8. Iridium-Cosmos collision and its implications for space operations

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8.1. Introduction

The physical condition of the environment in which space activities take place must be conducive to the safe and sustainable development and implementation of all space operations. Rapidly increasing debris in space is posing serious risks to space activities of all nations. Such risks are real, as evidenced by an unprecedented collision between a defunct Russian satellite weighing about 900 kg (Cosmos 2251) and an active about 500 kg U.S. commercial satellite (Iridium 33). The theory of "big sky" or "vastness of space" is being questioned as space operators face new challenges primarily due to the enhanced risks posed by an ever increasing number of space debris, particularly in the region of space that is being used extensively for meeting important earthly needs, like communications, Earth observation, weather forecasting, reconnaissance, navigation and global positioning services, early warning, etc. The availability and risk-free utilisation of space is becoming difficult. The accident seems to have sounded a wakeup call for all countries, especially the space-faring nations and the States having an interest in the exploration and use of space. From that perspective, this paper addresses some relevant questions associated with the legal and policy aspects of the Iridium-Cosmos collision. Specifically discussed are the issues concerning possible liability of the States directly involved in the collision under currently applicable international law; the general space environment; added risks and costs due to the debris created by the collision; and, finally, the concerns of space operators and some governments and the efforts they are making to achieve and maintain safe and sustainable development and use of space. Undoubtedly, these issues are highly complex. However they are discussed here in a general fashion and no attempt is made to carry out a thorough critical analysis in this paper.

8.2. Determination of liability for damage

Since the Iridium-Cosmos collision involved satellites launched by at least two different States, it is international in nature and scope. As such, the law applicable to the accident essentially stems from two important international space treaties: i.e. the 1967 Outer Space Treaty[675] and the 1972 Liability Convention,[676] to which both the U.S. and the Russian Federation were parties at the time of the collision. These treaties impose liability on a "launching State", whose space object has caused damage.[677] Thus, it is imperative first to determine the status of each country as a "launching State". Under both treaties, the term "launching State" is defined similarly.[678] Applying the common definition, it is evident that the Russian Federation was the launching State for Cosmos 2251 satellite, since it was launched on 16 June 1993 by Russia with its Cosmos rocket from its Plesetsk cosmodrome.[679] The U.S. was a "launching State" for Iridium 33 commercial communications spacecraft since the U.S. can be deemed to have "procured" the launch of the satellite which was owned by an American private company, Iridium Satellite LLC (though the launch agreement seems to have been privately negotiated by the Iridium Corporation).[680] Interestingly, the Russian Federation and Kazakhstan were also launching States for Iridium 33, which was launched on 14 September 1997 with a Russian Proton K rocket from the Russian leased Tyuratam (Baikonur Cosmodrome) facility in the territory of Kazakhstan.[681] The issue concerning the possible liability of Kazakhstan is not addressed here.

Iridium 33, which "was part of a planned commercial communications network comprised of a constellation of 66 LEO spacecraft using L-Band to provide global communications services",[682] was licensed by the U.S. under its 1934 Communications Act (as amended),[683] partly a space legislation. Thus, the U.S. exercised jurisdiction and control over Iridium 33,[684] as it is entitled and indeed obliged under Article VIII of the Outer Space Treaty,[685] though it did not register the satellite with the UN as required by the Registration Convention[686] to which the U.S. is also a party.

Since the collision occurred in space, under Article III of the Liability Convention, a launching State is "liable only if the damage is due to its fault or the fault of persons for whom it is responsible"; i.e. it creates a rule of fault-based liability if the damage is caused in outer space. The burden of proving fault is cast upon the State that makes a claim; i.e., the State that is claiming compensation is under obligation to establish or to prove "fault" on the part of other State(s). What legal criteria are to be used for the determination of the precise meaning and scope of "fault"? Since the Liability Convention does not define the term "fault", one must look for its ordinary meaning in law, specifically under international law. Normally, "fault" in law is equated with negligence; and negligence is determined

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on the basis of duty of care. After tracing the origin of the international law principle of "fault" back to *The Jamaica Case of 1798,* Bin Cheng thoroughly discussed this principle and reached the conclusion that "[. . .] contrary to what is assumed by a majority of writers, fault in modern jurisprudence is no longer identified exclusively with negligence or malice. [. . .] it means any act or inaction which violates an obligation [duty]."[687] Thus, the questions that need to be addressed are: (a) whether any of the States concerned was under a duty, and if so what was the nature of that duty; (b) whether leaving one's dead satellite in orbit is a negligent act and (c) whether inaction or failure to take action to avoid collision amounts to negligence (fault)?

It is necessary to recall what actually happened in the Iridium-Cosmos collision in order to determine whether any of the parties could be considered to have been at fault. The collision occurred on 10 February 2009 at 11.56 AM EST, at an altitude of about 800 km over Northern Siberia.[688] Both satellites were orbiting at a speed of about 17,000 mph (7.5 km/s); i.e. about 9–10 times the speed of a bullet fired from a rifle. At the time of collision, Cosmos 2251 was a "free flying" dead space object; i.e. without any station-keeping or manoeuvring capability. On the other hand, Iridium 33 was a normal operational satellite providing telecommunication services. It was fully equipped and capable of making manoeuvres, if desired; i.e. its behaviour could be controlled and its orbit could be adjusted to avoid any collision with other space object(s).

It is known that Russia had abandoned its Cosmos 2251 satellite when it became non-operational about 10 years ago. Russia did not take any action to remove this space object (actually debris)[689] from its orbit in LEO. Such inaction is considered contrary to Russia's obligation under the Outer Space Treaty,[690] particularly its Article IX, which, in part, specifies that States must conduct all their activities in outer space with due regard to the corresponding interests of all other States parties to the Treaty. Thus, such inaction and disregard of the interests of other States on the part of Russia amounts to Russia's fault and Russia should be considered liable to the U.S. for the destruction of the Iridium 33 spacecraft belonging to an American company. However, since the dawn of the space age, the practice among launching States, though unfortunate, has been the routine abandonment of dead satellites. Thus, one may assert that due to this practice of over 50 years, a new rule of customary international law has evolved that modifies a State's general obligation under Article IX of the Outer Space Treaty,[691] and States are therefore entitled to leave their dead satellites in orbit without any responsibility for keeping outer space free of hazards. However, this assertion is not tenable since the two essential elements or requirements that must exist in order for a practice to become a rule of customary international law (i.e. steady space practice and *opinio juris*)[692] are missing. The practice has not been

followed regularly by States. Neither have space-faring States expressed a legal right in the past to abandon their dead satellites in space. For several years, most space-faring States have adopted regulations and policies which require their respective agencies and commercial operators to de-orbit or relocate their near-death (near end-of-life) satellites in all orbits.[693] There are many examples of the routine implementation of such regulations and policies, the result being that numerous satellites have been de-orbited.

