Roscosmos. In 2003 the third Branch Standard, OST 134-1031-2003 “Space Technology Items. General Requirements on Spacecraft Shielding Against Space Debris and Meteoroids”, had come into force.
- Roscosmos had participated actively in preparing the “IADC Space Debris Mitigation Guidelines” (2002) and the “UN COPUOS Space Debris Mitigation Guidelines” (2007). In 2008 the President of Russian Federation approved “The keystones of the Russian Federation Space Policy up to 2020 and beyond”. The “...ecological safety of space activity, implementation of technologies and the designs minimizing production of space debris at launch and operation of spacecraft and orbital stations” were determined as the high priority issues in this document. Since January 1, 2009 the new Russian National Standard GOST R 52925-2008 “General Requirements to Spacecraft and Orbital Stages on Space Debris Mitigation” had come into force. The requirements of the Standard should be applied to new designed and updated space vehicles of different type: civil, science, commercial, military and manned missions. Application of the Standard requirements spreads to all

stages of life cycle of space vehicles: design, manufacturing, launch, operation and disposal. The requirements of the Standard are fully in line with the UN Mitigation Guidelines.

- A number of actions under Roscosmos authority may be recognized as the best debris mitigation practices all over the world. Among them there is the controlled re-entry of the “Mir” orbital station of 120 tons in mass when the worldwide community was highly concerned about the danger it represented for the population and for property on the Earth’ surface. Another example is the successful disposal in March 2006 (in accordance with the IADC rules) of the emergency spacecraft “Express AM — 11” by using of correction and orientation engines. It should be recalled also the annual successful practices (five to six times per year) by the TSNIIMASH Mission Control Center in splashing down of the “Progress” cargo vehicles and in soft landing of the manned vehicles “Soyuz-TM” to restricted on-ground areas that are used in service of the International Space Station (ISS). Another excellent example of international cooperation in space between Russian and US specialists (TSNIIMASH and NASA Mission Control Centres) is safety assurance of the ISS crew and of the ISS as a whole.
- Roscosmos is in charge of implementing the UN COPUOS Guidelines.
- » **The United States** has the most elaborate regime for the implementation of the Space Debris Mitigation Guidelines. The debris mitigation measures are implemented through licensing mechanisms of the Department of Transportation and the Federal Communications Commission (FCC). NASA also executes its own debris mitigation standards. In conducting its space activities, the U.S. Department of Defense (DOD) follows its own Orbital Debris Mitigation Standards. In 2004, the U.S. Congress created a pilot Commercial and Foreign Entities (CFE) Program to determine feasibility and desirability of providing space surveillance data support.
 - The 2004 regulations authorize the Secretary of Defense to provide non-US Government entities (also called CFEs) (i) satellite tracking services and (ii) space surveillance data and analysis.
 - CFE conjunction analysis (CA) and launch support services require, under signed agreement, more detailed information and safety of flight information for conjunctions/close approaches. Thus the CFE Program enhances SSA and consequently improves the safety of flight as there are fewer chances of catastrophic collisions in space.³² The program helps to identify sources of anomalies and better assess effectiveness of international and national debris mitigation measures.
 - The National Space Policy of 2010 specifically states that: “For the purposes of minimizing debris and preserving the space environment for the responsible, peaceful, and safe use of all users, the United States shall:
 - Lead the continued development and adoption of international and industry standards and policies to minimize debris, such as the United Nations Space Debris Mitigation Guidelines;

³² Catastrophic collisions have a specific incident energy of more than 40 kJ/kg, leading to a total fragmentation (typically caused by any catalogue object larger than 10cm).

- Develop, maintain, and use space situational awareness (SSA) information from commercial, civil, and national security sources to detect, identify, and attribute actions in space that are contrary to responsible use and the long-term sustainability of the space environment;
 - Continue to follow the United States Government Orbital Debris Mitigation Standard Practices, consistent with mission requirements and cost effectiveness, in the procurement and operation of spacecraft, launch services, and the conduct of tests and experiments in space;
 - Pursue research and development of technologies and techniques, through the Administrator of the National Aeronautics and Space Administration (NASA) and the Secretary of Defense, to mitigate and remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment; and
 - Require the head of the sponsoring department or agency to approve exceptions to the United States Government Orbital Debris Mitigation Standard Practices and notify the Secretary of State.”³³
- The U.S. follows its Orbital Debris Mitigation Standard Practices, which are largely aligned with UN COPUOS Guidelines. The Defense Department Directives and Instructions also adhere to the UN COPUOS Guidelines. Similarly, other government agencies, like NASA (through NASA Technical Standard 8719.44), the FAA (under its commercial launch licensing procedures), and the FCC (by radio frequency licensing procedures) apply space debris mitigation measures within their respective jurisdictions.

F. Different Perspectives on the Implementation of the Guidelines

The interests of all States and their citizens should be considered, regardless of their degree of economic or outer space capability. A challenge for the international community will be to balance the interests of current and future generations, as well as the general public, non-space-active States, and current space actors. The following are some observations from different perspectives on the need to overcome the challenges posed by space debris:

» From the private sector perspective:

- Utilizing operational commercial satellites in a SSA network is an option. Commercial satellites can have an additional sensor that would be networked with all other SSA data to improve situational awareness.
- The increasing density of space-debris raises concerns on the commercial sustainability of operations in particular orbits. As a result, commercial operators believe that decisions made in the next five to ten years are crucial to the long-term sustainability of private commercial spacecraft operations.
- The private sector would benefit from a space traffic management system. Commercial operators envision a space traffic management system that

³³ “National Space Policy of the United States of America”, Office of the President, June 28 2010, online at www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf.

includes: a distributed network, common software, and multiple analysis centres.

- » **From the NGO/professional organization viewpoint:**
 - Space debris is an important environmental issue.
 - The risks of space debris include risks to terrestrial activities such as civil aviation.
 - International harmonization of policy and space safety standards amongst aerospace professionals is one contribution that can be made.
- » **From the International Standards Organization perspective:**
 - The UN COPUOS Guidelines are viewed positively.
 - But the Guidelines lack effectiveness if they cannot be validated, verified, or enforced, and are not effective in practice. The ISO thus developed new standards and the top level standard, ISO 24113:2010, has been updated and covers space systems — Space debris mitigation requirements.³⁴
 - Implementation of safety standards for spacecraft orbit and constellation design is critical.
 - There is a need to institutionalize consensus on feasible space debris mitigation technology and design methods; many ISO debris standards are now completed and more are in preparation. Space debris is an important environmental issue.
- » **From the technical perspective — satellite de- and re-orbiting:**
 - Of the 1,200 objects in or near GEO, only 381 are under orbit control.
 - As long as satellites are station-kept in slots, there is plenty of room for growth.
 - A problem for the long-term sustainability of GEO is drifting or librating satellites that are no longer in use.
 - In 2008, only seven of twelve retired GEO spacecraft were re-orbited properly.
 - Although not really being thought of for current planned MEO navigation satellite constellation systems, de-orbiting or re-orbiting needs to be considered for MEO navigation constellations.
 - Appropriate de-orbiting (from LEO) and re-orbiting (e.g. from GEO) with verification is necessary for the mitigation of space debris.

