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Long-term sustainability of outer space activities

Long-term sustainability of outer space activities

Preliminary reflections

The present document should be read together with document A/AC.105/C.1/L.303.

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Long Term Sustainability of Space Activities

Preliminary reflections

January 2010

Note: this document is to serve as a supporting document for consideration by Member State delegations to the 47th session of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) Scientific and Technical Sub-Committee (8 to 19 February 2010) in its discussion of the new agenda item on the issue of the long term sustainability of outer space activities (item 14 of the agenda).

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Preamble

This preliminary reflections document on the issue of the "Long Term Sustainability of Space Activities" is the result of the collective work of an informal working group of experts from about twenty countries, international organizations, commercial satellite operators and non governmental organizations who share a serious concern about the security and safety of space activities in the long term.

The purpose of this document is to present the technical and operational issues affecting the long term sustainability of outer space activities, to identify the existing international mechanisms addressing these issues which are already in place and point to possible improvements or complements to these mechanisms.

It is not intended as a final report on these issues but rather as a foundation basis for further work in this area, which will naturally take place within a dedicated working group of the Scientific and Technical Sub-Committee of the United Nations Committee on Peaceful Uses of Outer Space (UNCOPUOS).

My sincere thanks go the many contributors to this document, from space agencies, government departments, non governmental organizations and commercial satellite companies.

Gerard Brachet

Coordinator of the informal working group on Long Term Sustainability of Space Activities

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Section 1 – Background and introduction

Sustainability of space activities in earth orbit over the long term is increasingly a matter of concern for space faring nations and regional space organizations as well as for commercial satellite operators.

The ever increasing number of actors in outer space, both government and private, including potential providers of private space flight opportunities, the effect of space weather on space operations and the proliferation of space debris produced by an increasing use of outer space by the community of nations, all call into question the ability to continue operating in a safe environment, at least in the low earth orbits (LEO) and in the geostationary Earth orbit (GEO).

Furthermore rocket launches, space vehicles return operations, and space debris re-entries entail potential safety risk for populations and international air and sea travellers.

1.1 The legal framework

The legal background for the long-term sustainability of space activities can be found in several instruments and provisions of international law as well as national legislations which deal with the concerns relevant to the sustainable future of space activities, namely the *rational use of outer space*, the *responsibility of States for space activities, international liability in case of damage* and the *transparency in the utilization and the exploitation of outer space, in particular Earth's orbits*.

A first set of relevant principles is made of the principles stated by the 1967 UN Outer Space Treaty. Those principles feature the freedom of access to and use of Outer Space, the non-appropriation under national sovereignty of Outer Space, the respect of the space environment, including Earth's orbits, the sharing of information on space activities and their outcome.

Another important set of principles are related to States' international responsibilities for space activities. States are responsible for their own governmental activities and for private activities performed under their jurisdiction. This requires States to authorize and supervise such latter activities. Furthermore, according to the 1967 UN Outer Space Treaty as complemented by the 1972 UN Liability Convention, States which launch or procure a launching or from whose territory or facility an object is launched are internationally liable for any damage caused by this space object on the Earth's surface and to aircraft in flight as well as for damage caused by their fault to another space object in flight. It must be noted that the definition of a "space object" includes the object as well as any of its parts. In connection to the international responsibilities principle, the space object registration mechanism is set up by the 1967 UN Outer Space Treaty as complemented by the 1975 UN Registration Convention. This set of provisions requires that any object launched in Outer Space be registered by (one of) the launching State(s). This State thereby exercises its jurisdiction and control on and onboard the space object.

Besides the UN treaties and conventions, the United Nations General Assembly has adopted several resolutions related to various specific aspects of space activities. Those resolutions have no binding effect per se, although some of them have generated constant practice from space faring nations and contain important principles and recommendations[1].

An important text has been adopted within the UNCOPUOS Legal Sub-Committee at its 39th session, as inserted in the Main Committee's report adopted by the United Nations General Assembly (December 8, 2000). This text features the consensus achieved amongst UNCOPUOS' Member States on the access to and the use of the geostationary orbit, considering the interests and needs of developing countries.

Finally, any potential work in UNCOPUOS with respect to best practices for space operations should keep in mind the United Nations General Assembly Resolutions adopted through the First Committee on transparency and confidence-building measures[2] .