As the State having jurisdiction over and responsibility for actions of Iridium Corporation under the above-mentioned Article IX of the Outer Space Treaty and the Liability Convention,[694] the U.S. is obliged not to cause damage to, or interfere with the operation of, satellites belonging to other States. Nevertheless, it appears that the U.S. suffered loss due to its own inaction/inability to predict and/or avoid collision. Rationally speaking, one must expect, or lay the responsibility on, the owner/operator of a functional satellite (i.e. Iridium 33) to carry out appropriate manoeuvre(s) to avoid a collision with those satellites that have the right to operate under Article 1 (2) of the Outer Space Treaty.[695] Though capable of implementing its collision-avoidance procedures, the Iridium Corporation did not take any action in this regard since it had no prior warning about the possibility of the Iridium-Cosmos collision. According to Jeffrey White, Regional Director EMEA and Russia for Iridium Satellite LLC, "Iridium does not utilize any standard processes for collision risk monitoring/collision avoidance".[696] The Iridium Corporation, like any other satellite operator, is aware of the position-situation of its own satellites but not of other satellites in the neighbourhood. For monitoring and conjunction (possibility) predictions about collisions between objects in space, several operators rely upon civil and commercial tools and resources like SOCRATES (developed and operated by Analytical Graphics Inc. (AGI)). However, they are limited in their capabilities and are unable to monitor all satellites all the time. Moreover, their conjunction predictions are not precise and highly reliable. Jeffrey White reiterated the statement of AGI that "the Iridium 33/Cosmos 2251 conjunction was not even in the top 150 most probable predicted conjunctions for that particular day . . . [In fact] . . . 16 other Iridium satellites had higher probability conjunctions that day than did Iridium 33".[697] The other entity involved in monitoring and conjunction predictions has been the Space Surveillance Network (SSN), an official establishment of the U.S. Government, which operates the world's most advanced and extensive multi-billion U.S. dollar system for carrying out space situational awareness (SSA) activities and conjunction predictions. It disseminates the coordinates and velocity of the satellites through the internet free of charge. However, due to lack of "computing power, trained personnel and sensor capabilities"[698] the SSN's priority has been the monitoring and conjunction predictions of U.S. military satellites and manned

spacecraft. The U.S. military does not analyse the collision probabilities of all satellites. It is clear that the SSN (i.e. the U.S. Government) did not monitor Iridium 33 before it collided with Cosmos 2251. Consequently, it failed: (a) to predict its possible collision with Cosmos 2251 and (b) to alert or instruct Iridium Corporation management to undertake appropriate manoeuvre(s) for changing its orbit in order to avoid the collision.

In April 2009, the U.S. House of Representatives Committee on Science and Technology's Subcommittee on Space and Aeronautics conducted hearings regarding the challenges posed (particularly by space debris) to space operators. In her opening statement, the Subcommittee Chairperson, Gabrielle Giffords, expressed the view that it was "difficult to believe that nothing could have been done to prevent the (Iridium-Cosmos) collision, given that one of the satellites was active and by all accounts would have had the capability to manoeuvre out of harm's way".[699]

Inaction or even inability on the part of the U.S. cannot relieve it of its international responsibility not to cause harm on the basis of the decision of the International Court of Justice in *The Corfu Channel Case*. In that case, the Court held Albania responsible for laying mines in its territorial waters over which it had exclusive jurisdiction, as a result of which British ships suffered damage. Albania pleaded that it did not know about the existence of the mines and thus could not prevent the accident. The Court dismissed Albania's plea stating "nothing was attempted by Albania to prevent the disaster, and these grave omissions involve her international responsibility."[700] It is well-known that the U.S. has been (and continues to) monitoring thousands of satellites (including pieces of debris), and has successfully avoided impending accidents by undertaking appropriate collision-avoidance manoeuvres numerous times. Even if there are technical limitations on the capabilities of the SSN, it is believed that the U.S. could or should have known about the possibility of the Iridium-Cosmos collision had it monitored these satellites in the same manner as it was (and is) surveying other satellites, like the International Space Station and the Space Shuttle space transportation system, with the regular monitoring of which the U.S. did avoid several potential accidents with space debris. Since the U.S. omitted, ignored, failed, or did not attempt to prevent the Iridium-Cosmos collision, it remains internationally responsible for the consequences of the accident.

As mentioned above, the U.S. registered Iridium 33 on its national registry but failed to register it with the UN. Thus, the U.S. is in violation of its international obligation under the Registration Convention. However, non-registration with the UN does not relieve the U.S. of its responsibility and possible liability for being the State that exercised jurisdiction and control over Iridium 33 and also for being its launching State. It may be noted here that, interestingly, neither did the Russian

Federation deregister its decayed Cosmos 2251 with the UN as required under the Registration Convention.[701] Similarly, although the Russian Federation too violated its obligation under the Registration Convention, the legal consequences of such inaction are not directly related to its liability under the Liability Convention.

If the U.S. is at fault in this case, is Russia entitled to claim compensation for the destruction of Cosmos 2251? For this, Russia needs to prove not only fault on the part of the U.S. but also the quantum and nature of the damage it suffered. In this regard, it may be difficult to accept that Russia suffered any damage (as understood under the Liability Convention)[702] as a result of the destruction of its dead and abandoned satellite.

In sum, it is submitted that the Russian Federation had no right under customary international law to abandon its decayed Cosmos 2251 in space. Neither was the U.S. (for and on behalf of Iridium Corporation) free not to take any action to prevent the collision which occurred on 10 February 2008. The case of Iridium-Cosmos collision seems to have been resolved by mutual understanding since there is no information available in the public domain about any legal action (option) that is being considered or pursued by either party. It is contemplated that, perhaps the absence of an ensuing claim for any compensation is due to the fact that the parties have realised the weaknesses of their respective legal positions; i.e. Russia did not suffer any real damage and the U.S. was at fault (or at least was contributorily negligent) primarily due its own lack of knowledge of, or inaction or inability to prevent, the accident.

8.3. Consequences and implications of the collision

8.3.1. Regulatory uncertainty

Since the issue of the Iridium-Cosmos collision has not been litigated in any international or national court of law, it did not authoritatively clarify the applicable law (i.e. the concept of fault) to cases of accidents in space.

The incident demonstrated, however, that States, particularly major space-faring nations, are not regularly and faithfully observing the binding obligations they have voluntarily assumed under the Registration Convention. This unfortunate observation raises the following two concerns: (a) small and emerging space-faring nations might follow the unfortunate practice of the U.S. and the Russian Federation and (b) States might be expected not to seriously comply with non-binding principles[703] related to the prevention of space debris.

In addition, the collision unmistakably indicates the lack of prompt availability of sufficient, precise and timely information, both from commercial and governmental (security) sources that could be used by civil and commercial space operators to formulate advance warnings and take any collision-avoidance actions or procedures in a timely manner. Moreover, the capabilities for monitoring space situation and conjunction predictions were essentially within the U.S. alone. In such a case, it will be extremely difficult, if not impossible, to collect full, accurate, and unbiased evidence comprising of all the appropriate facts and circumstances of an accident in space should one occur and the case is brought before a judicial tribunal. The collection of such evidence would, a priori require: (a) the presence of fairly detailed and agreed upon "rules of the road" or "space navigational rights, responsibilities and procedures" (b) a significant amount of financial resources needed for advanced capabilities for precise monitoring, cataloguing and analysing extensive amounts of data about complete space situation and traffic in space and finally, (c) appropriately trained human resources possessing the necessary expertise and working within or through an independent international body. Thus, the Iridium-Cosmos collision signifies the urgent need of rules, procedures, resources and a neutral international body (fully equipped with the appropriate mandate, resources and regulatory infrastructure) for the collection and determination of relevant evidence.

