Space Debris Pollution: A Convention Proposal

Thierry Sénéchal

1. INTRODUCTION AND CONTEXT

A hundred times every day I remind myself that my inner and outer life depend on the labors of other men, living and dead, and that I must exert myself in order to give in the same measure as I have received and am still receiving.

Albert Einstein

1.1 Space Debris: The Problem

On 11 January 2007 a Chinese ground-based missile was used to destroy the Fengyun-1C spacecraft, an aging satellite orbiting more than 500 miles in space since May 1999. Although the test was hugely successful from a military point of view, demonstrating China's ability to use very sophisticated weapons to target regions of space that are home to various satellites and space-based systems, it caused great concerns to both the military and scientific communities. Indeed, the event is a real danger in the sense it may fuel an arms race and weaponization of space, with some countries being tempted to show they can easily control space as well. From the scientific perspective, the Chinese destruction of Fengyun-1C gave a new dimension to the space debris issue.

In shattering the old weather-watching satellite into hundreds of large fragments, the Chinese created a large "debris cloud." The debris is now spreading all around the earth; the majority resides in very long-lived orbits. The debris cloud extends from less than 125 miles (200 kilometers) to more than 2,292 miles (3,850 kilometers), encompassing all of low Earth orbit. As of 27 February 2007, the U.S. military's Space Surveillance Network had tracked and cataloged 900 debris fragments greater than 5 centimeters in size, large enough to create potentially serious collision problems. The total count of objects could go even higher based upon the mass of Fengyun-1C and the conditions of the breakup, which could have created millions of smaller pieces.

The Chinese test has demonstrated that the actual system for preventing the creation of space debris is still weak—with a single test threatening to put in shamble the long-term efforts made by other countries. In particular, questions are now raised as to the extent to which the existing organizations working on space debris could take measures to protect the orbital space from pollution. The test also shows that the various existing treaties and conventions regulating outer space activities do not play a significant role in preventing such an incident because they lack coverage on such issues or are impossible to enforce.

1.2 Space Debris: Managing the Future

It is time to recognize that while space may be infinite, Earth orbital space is a finite natural resource that must be managed properly. The outer space environment should be preserved to enable countries to explore outer space for peaceful purposes, without any constraints. It has become obvious that space debris poses a danger to human life as well as to the environment and the economic activities of all nations in space.

The problem we face is complex and serious; the danger posed by the human-made debris to operational spacecraft (pilotless or piloted) is a growing concern. Because debris remains in orbit for long period of time, they tend to accumulate, particularly in the low earth orbit. What is certain today is that the current debris population in the Low Earth Orbit (LEO) region has reached the point where the environment is unstable and collisions will become the most dominant debris-generating mechanism in the future. The tremendous increase in the probability of collision exists in the near future (about 10 to 50 years). Some collisions will lead to breakups and will sow fragments all over the geosynchronous area, making it simply uninhabitable and unreliable for scientific and commercial purposes.

In the early years of the space era, mankind was concerned primarily with conquering space. The process of placing an aircraft in Earth's orbit and targeting the moon was such a challenge that little thought was given to the consequences that might arise from these actions. Space debris has thus been created at the time of the cold war, when the military and space race between the two great powers of the time was at its peak. Not much can be done to change what has been done during the last decades of the 20th Century.

As with many aspects of Earth-bound pollution, it is taking time to recognize the damaging effects of what we call now "space junk" or space pollution. Space debris is a source of increasing concern. The scientific and engineering communities have studied the problem of space debris for decades and warned of the dangers. Large space debris has been tracked and catalogued. The increased pace of small debris has also been studied using sophisticated models. Although space debris has been extensively studied by public and private research institutions around the world since the 1980s, its implications have only been discussed in narrow circles of specialists at international conferences.

1.3 Advocating for a Global Space Debris Convention

The time is right for addressing the problem posed by orbital debris and realizing that, if we fail to do so, there will be an increasing risk to continued reliable use of space-based services and operations as well as to the safety of persons and property in space. We have reached a critical threshold at which the density of debris at certain altitudes is high enough to guarantee collisions, thus resulting in increased fragments. In a scenario in which space launches are more frequent, it is likely that we will create a self-sustaining, semi-permanent cloud of orbital "pollution" that threatens all future commercial and exploration activities within certain altitude ranges. The debris and the liability it may cause may also poison relations between major powers.

Because space debris is a global challenge that may impact any country deciding to develop space activities, the issue cannot be resolved among a few countries. This is why I am advocating that a global convention on space debris is a requirement for preserving this special environment for future generations. Following the logic of the Brundland Report, we need development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."[1]

A global convention is needed for the simple reason that the successful approval of voluntary guidelines has not been consistent over the last years. For instance, the Chinese test is an example of failure to enforce mitigation standards for space debris. If rightly discussed and implemented, an international convention would increase mutual understanding on acceptable activities in space and thus enhance stability in space and decrease the likelihood of friction and conflict. It would also provide the mechanisms to study, mitigate, and remediate the consequences posed by space debris. More importantly, the convention would serve as an agreement between the different countries and would be legally binding to the contracting States. Other important issues would also need to be addressed. For instance, the destruction of spacecraft is presently not covered. The liability and dispute mechanism and compensation of a damage resulting from "tracked" debris are non-existent. This is why a specific international convention is much needed.

2. SPACE POLLUTION, A REALITY

2.1 Space Debris: Definition

Since the launch of Sputnik I in 1957, space activities have created an orbital environment that poses increasing risks to existing space systems, including human space flight and robotic missions. It is crucial to understand what is meant by debris in the context of space. In this paper, I am only concerned with man-made debris and not the natural fast-moving rocky particles called meteoroids. It is true that meteoroids can also be a source of great concern, some of them being very large, with a mass of several thousand metric tons. Every day Earth's atmosphere is struck by millions of small meteoroids but most never reach the surface because they are vaporized by the intense heat generated when they rub against the atmosphere. Non man-made debris is beyond the scope of this paper.

2.2 Source of Debris

2.2.1 Categories of Space Debris

In his article "Space Debris: Legal and Policy Implications,"[2] Howard Baker divides space debris into four classes: inactive payloads, operational debris, fragmentation debris and microparticulate matter. I refer to these categories in my paper as follows:

(1) **Inactive payloads or inoperative objects:** Inactive payloads are primarily made up of satellites that have run out of fuel for station-keeping operations or have malfunctioned and are no longer able to maneuver. However, the use of the term "inactive payloads" requires clarification. Because satellites can be deactivated for periods of time and then later reactivated, and because debris may include objects manufactured in outer space and not just payloads, the term "inoperative objects" may be more correct when referring to objects which entities can no longer control.

(2) **Operational debris:** Operational debris includes any intact object or component part that was launched or released into space during normal operations. The largest single category of this type of debris is intact rocket bodies that remain in orbit after launching a satellite.

(3) **Fragmentation debris:** Fragmentation debris is created when a space object breaks apart. This type of debris can be created through explosions, collisions, deterioration, or any other means. Collisions are another source of fragmentation debris. Debris of this type may result from collisions between space object and either natural or artificial orbital debris.

(4) **Microparticulate matter:** Surface degradation is also a cause of space debris. Surfaces of spacecraft are exposed to the deleterious space environment of ultraviolet radiation, atomic oxygen, thermal cycling, micro-particulates, and micrometeoroids. This can lead to degradation in the optical, thermal and structural integrity of surfaces and coatings with subsequent shedding of materials into the space environment. Indeed, debris can be created as the result of the gradual disintegration of the surfaces on a satellite due to exposure to the space environment.

2.2.2 Examples of How Debris is Created

Debris in space is composed of various elements from various space missions. From 1957 through 2006, the total number of space missions to reach Earth orbit or beyond was 4,477. The types of debris are manifold. For example, many upper stages from launch vehicles have been left in orbit after they are spent. Many satellites are also abandoned after the end of their useful life. Another source of debris is spacecraft and mission operations, such as deployments and separations. A major contributor to the orbital debris background has been object breakup. Breakups generally are caused by explosions and collisions. According to a recent paper by the IAA,[3] it is noted that, as of 2005, more than 180 in-orbit explosions have occurred, generating about 40% of the orbital debris population. For instance, on 29 June 1961, the Able Star upper stage used to launch the Transit 4A satellite exploded and produced 296 catalogued pieces of debris, 181 of which were still in orbit in 1 January 2007.

Let's consider some recent cases. In 2006, in February, the 45-year-old Vanguard 3 (1959-007A) released a single piece of debris with very low velocity while in an orbit of 510 km by 3310 km.[4] The likely cause was the impact of a small (untracked) particle or surface degradation of the spacecraft. In November of the same year, shortly after reaching an orbit of approximately 850 km circular on 4 November 2006, a Delta IV second stage unexpectedly released more than 60 debris in a retrograde direction with velocities mostly in the range of 0-50 m/s. In December, a 17-year-old Delta second stage (1989-089B) released as many as 36-tracked particles from an orbit of 685 km by 790 km. The debris exhibited orbital decay rates higher than normal and all but three have already reentered the earth's atmosphere.