³⁴ The latest high level standard for space debris mitigation. Work has been ongoing for nearly 10 years. www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=42034&ICS1=49&ICS2=140.

- » **From the non-space faring nations perspective:**³⁵
- Most non-space faring nations lack existing national mechanisms to implement space debris mitigation guidelines.
 - Space-faring nations need to find methods to involve developing nations in the process and, conversely, developing nations need to look for ways to engage in ongoing mitigation efforts.
 - Reasons for non-space faring nations to participate include:
 - Public safety (re-entry of debris)
 - Risk of loss of their space assets
 - Minimum actions from non-space faring nations that are relatively easy to achieve:
 - Emergency preparedness,
 - Science and technology education,
 - Collaboration and knowledge-generation and sharing.
 - Non-space faring nations can actually bring these benefits to the process:
 - Non-space faring nations can make contributions to space situational awareness by informing other countries of information garnered by the non-space faring nations.

G. Specific Concerns about the UN COPUOS Guidelines

- UN COPUOS Guidelines do not focus on the disposal of the huge amount of sub-catalogue size debris currently orbiting in space (e.g. remediation). More technical work is required before there can be international agreement in this area.
- UN COPUOS Guidelines do not address the liability aspects of space debris recovery.

³⁵ The term 'non-space faring nation' is used here to indicate non-space-active States or emerging space nations but without owning independent launch capabilities. It should also be noted that today many non-space faring nations own space assets that include (a) communication satellites in the GEO and (b) earth observation satellites in LEO. The preservation of these space assets is critical for the social and economic development of the countries that have made such investments and non-space faring nations have self-interest in space debris mitigation. Therefore, they also have an interest in preventing the degradation of the space environment and in preserving the legal right to use and explore outer space without discrimination of any kind. All non-space faring nations, in addition to space-faring nations, should implement the Guidelines via appropriate national enabling legislation, avoid using launch services from providers that do not comply with UN COPUOS Guidelines, and contribute to international efforts to track space debris. While a relevant distinction for the purposes of space debris mitigation can be made between nations with technical capability and those with less or none, non-space faring nations, in particular those who own space assets, need to be more involved in the process.

- UN COPUOS Guidelines do not address the generation of space debris in a non-peaceful context.
- UN COPUOS Guidelines do not establish legally binding requirements. As a result, a “tragedy of the commons” situation may arise wherein actors adhering to the measures are at a competitive disadvantage when foreign competitors do not have to comply with regulations.
- The UN COPUOS Guidelines cannot stabilize the space debris environment and do not give guidance to liability and insurance.

The adoption and implementation of the UN COPUOS Space Debris Mitigation Guidelines is voluntary. If these Guidelines are to become effective States must adopt (and enforce) them through their respective domestic policies, laws and regulations. In addition, as described above, the Guidelines are limited in scope and application. It is therefore imperative that States and other stakeholders explore and adopt alternative initiatives to mitigate (and eventually remove) space debris.

III. Future Implementation Strategies and Recommendations

The objective of this Section is to evaluate other initiatives which could be complementary to, and go beyond, the UN COPUOS Space Debris Mitigation Guidelines, for the purpose of enhancing the sustainability of the use of space by all States. In other words, the Section is intended to generate action items for States to consider while dealing with matters related to space debris, including implementation measures and areas for further research and development.

A. Introduction

There are a variety of mechanisms that can be implemented to control space debris and ensure long-term sustainability of the use of space. They fall within a continuum of law and policy and include technical measures.

Measures to prevent, mitigate, and/or remediate space debris can be categorized as short-term (0-5yrs), medium-term (5-20yrs), and long-term (20+yrs) goals. In the short-term, measures can be proposed that improve the implementation of current UN COPUOS Guidelines, strengthen public-access SSA, and encourage technical research and collaboration. In the medium-term, stronger international arrangements can be implemented amongst government and non-government space stakeholders. In the long-term, binding international legal agreements, and perhaps even an international organization that provides STM (Space Traffic Management), can be achieved.

The nexus between prevention, mitigation, and remediation, is that remediation is the long-term goal with respect to space debris since it is not technically or economically feasible at this time. This is why prevention and mitigation today are so important; because together they buy some time during which the technology for remediation can develop.

B. Law and Policy Options

There are various proposed law and policy strategies to further the sustainable use of outer space by preventing and mitigating space debris. On one side of the continuum are legally binding international agreements that States may implement amongst themselves and upon non-State actors through domestic legislation and regulation. On the other side are non-binding measures undertaken by States and/or private actors. In between there is a multiplicity of methods of varying legal and political form. Each has advantages and disadvantages, strengths and weaknesses. They are not mutually exclusive and can be implemented as complementary initiatives.

The subsequent list describes and assesses some specific options:

- *Maintaining the status quo:*

Assessment: This is an unacceptable option as space debris poses a risk to the long-term sustainable use of outer space for human benefit on Earth. Action must be taken to prevent and/or mitigate space debris generation, as soon as possible.

- *Transforming the UN COPUOS Guidelines into a set of Principles adopted by the General Assembly with mandatory wording obliging States to adopt the UN COPUOS Guidelines in national legislation.*

Assessment: The rationale would be to simply transform the current UN COPUOS Guidelines into a set of Principles in the same way as the Direct Satellite Broadcasting Principles, Nuclear Power Sources (NPS) Principles, Remote Sensing Principles. The relevance of such option is interesting taking into account in particular the validity of the NPS Principles giving the predominant means for implementing safety measures in national procedures. Although not legally binding per se, such a declaration of Principles would establish additional political support for the Guidelines. It could also generate public exposure for the issue of space debris and its importance to the long-term sustainability of outer space. Such declaration/resolution should also make provision for the creation of an appropriate expert body (or preferably to additionally mandate a existing one, like the United Nations Office for Outer Space affairs), with the task of regularly collecting information and coordinating national efforts towards implementation of the UN COPUOS Guidelines and other space debris mitigation mechanisms. However, States may attempt to ignore compliance with such a resolution by pleading its non-binding nature.