8.3.2. Increasing risks and cost of space operations

Initially, the Iridium Corporation and Russia downplayed the problem caused by the Iridium-Cosmos collision. However, several experts, space entrepreneurs and government spokespersons expressed serious concerns related to national security, cost of space operations and even the very viability of space programmes in the future. For example, a day after the accident, the U.S. Marine Gen. James E. Cartwright, Vice Chairman of the Joint Chiefs of Staff, speaking on the national security ramifications of the collision, is reported to have said that "Many of the commercial and national security satellites, particularly communications satellites, rely on certain spacing between other objects in order to be effective. Losing a spot because of debris could have a financial or operational impact on anyone wanting to use the space. If that's going to be long term, that's a problem for us."[704] Similarly, Lieutenant General Larry James, head of the U.S. Strategic Command's Joint Functional Component Command for Space, said the Iridium-Cosmos collision, "which was not predicted by the U.S. military or private tracking groups, had a big impact on future U.S. military planning by tangibly demonstrating the vulnerability of our space assets."[705]

Today the global space industry generates over 250 billion U.S. dollars worth of economic activity that employs hundreds of thousands of high-tech, high-wage middle class workers.[706] A dire warning about the economic and operational implications of the Iridium-Cosmos collision has been well expressed by Launch-space Staff: "Should such an event occur, several bad things will happen to many satellite operators. If another Iridium satellite is involved the company would be forced to replace the lost satellite. The frequency of close encounters in orbits near that of Iridium's constellation would suddenly increase to levels that would cause several operators to reassess the viability of existing space applications. Satellite insurance providers might be forced to raise premiums on in-orbit performance to record high levels. Future launch plans for almost all low orbit satellites may be curtailed. Space-based services to the world would diminish over time. The economic impact is not even calculable. This is scary!"[707]

In order to avoid collision, an active satellite would have to change its orbital path with the use of onboard fuel. Such a manoeuvre depletes the necessary fuel and consequently shortens the operational life of the satellite. GeoEye, an American private satellite imaging enterprise, had to manoeuvre its Ikonos satellite several times in order to avoid collisions with pieces of space debris. Consequently, these manoeuvres resulted in the imposition of extra costs on the company in terms of wastage of fuel (thus shortening the satellite's lifespan) and personnel time to execute these manoeuvres.[708] In 2007, an American 1.3 billion U.S. dollars Terra satellite had to be manoeuvred to avoid collision with a piece of debris from the Chinese Fengyun-1 C satellite destroyed by China's ASAT test.[709]

Space debris poses risks not only to unmanned satellites but also to spacecraft with humans on board; e.g. the International Space Station (ISS) and the U.S. Space Shuttle. It has been reported that the crew of the ISS had to make several manoeuvres and sometimes take refuge in Soyuz spacecraft in order to avoid possible collisions with space debris.[710] The windshield windows of the Space Shuttle had to be replaced several times due to the damage caused by space debris present in the orbit used by the Shuttle. According to the U.S. House of Representatives Committee on Science and Technology, "the recent Iridium-Cosmos collision has added to the debris field in LEO and represents a 71% increase in the amount of threatening debris to STS-125 [Space Shuttle]."[711]

Due to the gravity of the Earth, pieces of space junk are expected to reenter the Earth's atmosphere and possibly burn up at the time of reentry. However, the life span of orbiting debris depends on the altitude of its orbit. It takes about one year for pieces of debris at an altitude of 400 km to come down. Nevertheless, if the orbit of debris is at an altitude of 1000 km, it could take over a thousand years for it to reenter the Earth's atmosphere.[712] Thus, the junk in the geostationary orbit (i.e. about 36,000 km above the Earth's equator) will remain there for millions of years;

i.e. forever. Also, all pieces of space debris, especially the bigger ones, do not burn up during their reentry into the Earth's atmosphere, and sometimes, they land on unpredictable places. Thus, space debris poses risks to humans or can cause damage or gives rise to environmental concerns on the surface of the Earth. Here are some examples: in 1978 the Soviet satellite Cosmos 954 disintegrated and scattered radioactive debris over a large area in Northern Canada.[713] Similarly, in 1979 the U.S. space laboratory Skylab broke down and showered hundreds of pieces of debris over Western Australia and the Indian Ocean. There were serious concerns expressed by the public over the possibility of Russia's Mir Space Station coming down. Fortunately, on 23 March 2001, it successfully de-orbited, broke apart at reentry into the atmosphere and the unburned pieces crashed over the South Pacific Ocean without any damage to anyone. In December 2008, NORAD's operation centre could not predict the precise time and place of the coming down of an earlier launched Russian Proton K rocket, which without prior warning, crossed through Canadian airspace and landed uneventfully in Labrador, Canada. This event was considered to be a "reminiscent of a 2005 incident, when a U.S. military rocket splashed down in the vicinity of the Hibernia oil platform, on Newfoundland's Grand Banks, shortly after its launch from Florida".[714]

Since the beginning of the space age in 1957, several thousand satellites and rockets have been launched by or on behalf of about 50 countries. Most of these satellites have become spent since, yet they remain in orbit. Consequently, space around the Earth is increasingly becoming polluted and contaminated with dead satellites (including those with nuclear reactors on board), break-ups of spacecraft and rocket bodies, leftover fuel or other reactive chemicals, debris caused by accidental collisions between orbiting objects or by deliberate destruction of satellites (e.g. ASAT tests), etc. The U.S. Department of Defense (DoD) has been tracking about 19,000 space objects 10 cm (4 inches) or larger in diameter, out of which only about 900 are operational and manoeuvrable satellites.[715] In addition, it is estimated that there are more than 300,000 untracked objects measuring between 1 and 10 cm in diameter orbiting the Earth and millions smaller than 1 cm. Their number is expected to increase fast in the near future.[716] As several new countries are entering the space field and the current crop of space-faring nations are launching more satellites, "a conservative estimate projects that the number of active satellites will jump from 1300 to 1500 over the next decade".[717] This will inevitably be accompanied by an equivalent increase in the rate of generation of space debris.

Pieces of space debris sometime travel at speed of about 35,000 km per hour. "At such high velocity, even small junk can rip holes in a spacecraft or disable a satellite."[718] No satellite can be reliably protected against this kind of destructive force.