1.2 Long term sustainability of space activities

The issue of sustainability of space activities has already been addressed by many sectors of the space community, for example the Inter-Agency Space Debris Coordination Committee (IADC) which focussed on the proliferation of space debris, by the International Academy of Astronautics which published a report on space traffic management in 2006[3] or by the International Association for the Advancement of Space Safety (IAASS), which published a report called "An ICAO for Space?" in 2007. It was also raised by the chairman of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), the committee mandated by the UN General Assembly to elaborate appropriate resolutions, principles or international conventions relative to the peaceful uses of outer space, in his paper "Future role and activities of the UNCOPUOS"[4] presented to member states' delegations at the plenary session of UNCOPUOS in June 2007.

However, before formally bringing this topic to the agenda of the UNCOPUOS, informal consultations with the relevant actors can provide a useful forum for exploring how, based on concrete experience, a possible international consensus might be reached on recommendations or guidelines on "best practices in space operations".

To this effect, a first informal working group meeting was convened at the initiative of France in Paris on February 7 and 8, 2008. Representatives from fifteen states actively involved in space activities participated in this first meeting, as well as five commercial satellite operators and international governmental organizations.

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[1] The most relevant resolutions with respect to the issue of long-term sustainability of space activities are the following: Resolution 47/68 of 14 December 1992, on the Use of Nuclear Power Sources in Outer Space; Resolution 51/122 of 13 December 1996, featuring the Declaration on international cooperation in Outer Space. Two other technical resolutions are relevant as far as the improvement of the transparency and the reliability of space activities is concerned: Resolution 59/115 of 10 December 2004 on the Concept of "Launching State"; Resolution 62/101 of 17 December 2007 on the States' registration practices. Two resolutions of December 1961 (Res. 1721 A and B) must also be noted since they provide the legal basis to some States for communicating information and data about space objects and activities to the UN Secretary General.

[2] Those are resolutions on the Transparency and Confidence-Building Measures in Outer Space Activities (i.e. 61/75 of 6 December 2006 and 62/43 of 5 December 2007).

[3] Cosmic Study on Space Traffic Management, IAA, 2006.

[4] A/AC.105/L268 of 10 May 2007(section D).

The informal working group defined four primary objectives for its work :

1. To identify and exchange views on the concerns associated with long term sustainability of activities in space;

2. To exchange views on what information and data are needed to better monitor the space environment in order to operate safely in space;

3. To exchange views on possible mechanisms to ensure the safety of space activities in the long term;

4. To prepare an outline document to be submitted to the UNCOPUOS with a view to consideration of this topic and setting up a dedicated Working Group under a multi-year work plan.

During its first meeting, the informal working group tasked a drafting committee to develop the outline document referred to in item 4 above. Its purpose was to present the issue of "Long Term Sustainability of Space Activities" and to introduce some thoughts on possible recommendations and mechanisms that would contribute to keeping outer space safe and secure for the long term.

The present paper, entitled "Preliminary reflections", is the outcome of the work of the drafting committee.

Section 2 – The issue of Space Debris

A major threat to the long-term sustainability of space activities is the growing population of space debris. Space debris is defined as all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional. This population, comprising non-operational spacecraft, derelict launch vehicle upper stages, mission-related objects and fragments from satellites and orbital stages that are in orbit about the Earth, continues to increase. As of July 2008, the number of orbital debris varies with size, ranging from approximately 18,000 tracked objects greater than 10cm in size to more than tens of millions estimated objects greater than 1mm in size. Because of the high relative velocities of orbital debris (1 to 14 km/s depending on the orbit regime and geometry of the collision), even the small objects represent a collision hazard to the population of operational satellites in orbit around the Earth. Failure to limit the growth of the orbital debris population will lead to major restrictions on our ability to exploit space for a range of scientific, economic, and strategic purposes, including environmental monitoring, communications and navigation.

Space debris mitigation measures can be divided into two broad categories: 1) those that restrict the generation of potentially harmful space debris in the near term; and 2) those that limit or lessen their generation over the longer term. The former involves the curtailment of the production of mission-related objects and the avoidance of break-ups. The latter concerns end-of-life procedures that remove de-commissioned spacecraft and launch vehicle orbital stages from regions populated by operational spacecraft, as well as active measures to remove space debris from protected regions.

Space debris remediation is a further step which requires the active removal of those derelict satellites or launcher upper stages which may be in orbit for a long time before re-entry and also may have a substantial amount of residual propellant on-board.