There is also unusual debris. Galaxy 3R, a U.S. geosynchronous satellite launched in 1995, suffered a failure of its spacecraft control processor in January 2006. Attempts to recover control of the spacecraft were unsuccessful and the spacecraft operator was unable to boost the vehicle into a disposal orbit above the geostationary arc, so Galaxy 3R remains where it failed. There also exists celebrated space debris such as Ed White's spacesuit glove that drifted out of Gemini during the first U.S. spacewalk in 1965, and the loss of a powered screwdriver during the repair of the Solar Max in 1984.

2.3 Tracking and Cataloguing Space Debris

More than 30,000 objects had been officially cataloged by the U.S. Space Surveillance Network[5] (SSN) by the end of January 2007. SSN is the main comprehensive debris monitoring system for space debris. It has been tracking space objects since 1957 when the Soviet Union opened the space age with the launch of Sputnik I. The system was originally designed to detect objects of military significance, but it is capable of monitoring many other types of space objects.

Approximately, 8% of the cataloged population is operational spacecraft, while 50% can be attributed to decommissioned satellites, spent upper stages, and mission related objects. The remainder 43% originates from 160 on-orbit fragmentations that have been recorded since 1961. (The bigger debris is well-tracked as shown in the images below).[6] The total number of identified satellite breakups by 1 January 2007 was 189.

Figure 1: Space Debris Pollution Models

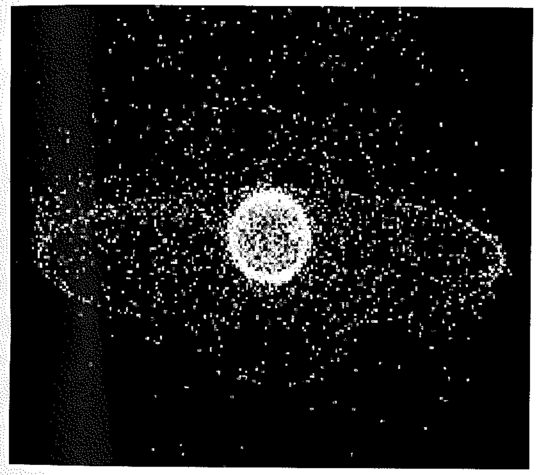


Image generated from a distant oblique vantage point to provide a good view of the object population in the geosynchronous region (around 35,785 km altitude). Note the larger population of objects over the northern hemisphere.

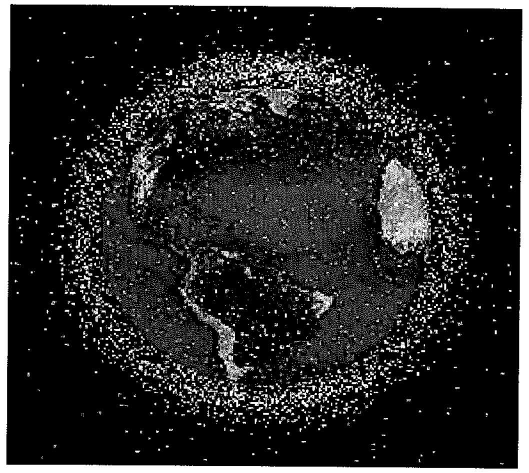


Image of the low Earth orbit, the region of space within 2,000 km of the Earth's surface. It is the most concentrated area for orbital debris.

Source: NASA orbital Debris Program Office

Most of space debris has a mean altitude of 528 miles (850 kilometers) or greater. This means most will be long-lived.[7] Most space debris will not fall to earth for thousands or even millions of years, and the vast majority of what does fall to earth will incinerate itself when it hits the upper atmosphere. The situation at some specific orbits can be described as a crowding problem. Such is the case at altitudes between 700 and 1,000 km, around 1,400 km, and in geostationary orbit. These altitudes correspond to appropriate orbits for specific missions: Remote-sensing sun-synchronous missions are primarily between 700 and 1,000 km, communication satellites in low Earth orbits are typically above 700 and below 1,500 km, and geostationary satellites are in orbit around 36,000 km.

2.4 Assessing the Threats: A Scientific and Economic Perspective

2.4.1 The risk of Collision: A Scientific Problem

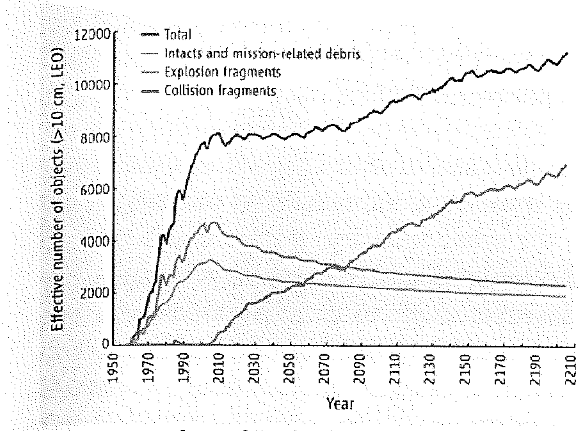
Collisions at orbital velocities can be highly damaging to functioning satellites and space manned missions. At orbital velocities of more than 28,000 km/h (17,500 mph), an object as small as 1 cm in diameter has enough kinetic energy to disable an average-size spacecraft. Objects as small as 1 mm can damage sensitive portions of spacecraft, but these particles are not tracked.[8] At a typical impact velocity of 10 km/s, a 1 cm liquid sodium-potassium droplet would have the destructive power of an exploding hand grenade. A fragment that is 10 cm long is roughly comparable to 25 sticks of dynamite.

The chance of a collision and substantial damage is not insignificant. The Space Shuttle has maneuvered to avoid collisions with other objects on several occasions. Regarding satellite constellations, if a potential collision will lead to the creation of a debris cloud that may result in damage to other constellation members, it may be worthwhile to perform a collision avoidance maneuver. Large particles obviously cause serious damage when they hit something. Part of a defunct satellite or any large debris resulting from a space launch would almost certainly destroy a satellite or kill a space explorer on impact.

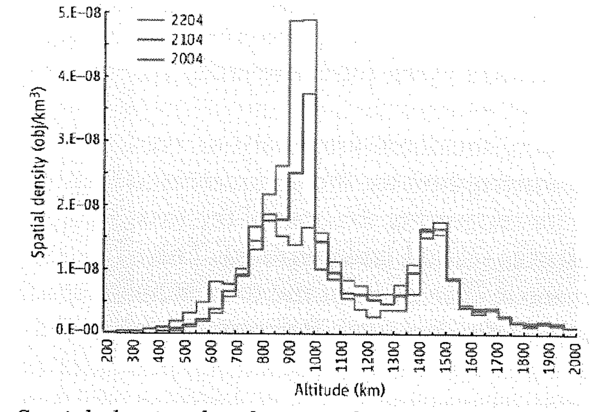
A source of risk is found in the likelihood of a chain of collisions in the coming years. Under such a scenario, space debris would grow exponentially as they start to collide. As a result, collisions would become the most dominant debris-generating mechanism in the future. Several studies demonstrated, with assumed future launch rates, the production rate of new debris due to collisions exceeds the loss of objects due to orbital decay.[9] As a result, in some low Earth orbit (LEO) altitude regimes, where the density of objects is above a critical spatial density, more debris would be created. The growth of future debris populations is shown in the following two graphs (See Figure 2). They show the effective number of LEO objects, 10 cm and larger, from the LEGEND simulation.[10]

A detailed analysis conducted by NASA specialists J. C. Liou and N. L. Johnson (2006) indicates that the predicted catastrophic collisions and the resulting population increase are non-uniform throughout LEO. They conclude that it is probable that about 60% of all catastrophic collisions will occur between 900 and 1000 km altitudes, with the number of objects 10 cm and larger tripling in 200 years, leading to a factor of 10 increase in collisional probabilities among objects in this region. They argue: "Even without new launches, collisions will continue to occur in the LEO environment over the next 200 years, primarily driven by the high collision activities in the region between 900- and 1000-km altitudes, and will force the debris population to increase. In reality, the situation will undoubtedly be worse because spacecraft and their orbital stages will continue to be launched." [11]

Figure 2: Debris Simulations from LEGEND



Effective number of LEO objects, 10 cm and larger from the LEGEND simulation.



Spatial density distributions, for objects 10 cm and larger, for three different years.

Source: J.-C. Liou and N. L. Johnson

2.4.2 An Increasing Space Market with Higher Risks of Economic Disruptions

The market for commercial space launchers has witnessed rapid growth over the past several years. If more space debris accumulates, the business is at risk. Today, more and more activities rely on well functioning communication equipment in space. Any disruption can have major consequential losses. World geopolitics has dramatically changed since the 1960's race to the moon. At the time, the U.S. and the Soviet Union competed with one another, both on Earth and in space.