- *Adopting a Space Debris Code of Conduct:*

Assessment: This is a logical 'next step' in the development of international policy and law policy regarding space debris prevention and mitigation. Politically, such a step is subject to less resistance than an internationally binding treaty. Current political posturing by major space-faring States indicates increased support for a Code of Conduct that includes space debris prevention and mitigation measures. A Code of Conduct, which is generally non-binding, could be drafted and proposed (i) either by an academic or interest group (e.g. like the Stimson Center 2007 www.stimson.org/space/?SN=WS200803121531 Model Code of Conduct for Responsible Space-Faring Nations), or (ii) through an international organization (e.g. like the revised 2010 European Union Draft Code of Conduct for Space Activities). A Code of Conduct whose membership is generally limited to a small group of States and includes some accountability as to non-implementation is more likely to succeed in implementation and adherence. In addition, such a Code of Conduct could be nationally binding when implemented through domestic law (e.g. Missile Technology Control Regime - MTCR – is being implemented through export control legislation and/or regulations) and thus could prove to be a good option for facilitating the implementation of the UN COPUOS Guidelines.

- *States could unilaterally declare to accept a legally binding international obligation to implement the UN COPUOS Guidelines.*

Assessment: Unilateral State declarations involve only national actions but can have international legal implications. The UN COPUOS Guidelines could be unilaterally accepted by a State and others may follow. To the extent that the prevention and mitigation of space debris requires coordinated and harmonized

action by all space-faring States in order to most effectively address the issue, a unilateral State action is of limited use.

- *States could enter into binding international legal agreements (i.e. bilateral, regional, or multilateral treaties) on space debris or associated mitigation, tracking, and/or remediation measures.*

Assessment: As a general rule, States prefer not to enter into binding international legal agreements unless considered necessary and in their self-interest. Several decades have passed since the world community last drafted a multilateral convention establishing principles of Space Law. The issue of space debris is currently being resolved on the domestic level via national legislation and regulations. There are advantages to maintaining “domestic” level solutions, so long as the self-interest of all space-faring States results in compliance with internationally non-legally binding standards. Elevating prevention and mitigation commitments to the international level could be politically acceptable, but it will depend significantly on the factual circumstances surrounding the nature of the agreement and also the specific terms of the agreement itself. In the long-term, it is anticipated that internationally legally binding general commitments to prevention, mitigation, and remediation, coupled with monitoring and enforcement mechanisms, will have to be adopted. This is particularly true in order to establish universal and uniform requirements, standards, and procedures for space debris mitigation and remediation to ensure long-term sustainability of use of space by all States.

- *ISO and/or other industrial standards can be adopted by commercial manufactures and space launch/spacecraft purchasers.*

Assessment: Non-legally binding international guidelines (such as UN COPUOS and IADC Guidelines) can be complemented through industry licensing processes for the organizations, designers, and operators of space assets that conform to international standards. Purchasers of space launch vehicles and spacecraft should voluntarily prefer designers and operators of commercial space assets who carry out the requirements of international standards, supporting the commercial integration of space debris mitigation measures in the manufacturing of space products. Industrial standards therefore constitute an important mechanism to improve debris mitigation.³⁶ Strengths of industrial standards include voluntary acceptance, commercial input, and their self-regulating nature. A principal concern with industrial standards is that they should not supersede the safety standards, regulations, and testing procedures promulgated by local or national governments or agencies, define acceptable levels of risk, or supplement policy standards. Most effectively, industrial standards should be implemented in conjunction with legally binding national and/or international standards. Industrial standards can also advance prevention and/or mitigation measures by providing standards beyond those currently obligated under the law of the launching and/or State of registration.

³⁶ There are four standards organizations in the field of space: ISO, ASTM, ISSAA, and ECSS. ISO is the primary international organization.

- *Financial incentives can be provided to States and commercial actors adhering to and implementing UN COPUOS Guidelines.*

Assessment: States adhering to and implementing UN COPUOS Guidelines can be encouraged with incentives such as: (a) prioritized allotment of orbital slots by the ITU; (b) discounts on insurance premiums for satellite coverage; (c) and, discounts on launch prices. The advantage of such inducements is that they provide a tangible benefit to those States who adhere, providing voluntary inducement without necessitating punitive measures. In order for orbital allotment incentives to be implemented, political consensus among the most influential States in the ITU will be required. In order to support discounts on insurance premiums and launch costs, commercial insurance and launch service providers will need to be supported by tax and/or other financial incentives from national governments that offset any revenue loss due to discounted insurance premiums and/or launching costs.

- *A commercial "data centre" can be established from which operators can coordinate conjunction analysis and provide collision warnings.*

Assessment: The international commercial space telecommunication industry is currently experimenting with a commercial Space Data Center run by AGI on behalf of the Space Data Association. Initial reports indicate the data centre is fulfilling its mandate to exchange operation data to ensure safety, technical support to improve operational integrity, and share the associated costs. However, this Center has operational limitations. For example, it relies on the U.S. government and other tracking networks for data on 'non-active' satellites and other space.

- *A State-commercial SSA coordination that results in improved SSA data and conjunction analysis sharing between government (e.g. U.S. JSpOC/CFE program) and commercial entities can be implemented.*

Assessment: Neither governments nor commercial entities can have sufficient SSA data by themselves. Each has part of a complementary data set, and both benefit from sharing. Ideally, the most accurate data from government satellite catalogues should be available in real-time to commercial satellite operators in order to support conjunction analysis and collision warning. However, for reasons of national security, States are not likely to share their most detailed information and currently only the United States shares any data at all. One solution to facilitate this type of data-sharing is to address the underlying security dilemmas associated with space situational awareness data via international agreements that inter alia provide for data sharing to support conjunction analysis and collision warning while still protecting national security and data privacy needs. However, the availability of precise, actionable orbit data, called Special Perturbations (or SP) data in the U.S. (as opposed to the less accurate, non-actionable General Perturbations (or GP) data in TLE format), may be questionable.

- *A public, open-source, world-wide SSA space objects catalogue and tracking network can be established.*

Assessment: An open-source SSA tracking network and catalogue is possible, but faces serious challenges. Foremost among them is financial impact. The

majority of SSA tracking is undertaken by government entities. Without the participation of major space-active SSA State governments, an open-source SSA network would have to rely on public and private tracking and analysis. It is possible such an open-source network could be achieved on a limited basis through academic institutions, commercial operators, limited government participation, and/or amateur astronomers. In this context, the maturation of the International Scientific Optical Observation Network (ISON), a collection of more than 20 scientific and academic institutions around the world, bears watching.