Tab. 2: *The Known or Suspected Past Collisions between Objects in Space.*

Year	Event
1991	Inactive [Russian] Cosmos 1934 satellite hit by catalogued debris from [Russian] Cosmos 296 satellite
1996	Active [French] Cerise satellite hit by catalogued debris from [European] Ariane rocket stage
1997	Inactive [U.S.] NOAA 7 satellite hit by uncatalogued debris large enough to change its orbit and create additional debris
2002	Inactive [Russian] Cosmos 539 satellite hit by uncatalogued debris large enough to change its orbit and create additional debris
2005	Inactive U.S. rocket body hit by catalogued debris from Chinese rocket stage
2007	Active [European] Meteosat 8 satellite hit by uncatalogued debris large enough to change its orbit
2007	Inactive [U.S.] NASA OARS satellite believed hit by uncatalogued debris large enough to create additional debris
2009	Active [U.S.] Iridium 33 satellite hit by inactive [Russian] Cosmos 2251

The probability of inter-debris collisions increases as the debris population grows, thereby creating the potential to create even more debris. It is estimated that 40% of tracked debris results mostly from break-ups of spacecraft and rocket bodies.[719] There is a trend of a steadily increasing number of such break-ups.[720] Since 1991, there have been several major debris generating collisions in space that are believed to have significantly increased the space debris population. Table 2 above, which has been compiled by David Wright of the Union of Concerned Scientists, shows the known collisions in space, and the three italicised entries are those that resulted in the destruction of operational satellites.[721]

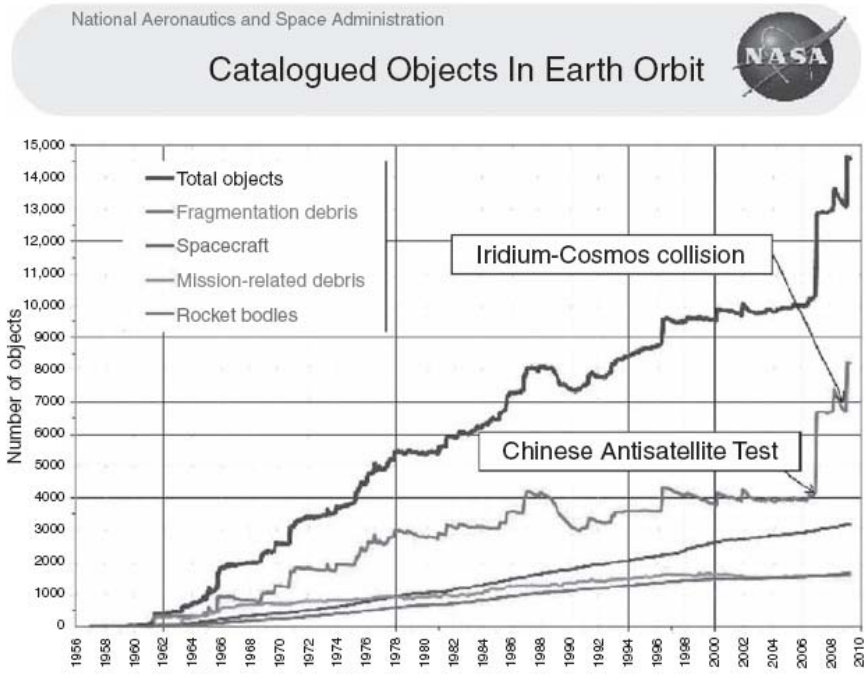
The extent of the debris clouds generated by the Iridium-Cosmos collision ranges from 200 to 1700 km. The SSN has identified about 1500 pieces larger than 10 cm that were created by the Iridium-Cosmos collision.[722] Half of these pieces might fall back to Earth within 5 years. Some will remain in orbit by the end of the century and even for "significantly longer periods"[723] afterwards. Sadly, after the Iridium-Cosmos collision, scientists predict the possibility of more accidents in the future.[724]

Due to rapidly increasing rate of production of space debris, several experts have expressed alarm about the shortage of "space in space", and scientists predict that '"close encounters" between satellites and debris in orbit will rise by 50% in the next 10 years, and by 250% by 2059, to more than 50,000 a week'.[725] If the number

of spacecraft with nuclear reactors on board increase,[726] the chances of radioactive contamination of space and possibly the safety of the public and property on Earth will grow, if such satellites somehow collide in space with debris or an operational satellite.

Deliberate destruction of satellites, primarily by ASAT tests, has been another disturbing source of space debris. During the 1980s both the United States and the Soviet Union carried out several of such tests. The latest ASAT test was carried out by the Peoples Republic of China on 11 January 2007. With the use of its ground-based medium-range ballistic missile, China successfully destroyed a dead Chinese weather satellite orbiting at an altitude of about 800 km.[727] It is estimated that as a result of the test, the satellite "shattered into thousands of pieces that were thrown into a wide range of orbits ranging in altitude from 3800 km on the high end down to about 200 km at the lowest."[728] According to Nicholas Johnson, NASA's Chief Scientist for Orbital Debris, this test, "is by far the worst satellite fragmentation in the history of the space age, in the past 50 years"[729] as it created about 2500 new pieces of junk and thus added 25% more debris. In Table 3 below, Johnson shows significant increases in the space debris population caused by the 2009 Iridium-Cosmos collision as well as the 2007 Chinese ASAT test.[730]

Tab. 3: *Catalogued objects in Earth orbit.*



The region in space where the Chinese ASAT test and the Iridium-Cosmos collision took place is one that is heavily used by satellites belonging to several countries. Thus, the Iridium-Cosmos debris has worsened a situation that was already serious and enhanced the risks to satellites of several nations for a long time. It has correctly been pointed out by experts that "Orbital debris is the gravest threat to new and existing space systems."[731] Consequently, the Iridium-Cosmos collision has raised serious concerns and urgent calls signaling the need for appropriate policies and means to avoid the repetition of similar mishaps and to maintain space for safe and sustainable use by all nations.

8.4. Efforts to keep space for safe and sustainable development and use

8.4.1. Prevention: debris mitigation regulatory measures

The international space community, and even the general public, is becoming aware of and concerned about the danger posed by rapidly increasing space debris. A UN general circular, recently distributed around the world, highlighted the *Space Debris Problem as One of the Ten Stories the World Should Hear More About*.[732] There are often news and discussions about space debris in all sorts of media, at least in the Western world. Almost all major space-related academic and governmental conferences or seminars invariably deal with the space debris problem, either directly or indirectly. This growing awareness of the negative impact of space debris upon public safety on the Earth as well as the safety and sustainability of space operations seems to have encouraged some space-faring nations to take steps to mitigate the production of new debris through the development of national space debris mitigation measures.[733] However, such initiatives are useful only in the short term, since they apply exclusively to respective national space operations and consequently their effectiveness is limited as a single major accident could create hazards for the space activities of all States. It seems imperative that all space-faring and space-aspiring nations ought to be involved in the adoption and effective application of all sorts of measures in a coordinated manner to prevent the production of new pieces of debris and elimination of the existing space debris.