Today, the space market is again on the upward trend. By the end of last century, the world satellite market generated revenues of about $11 billion. In terms of satellite launches, the year 2002 has shown the highest number of launches with 289. Today, the worldwide revenues for the market are around the $16 billion. The health of the global telecommunications market determines to a great extent the sustainability, and therefore the continuity, of space industry. For instance, of the 155 satellites successfully launched by Ariane-4, the French space launcher, in the course of its operation, 139 are telecommunications satellites. Of the 39 satellites launched by Ariane-5 by mid-2005, 26 are telecommunication satellites. It is estimated that 90% of the value of satellite payloads launched by Ariane-5 will be telecommunications-related.[12]

Several trends are positively impacting on the commercial satellite market. First, new needs have appeared. Networks of Little LEOs, Big LEOs, LEO broadband systems, MEOs and GEOs are scheduled for launch within the next seven years. With improvements in satellite components, technologies and production processes, satellite systems are improving in function, as well as in production and operational costs.

Second, the space market is also gaining prominence in many countries. For instance, Brazil and Mexico have become important operators of space systems. Today, the Brazilian Instituto Nacional De Pesquisas Espaciais' (INPE) has an ambitious and visionary space program dating back to 1979. Since 1992, Argentina's space activities have been considerably developed. In

1994, a Space Plan for 1995-2006 was drawn and a U.S.$700 million budget allocated, for the launch of science and telecommunication satellites. South Korea, India, China and Japan all have strong space programs capable of integrating and launching satellites. As pointed by Frost and Sullivan, the "space systems market is encouraged by a new space race among Asian rocket and satellite builders vying for commercial customers on the global market."[13]

At this pace, incidents are likely to occur. As a result, in case of damage and consequential business interruption for the commercial operators, there must be a compensation instrument put in place for recovering the cost of the loss. Typically, in the space industry, there are about 10-15 large insurers (called underwriters). There are about 13 international insurance underwriters that provide about 75% or so of the total annual capacity. However, none of them provides coverage for space debris damages. Because damages and losses caused by space debris are difficult to cover from a traditional insurance perspective, it is important to draft an international convention that would define the extent of national jurisdiction in outer space. In the following pages, I discuss how a liability and compensation mechanism can be implemented.

2.5 Efforts Made by Space-faring Countries and International Organizations

Many space-faring nations have started to realize the problem posed by space debris and have adopted various measures to mitigate it. Today, there is a wide interest in the problem from the scientific community and various initiatives and organizations have been set up to debate and promote various guidelines or codes of conduct.

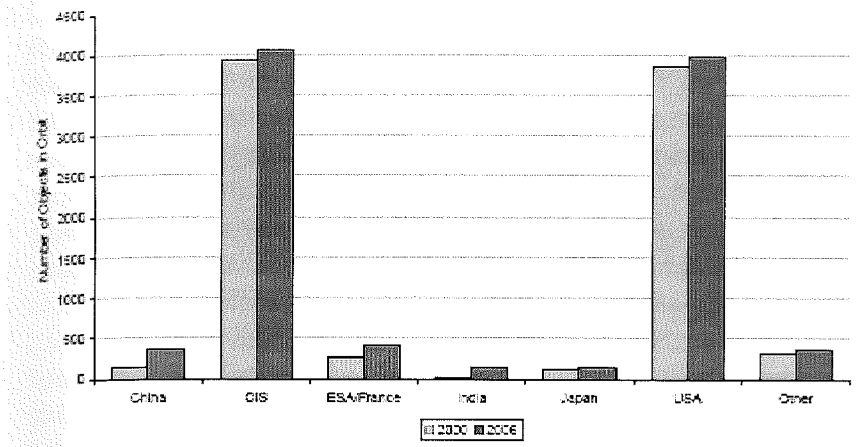
2.5.1 Space Debris Activities in a Global Context

Space debris activities started to display momentum in the 1960s with initial interest by the U.S.A. In the mid-1970s, the problem was first raised at the international level when the IAF started to organize the Safety and Rescue Symposia congresses. But we have to wait until the early 1980s to bring space debris issues to the forefront of scientific agenda. In July 1982, NASA conducted the first dedicated conference on orbital debris. In September 1985, as a response to the decays of Skylab and Cosmos 1402, ESA organized a workshop on the re-entry of space debris. In April 1993, ESA also organized the first European conference on space debris with participants from the major space-faring nations. Since the mid-1990s, space debris research has gained considerable interest. According to Klinkrad,[14] regular NASA/ESA coordination meetings have taken place since 1987. Starting in 1989, NASA also created coordination initiatives with the Russians. At the same time, the International Academy of Astronautics (IAA) published its position paper on space debris, produced by an international ad-hoc group of experts.

2.5.2 The Role of the U.S.

It is worth noting that the debris problem has its origin in the space competition between the former USSR and the U.S. Since 2000, the number of in-orbit objects larger than a bowling ball has increased by nearly 10 percent, with the United States and Russia each contributing approximately 40 percent of the total debris. The following graph illustrates the origin of space debris and clearly it becomes obvious that the role of the U.S. in dealing with this problem cannot be marginal.

Figure 3: Growth in Number of Objects in Orbit, by Country/Organization, from 2000 to 2006[15]



Source: Futron Corporation, 2006

Although at this time the U.S. Government does not see the need or benefit for a new legal regime to address the topic of space debris, the U.S. has played a crucial role in tracking, cataloguing, and modeling space debris. NASA has been at the forefront of orbital debris mitigation efforts in the U.S. government. With authority over all civil government space missions, the agency has developed a policy and specific procedural requirements for orbital debris mitigation.

A NASA Orbital Debris Program Office, located at the Johnson Space Center,[16] is recognized worldwide for its leadership in addressing orbital debris issues. The NASA Orbital Debris Program Office has taken the international lead in conducting measurements of the environment and in developing the technical consensus for adopting mitigation measures to protect users of the orbital environment. Researchers at the center develop an improved understanding of the orbital debris environment and devise measures that can be taken to control its growth. The Office plays a key role within the Scientific and Technical Subcommittee of the UN Committee on the Peaceful Uses of Outer Space in promoting mitigation guidelines.

Space debris has been clearly identified in the new National Space Policy of the U.S. signed on 31 August 2006 by President George W. Bush. The document flagged the progress made both nationally and internationally regarding proliferation of orbital debris over the past decade but also underscored the worrisome nature of space junk. The White House document stated: "Orbital debris poses a risk to continued reliable use of space-based services and operations and to the safety of persons and property in space and on Earth. The United States shall seek to minimize the creation of orbital debris by government and non-government operations in space in order to preserve the space environment for future generations."[17]

This is a major step but the intentions have to be followed by actions. For instance, joint DoD/NASA guidelines known as the U.S. Government Orbital Debris Mitigation Standard Practices have been issued in 2000 for mitigating the growth of orbital debris. However, they are not considered binding regulations and responsibility and accountability is not legally enforceable. More importantly, national security and other government programs can be granted orbital debris waivers today, demonstrating that the current regulatory regime contains loopholes in terms of applicability of standards.[18]

2.5.3 The Role of Russia

The Federal Space Agency of Russia is active in the field of space debris problems. The Agency is mostly concerned with the safety of spacecraft and International Space Station (ISS). The activity on debris mitigation is presently being carried out within the framework of Russian National Legislation, taking into account the dynamics of similar measures and practices of other space-faring nations. Since 2000, designers and operators of spacecraft and orbital stages have been asked to follow the requirements of Federal Space Agency's standard entitled, "Space Technology Items, General Requirements for Mitigation of Space Debris Population."

The Russian Federation is now working on a set of mitigation measures. A national standard called "General Requirements to Spacecraft and Orbital Stages on Space Debris Mitigation" is being developed and shall provide general space debris mitigation requirements to design and operate spacecrafts and orbital stages. At this time, the implementation of requirements remains voluntary. In terms of international cooperation, and similar to the U.S. position, the Russian Federation is convinced that development of space debris mitigation guidelines of the Scientific and Technical Subcommittee of the UN Committee on the Peaceful Uses of Outer Space is the essential input in developing an internationally approved set of measures to protect near-Earth space environment. For the disposal of satellite at geosynchronous altitude, Russia also proposes to base the standard on IADC Space Debris Mitigation Guidelines.

2.5.4 The Role of the European Union

ESA has a long history in tracking space debris. In 1986, the Director General of ESA created a Space Debris Working Group with the mandate to assess the various issues of space debris. The findings and conclusions are contained in ESA's Report on Space Debris, issued in 1988. In 1989, the ESA Council passed a resolution on space debris where the Agency's objectives were formulated as follows: 1) Minimize the creation of space debris; 2) reduce the risk for manned space flight, 3) reduce the risk on ground due to reentry of space objects, 4) reduce the risk for geostationary satellites. ESA's Launcher Directorate at ESA Headquarters in Paris also coordinates the implementation of debris mitigation measures for the Arianespace launcher.