C. Technical Measures

(i) End-of-Life Disposal

Technical implementation of de-orbiting guidelines needs to be improved. The UN COPUOS Guidelines provide for satellites and launchers in Low Earth Orbit to be re-orbited into orbits with a residual lifetime of less than twenty-five years. Long-term simulations have shown that this is a very efficient measure to stop the accumulation of space debris in LEO. However, this is economically not feasible for satellites in high-altitude orbits. The best end-of-life solution for GEO spacecraft, as of today, is to dispose of them in a graveyard orbit more than 235 kilometres above the nominal GEO altitude. The corresponding IADC and UN COPUOS Guidelines are followed more and more, but still about half of all satellites in orbit are not properly re-orbited at the end of their lives.³⁷

(ii) Testing, Validation, and Modelling (TVM)

Improved TVM is needed to more effectively predict debris and fragmentation events and to improve the materials and other remediation measures implemented on spacecraft and launch vehicles. Computer models are needed that can better predict debris and fragmentation.

³⁷ GEO re-orbiting statistics from 1997 to 2008 show that adherence to the UN COPUOS Guidelines is slowly improving over time: from 30 per cent (twenty-six out of eighty-seven) in the years 1997-2002 to 55 per cent (fifty-one out of ninety-two) in 2003 – 2008. During the year 2008, twelve GEO spacecraft reached their end-of-life. Seven of them were re-orbited in accordance with the Guidelines, two were re-orbited with an insufficient GEO clearance and three spacecraft were abandoned without any re-orbiting manoeuvre. In the past twelve years only seventy-seven retired GEO spacecraft (i.e. 43 per cent) were disposed of in accordance with the IADC Guidelines. In the last six years, fifty-one out of ninety-one GEO spacecraft (55 per cent) were properly re-orbited. In 2008, a total of twenty-nine GEO new spacecraft were deployed, and twelve spacecraft were retired. Seven of these were re-orbited in compliance with the Guidelines.

(iii) Technical Coordination: SSA/STM

Space Situational Awareness (SSA) and Space Traffic Management (STM) are distinct, yet intimately related, concepts. STM cannot be undertaken without SSA. Likewise, SSA is only useful in a debris mitigation context if you can use it to accomplish management of active satellites.

Although there is no authoritative definition of STM, a recent study on STM³⁸ defined STM as:

“The set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference.”

Essentially, the use of STM is to avoid physical interference (only one element of a comprehensive SSA/STM system).

Today, there are several SSA/STM service providers. It should be understood that each service provider has been developed with different objectives, capabilities, and clients. They are:

- MIT/Lincoln Laboratory;
- The Center for Space Standards and Innovation SOCRATES program providing prototype service for LEO and GEO satellites;³⁹
- The Space Data Association,⁴⁰ which is “a non-profit association that brings together satellite operators who value controlled, reliable and efficient data-sharing critical to the safety and integrity of the space environment and the RF spectrum.” The SDA was founded by the commercial satellite operators Inmarsat, Intelsat and SES;
- ESA and others providing service for several satellites;
- International Scientific Optical Network;
- NASA, in conjunction with the U.S. military, provides coverage for manned space vehicles; and
- U.S. Strategic Command provides daily screening for all active satellites
- U.S. Strategic Command’s SSA Sharing Program⁴¹ which is open to all satellite operators.

³⁸ P. Lala, *Study on Space Traffic Management*. Online at: www.unidir.org/pdf/articles/pdf-art2677.pdf.

³⁹ CSSI conjunction assessment and collision avoidance services [Center for Space Standards and Innovation (CSSI) in Colorado Springs]. The commercial operators provide positional data on their satellites as well as information on upcoming manoeuvres, which CSSI combines with the public data from the US military. This allows CSSI to perform conjunction assessment and collision avoidance services. This data centre has more computational and analytical capacity than the CFE program, but lacks the high accuracy catalogue data on the non-participating satellites and all of the space debris (which makes up 95 per cent of the catalogue).

⁴⁰ See Space Data Association home page, www.space-data.org/sda/.

⁴¹ It should be noted that as of December 2009, CFE has been renamed the SSA Sharing Program. See, SWF Issue Brief, SSA Sharing Program, 10 November 2010, Secure World Foundation.

A coordinated global SSA/STM is needed to provide accurate and timely data on active and inactive space objects and debris, as well as collision/conjunction alerts. The rationale for this global coordination is that the safety of commercial space activities can be ensured only if there is a commitment from governments to monitor uncontrolled space objects and satellite operators to provide the locations and manoeuvre plans for their satellites. It should be noted that real time is not the goal nor is it feasible. All the warnings should be done days in advance. Whenever possible, all stakeholders should be invited to participate, including industry and insurers.

The two key tools this system would provide are orbital data and analytical capacity to utilize that data in decision-making processes of all space actors. This data would include the orbits of objects in Earth orbit along with solar and geomagnetic activity and that affect atmospheric density. This information would allow for the precise estimation of where satellites on orbit will be located. The analytical capacity would include both conjunction assessment (the ability to predict close approaches between two objects) and collision avoidance (ability to design a manoeuvre to avoid high risk conjunctions). In addition, such a system would need to provide space weather predictions and some level of anomaly resolution to space actors.

Several issues need to be considered concerning the feasibility of an international SSA system. These include national security concerns, data sources, financing, liability, public access, and participation. National security implications for government data providers is a serious issue because States with sophisticated SSA systems do not want to reveal classified space objects. However, there is a distinction between civil and military SSA. The fundamental difference between civil SSA and military SSA systems lies in the types of information that each provides. Civil space situational awareness only needs to focus on the location of an object in Earth orbit and a point of contact for that object, along with information about space weather. The additional military requirements of determining function, intent, and capabilities and limitations are not intended to be part of the capabilities of the civil SSA system. Military participation in a civil SSA system should not be a problem because there is no need to 'declassify' or 'reveal' strategic classified satellites. In other words, the tracking and disclosure of the many classified military and intelligence satellites in orbit is not necessary for an international civil SSA system to function. Governments who choose to keep the locations of their satellites hidden are self-interested to operate them in a safe manner (consider that letting a supposedly invisible satellite hit another object not only renders it visible but also destroys its ability to perform its critical mission).

With regard to data sources, (a) Radar and Optical Telescopes and (b) Commercial Satellite Operators should be the primary SSA data providers. Currently, there are in existence many radar and optical telescopes in different countries around the globe. Some are military in nature, some scientific or civil. While each one individually provides very little SSA, combining the data from all these existing sensors would provide much of the capability needed for true global coverage and capacity. Satellite owner-operators should also provide information. Satellite owner-operators usually have real-time data on the locations of their satellites that is more accurate than any ground-based sensor could obtain. Provision of such data would free up sensor capacity to track other objects. An additional data source is identified that

satellites (civil and/or commercial) could have low-cost sensors on-board that can be integrated into a global SSA.