At the international level, there are no effective and binding rules, standards and procedures in existence that apply to space debris. After debating the issue since 1994, the UN Committee on Peaceful Uses of Outer Space (COPUOS) adopted Space Debris Mitigation Guidelines,[734] which were endorsed by the UN General Assembly in its resolution 62/217 of 21 December 2007. The Guidelines aim at

curbing pollution in space, and at promoting international efforts for safe spacecraft operations. The Guidelines are based on and consistent with the Inter-Agency Space Debris Coordination Committee (IADC) guidelines. The COPUOS believed that the Guidelines would increase mutual understanding on acceptable activities in space and thus enhance stability in space-related matters and also decrease the likelihood of friction and conflict. Such preventive measures, if fully and effectively implemented by all space-faring nations, are very important but are not sufficient to keep the space environment safe enough to facilitate sustainable development of the space operations of all nations as the Guidelines do address the extensive amount of existing debris currently in orbit. They are aimed at mitigating the production of new debris only.

Unfortunately, the Guidelines are one of the lowest forms of any statements on highly serious space-related international concern by a UN body. They are voluntary, legally non-binding, and present only general recommendations in the form of seven principles (or goals) to be implemented (or achieved) through national legislation and regulatory mechanisms. Moreover, it is believed by some experts that the goals set in the Guidelines might prove more difficult to achieve than their negotiation, during a period of about fifteen years, primarily because of the different views, approaches and concerns within various national (regulatory and technical) institutions that are involved in the design, adoption and implementation of detailed domestic rules, procedures and standards for mitigating space debris.

Nevertheless, irrespective of their inherent weaknesses, it seems imperative that the Guidelines must be implemented effectively nationally as soon as possible rather than waiting for the adoption of perfect implementation mechanisms and standards. At the same time, the international community must continue seriously searching for means to strengthen them and to coordinate national space debris mitigation efforts. For this purpose, the COPUOS (actually its Scientific and Technical Sub-Committee) should make concerted efforts, in collaboration with neutral national or international bodies, like the IAASS (International Association for the Advancement of Space Safety), or any other neutral group of technical experts, to develop and adopt technical standards and regulatory procedures so that they could be followed uniformly by all nations and space operators.

8.4.2. Prevention: space situational awareness and space traffic management

Most of the satellites, especially civil and commercial satellites, "fly blind"; i.e. they are not aware of other spacecraft that are in their vicinity in space. The first and the

most important practical step to prevent Iridium-Cosmos collision like accidents "is to determine what is in Earth orbit and where it is going: space situational awareness (SSA)."[735] According to the testimony of the Secure World Foundation, the "owner or operator of a particular satellite usually has excellent knowledge about the position of that satellite in space, but little to no information about the locations of other objects around them. This situation was the *root cause* behind the collision of two satellites in February – the owner of the Iridium satellite, which could have potentially manoeuvred it out of the way, did not know about the impending close approach."[736] As noted above, the U.S. Government Space Surveillance Network neither monitored Iridium 33 nor could it alert its operator about the possible collision. However, since the Iridium-Cosmos collision the U.S. "SSTRATCOM has been providing daily conjunction reports for the Iridium constellation."[737] In fact, the U.S. has started significantly enhancing its SSA capabilities (monitoring, conjunction prediction and information distribution) by adding new staff and facilities that track on a daily basis 800 new space objects and distribute conjunction reports to civil and commercial satellite operators through its DoD Commercial and Foreign Entities (CFE) pilot programme.[738] Several friendly foreign governments and their entities also benefit from the programme. In order to further improve its SSN, the U.S. government is planning for a new system called "space fence", which "will constantly report the motion of all objects 5 cm wide and larger in medium and low-Earth orbits."[739] However, the CFE programme is not open to all space operators from all countries since the DoD prefers not to divulge sensitive information, particularly about its military satellites. This pretext of the DoD is considered and not fully convincing since "many sensitive satellites are large and easily found, even by amateur astronomers."[740]

Because of the limitations of the CFE, three major commercial satellite operators (i.e. Intelsat, SES and Inmarsat) have recently decided to set up their own Satellite Data Association (SDA) and "have issued a request for proposals for a company to design and operate a database on satellite positions, planned manoeuvres and signal transmissions with a view to reducing the chance of orbital collisions."[741] It is too early to judge the viability and possible success of the SDA, but it certainly seems to be an appropriate and timely step in the right direction for the commercial space operators to protect their investments and interests. Preferably, a neutral international system (a space data center) mandated to carry out SSA activities and to provide regular and precise conjunction reports to all space operators is needed. Instead of clinching to outdated theories of absolute national sovereignty and freedom of action in a highly globalised and interdependent world, it is in the interest of all nations to collectively resolve the problem of space debris, which adversely affects all satellites in orbit without

discrimination. China, France, Germany, India, Japan and Russia have their own, though limited, space surveillance facilities in one form or another. However, no country shares SSA information regularly with anyone. As major space-faring nations, they all should pool their resources together and set up a cooperative system, preferably under an international agreement, that will help them, their space operators and other interested public or private entities in the pursuit of safe and sustainable utilisation of space. Such capabilities will be indispensable for undertaking manoeuvres not only for collision avoidance but also for the purpose of de-orbiting satellites, when required. The operations of such a system need not be expensive since it should employ a small group of appropriately trained and experienced experts and acquire the necessary equipment, especially high powered computers. The most expense tool for carrying out the work of the system will be the raw satellite data, but that may be procured from (or provided by) participating national systems, like the U.S. Space Surveillance Network and other suppliers. Moreover, such a neutral international system could provide unbiased and accurate statements of facts and expert opinions which are necessary for the proper resolution of disputes and problems like the one created by the Iridium-Cosmos collision. The second important step to prevent space collisions is to have precise "rules of the road" for all space operators; i.e. space traffic management rules.[742] Simply speaking, as all users of roads on the Earth must know the rules for using the highway in order to avoid accidents, similarly spacecraft orbiting around the Earth and space transportation operators must follow predetermined, uniform, universal, precise, legally binding and effectively enforceable rules. There exist no such rules today, except those that are set through the International Telecommunication Union (ITU) for the satellites operating in the geostationary orbit. New modes of transportation, namely orbital and suborbital-orbital spaceflights, are becoming viable and will be used routinely in the near future for transporting people and cargo from point-to-point on the surface of the Earth through space, and also as a viable means of space transportation and travel, including space tourism. The safety of space operations and space travel will depend, among other things, upon the safe and secure construction and operation of all modes of space transportation and the rules they will follow in their flights through airspace and outer space. It is, therefore, logical that international space safety and traffic management regulations should be negotiated through the International Civil Aviation Organization (ICAO), which has extensive experience in such rules with respect to aviation. The rationale for this suggestion is the same as that followed by the U.S. in gradually extending the mandate of the Federal Aviation Administration (FAA) to set rules and procedures for space transportation systems and implementing them, as and when necessary.