Over the last few years, ESA developed debris warning systems and mitigation guidelines. Following the publication of NASA mitigation guidelines for orbital debris in 1995, ESA published a Space Debris Mitigation Handbook, issued in 1999, in order to provide technical support to projects in the following areas: Description of the current space debris and meteoroid environment, risk assessment due to debris and meteoroid impacts, future evolution of the space debris population, hyper-velocity impacts and shielding, cost-efficient debris mitigation measures. The Handbook has already been updated.[19]

2.5.5 The Role of the Inter-Agency Space Debris Coordination Committee (IADC)

The Inter-Agency Space Debris Coordination Committee (IADC) is one of the world's leading technical organizations dealing with space debris. ESA is a founding member of IADC, together with NASA, the Russian Aviation and Space Agency, and Japan. IADC is today an international

forum of governmental bodies for the coordination of activities related to the issues of man-made and natural debris in space. It is composed of the following members: Italian Space Agency (ASI), British National Space Centre (BNSC), the Centre National d'Etudes Spatiales (CNES), China National Space Administration (CNSA), Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), the European Space Agency (ESA), the Indian Space Research Organisation (ISRO), Japan Aerospace Exploration Agency (JAXA), the National Aeronautics and Space Administration (NASA), the National Space Agency of the Ukraine (NSAU) and the Russian Federal Space Agency (ROSCOSMOS).

The primary purpose of the IADC is to exchange information on space debris research activities between member space agencies, to facilitate opportunities for co-operation in space debris research, to review the progress of ongoing co-operative activities and to identify debris mitigation options. Generally speaking, the organizations reached a consensus of adopting the mitigation guidelines as proposed by the IADC. The "IADC Space Debris Mitigation Guidelines" was drafted in 2002 as the first international document that is specialized in field of space debris mitigation and based on a consensus among the IADC members. In February 2003, at the fortieth session of the Scientific and Technical Subcommittee of the UNCOPUOS, the IADC presented the "IADC Guidelines" as its proposals on debris mitigation. This document serves as the baseline for the debris mitigation in two directions: 1) toward a non-binding policy document, and 2) toward applicable implementation standards.[20]

One criticism of the IADC Space Debris Mitigation Guidelines is that they remain voluntary and are not legally binding under international law. Still, IADC is an ideal forum on space debris due to its wide membership among the leading space agencies and provides a basis for further international cooperation when elaborating a space debris convention. Indeed, IADC standards have facilitated the discussion on space debris mitigation guidelines and opened the door to further research related to the cost of mitigation measures. Thus, recently, various studies have been conducted on the effectiveness and the costs of debris mitigation measures. These studies examine a number of important problems: prevention of on-orbit explosions and operational debris release, reduction of slag debris ejected from solid rocket motor firings, de-orbiting of space systems in LEO with various limitations on the post-mission lifetime, and re-orbiting of space systems to above the LEO & GEO protection zones (graveyard orbiting).

2.5.6 The Role of the United Nations

Over the past years, the United Nations On Peaceful Use of Outer Space (UNCOPUOS) and its Scientific and Technical Subcommittee (STSC) have played an important role in debating space debris issues. UNCOPUOS was set up by the General Assembly in 1959 in resolution 1472 (XIV). At that time, the Committee had 24 members. Since then, it has grown to 67 members--one of the largest Committees in the United Nations. In addition to states, a number of international organizations, including both intergovernmental and non-governmental, have been granted observer status with UNCOPUOS and its Subcommittees.

The Committee has the following goals: 1) review the scope of international cooperation in peaceful uses of outer space, 2) devise programs in this field to be undertaken under United Nations auspices, 3) encourage continued research and the dissemination of information on outer space matters, and 4) study legal problems arising from the exploration of outer space. The resolution establishing UNCOPUOS also requested the UN Secretary-General to maintain a public registry of launchings based on the information supplied by states launching objects into orbit or beyond. Those terms of reference have since provided the general guidance for the activities of the Committee in promoting international cooperation in the peaceful uses and exploration of outer space. The Committee is divided in two standing subcommittees: the Scientific and Technical Subcommittee and the Legal Subcommittee. The Committee and its two Subcommittees meet annually to consider questions put before them by the General Assembly, reports and issues raised by the Member States.

The agenda of the Committee is quite large. For instance, the forty-fourth session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space was held from 12-23 February 2007 at the United Nation Office at Vienna. The session covered a wide array of issues, including space debris; matters relating to remote sensing of the Earth by satellite, including monitoring of the Earth's environment; use of nuclear power sources in outer space; near-Earth objects; space-system-based disaster management support; physical nature and technical attributes of the geostationary orbit; etc. The Committee has also been concerned with space objects with nuclear power sources on board and problems relating to their collision with space debris.

The United Nations Office for Outer Space Affairs (UNOOSA) implements the decisions of the General Assembly and of UNCOPUOS. The office has the dual objective of supporting the intergovernmental discussions in UNCOPUOS and of assisting developing countries in using space technology for development. The Office is the focus of expertise within the United Nations Secretariat. It serves as the secretariat for the intergovernmental Committee (UNCOPUSOS), and implements the recommendations of the Committee and the United Nations General Assembly. The Office is also responsible for organization and implementation of the United Nations Programme on Space Applications (UNPSA).

UNPSA is part of the Office for Outer Space Affairs. Its mission is stated as follows: "Enhance the understanding and subsequent use of space technology for peaceful purposes in general, and for national development, in particular, in response to expressed needs in different geographic regions of the world."[21] Its primary function is the organization of a series of 8-10 annual seminars, workshops, and conferences on particular aspects of space technology and applications. These activities are organized primarily for the benefit of the developing countries and emphasize the use of space technology and applications for economic and social development. In the past years, the space debris issues have not been part of the curriculum of the workshops and seminars. The Programme also provides technical assistance to Member States of the United Nations in organizing and developing space applications programs and projects.

2.6 The Corporate and Civil Society Perspective

2.6.1 The Corporate Responsibility

The role of space corporations is seen as important because commercial activity in space is increasing and thus potentially creating more debris. Until recently, space debris was a subject fraught with uncertainties, usually shunned by aerospace corporations around the world and

inadequately addressed by many space agencies. As the issue gained prominence in the mid-1990s, the private sector has been seeking to find the most appropriate response to address the space debris problem. However, the space industry has been struggling to provide the required solutions. As competition has increased and profits have shrunk, many of the space corporations have adopted "lean" approaches, the "better, faster, cheaper" concept resting on the interconnection of decreased mission costs and increased risk. Most of the time, the prudent vehicle design and related operation that may decrease the level of debris are coming at a cost that is perceived too high by the industry.

At a time when there is so much talk about the commercialization of space and space tourism, it is important to raise the awareness of the space industry that it is in the interest of all parties to find the best and most acceptable solution to the problem. Today, space corporations around the world are rightly considered the first line of defense for preventing debris to accumulate. As space activity increases, the accumulation of debris is also on an upward trend. Over the recent years, companies have been facing new demands to engage in public-private partnerships and are under growing pressure to be accountable not only to shareholders, but also to society-at-large.

When addressing the problem posed by space debris, it is thus time to include the space industry in the international effort to tackle this pressing issue. The space industry does not bear the responsibility for leveling the playing field and ensuring that space free of pollution. However, government and the private sector must construct a new understanding of the balance of public and private responsibility and develop new governance for activity in space and thus creating social value.[22]

2.6.3 The Role of Civil Society

The number of non-profit organizations in the area of space is considerable. Many of them have gained prominence. I can mentioned the following: the American Astronautical Society that offers society overview, news, publications, schedule of events, member services and scholarship information; the British Interplanetary Society; the International Space Business Council; the Committee on Earth Observation Satellites (CEOS) which provides newsletters, events and publications related to space agencies responsible for earth observation. More scientific and professional associations are also very powerful, i.e. the Forum for Aerospace Engineers or the Foundation for International Development of Space. In the area of space debris, the Center for Orbital and Reentry Debris Studies contains information in the areas of space debris, collision avoidance, and reentry breakup. The Center is part of the Aerospace Corporation, a nonprofit corporation originally serving the U.S. government in the scientific and technical planning and management of its space programs. Web-based organizations are also a source of diffusion of various space information, i.e. Space-Talk, which provides message forums about space, astronomy, and related topics.

However, these non-for-profit and non-governmental organizations (NGOs) have had a limited role to play in the field of space in the recent years. Unlike the representatives of citizen organizations, which are increasingly active in policy making in the traditional field of expertise such as human rights, women's right, the environment, and sustainable development, the space NGOs are not the most effective voices when it comes to space pollution. Although we see many

NGOs working closely with the United Nations departments and agencies, the civil society groups are not involved with UNCOPUOS' space activity and debris mitigation work.