Data sharing is critical to a successful international civil SSA system. Models of data sharing need to be developed. According to one model, the *Participant Choice Open-Source Model*, each participant in the system chooses what data they will provide to a central clearing house. All participants would have access to all of the shared data in the clearing house, enabling them to do their own independent or regional analysis. All participants would also have access to analytical support from the central data clearing house to offset the lack of indigenous capability. Once again, national security and protection of proprietary data may be a concern and, thus, any data sharing model used for such a system would need to have the appropriate balance between security and dissemination, to ensure that sensitive government and commercial data is protected while still reaping the benefits of sharing.

An international civil SSA could provide several complementary benefits within the larger space debris mitigation context. It would primarily serve to provide the basic data necessary for all space actors to make educated, safe, and efficient decisions in operating their spacecraft. It would also increase international awareness and understanding of the space debris problem and the long-term sustainability of space. It is hoped that the increased transparency and cooperation such a system would bring about would, in turn, lead to a reduction of tensions between States on space issues, and in the future such a system could serve as a potential verification mechanism for space governance initiatives.

STM should use actionable orbit data and additional data (e.g. SSA) to look for and assess close approaches and other interference events among orbiting objects, and provide timely warnings to satellite operators of coming events that exceed an action threshold. Warnings would include notices of close approaches, and alerts of possible radio frequency interference events. Services provided would include assistance to operators to assess and verify that proposed manoeuvres could be performed safely.

In this context, the primary distinction between STM and SSA is the provision of manoeuvring instructions. In a typical STM model, there is a centralized manager of data who disseminates to satellite operators instructions to avoid collisions (and/or radio frequency interference). In a typical SSA model, the data to assess close approaches is available to all operators, but the operators carry out their own analyses and determine for themselves whether or not manoeuvres are necessary. In the event that an SSA system also includes this type of analysis, it will only provide alerts and not manoeuvring instructions.

A question arises whether or not any resulting STM system should have enforcement authority over satellite operators. A major argument against the proposition for enforcement is that if there is no enforcement authority, then the STM is only a recommended course of action that might not be followed. On the other hand, self-interest dictates that STM manoeuvring instructions should be followed. In aviation, similar problems exist. The failure of all aircraft and air traffic controllers to follow exact manoeuvring instructions can result in collision. However unlike air traffic control, which operates using data on aircraft flying within specific regions and boundaries, a space traffic management service must

have the best orbital data on all orbiting objects to fulfil its mission. Moreover, one should keep in mind a distinction between air traffic management (where everything involves potential loss of human life) and space traffic management (where only certain objects have humans on board).

The technical tools related to a space traffic management service are available and have been tested under operational conditions by The Aerospace Corporation, MIT Lincoln Laboratory, ESA, Mission Control Centre of TSNIIMASH in Russia, and others. As discussed within the context of SSA, US STRATCOM provides data that support STM services by NASA for manned vehicles and STM services for robotic missions by JSpOC. Space Data Association, a non-profit consortium of commercial satellite operators, is currently providing a basic level of STM service to a number of operators of geostationary satellites.

The minimum criteria for a successful STM system can be categorized as either (i) Command Level or (ii) Service Level.

(a) Command Level Criteria:

- Incorporate data from all operators:
 - All private operators
 - All government-operated satellites
- Operator requirements:
 - Protect proprietary and sensitive data
 - Satellites able to manoeuvre
 - Satellite operators coordinate manoeuvres with others
 - Operators provide data on satellite positions and manoeuvres
- Government requirements:
 - Protect sensitive data
 - Get information on satellite manoeuvres
 - Satellite operators coordinate manoeuvres with others
 - Know what satellites are operating where to assist government regulators in the assignment of operational orbits and slots
 - Assure that operators are meeting government requirements
 - Regulatory, licensing, or treaty requirements
 - Space debris mitigation requirements

(b) Service Level Criteria:

- Must be ongoing, reliable, and available twenty-four hours a day and seven days a week;
- Must be available to all satellite operators world-wide, independent of disputes and boundaries;

- Must provide alerts and warnings that are accurate and timely, allowing operators sufficient time and opportunity to assess threats and plan fuel-efficient manoeuvre strategies;
- Must assist operators with problems and be on-call when needed to verify manoeuvre plans, provide contact points for coordination of manoeuvres, and provide specialized services during manoeuvres and orbit insertion;
- Must provide information (which has been previously approved by the concerned management body) to governments on operator activities such as satellite de-orbits and repositioning necessary for compliance verification.

Issues associated with a space traffic management service include liability related to interference predictions, satellite operator liability related to actions taken or not taken that lead to interference, and protection of operator-proprietary data and any sensitive data provided by governments or tracking services. Such liability needs to be addressed for setting up an international, operational, and coordinated SSA/STM system.

Another issue is the need for an organizational structure that engenders trust from private operators and governments that the services provided meet operator requirements, that data is protected, and costs are reasonable. One organizational approach for STM is to establish an "International Space Operations Clearinghouse" (ISOC), an international organization governed by a Board of Directors made up of representatives of investors, which could comprise of governments of space-faring nations (including non-space faring nations) and major satellite operators (e.g., earlier Intelsat model). The proposed ISOC would accept and integrate tracking and manoeuvre data from governments, satellite operators, and other sources; provide data to governments on locations and manoeuvres of subscriber's satellites (governments would use this data to perform their own analyses for interference with sensitive satellites); and, would provide warnings of upcoming interference events and verify that planned manoeuvres would have the desired result and would not create interference with another object. The service could expand to include warnings of radio frequency interference or other events. The ISOC's Board of Directors would define and enforce data protection requirements, would set rates for services, and would specify how 'profits', if there are any, from the service might be used (most likely, any profits would be used to improve the service).

When merging civil and military initiatives toward enhanced space situational awareness, the data policy to be adopted could be based on previous experience. The long-term objective would be to achieve international cooperation. In the meantime, however, space actors need to have access to the existing space situational awareness infrastructure in order to determine the characteristics of the actual space environment.

Other proposals to improve and implement SSA/STM include:

- Developing new mechanisms for sharing space traffic information between nations;
- Maintaining and expanding the US SSA Sharing Program;⁴²

⁴² In October 2009, CFE program operations transferred from Headquarters AFSPC to

- Taking advantage of data readily available from commercial operators (e.g. see SDA “Space Data Center” Prototype);
- Creating new data sources (e.g. launching low-cost sensors on every satellite going to orbit);
- Beginning an international dialogue on Rules of the Road for space (additional non-legal binding guidelines) such as: (a) a formalization of existing rules regarding the movement of spacecraft between orbital locations; (b) protocols for informing other operators when one of their spacecraft could potentially cause damage to other space objects; (c) protocols for managing the loss of control of a satellite.