8.4.3. Cure: removal of space debris

As noted above, without effective and timely efforts and means to physically remove space junk from space, particularly from the densely populated orbits, the space environment would not only remain hazardous for space operations but could also become more dangerous as additional debris would be created by collisions between pieces of existing debris (i.e. "domino effect" also known as "Kessler Syndrome"). For the last two decades, there have been in place some national regulations and policies requiring space operators to de-orbit their satellites when they approach the end of their lives and place them in the so-called graveyard orbit above the geostationary orbit. These policies have not been consistently followed and thus are correctly considered to "abjectly fail to remove risks imposed by derelict spacecraft, due in great part to the false sense of security created by the term [de-orbit]".[743] Nevertheless, since the Iridium-Cosmos collision, various concepts for space debris removal are being actively conceived, proposed, debated, and developed. Some of them include: (a) the development of specially designed "Debris Collection Spacecraft" that would be capable of rendezvousing with space object, manoeuvring and removing them[744] and (b) an idea to develop a spaceship to collect all the debris and push it closer to the Earth so that it burns up at the time of reentry into the Earth's atmosphere.

The following two proposals seem to be more serious: (a) on 11 October 2009, *The Observer* reported that German robots that are being designed "can rescue failing satellites and push "dead" ones into deep space . . . .[They might] be ready in four years . . . . and will dock with failing satellites to carry out repairs or push them into "graveyard orbits", freeing vital space in geostationary orbit".[745] This proposal appears to be interesting and somewhat valuable but tends to postpone the real and desired solution of removing pieces debris from space (not only from their respective orbits). (b) The second one is the initiative, taken in September 2009, by the Defense Advanced Research Projects Agency (DARPA), which is a part of the U.S. DoD. DARPA issued a Request for Information regarding the design and development of capabilities for removal of space debris. The programme "will involve all space-faring nations, tens of billions of dollars and decades of development, testing and operations".[746] The second proposal seems to be a good and possibly viable solution because of the involvement of all space-faring nations. However, the costs involved, the national security interests and long time to develop might prove challenging to overcome. In addition, both these proposals might also have to overcome the perception that the capabilities and tools developed for space debris removal might also be used as space weapons. Secondly, under current space law, there is no right of salvage; i.e. no right to collect and destroy satellites (including debris) belonging to others. Defunct satellites or

their component parts remain under the jurisdiction and control of the owner, unless specifically disclaimed. Such right needs to be created before technical solutions, like the foregoing can be used to sufficiently eliminate risky space debris. Nevertheless, small pieces of debris (millions in number) orbiting at extremely high speed will remain a problem, especially for space travellers and for insufficiently protected satellites. The search for an appropriate cure will and must continue until safe and sustainable use of space is assured for all space operators.

8.5. Conclusion – message

A safe space environment is imperative for the sustainable development of the space operations of all nations for civil, commercial and security purposes. It is inevitable that as space becomes more crowded, Iridium-Cosmos collision like accidents would happen. The collision highlighted an urgent need and initiated intensive efforts to search for technical, policy, organisational and regulatory solutions, including expanded space situational awareness, safety standards, space traffic rules, removal of existing debris, etc. One can only hope that something positive might come out of the tragic accident of 10 February 2009. It is submitted that the COPOUS Space Mitigation Guidelines must be enhanced and strengthened at the international level in order to expressly include a clear obligation to remove defunct satellites and a right to salvage. I reiterate here my earlier statement, i.e. Space debris is primarily a global issue. Global problems need global solutions, which must be effectively implemented internationally as well as nationally. In addition, COPUOS must intensify efforts to ensure that the Registration Convention is adhered to by all parties to the treaty. It is believed that the proposed neutral international space data center could help all space operators in achieving safe and sustainable utilisation of space. It is unfortunate and ironic but true that events like the Iridium-Cosmos collision are sadly necessary for appropriate solutions to the problems which would not otherwise be resolved in a timely manner. *Nécessité fait loi.*

[675] Treaty on Principles governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (hereafter Outer Space Treaty), London/Moscow/Washington, done 27 January 1967, entered into force 10 October 1967, 610 UNTS 205, 6 ILM 386 (1967).

[676] Convention on International Liability for Damage Caused by Space Objects (hereafter Liability Convention), London/Moscow/Washington, done 29 March 1972, entered into force 1 September 1972, 961 UNTS 187, 10 ILM 965 (1971).

[677] Article VII of the Outer Space Treaty stipulates that a launching State is internationally liable for damage caused by its space object. Similarly, Articles II and III of the Liability Convention provide that a launching State is (a) absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight and (b) liable if the damage is caused in outer space and is due to its fault or the fault of persons for whom it is responsible.

[678] Article VII of the Outer Space Treaty and Article I (c) of the Liability Convention similarly specifies that a 'launching State' is a State that launches or procures the launching of an object and a State from whose territory or facility an object is launched.

[679] Information Furnished in Conformity with the Convention on Registration of Objects Launched in to Outer Space. "Note verbale dated 14 June 1994 from the Permanent Mission of the Russian Federation to the United Nations addressed to the Secretary General". UN Doc. ST/SG/SER.E/275 of 13 June 1994. Vienna: United Nations: 2. It should be noted that there is a typographical error in writing the number of the satellite; i.e. it is listed as 2551, but the number should have been 2251.

[680] According to Article VI of the Outer Space Treaty, States bear international responsibility for national activities in outer space, whether such activities are carried on by their governmental agencies or by non-governmental (private) entities, and for assuring that their national activities are carried out in conformity with the provisions set forth in the Treaty. The activities of non-governmental entities require authorisation and continuing supervision by the appropriate State. NASA National Space Science Data Centre, an official entity of the U.S. Government, enlists Iridium LLC of the United States as the funding agency of Iridium 33 satellite: see NASA National Space Science Data Centre. 2 Nov. 2009. http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=1997-051C.

[681] NASA National Space Science Data Centre. 2 Nov. 2009. http://nssdc.gsfc.nasa.gov/nmc/spacecraftOrbit.do?id=1997-051C. On 4 March 1998, Russia informed the UN that "On 14 September 1997, seven Iridium satellites were placed in Earth orbit by a single Proton carrier rocket from the Baikonur launch site. [. . .] The satellites are owned and operated by the Motorola company (United States of America)". See: Information Furnished In Conformity With The Convention On Registration Of Objects Launched Into Outer Space. "Note verbale dated 4 March 1998 from the Permanent Mission of the Russian Federation to the United Nations addressed to the Secretary-General". UN Doc. ST/SG/SER.E/332 of 19 March 1998. Vienna: United Nations.

[682] Ibid.

[683] "Communications Act of 1934". Federal Communications Commission. 3 Nov. 2009. http://www.fcc.gov/Reports/1934new.pdf. Also applicable are the U.S. Code of Federal Regulations: Title 47-Telecommunication; Chapter I-Federal Communications Commission; Part 25-Satellite Communications.

[684] The official U.S. Registry of Space Objects Launched into Outer Space, which is maintained by the U.S. Department of State's Bureau of Oceans and International Environmental and Scientific Affairs, enlists Iridium 33 (with International Code 1997-051 C and NORAD 24946), for which the USA is the flag state and affirms that the satellite was not registered with the UN by the U.S. See: U.S. Space Objects Registry. 2 Nov. 2009. http://usspaceobjectsregistry.state.gov/registry/dsp_DetailView.cfm?id=1517. Similarly, the SPACEWARN Bulletin Number 527 substantiates that Iridium 33 was an American communications spacecraft that was launched with a Russian Proton-K rocket. See: "SPACEWARN Bulletin Number 527". 1 October 1997. NASA National Space Science Data Centre. 2 Nov. 2009. http://nssdc.gsfc.nasa.gov/spacewarn/spx527.html.