I conclude this chapter by saying that the evolving spacecraft technologies, together with stricter enforcement of orbital debris mitigation regulations, present significant challenges but also opportunities for forward-looking satellite and launch vehicle operators and manufacturers. It is obvious that private sector corporations have everything to gain by equipping themselves with strong mitigation tools to prevent an accumulation of space debris. Together with the civil society organizations, they must participate vitally in the international system that will draft a space debris legal regime. They have the capacity to contribute valuable information and ideas, advocate effectively for positive change, provide essential technical capacity, and generally increase the accountability and legitimacy of the global governance process.

3. POLITICAL AND LEGAL FRAMEWORK GOVERNING SPACE ISSUES

3.1 Review of Existing Treaties, Conventions and Agreements Regulating Space Activities

3.1.1 Space Law Infancy

Before turning to the modalities of a space debris convention, I will review some of the existing conventions regulating space activities. One of the main problems of existing space law is that it does not address issues of controlling and limiting the proliferation of space debris. Furthermore, satellite and launch-vehicle manufacturers are not presently legally bound to employ mitigation measures.

It is important to note that the field of the space law is still in its infancy. The inception of this field began with the launching in October of 1957 of the world's first satellite by the Union of Soviet Socialist Republic. In 1958, United States and Soviet leaders each asked the United Nations to consider the legal issues associated with space activity. The United Nations subsequently created the previously discussed UNCOPUOS.

Many conventions have been enacted, but the main treaties and conventions were drafted at the beginning of space exploration in the 1960s and 1970s, and under the political and military pressure of the space race between the U.S. and the former Soviet Union. They fail to account for the rapid changes in today's field, where commercial space transportation is becoming widely available with substantially lower launch costs and new countries are becoming active in space exploration. The market for commercial space launchers has witnessed rapid growth over the past several years. The exiting treaties and conventions fail to account for this reality.

The first key treaty, the Outer Space Treaty, was established in 1967. The Treaty has 96 state parties signed on and contains a measure to not place in orbit around the Earth, install on the Moon or any other celestial body or otherwise station in outer space, any weapons of mass destruction, nuclear or otherwise. It limits activities on the Moon and other celestial bodies exclusively to those for peaceful purposes and forbids the development of military bases, installations, fortifications or weapons testing of any kind on any celestial body. In 1979, a similar treaty was published, and opened for signatures. It aims to achieve the same rules for other celestial bodies. However, probably because of its provisions prohibiting the ownership of

real estate in space, the treaty was virtually ignored by the world community. Only nine countries have ratified and just five others have signed it.

Other treaties have been presented and ratified, including treaties on the registering of objects launched into Outer Space, agreements on the rescuing of astronauts, and rules on international liability for damage caused by man-made space objects.
(See Table 1 summarizing the five most important space treaties and conventions.) The treaties all elaborate on provisions of the Outer Space Treaty. The Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water (5 August 1963) is targeted to control nuclear weapon proliferation. This treaty recognizes that space can be used for undesirable military projects. It bans the carrying out of any nuclear weapon test explosion or any other nuclear explosion in the atmosphere and beyond its limits, including outer space.

3.1.2 Failure to Recognize Space Debris in Legal Regimes

There is a critical weakness in the international law on space debris. Existing space law is related to the use of space and not to debris regulation. Most of existing treaties have been overtaken by technology advancement. While the rules developed by the Outer Space Treaty or the Registration Convention are useful, it does not apply to the space debris issue. This means that commercial and government-sponsored space launches can still create more debris without limits. Today, any country or corporation can launch a rocket and/or place equipment into orbit without permit. The only constraint is that they are required to record the launching as stipulated under the Registration Convention.

Furthermore, nothing is said about the destruction of satellites in space and the creation of space debris resulting from it. In international law, nothing can prevent a nation from destroying one of its own satellites. In the end, China was free to target one of its old weather satellites with an ASAT weapon and blow the spacecraft apart because 1) it can; and 2) ASAT testing is not forbidden under international law. The arms control provisions of the Outer Space Treaty forbids the placing of nuclear weapons or any other kinds of weapons of mass destruction in orbit. The treaty also forbids establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on the Moon and other celestial bodies (Art. IV). However, nothing is mentioned about spacecraft destruction and space debris thus created.

Recently, in February 2007, the UN reached a consensus on the draft of space debris mitigation guidelines and adopted them.[23] However, all of the existing guidelines remain voluntary and are not legally binding under international law. At the UN level, some nations have expressed the view that a legally non-binding set of guidelines was not sufficient. Some delegations at the Scientific and Technical Subcommittee (UNCOPUOS) expressed the view that the Subcommittee should consider submitting the space debris mitigation guidelines as a draft resolution of the General Assembly rather than as an addendum to the report of the Committee. At the meeting of UNCOPUOS on February 2007 in Vienna, the view was also expressed that the states largely responsible for the creation of the present situation and those having the capability to take action on space debris mitigation should contribute to space debris mitigation efforts in a more significant manner than other States.

Indeed, the adoption of voluntary guidelines is a major step for proposing a cooperative approach to solving emerging problems related to space debris. However, non-binding guidelines may not prove sufficient. This is why some countries are proposing a set of rules and calling for a legal regime to be implemented.

3.1.3 Weakness of the Space Liability and Dispute Settlement Mechanism

The 1972 Convention on International Liability for Damage Caused by Space Objects, commonly known as the "Liability Convention,"[24] sets forth the rules for personal injury and property damage and for resolution of those issues at the international level. Articles I and II of the agreement, for instance, provide that a country which launches or procures the launching of a space object or from whose territory a space object is launched, is liable for damage caused by its space object on the surface of the earth or to aircraft in flight. With respect to damage caused elsewhere than on the surface of the earth, however, the notion of liability is not clearly established.

The notion of direct damage is established under Article VII of the Outer Space Treaty. It says that each "State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the moon and other celestial bodies."[25] However, there is a terrifyingly large legal gap when it comes to dispute resolution and compensation mechanisms. The issue of liability protocols in case of a commercial disruption by debris is also not covered by any convention.

Right now, the dispute resolution mechanism is informal. Article III Outer Space Treaty says that parties to the treaty shall carry on activities "in accordance with international law, including the Charter of the United Nations."[26] Article 33 of the UN Charter says that parties shall first "seek a solution by negotiation, enquiry, mediation, conciliation, arbitration, judicial settlement, resort to regional agencies or arrangements, or other peaceful means of their own choice."[27] In the event that such means fail to achieve a resolution of the issue, Article 36(3) indicates "legal disputes should as a general rule be referred by the parties to the International Court of Justice."

In the absence of an agreement establishing binding procedures for the field of space law, it is likely that most national governments will seek to continue to resolve their disputes through the existing diplomatic channels. Private parties to a dispute, i.e. a commercial firm, would therefore be at a disadvantage under the existing regimes. For this reason, it is advocated that an international convention set up the mechanism for resolving disputes, both public and private.

3.2 The Five Main Treaties Regulating Outer Space

There are five international treaties negotiated and drafted under the United Nations auspice at the COPUOS and adopted by the United Nations General Assembly. However, because some space-faring nations are not signatories to all treaties, there is no fully international agreement to abide by this body of law. They are summarized in the Table 1.[28]

Before I turn to the discussion on the proposed convention on space debris, I conclude that the

present outer space regimes have no coverage of the space debris problem. The paucity or outright absence of law regarding certain key subjects such as liability and dispute resolution is causing concerns for the future. Under the scenarios discussed in Chapter 2, some regions of space are not safe anymore. Some governments and private sector actors are unsure of their rights and have no assurance that their efforts to go to space will be legally protected. This is why an international legal regime is proposed with new laws that would encourage a peaceful use of space for all.

Table 1 - Outer Space Treaties, Conventions and Agreements

Name of Treaty/ Convention	Short Name	Date of Signature and ratification/ signature (As at 1 January 2005)	Main Objective(s)
Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies[29]	The Outer Space Treaty (OST)	Adopted on 19 December 1966. Entered into force on 10 October 1967 Ratified by 98 nations and signed by 27	Establish a framework for international space law; provide that space shall not be subject to national appropriation and that exploration and use of space shall be for the benefit of all countries; limits military use of space.
Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space	The Rescue Agreement (ARRA)	Adopted on 19 December 1967. Entered into force on 3 December 1968 Ratified by 88 nations and signed by 25	Call for the rendering of all possible assistance to astronauts in the event of accident, distress or emergency landing. Establish a procedure for returning space objects found beyond the territorial limits of the launching authority.
Convention on International Liability for Damage Caused by Space Objects	The Liability Convention (LIAB)	Adopted on 29 November 1971. Entered into force on 1 September 1971 Ratified by 82 nations and signed by 25	Provides that the launching State is liable for damage caused by its space objects on the Earth's surface or to aircraft in flight and also to space objects of another State or property onboard such objects.
Convention on Registration of Objects Launched Into Outer Space	The Registration Convention (REG)	Adopted on 12 November 1974. Entered into force on 15 September 1976 Ratified by 45 nations and signed by 4	The Convention provides that launching States shall maintain registries of space objects and furnish specified information on each space object launched, for inclusion in a central United Nations register.
Agreement Governing the Activities of States on the Moon and Other Celestial Bodies	The Moon Treaty	Adopted on 5 December 1979. Entered into force on 11 July 1984 Ratified by 11 nations and signed but not ratified by 5	Provide that the Moon and its natural resources are "the common heritage of mankind" and that an international regime should be established to govern the exploitation of such resources when such exploitation is about to become feasible.