(iv) Technical Coordination: Case Study of the SDA Space Data Center

The Space Data Association (SDA) is a non-profit association founded by satellite operators Inmarsat, Intelsat, and SES. SDA’s mandate is to exchange operational data to help ensure safety, provide technical support to improve operational integrity, and share the associated costs.⁴³ The “Space Data Center” provides and shares information among fellow operators regarding satellites under their control. As of January, 2011, the Space Data Center has twenty participating operators and provides safety services for almost 1200 satellites in GEO and 114 satellites in LEO.⁴⁴ The Data Center is an interactive repository for commercial satellite orbit, manoeuvre, and frequency information. Satellite operators routinely deposit their fleet information into the Data Center and retrieve information from other member operators when necessary. The Data Center allows operators to augment the existing Two Line Element (TLE) data with precision orbit data and manoeuvre plans from the operator’s fleets.

One major shortcoming of the Data Center is that its operators must still rely on governments, and primarily the U.S. Government, to monitor dead satellites and other objects drifting in GEO that could collide with active satellites. In addition, separate tools are necessary to exchange data with each operator. Some operators write their own software tools for monitoring and predicting the close approach of other spacecraft while others contract with third parties for this service. The magnitude of the effort to maintain “space situational awareness” grows quickly as the number of coordinating operators increase. To mitigate this, the SDA has developed tools to automatically translate data between the different formats used by the operators. Unfortunately some operators are not able or willing to participate in close approach monitoring due to lack of resources or capabilities.

Headquarters USSTRATCOM in its efforts to, inter alia, minimize generation of space debris. In the process it was renamed the SSA Sharing Program.

⁴³ SDA was established in the Isle of Man in 2009. “Space Data Center Launches Initial Operations,” available at: www.space-data.org/sda/wp-content/uploads/downloads/2010/11/sdc_agi_initial_ops_0710.pdf.

⁴⁴ “Space Data Association Now Perform Conjunction Screening for More than 300 Satellite”, Space Data Association Press Release, January 21, 2011, online at www.space-data.org/sda/wp-content/uploads/downloads/2011/01/SDA_press_release_21_Jan_2011_RELEASED.pdf.

The SDA Space Data Center is currently being expanded to:

- Develop data sharing relationships with governments and other data providers to get access to tracking data on space debris;
- Provide collision avoidance manoeuvre planning assistance to operators; and
- More satellite operators.

D. Other Recommended Actions

(i) Further Technology Research and Development

The long-term sustainability of outer space requires technical research and developments that supports prevention, mitigation, and remediation. Technical research to remove inoperable satellites from LEO and GEO protected zones should be intensified and the results must be made available to all States and operators. Technical research into passivation techniques, as well as long-term structural behaviour of the materials used in the satellites and the rocket bodies, should be undertaken and the results of such research and development should be made accessible to manufacturers dealing with launch vehicles and satellites. Research and development should be pursued regarding the feasibility and configuration of an active debris disposal system to remove big inoperable satellites from special protected zones. These objects will otherwise fuel collision cascading. Moreover, technology must be developed in relation to the medium-sized debris items which cannot be seen by the present generation of sensors, but which are big enough to overcome existing satellite protection mechanisms. In addition:

- The re-orbiting of GSO satellites at the end of the mission should be carried out to result in very low eccentricity because higher eccentricity will make the satellite cross the GSO circle, which is dangerous for operational satellites. This requires special training to the satellite operators for disposal operations.
- Missions should be designed such that orbits of the final stages of the launch vehicles with GSO orbiting capability do not cross GSO every day, and their apogee should be well below GSO and their perigee above LEO protected region. Taking advantage of data readily available from commercial operators (e.g. see SDA "Space Data Center" Prototype);
- The system engineering and technology of passivation should be simplified and made reliable so as not to pose any unacceptable risks to the main mission.

(ii) Areas for Further Law and Policy Studies:

- How to incentivize/enforce adherence to the UN COPUOS Guidelines and consideration in all satellite mission designs?
- How can reporting of efforts for national implementation of the UN COPUOS Guidelines be made more regular and rigorous?
- How can existing international space law treaties be properly interpreted, applied, adjusted or improved to clarify and/or impose international liability on the actors who leave their non-functional satellites in orbit?

- What type of international legal mechanism is appropriate to control space debris, beyond the UN COPUOS Guidelines, particularly for remediation or salvage of space debris?
- What is the role and mechanism for commercial operators to participate as partners with governments in this process?
- Should a space debris regime be part of a larger space safety or space security regime?
- How can we take probable future needs for space traffic management into consideration within the space debris regime?
- How do we ensure that the debris mitigation methods are validated, verified, enforced, and have demonstrated sufficiency?
- What role can a space debris/safety regime play in the overall context of global human and environmental security?
- What rational mechanisms can be developed to prevent an increase of space undesirable potential while tests/utilization of space debris remediation technologies?
- What transparency/confidential measures can be recommended for space traffic management into consideration within the space debris regime?
- How can the non-space faring nations be involved in a meaningful and constructive way?

Appendix 1

Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*

1. Background

Since the Committee on the Peaceful Uses of Outer Space published its Technical Report on Space Debris in 1999,^a it has been a common understanding that the current space debris environment poses a risk to spacecraft in Earth orbit. For the purpose of this document, space debris is defined as all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional. As the population of debris continues to grow, the probability of collisions that could lead to potential damage will consequently increase. In addition, there is also the risk of damage on the ground, if debris survives Earth's atmospheric re-entry. The prompt implementation of appropriate debris mitigation measures is therefore considered a prudent and necessary step towards preserving the outer space environment for future generations. Historically, the primary sources of space debris in Earth orbits have been (a) accidental and intentional break-ups which produce long-lived debris and (b) debris released intentionally during the operation of launch vehicle orbital stages and spacecraft. In the future, fragments generated by collisions are expected to be a significant source of space debris.

Space debris mitigation measures can be divided into two broad categories: those that curtail the generation of potentially harmful space debris in the near term and those that limit their generation over the longer term. The former involves the curtailment of the production of mission-related space debris and the avoidance of break-ups. The latter concerns end-of-life procedures that remove decommissioned spacecraft and launch vehicle orbital stages from regions populated by operational spacecraft.