[685] According to Article VIII of the Outer Space Treaty, a State "on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object".

[686] Convention on Registration of Objects Launched into Outer Space (hereafter Registration Convention), New York, done 14 January 1975, entered into force 15 September 1976, 1023 UNTS 15, 14 ILM 43 (1975). Article IV (1) of the Convention requires each State of registry to furnish to the Secretary-General of the United Nations information concerning each space object carried on its registry.

[687] Cheng, Bin. General Principles of Law as Applied by International Courts and Tribunals. Volume 2 of Grotius classic reprint series. Cambridge: Cambridge University Press, 2006: 225.

[688] NASA National Space Science Data Centre. 2 Nov. 2009. http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=1997-051C.

[689] The Cosmos satellite involved in this collision was a 'space object' under the Liability Convention, irrespective of the fact that it was non-functional or a piece of space debris. It should be kept in mind that Cosmos 954 too was a non-functional object when it crashed into Canadian territory and the Soviet Union did pay to Canada "the sum of three million Canadian dollars (C$ 3,000,000.00) in full and final settlement of all those matters [. . .] [connected with the disintegration of the Soviet satellite Cosmos 954 in January 1978], including the claim advanced by Canada in this respect". See: Disintegration Of Cosmos 954 Over Canadian Territory In 1978. 2 April 1981. Doc. Ref. Canadian Department of External Affairs. Communiqué No. 27.

[690] Article 1 (2) of the Outer Space Treaty specifies that, "Outer space [. . .] shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law". By implication, this Article obliges States to refrain from causing damage to, and interfering with the similar use of space by, other States.

[691] According to the Deputy Legal Advisor to the United States Department of State, the emergence of a new customary rule may result in a modification in the operation of a prior treaty rule. To substantiate his opinion, he relies on Article 68(c) of the 1964 International Law Commission draft articles on the law of treaties, which stated that "the operation of a treaty may be modified by subsequent emergence of a new rule of customary law relating to matters dealt with in the treaty and binding upon all the parties". 2 ILC Yearbook 198 (1964); adopted unanimously, 1 ILC Yearbook 318 (1964). 2 Nov. 2009. http://www.state.gov/s/l/65626.htm. Also, the International Court of Justice recognised in the 1974 *Fisheries Case* that the right of a State to set up twelve-mile fishing zones had crystallised as customary international law notwithstanding the provisions in the 1958 High Seas Convention creating freedom of fishing on the high seas. See: *Fisheries Jurisdiction Case* (United Kingdom v. Iceland, Merits), Judgment of 25 July 1974 (1974) I.C.J. Rep. 3.

[692] A practice of States becomes a rule of customary international law only when it is followed with a sense of legal obligation (*opinio juris sive necessitatis*). *North Sea Continental Shelf Cases* (Denmark/The Netherlands v. Federal Republic of Germany) Judgment of 20 February 1969 (1969), I.C.J. Rep.:3. at page 44: "Not only must the acts [of States] concerned amount to a settled practice, but they must also be such, or be carried out in such a way, as to be evidence of a belief that this practice is rendered obligatory by the existence of a rule of law requiring it."

[693] For example, see U.S. Government Orbital Debris Mitigation Standard Practices. 2 Nov. 2009. http://www.orbitaldebris.jsc.nasa.gov/library/USG_OD_Standard_Practices.pdf.

[694] It may be also noted that normally, a State is not considered responsible for an illegal act of its non-State actors unless there is a genuine link between the act and the State; i.e. an illegal act must be somehow imputable to the concerned State. However, that principle of international law has been modified by Articles VI and VII of the Outer Space Treaty, which make a State responsible (and possibly liable) for the space activities of all its entities. Even under general International law, according to Richard S.J. Tol and Roda Verheyen, "as soon as an activity is permitted or licensed by a state (under the control of . . .), the resulting behaviour is attributable to the state because [the principle that] states must exercise due diligence in [the] control of private persons is an acknowledged principle". Tol, Richard S. J. and Roda Verheyen. "State Responsibility and Compensation for Climate Change Damages – a Legal and Economic Assessment". Energy Policy 32.9 (2004): 1111. As noted earlier, the operation of Iridium 33 was licensed by, and under the control of, the U.S. Government, thus the U.S. was (and will remain) responsible (and possibly liable) for any damage, harm or injury caused by or with this satellite (or its debris).

[695] Article 1 (2) of the Outer Space Treaty specifies that, "Outer space [. . .] shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law".

[696] White, Jeffrey. "Iridium Satellite: Aviation – We are everywhere you want to fly". 5 Nov. 2009. http://www.eurocontrol.int/nexsat/gallery/content/public/Steering%20Group/Meeting10/IRIDIUM_JeffWhitePresentation32109.pdf.