4. A PROPOSAL FOR AN INTERNATIONAL CONVENTION ON SPACE DEBRIS

The questions thus become: What to do to prevent the further increase of space debris? How to reconcile the military and public policy dimensions and especially avoid a new weapons race in the space? How to negotiate a convention leading to the implementation of appropriate orbital debris mitigation policies and guidelines?

4.1 Opportunity of a Legal Regime for Space Debris

I advocate the necessity to draft and negotiate an international convention on space debris. However, I do recognize that negotiating a comprehensive convention with legal status is a long and intense process. Furthermore, the regime governing space debris to be created by this instrument would have significant legal and political consequences. The main issues are how to decide on the scope of such a convention and attach to it a proper monitoring and dispute settlement mechanism.

In the past, these issues have proven to be problematic. Treaty negotiators have revisited many issues that have been a source of debate for years, even centuries. Who has the right to participate in the drafting of such an instrument and how should nations insure implementation of the convention by all signatories? Should a new convention be developed from scratch or would a Memorandum of Understanding or some other informal agreement suffice? If a new convention is needed, should it be framed on a global scale? From a technical and political point of view, who should be part of such a treaty-making process? What organization can take the lead and how should compliance and monitoring be insured in a fair and equitable basis? These are the main questions that the negotiators have to answer before reaching a compromise.

4.2 Memorandum of Understanding, Code of Conduct or Convention?

Experts and policy-makers diverge on the types of instrument and scope for dealing with space debris. Various proposals have been suggested, including: a Memorandum of Understanding (MOU) among space-faring nations; a code of conduct; or a broader convention. When the current work at UNCOPUOS is taken into account, one realizes that the scientific community would likely be satisfied with a framework that would seek to mitigate debris in space. Some nations would also prefer to have a set of binding instruments with a wide coverage, including registration of debris, mitigation, and dispute settlement.[30] From interviews with various experts, however, I realized that the questions relating to liability, system design, and compensation of damages caused by debris are not included in the present discussions on space debris.
One approach advocated by the Henry L. Stimson Center's Space Security Project is the negotiation of a code of conduct between space-faring nations to prevent incidents and dangerous military activities in space.[31] Key activities to be covered under such a code of conduct would include avoiding collisions and simulated attacks; creating special caution and safety areas around satellites; developing safer traffic management practices; prohibiting anti-satellite tests in space; providing reassurance through information exchanges, transparency, and notification measures; and adopting more stringent space debris mitigation measures.

Codes of conduct have already been used in international relations. These codes gained currency when instituted to deal with the threats posed by arms proliferation. During the Cold War, the United States entered into executive agreements with the Soviet Union to prevent dangerous

military practices at sea, on the ground, and in the air. As such, the 1989 Prevention of Dangerous Military Practices Agreement signed by Washington and Moscow continues to have great value and provides "rules of the road" to help prevent incidents and dangerous military practices. However, codes of conduct are indeed very difficult to implement among nations. They have no binding or enforcement mechanisms and it is very difficult to have all powers agree on the scope of such codes.

On the other hand, a convention is a legally binding agreement. Once a convention has been "adopted" (meaning that it is open for countries to join), countries can choose whether or not to join a convention. When they choose to join, they become "States Parties" and must comply with their obligations as described in the convention. When enough countries become States Parties, then the convention "enters into force," meaning that it becomes active and parties must act to implement their obligations under the convention. The convention must be ratified at the national level before it is in force. A convention that has been signed but not ratified has little value. Only by signing and ratifying the convention are governments legally required to follow the recommendations of those documents.

Whatever the type of instrument chosen, the recognition and enforcement of one legal system to another has long been understood as a fundamental requirement for dealing satisfactorily with global issues. For many countries, the enforcement of international treaties is not a matter of general international law but is addressed through national negotiations, issues of sovereignty being of prime importance. This is why public awareness is so critical in dealing with space debris. If the general public is not aware of the situation, it is unlikely that politicians will put the problem on the top of their agenda. Without public awareness, the ratification process will be a struggle.

4.3 Framing and Drafting a Convention: Challenges and Opportunities

I believe that the way to limit the impact of space debris is to adopt a new convention that can be ratified and implemented by all space powers. The need for an international convention is based on the view that a set of international rules is needed to reduce the growth of orbital debris along with a legal regime under which liability and compensation can be assigned. Given the amount of debris in orbit, the entire space community is ready to take initiative because debris impacts can severely affect space operations and threaten the occupants of manned spacecraft. Indeed, it is crucial to internationally introduce new rules and to involve the space powers in generating a common framework governing space debris.

The space powers have much to gain from a strong, well-crafted multilateral instrument that removes or minimizes the many procedural and technical obstacles that can delay efforts to resolve the problem. Although international cooperation in the space debris field is substantial, all major players need to recognize that circum-terrestrial space is a strategic resource that must be better managed. All reasonable and practicable efforts must thus be taken to preserve it for future generations.

I propose that the convention have the following broad purposes:

1. Increase the visibility of space debris problems, within the scientific community and civil society in general;

2. Clarify the obligations of governments with respect to space debris and ensure that governments who become States Parties to the convention make legislative and programmatic changes at the national level to implement their legal obligations under the convention; and

3. Establish systems for international cooperation through which governments, space organizations, and other actors can share knowledge and ideas and work together to reduce space pollution and the dangers now posed by existing pollution.

4.4 Defining the Scope of the Convention

I am advocating a focused approach to increase the likelihood of success of a convention on space debris. The wider the scope, the more difficult it will be to implement a convention. This is why a proposed convention should be aimed at making progress in the area of risk and liability by: (1) requiring signatory countries to make certain substantive commitments for limiting space debris and providing compensation if they are deemed liable; (2) requiring Parties to adopt domestic procedures to match international standards and guidelines; and (3) providing a solid basis for international compliance and cooperation for limiting the level of space debris.

The overall purpose of a convention can be organized around four main objectives:

Objective 1: Independent Tracking and Cataloguing of Space Debris

Before determining the most effective measures that should be taken to solve the space debris problem in Earth orbit, it is essential to quantify the problem not only in terms of the current orbital debris environment, but also in terms of future growth potential absent remedial action. Such initiative cannot be solely carried out independently by states. In doing so, there will be a risk that data are not made available or manipulated in case of major disagreement and international litigation if a major incident occurs.

I propose that internationally independent and harmonized procedures for data quantification of space debris be the first objective. The convention should also encourage the tracking of small-size debris. An official register of space debris must be maintained and operated by an independent agency (i.e. the UN), and has the capacity to catalogue debris and make the information available to the entire community. Today various tracking and monitoring initiatives have been implemented by space-faring nations and it is important to put in place a common effort to quantify the problem. In doing so, signatory members of the convention would have the means of reducing the gaps in space situational awareness. More importantly, I advocate that an independent tracking system be implemented under the auspice of the United Nations or another independent body. At present, too many nations have tracking capabilities for space debris. The leading authority for debris tracking is the U.S. Space Surveillance Network (SSN). The USSSN publishes the Satellite Catalog and tracks objects in LEO at least 10 cm in diameter. New entrants have made the case for developing their own capabilities.

Europe has its own Space Debris Advisory Group (SDAG) and the French military ship Monge can detect objects of about 2 cm in size at a range of 1000 km. ESOC, ESA Space Operations Centers, is also coordinating all space debris research activities within ESA and maintaining a database on known space objects called DISCOS. ESA's activities are harmonized with European national space agencies with specialists from national organizations and institutes in Europe (via the Space Debris Advisory Group SDAG) and outside Europe (via the Inter-Agency Space Debris Coordination Committee IADC). A space-debris-monitoring-center was opened in China in March 2005. The CAS Space Object and Debris Monitoring and Research Center have been founded at the Purple Mountain Observatory (PMO) in Nanjing and it will build a security warning system in China's spaceflight field against space debris.

Debris below 1 cm can be mitigated, i.e. by developing new spacecraft design and shielding systems. However, the objects between 1 cm and 5 cm are numerous and difficult to detect. As a result, an effort should be particularly targeted at smaller debris (less than 5 cm) that are the most difficult to identify and track. Debris above 5 cm is currently catalogued and tracked, but still, a consensus must be achieved in doing the quantification work under a single agreed methodological approach.