2. Rationale

The implementation of space debris mitigation measures is recommended since some space debris has the potential to damage spacecraft, leading to loss of mission, or loss of life in the case of manned spacecraft. For manned flight orbits, space debris mitigation measures are highly relevant due to crew safety implications. A set of mitigation guidelines has been developed by the IADC, reflecting the fundamental mitigation elements of a series of existing practices, standards, codes and handbooks developed by a number of national and international organizations. The Committee on the Peaceful Uses of Outer Space acknowledges the benefit of a

* *Official Records of the General Assembly, Sixty-second Session, Supplement No. 20 (A/62/20)*, paras. 117 and 118 and annex. The UN General Assembly in its Resolution endorsed the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space in 2007.

See: United Nations General Assembly, Sixty-second session, Agenda item 31, Document A/RES/62/217 (10 January 2008), paragraph 26.

^a United Nations publication, Sales No. E.99.I.17.

set of high-level qualitative guidelines, having wider acceptance among the global space community. The Working Group on Space Debris was therefore established (by the Scientific and Technical Subcommittee of the Committee) to develop a set of recommended guidelines based on the technical content and the basic definitions of the IADC space debris mitigation guidelines, and taking into consideration the United Nations treaties and principles on outer space.

3. Application

Member States and international organizations should voluntarily take measures, through national mechanisms or through their own applicable mechanisms, to ensure that these guidelines are implemented, to the greatest extent feasible, through space debris mitigation practices and procedures.

These guidelines are applicable to mission planning and the operation of newly designed spacecraft and orbital stages and, if possible, to existing ones. They are not legally binding under international law. It is also recognized that exceptions to the implementation of individual guidelines or elements thereof may be justified, for example, by the provisions of the United Nations treaties and principles on outer space.

4. Space debris mitigation guidelines

The following guidelines should be considered for the mission planning, design, manufacture and operational (launch, mission and disposal) phases of spacecraft and launch vehicle orbital stages:

Guideline 1: Limit debris released during normal operations

Space systems should be designed not to release debris during normal operations. If this is not feasible, the effect of any release of debris on the outer space environment should be minimized.

During the early decades of the space age, launch vehicle and spacecraft designers permitted the intentional release of numerous mission-related objects into Earth orbit, including, among other things, sensor covers, separation mechanisms and deployment articles. Dedicated design efforts, prompted by the recognition of the threat posed by such objects, have proved effective in reducing this source of space debris.

Guideline 2: Minimize the potential for break-ups during operational phases

Spacecraft and launch vehicle orbital stages should be designed to avoid failure modes which may lead to accidental break-ups. In cases where a condition leading to such a failure is detected, disposal and passivation measures should be planned and executed to avoid break-ups.

Historically, some break-ups have been caused by space system malfunctions, such as catastrophic failures of propulsion and power systems. By incorporating potential break-up scenarios in failure mode analysis, the probability of these catastrophic events can be reduced.

Guideline 3: Limit the probability of accidental collision in orbit

In developing the design and mission profile of spacecraft and launch vehicle stages, the probability of accidental collision with known objects during the system's launch phase and orbital lifetime should be estimated and limited. If available orbital data indicate a potential collision, adjustment of the launch time or an on-orbit avoidance manoeuvre should be considered.

Some accidental collisions have already been identified. Numerous studies indicate that, as the number and mass of space debris increase, the primary source of new space debris is likely to be from collisions. Collision avoidance procedures have already been adopted by some Member States and international organizations.

Guideline 4: Avoid intentional destruction and other harmful activities

Recognizing that an increased risk of collision could pose a threat to space operations, the intentional destruction of any on-orbit spacecraft and launch vehicle orbital stages or other harmful activities that generate long-lived debris should be avoided. When intentional break-ups are necessary, they should be conducted at sufficiently low altitudes to limit the orbital lifetime of resulting fragments.

Guideline 5: Minimize potential for post-mission break-ups resulting from stored energy

In order to limit the risk to other spacecraft and launch vehicle orbital stages from accidental break-ups, all on-board sources of stored energy should be depleted or made safe when they are no longer required for mission operations or post-mission disposal.

By far the largest percentage of the catalogued space debris population originated from the fragmentation of spacecraft and launch vehicle orbital stages. The majority of those break-ups were unintentional, many arising from the abandonment of spacecraft and launch vehicle orbital stages with significant amounts of stored energy. The most effective mitigation measures have been the passivation of spacecraft and launch vehicle orbital stages at the end of their mission. Passivation requires the removal of all forms of stored energy, including residual propellants and compressed fluids and the discharge of electrical storage devices.

Guideline 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission

Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the LEO region should be removed from orbit in a controlled fashion. If this is not possible, they should be disposed of in orbits that avoid their long-term presence in the LEO region.

When making determinations regarding potential solutions for removing objects from LEO, due consideration should be given to ensuring that debris that survives to reach the surface of the Earth does not pose an undue risk to people or property, including through environmental pollution caused by hazardous substances.

Guideline 7: Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission

Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the GEO region should be left in orbits that avoid their long-term interference with the GEO region.

For space objects in or near the GEO region, the potential for future collisions can be reduced by leaving objects at the end of their mission in an orbit above the GEO region such that they will not interfere with, or return to, the GEO region.

5. Updates

Research by Member States and international organizations in the area of space debris should continue in a spirit of international cooperation to maximize the benefits of space debris mitigation initiatives. This document will be reviewed and may be revised, as warranted, in the light of new findings.

6. Reference

The reference version of the IADC space debris mitigation guidelines at the time of the publication of this document is contained in the annex to document A/AC.105/C.1/L.260. For more in-depth descriptions and recommendations pertaining to space debris mitigation measures, Member States and international organizations may refer to the latest version of the IADC space debris mitigation guidelines and other supporting documents, which can be found on the IADC website (www.iadc-online.org).

Appendix 2

McGill-Cologne Declaration on Space Debris

The International Interdisciplinary Congress on Space Debris, comprised of a group of invited experts of various fields, including natural sciences, engineering, physics, astrophysics, business, political science and law, from Canada, Colombia, Czech Republic, China, France, Germany, Ghana, India, Italy, Japan, the Netherlands, Nigeria, Romania, Russian Federation, Sweden, United Kingdom, and the United States of America having convened at two Sessions, one in May 2009 at McGill University in Montreal, Canada and the second in April 2010 at Cologne University in Cologne, Germany:

Convinced that the outer space environment is significantly deteriorating due to increasing amounts of space debris, particularly debris generated by the intentional destruction of satellites, and by recent accidents, like the collision between Iridium 33 and Cosmos 2251;

Believing that in the absence of technical and regulatory measures that effectively address this situation, the safe and sustainable access to and use of outer space, particularly in those orbits from which spacecraft provide important applications for the benefit of humankind, such as telecommunications, weather forecasting, environmental monitoring, natural resource management, science and astronomy, and position-navigation-timing, is increasingly being threatened;