[697] Ibid.
[698] "Vacuum in Space". 16 Feb. 2009. International Herald Tribune. http://www.iht.com/articles/2009/02/16/opinion/edspace.php.
[699] "Committee Examines Ways to Make the Space Environment Safer for Civil and Commercial Users". 28 Apr. 2009. Press Release from the Committee on Science and Technology of the U.S. House of Representatives. 23 Sept. 2009. http://science.house.gov/press/PRArticle.aspx?NewsID=2447.
[700] *The Corfu Channel Case* (Merits), Judgment of 9 April 1949 (1949) I.C.J. Rep.: 4. at p. 23.
[701] The Registration Convention, Article IV (3).
[702] According to Article I (a) of the Liability Convention, the term 'damage' "means loss of life, personal injury or other impairment of health; or loss of or damage to property".
[703] For example, the principles incorporated in the 2007 COPUOS Space Debris Mitigation Guidelines, discussed below.
[704] Stump, Adam M. "Satellite Collision Debris May Affect Space Operations, Cartwright Says". 12 Feb. 2009. American Forces Press Service. 19 Feb. 2009. http://www.defenselink.mil/news/newsarticle.aspx?id=53077.
[705] Shalal-Esa, Andrea. "Pentagon May Reach Satellite Analysis Goal Early". 28 Apr. 2009. Reuters. 2 Nov. 2009. http://www.reuters.com/article/idUSN2836780620090428.
[706] "Global Space Economy Revenues Reach 257 bln in 2008: Report". 31 Mar. 2009. Chinaview. 2 Aug. 2009. http://news.xinhuanet.com/english/2009-03/31/content_11106035.htm.
[707] "Space Debris – Problem Solved". 31 Aug. 2009. Space Daily. 30 Aug. 2009. http://www.spacedaily.com/reports/Space_Debris_Problem_Solved_999.html.
[708] Moskowitz, Clara. "U.S. 'Decades Behind' on Space Debris Threat, Official Says". 6 Nov. 2009. Space.com. 8 Nov. 2009. http://www.space.com/missionlaunches/091106-space-junk-risk-increase.html.
[709] "Space Debris: A Growing Challenge". Oct. 2009. Aerospace America. 2 Nov. 2009. http://www.gsb.stanford.edu/news/packages/2009/PDF/AIAA-SpaceDebris_OCT2009.pdf: 31.
[710] Ibid.
[711] Hearings on "Keeping the Space Environment Safe For Civil and Commercial Users". 28 Apr. 2009. U.S. House of Representatives Committee on Science and Technology Subcommittee on Space and Aeronautics.
[712] "Astronomy Question Of The Week: Is Space Debris Dangerous". 25 Aug. 2009. Spacemart. 25 Aug. 2009. http://www.spacemart.com/reports/Astronomy_Question_Of_The_Week_Is_Space_Debris_Dangerous_999.html.
[713] See *supra* footnote 690.
[714] "Space Debris Poses Risk". 3 Aug. 2009. The Times & Transcript. 3 Aug. 2009. http://timestranscript.canadaeast.com/newstoday/article/748848.
[715] Glassman, Albert. "The Growing Threat of Space Debris". July 2009. Todaysengineers. 2 Nov. 2009. http://www.todaysengineer.org/2009/jul/space_debris.asp.
[716] "Committee Examines Ways to Make the Space Environment Safer for Civil and Commercial Users". 28 Apr. 2009. Press Release from the Committee on Science and Technology of the U.S. House of Representatives. 23 Sept. 2009. http://science.house.gov/press/PRArticle.aspx?NewsID=2447.
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[717] "Space Debris: A Growing Challenge". op.cit. *supra* footnote 710.
[718] Lovgren, Stefan. "Space Junk Cleanup Needed, NASA Experts Warn". 19 Jan. 2006. National Geographic News. 19 Feb. 2009. http://news.nationalgeographic.com/news/2006/01/0119_060119_space_junk.html.
[719] Ibid.
[720] NASA, Orbital Debris Quarterly News 11.1 (2007): 2.
[721] Wright, David. "Colliding Satellites: Consequences and Implications". 26 Feb. 2009. Union of Concerned Scientists. 11 Oct. 2009. http://www.ucsusa.org/assets/documents/nwgs/SatelliteCollision-2-12-09.pdf.

[722] "United Nations' COPUOS Receives Update on Iridium-Cosmos Collision". NASA Orbital Debris Quarterly News 13.3 (2009): 2.
[723] Ibid.
[724] Swaine, Jon. and Stephen Adams, "Experts Warn of More Space Crashes After U.S. and Russian Satellites Collide: Space Scientists Issued a Stark Warning Yesterday Over the "Inevitable" Prospect of More Satellites Crashing into Each Other". 12 Feb. 2009. The Telegraph. 15 Mar. 2009. http://www.telegraph.co.uk/science/space/4603851/Experts-warn-of-more-space-crashes-after-US-and-Russian-satellites-collide.html.
[725] Moskowitz, Clara. "U.S. 'Decades Behind' on Space Debris Threat, Official Says". 6 Nov. 2009. Space.com. 8 Nov. 2009. http://www.space.com/missionlaunches/091106-space-junk-risk-increase.html.
[726] It has recently been reported that several nuclear-powered manned spacecrafts might be launched soon both by NASA and Russia. See: "Russia Goes All Out To Develop Nuclear-Powered Spacecraft". 16 Nov. 2009. Space Travel. 16 Nov. 2009. http://www.space-travel.com/reports/Russia_Goes_All_Out_To_Develop_Nuclear_Powered_Spacecraft_999.html; Kislyakov, Andrei. "Old Russian Nuclear Satellite Returns". 30 Jan. 2009. Spacedaily. 2 Nov. 2009. http://www.spacedaily.com/reports/Old_Russian_Nuclear_Satellite_Returns_999.html; Isachenkov, Vladimir. "Russia Hopes Nuclear Ship Will Fly Humans to Mars". 29 Oct. 2009. Associated Press. 2 Nov. 2009. http://www.google.com/hostednews/ap/article/ALeqM5jfhjVbCZfHYXlG0zJNKwYr8BtNqgD9BKPDOO0.
[727] "China Confirms Satellite Downed". 23 Jan. 2007. BBCnews. 2 Nov. 2009. http://news.bbc.co.uk/2/hi/asia-pacific/6289519.stm.
[728] Morring, Jr., Frank. "China Asat Test Called Worst Single Debris Event Ever". 11 Feb. 2007. Aviation Week & Space Technology. 10 Mar. 2007. http://www.aviationweek.com/aw/generic/story_generic.jsp?channel=awst&id=news/aw021207p2.xml.
[729] Ibid.
[730] Johnson, Nicholas L. "Preserving the Near-Earth Space Environment with Green Engineering and Operations". 30 Sept.–1 Oct. 2009. Presentation. NASA Green Engineering Masters Forum. 3 Nov. 2009. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20090032041_2009032577.pdf.
[731] "Space Debris: A Growing Challenge". op.cit. *supra* footnote 710.
[732] "Space Debris: Orbiting Debris Threatens Sustainable Use of Outer Space". 2008. United Nations. 10 Oct. 2009. http://www.un.org/en/events/tenstories/08/spacedebris.shtml.
[733] See, UN Doc. A/AC.105/820/Add.1 of 15 December 2003; UN Doc. A/AC.105/820/Add.1 of 4 February 2004; Roscosmos. "Activity of Russian Federation on Space Debris Problem". Presentation. 46th Session of the Scientific and Technical Subcommittee of UNCOPUOS. Vienna, Austria. 17 February 2009. 2 Nov. 2009. http://www.unoosa.org/pdf/pres/stsc2009/tech-46.pdf; Wirt, Uwe. "UN-Space Debris Mitigation Guidelines – National Implementation Mechanism." Presentation. 48th Session of the Legal Subcommittee of UNCOPUOS. Vienna, Austria. 31 March 2009. 2 Nov. 2009. http://www.unoosa.org/pdf/pres/lsc2009/pres-06.pdf; Klinkrad, Heiner. "Space Debris Mitigation Activities at ESA". Presentation. 46th Session of the Scientific and Technical Subcommittee of UNCOPUOS. Vienna, Austria. 17 February 2009. 2 Nov. 2009. http://www.unoosa.org/pdf/pres/stsc2009/tech-40.pdf; NASA "USA Space Debris Environment and Policy Updates". Presentation. 45th Session of the Scientific and Technical Subcommittee of UNCOPUOS. Vienna, Austria. 11–22 February 2008. 2 Nov. 2009. http://www.unoosa.org/pdf/pres/stsc2008/tech-26E.pdf.
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[735] "Keeping the Space Environment Safe for Civil and Commercial Users". Testimony of Secure World Foundation. U.S. House Committee on Science and Technology, Subcommittee on Space and Aeronautics. Hearing on 28 April 2009.

[736] Ibid. Emphasis added.
[737] Jeffrey White. op.cit. *supra* footnote 697.
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