Indeed, there is a need to construct a uniform database from existing catalogues of space objects and new tools and models must be developed to deal with the risk of exponential growth of space debris.[32] This uniform database will be maintained by the UNOOSA secretariat. Specific procedures will need to be drafted and enforced to ensure that UNOOSA collects information and data in a timely and exhaustive manner. In addition, the UNOOSA secretariat will need to recoup the data from the different nations and ensure their veracity. It is proposed that UNOOSA make this information available on-line for full access by the space industry, civil society, and the general public.

Objective 2: Adoption of Enforceable Space Debris Mitigation and Disposal Standards

I advocate the need for international standards that can enforce appropriate debris mitigation and disposal measures for spacecraft and launch services providers. Although the voluntary implementation of debris mitigation and disposal measures by many space operators have shown a changing trend toward a safer environment in the LEO and GEO region, competition and new entrants in the market may change this reality.

I do not believe that a pledge to avoid creating persistent space debris by following voluntary-adopted guidelines is sufficient. The Chinese test has proven that international efforts to mitigate space debris can be easily challenged. Still, in recent years, China has made several proposals to the UN Conference on Disarmament on possible elements for a future treaty banning the weaponization of space.[33] In 2002, China also expressed its intention to follow the IADC mitigation guidelines. Enforceable space debris mitigation measures are therefore much needed.

Several national and international organizations of the space-faring nations have established their own space debris mitigation standards or handbooks to promote efforts to deal with space debris issues. NASA (USA), CNES (France), NASDA (Japan), RASA (Russia) have elaborate procedures that should be harmonized into a single framework. Although most states agree that it is important to comply with some mitigation standards, there are however different expectations on various technical issues, i.e. reorbiting of satellites, passivation (deactivating equipment), end-of-life operations and development of specific software and models for space debris. Today, due to the lack of global conventions, there are no legal means for forcing the adoption of a uniform set of rules by state members.

I am aware that the adoption last February 2007 of the UNCOPUOS STSC "Space Debris Mitigation Guidelines" sets in motion a means of achieving the goals of reaching an agreement on mitigation guidelines. The endorsement of these guidelines by the full UNCOPUOS is expected in June 2007, followed by a possible endorsement by the UN General Assembly before the end of the year. This is a major step forward for creating a uniform set of mitigation guidelines at the UN and the Working Group on Space Debris has successfully developed draft space debris mitigation guidelines.

However, a more comprehensive and binding system is needed to account for the existing space pollution and new space-faring countries and international corporations entering the market. This is why I support the idea of a framework convention that would provide this set of binding procedures agreed to by a large consensus. Under the convention, a mechanism would facilitate coordination and implementation of the guidelines. I would strongly stress the need for a high-level intergovernmental mechanism to ensure compliance and monitoring. Despite the various efforts to avoid debris, the situation is unlikely to improve unless concentrated, coordinated, and systematic steps are taken to mitigate the risks that are now so clearly understood. As a result, the convention must urge that every user of the various space orbits remove its space object from orbit after its work is completed to eliminate danger to other users. This is why the space industry and professional associations have to be associated with the drafting of a space debris legal regime.

Objective 3: The "Space Preservation" Provision

A convention should also propose that some orbital regions be protected because of their scientific and economical importance. Examples here might include the Low Earth Orbit (LEO), ranging up to 2,000 km altitude, and Geostationary Earth Orbit (GEO), about 36,000 km altitude.

The international convention would ensure that no orbital debris creation takes place within these protected regions. To do so, the convention regulating space debris must incorporate a "Space Preservation" clause that would prohibit the creation of major pollution in such zones. Within the Space Preservation Provision, parties to the convention would be compelled to follow the internationally agreed standards for debris mitigation. Any party to the convention infringing on the agreed mitigation guidelines would have a penalty to pay. At the same time, the convention would implement a mechanism of conditional launch license issuance for space operators, depending on the acceptance of space debris mitigation procedures. The same measures would apply to military activities in space.

The idea of "Pollution permits" could also be developed. Under the convention, a cap would be set that reduced on a declining scale the amount of space debris being generated. Nations and operators would be issued tradable certificates that matched their share of the cap. Parties that cut space debris below their cap would have extra certificates to sell to other parties that could not meet their goals. This policy would encourage the development and adoption of space debris

mitigation and disposal measures. It should be noted that emissions trading for reducing pollution has been successful in the context of various environmental programs. Experience shows that properly designed emissions trading programs can reduce compliance costs significantly.[34] The mechanism for trading debris could work as follows:

Table 2: Pollution Permit Mechanism for Space Debris

Pollution Permit System and Emission Trading[35]

Pollution permits work by obliging polluters to pay for their noxious emissions. Consequently, they have a clear incentive to make real reductions. A Space Debris emission trading system would be set up to allow stakeholders to the convention to define the overall level of space pollution that is socially acceptable, and then issue tradable permits corresponding to that amount.

Corporations and space agencies who wish to pollute must hold permits equal to their pollution quotas. This market-based approach to pollution control would therefore provide firms and space agencies with economic incentives to minimize pollution as they can sell unused permits to other firms or agencies rather than being charged regulatory penalties, which tend to have high costs.

Therefore, the firms and agencies adopting mitigation guidelines would be given financial incentives. Cleaner companies benefit, while polluters are forced to pay to acquire additional permits. This puts them under pressure to cut back on their emission levels in order to maintain their competitiveness and their reputation; and it is a social benefit to the entire environment if they can. If the nature of the production process makes it hard or very expensive for them to reduce emissions, they can only continue doing so by striking a deal with other firms or agencies that have already made cuts. So the overall environment gains, either way.

In the United States, the emission trading systems have been quite successful. The Acid Rain Program launched in 1995 allowed companies to trade permits in sulfur dioxide, which is mainly produced by power generators burning high-sulfur coal. The results have been better than planned. So far the initiative is ahead of target with participating firms reducing compliance costs by up to 50 percent. The U.S. Acid Rain Program is based on two key criteria that encourage successful emissions trading: first, there needs to be an established regulatory and monitoring regime that pursues explicit reduction targets; and secondly, the source of pollution must be clearly traceable.[36]

The technical realities of cleaning up the space environment must also be addressed by a convention. One of the most important measures to adopt is the removal of inactive satellites and other equipment from earth orbit. Although such an initiative has cost implications, it is important to propose clear recommendations of disposal of dangerous objects. Proposals for the "clean-up" of the satellite-crowded geostationary region may include the use of special towing spacecraft to detect, capture, and transfer defunct objects to storage orbits, the establishment of space platforms with separable one-time towing modules and the transfer of uncontrollable objects to higher orbits to prevent their descent to Earth.

These issues are complex and can only be addressed if space powers are committed under an enforceable framework. Signatory parties could create a sub-committee to make on- going practical recommendations for cleaning up pollution from the most hazardous material. As pointed out by Nicholas Johnson, Chief Scientist at NASA, the success of any environmental remediation policies will probably be dependent on the development of cost-effective, innovative ways to remove existing derelict vehicles. The development of any new technology to remediate pollution in space certainly requires both governments and the private sector working together. Without environment remediation and definition of protected zones, the risks to space system operations in near-Earth orbits will continue to climb.

Objective 4: Liability, Compensation, and Dispute System Design

Disputes are a reality of modern life that can be costly and painful if not addressed quickly and fairly. With the rise of private activities in space, questions of the control of such activity arise, especially those of responsibility and liability.[37] Even if nations can easily agree on tracking and mitigation measures, there is still the question of liability in specific situations and how to resolve disputes.

For instance, if a debris cloud from one satellite causes damage to another, whose responsibility is it? Imagine that the recent Eutelsat satellite equipped with 64 transponders to be part of a fleet transmitting up to 950 television channels and 600 radio stations to 110 million cable customers in Europe, North Africa, and the Middle East is lost due to a collision. The impact would be immense from a societal and business perspective. Who pays for the damage? What about consequential losses, i.e. loss of business due to a major disruption in satellite telecommunication? Should a polluter-payer mechanism be put in place or should spacecraft owners be fully covered under specific insurance policies, if possible?

The space debris convention needs to consider the question of liability. First, the cost of equipment is important in the space industry and any destruction could lead to massive loss of assets and business. Second, some debris present serious hazards, i.e. nuclear powered satellites. Thus, the convention should also be aimed at defining a liability and compensation regime for damage. As commercial space activities increase with new space powers entering the field, it is crucial to ensure that the space equipment on which we rely on for communication and other purposes can be safely operated while in orbit. In case of damage, loss and major disruption, it is crucial to have a dispute handling mechanism in place to determine liability and claims compensation.