Welcoming the initiatives of the Scientific and Technical Subcommittee as well as of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space, and the Code of Conduct for Outer Space Activities proposed by the European Union, to address the space debris problem;

Encouraged by the development of the Space Debris Mitigation Guidelines adopted by the Inter-Agency Space Debris Coordination Committee as well as the Space Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space, as endorsed by the General Assembly of the United Nations in its Resolution 62/217 of 22 December 2007, as an important international cooperative step towards reducing space debris risks;

Recognizing that the principle of common but differentiated responsibility, as enabling all States to fulfil their obligations associated with current international efforts in preserving the terrestrial environment, is an important precedent to guide current and future space debris mitigation and remediation efforts;

Deeply concerned, however, that the current measures, while productive, are not sufficient to ensure the prevention of a continuous degradation of the outer space environment, and that further measures are urgently needed in order to ensure safe and sustainable use of outer space for all humankind;

Recalling the Treaty on Principles Governing Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty), the Convention on International Liability for Damage Caused by Space Objects, and the Convention on Registration of Objects Launched into Outer Space;

Recognizing that according to Article I of the Outer Space Treaty, the exploration and use of outer space is the province of all mankind and outer space is free for exploration and use by all States without discrimination of any kind;

Recognizing also that according to Article VI of the Outer Space Treaty, States Parties to the Treaty shall bear international responsibility for national activities in outer space;

Recognizing further that according to Article IX of the Outer Space Treaty, States are obliged to conduct all their activities in outer space with due regard to the corresponding interests of all other States;

Declares that:

- (1) States should make safe and sustainable use of outer space a policy priority and should preserve access to and use of this unique environment for future generations.
- (2) States should adopt and implement, in accordance with their national legislative processes, the Space Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space.
- (3) All space actors are urged to comply with the existing Space Debris Mitigation Guidelines and Recommendations in anticipation of harmonized regulation.
- (4) States and the entities for which they are responsible should cooperate to bring about increased space situational awareness by providing transparency with respect to their space activities, notification of debris, and exchange of data and other information, to ensure that the likelihood of collisions in the future is minimized.
- (5) States should establish mechanisms for:
 - (a) The promulgation and regular review of binding international uniform technical standards for debris mitigation based on evolving technical developments;
 - (b) Remediation based on evolving technical developments; and
 - (c) An appropriate means for their national implementation.
- (6) States procuring, launching, or operating spacecraft should contribute actively to the objective of space debris mitigation, remediation and operational control.

Done, at Cologne on the Thirtieth Day of April of the Year Two Thousand and Ten.

Stephan Hobe
Co-Chair

Ram Jakhu
Co-Chair

Appendix 3

List of Participants in the International Interdisciplinary Congress on Space Debris*

1. Adigun A. Abiodun (U.S.)
2. William Ailor (Aerospace Corporation, U.S.)
3. Fernand Alby (CNES, France)
4. Ciro Arevalo (COPUOS, Austria)
5. Priyankar Banyopadhyay (ISRO, India)
6. Gerard Brachet (ASA, France)
7. Maria Buzdugan (Milbank, U.S.)
8. Richard DalBello (INTELSAT, U.S.)
9. Kerstin Deiters (IASL, Cologne University, Germany)
10. Paul Dempsey (IASL, McGill University, Canada)
11. Karl Doetsch (Athena Global, Canada)
12. Catherine Doldirina (IASL, McGill University, Canada)
13. Berndt Feuerbacher (IAF, Germany)
14. David Finkleman (CSSI, U.S.)
15. Jeffrey Foust (Futron, U.S.)
16. Joanne Gabrynowicz (University of Mississippi, U.S.)
17. Hugues Gilbert (CSA, Canada)
18. David Harbecke (IASL, Cologne University, Germany)
19. Niklas Hedman (UN OOSA, Austria)
20. Andreas Herzig (IASL, Cologne University, Germany)
21. Stephan Hobe (IASL, Cologne University, Germany)
22. Anne Hurtz (IASL, Cologne University, Germany)
23. Indra Hornsby (MDA Information System, Canada)
24. Diane Howard (IASL, McGill University, Canada)
25. Wade Huntley (UBC, Canada)
26. Anne Hurtz (IASL, Cologne University, Germany)
27. Ram Jakhu (IASL, McGill University, Canada)

* All these Participants attended the Congress in their personal capacity and not as the representatives of their respective organizations and/or countries.

28. Feng Jiehan (WU, PRC)
29. Rüdiger Jehn (ESA, Mission Analysis Section, Germany)
30. Nicolas Kasirer (Faculty of Law, McGill University, Canada)
31. Heiner Klinkrad (ESA, Space Debris Office, Germany)
32. Manuel Metz (German Aerospace Center (DLR), Germany)
33. Jan Mey (IASL, Cologne University, Germany)
34. Gesa Milbrett (IASL, Cologne University, Germany)
35. Michael Mineiro (IASL, McGill University, Canada)
36. Rafael Molina (ESA, Independent Safety Office, The Netherlands)
37. Luca Del Monte (ESA, Headquarters, France)
38. Laura Montgomery (FAA, U.S.)
39. Kouichi Morimoto (JAXA, Japan)
40. K.R. Sridhara Murthi (ISRO, India)
41. Kiran Nair (Indian Air Force, India)
42. Takashi Nakajima (JAXA, Japan)
43. Darius Nikanpour (CSA, Canada)
44. Yaw Nyampong (IASL, McGill University, Canada)
45. Xavier Pasco (FRS, France)
46. Lubos Perek (CAS, Czech Republic)
47. Milan Plücker (IASL, Cologne University, Germany)
48. Claudio Portelli (ASI, Italy)
49. Masahiko Sato (JAXA, Japan)
50. Bernhard Schmidt-Tedd (DLR, Germany)
51. Tommaso Sgobba (ESA, The Netherlands)
52. Peter Stubbe (DLR, Germany)
53. Michael Taylor (USAF, U.S.)
54. Richard Tremayne-Smith (OoS, U.K.)
55. Peter van Fenema (Jonker c.s. Advocaten, the Netherlands)
56. Brian Weeden (Secure World Foundation, U.S.)
57. Carsten Wiedemann (TUBS, Germany)
58. Pearl Williams (DFAIT, Canada)
59. Ray Williamson (Secure World Foundation, U.S.)
60. Uwe Wirt (DLR, Germany)

61. David Wright (UCS, U.S.)
 62. Michael Yakovlev (ROSCOSMOS, Russia)
 63. Haifeng Zhao (Harbin Institute of Technology, P.R. China)
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