It is also important to consider the liability issue for re-entry debris. For instance, in 2006, a total of 237 spacecraft, launch vehicle orbital stages, and other cataloged debris reentered during the year. No instances of injuries or property damaged were reported. Of this 237, the total number of uncontrolled reentries was 223, including 13 payloads and 31 launch vehicle orbital stages with a total mass of about 70 metric tons.[38]

A few victims are said to have been injured in the past. Lottie Williams is on record as the first and only person ever to be hit by man-made space debris. While walking in a park in Tulsa, Oklahoma, on January 22, 1997, she noticed a light in the sky that she said looked like a meteor. Minutes later, she was hit in the shoulder by a 6-inch blackened metal object that was later confirmed to be part of the fuel tank of a Delta II rocket that had launched a U.S. Air Force satellite in 1996. On October 10, 2006, a cottage in Germany was burned down by a fire that was believed to be started by a small debris (no more than 10mm) and a 77-year-old man was injured by the fire.

As a result, compensation for damage and injury or death caused by space debris should be governed by an international regime elaborated under the auspices of the UN. I suggest that the "Convention on International Liability for Damage Caused by Space Objects" be extended to cover space debris and define the dispute handling mechanism in more details. The convention would lay down the principle of strict liability and create a system of compulsory liability

insurance. In terms of damage coverage, space equipment is usually covered by insurance policy. Coverage is usually split into the launch and in-orbit phase. The launch part is particularly risky and includes transport of the satellite through the Earth's atmosphere into space, the positioning of the satellite in orbit followed by commissioning and testing of all systems. The in-orbit policy, usually renewed yearly, covers damage to the satellite caused by technical failures, the harsh space environment with extreme temperatures, high solar radiations and solar flares, and exposure to meteoroids. Orbital debris is usually covered as well. On the other hand, space equipment beyond normal years of operation but still providing a service is not necessarily covered.

Because insurance companies are risk-adverse, it is likely that they will discontinue their coverage when the risk posed by space debris becomes unbearable for them. This is the reason why the proposed convention needs to incorporate a specific mechanism for settling disputes. While several mechanisms can help parties reach an amicable settlement (for example through mediation), all of them depend, ultimately, on the goodwill and cooperation of the members. This is why the convention must establish a method to reach a final and enforceable decision in a cost-effective manner. I propose the creation of a Dispute Board, set up at the outset of the convention. In Section 4.5, I provide the details of a proposed dispute mechanism.

4.5 A Space Debris Convention: Implementation Strategies

The complex interactions and procedures by which a space debris convention must be formulated, ratified, and implemented are cumbersome. In order to guarantee improvements, it is important to have a clear sense of purpose, with objectives clearly defined in the beginning. However, such an organization imposes new financial burdens on member states and, thus, requires a pooling of financial and technical resources, rather than relying on individual and national initiatives that currently duplicates one another.

4.5.1 Timing of the Space Debris Convention

There is the question of when: "Why worry about space debris and why propose a multi-lateral convention now?" Drafting, implementing, and ratifying a convention is a lengthy process. Indeed, it takes time to organize, especially with delegates working in various groups all over the world. The time and place have to be agreed upon well in advance and then delegates, sponsors, speakers, special guests, and others can arrive to discuss proposals. A successful convention is therefore a logistical exercise that depends on starting with a precise and detailed plan. I advocate drafting a plan for a space debris convention as soon as possible.

Other factors make it necessary to consider a convention now. First, from a commercial perspective, space activities are on an upward trajectory and new space powers are entering the commercial launching and space exploration market. As a result, most experts agree that space debris will continue to grow in the coming years. It should also be noted that space debris[39] will increase exponentially as compared to payloads.

Second, from a technical perspective, random collisions will soon start to occur and produce even more fragments. Under the "business-as-usual" scenario for future space flight activities, we should expect higher level of interactive collisions among larger, catalogued objects. Thus, fragments from collisions will grow to dominate the man-made debris that are larger than 1 cm in diameter. When orbiting debris collides, it usually does so at such a speed that it is more than pulverized; it is liquefied and turned into not one or two, or even dozens--but millions of new fragments. All of them are hazardous. This process of "collisional cascading" will result in a non-linear growth (collisional fragments that will trigger further collisions).

Third, a convention is needed to reduce hazardous objects in space. A less well known threat is that posed by earth satellites and equipment carrying hazardous materials. As a notorious case, the Radar-equipped Ocean Reconnaissance SATellite or RORSAT is an example. These nuclear-powered satellites were launched between 1967 and 1988 by the Soviet Union to monitor NATO and merchant vessels using active radar. Many incidents have occurred. As mentioned in Chapter 3, the satellite Cosmos 954 failed to boost into a nuclear-safe storage orbit as planned. Nuclear materials re-entered the Earth's atmosphere in 1978 and left a trail of radioactive pollution over an estimated 124,000 km^2 of Canada's Northwest Territories. Cleaning up the environment remains a technical and economic challenge but guidelines will at least start the process under the convention.

It will take time for the international community to draft a convention on space debris. The negotiations process itself may span several years. Negotiations on such a convention should begin soon so that countries can get down to the business of implementing the convention and mitigating the global problem of space debris.

One example of a convention which was drafted and implemented effectively and swiftly is the "Ottawa Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction." The work started in October 1996 at a conference in Ottawa, Canada by 50 participating countries, 24 observer states and dozens of international and non-governmental organizations. In the months following the conference, a 111 states' meeting was held in Vienna, Austria, in February 1997 for the first discussion of a draft convention. In June 1997, at a follow-up meeting, 97 countries signed the Brussels Declaration announcing their support for a convention to ban anti-personnel mines no later than December 1997.

The Convention was then negotiated over the course of three weeks in Oslo, Norway, in September 1997, with international and non-governmental organizations continuing to play an unprecedented role in the process by joining government delegations at the negotiating table. In December 1997, representatives from 150 governments attended the convention signing conference. One hundred and twenty two countries signed. By signing, countries signaled their intention to adhere formally to the instrument at a later date once the ratification at the national level was completed. They also promised to do nothing to undermine the objective and purpose of the convention. Less than nine months after the 1997 signing ceremony, 40 states had formally agreed to be bound by the convention by ratifying or acceding to the Convention – the number required for the Convention's entry-into-force. With this milestone having been achieved, the Convention entered into force on March 1, 1999.[40] This was a two and a half year process.

The Ottawa Convention process illustrates that the drafting, negotiating, and implementing of a convention can be done under a tight time frame. This is particularly true for a well-focused convention arising within a context of mounting political pressures.

4.5.2 Mobilizing and Finding Sponsoring States and/or Organizations

Obviously, an idea that eventually becomes an international convention on space debris originated in the brain of one person, though in retrospect it may be impossible to identify the original author. The creative process may also have been a substantially collective one from the very beginning. In any case, someone or some group has to put forward a proposal that will enter the consciousness of the international community.

Existing groups can lead the process, i.e. IADC or members of UNCOPUOS. The lead for proposing a convention on space debris may also come from a few space-faring nations, i.e. the ones creating the most debris today. However, it should be noted that, to date, the U.S. has been reluctant to participate in the drafting of such an international convention. The main reason is that a majority of the debris has come from the U.S. since the 1960s. The country prefers the adoption of voluntary guidelines, instead of a more stringent binding regime (See also Figure 3).

New entrants to the space market also have a crucial role to play and may wish to seize the opportunity to forward their agenda by creating a consensus and speaking with one voice. Indeed, it is important for the convention not be limited to just the major powers.

It should include the rapidly developing societies such as China, India, Korea, Brazil, Ukraine and many others. Most of these countries are now developing space programs. The organization and drafting of the convention has to be as democratic as possible and allow broad-based ownership of ideas. Many countries without space activities claim that they want to have the possibility to use space in a safe manner in the future. Therefore, the convention should not be limited to existing space powers. It should encourage the participation of all interest groups. Rather than a "treaty of scientific specialists," the convention has to encourage active involvement of all space powers as well as countries with an interest in shaping international space policy.

I propose that the convention go through the UN General Assembly; first, specific countries will have to put the idea of the convention on their political agendas. The members of the STSC group at UNCOPUOS constitute a reference group that could take the lead. This group must clearly include the most visible space-faring nations that are at the source of the space debris problem, including but not limited to Europe, China, and Russia.

4.5.3 Entry point for the space debris convention

The United Nations Office for Outer Space Affairs (UNOOSA) and its Committee on the Peaceful Uses of Outer Space (UNCOPUOS) are ideally suited to be the natural and legitimate entry point for the space debris convention.

Because the convention must be global, it thus needs to be drafted under the auspice of the United Nations. Over the last few years, UNCOPUOS and its secretariat at UNOOSA has been promoting a cohesive and integrated response to space challenges. Since the first launch of a satellite into space, the UN has provided a unique forum for countries, international organizations and non-governmental organizations to discuss issues related to the peaceful uses and exploration of outer space. Moreover, to date, the UN has organized three United Nations