The history of international discussions on space debris mitigation is presented in Annex 1. A significant part of the work has taken place within the Inter Agency Space Debris Coordination Committee (IADC), which published its first issue of the IADC Space Debris Mitigation Guidelines in 2002. States participating in the IADC then introduced its recommendations to the UN COPUOS. A dedicated Working Group of the Scientific and Technical Sub Committee was established in 2004, which elaborated a UN Space Debris Mitigation Guidelines Document, submitted for approval of the Scientific and Technical Subcommittee in February 2007 and endorsed by the full Committee in June 2007. These Guidelines were appended to the annual report of COPUOS to the UN General Assembly, which itself endorsed the document at the end of 2007 in its Resolution 62/217 (document A/RES/62/217 dated 10 January 2008).

The seven Guidelines in the UN document reflect the need to:

- Limit debris released during normal operations
- Minimize potential for break-ups during operational phases
- Limit the probability of accidental collision in orbit
- Avoid intentional destruction and other harmful activities
- Minimize potential for post-mission break-ups resulting from stored energy
- Limit the long-term presence of spacecraft and launch vehicle orbital stages in LEO after the end of their mission
- Limit the long-term interference of spacecraft and launch vehicle orbital stages with GEO region after the end of their mission

Each Guideline has its own recommended practices/application description and a related rationale/justification. In Resolution 62/217 “International cooperation in the peaceful uses of outer space” the UN General Assembly, when endorsing the Space Debris Mitigation Guidelines of COPUOS, invited Member States to implement those Guidelines through relevant national mechanisms.

As of the end of 2008, many space faring nations had implemented national regulations on space debris mitigation or were in the process of preparing such regulation. A review of the regulations already in place in some countries such as the United States, Canada, France, UK, Germany, Italy, within ESA, Japan, the Russian Federation, is provided in the second part of Annex 1.

Section 3 – Improving the safety of space operations

The term *safety* with reference to space activities is used in this paper in a wider sense, which refers not only to the human risk but also to the operational risk for strategic utilities on orbit as telecommunication satellites and global navigation systems, and to the related environmental risks.

3.1 Operations in the GEO orbit

3.1.1 Introduction

Over its nearly 50 year history, the commercial satellite industry, working in conjunction with national and international government agencies, has developed the procedures necessary to ensure the safe operation of its fleets as well as the preservation of the unique space environment. Over the decades, this industry has played an active role in developing technology, worked collaboratively to set standards, and partnered with various governments to develop successful international regulatory regimes. Nonetheless, increased utilization of the geostationary orbit (GEO) by commercial and governmental actors, combined with the potential for the introduction of new technologies, suggest that a review of current industry best practices for safety of operations in space might be in order. This section examines the current state of the space environment, data sharing and risk management practices in the commercial satellite industry and the relationship of these issues to safety of flight. In addition, this section examines new paradigms for facilitating increased communication among commercial and government operators to promote safety of space operations and reduce the possibility of creating dangerous, long-lived space debris. The challenge is to find the balance between the need for operators to protect sensitive information and capabilities and their need to share information to ensure the safety of space operations.

3.1.2 Risks

Operating with only general government oversight for day-to-day flight operations, commercial satellite operators have, over time, developed their own internal protocols and procedures to ensure the safe operation of their fleets. Operators have also become adept at formal and informal coordination and information exchange with operators who have spacecraft in adjacent or nearby orbital locations. For the most part, a commercial communication satellite flying within its station keeping "box" (usually ±0.1° in both longitude and latitude)[5] in GEO has few worries about a possible electromagnetic interference or a collision with another commercial operator, provided that national licensing procedures have adequately assessed potential EM interferences and collision risks for the station-keeping box. There are, however, other risks that commercial operators must consider:

- Some operators, particularly government operators, limit the amount of information they share regarding space objects under their control for national security purposes. This lack of information can cause problems for commercial operators, particularly if the commercial operator is sharing an orbital location with a government satellite. In this case, only the government has the information necessary to ensure safety of flight. Similar problems can occur when a commercial operator is relocating a spacecraft or operating a spacecraft in close proximity to an

[5] To prevent the possibility of RF (Radio Frequency) interference, current ITU rules are based upon geostationary fixed satellite service operators maintaining the position of their satellites within 0.1° of longitude to the East or West. Since one tenth of a degree, in GEO, is equal to 74km, this means that operators are required to fly their satellites along an arc approximately 148 km in length. The rules of individual countries may vary. For example, the US Federal Communication Commission's (FCC) rules generally require that US operators maintain a satellite within 0.05°of its assigned location. Some satellites operate in an inclined orbit mode and do not limit inclination in the North or South directions.

unknown government spacecraft. When appropriate levels of information are not shared, operators do not have access to the best information available, thus increasing operational complexity and cost while reducing safety of flight. The presence of unknown space objects increases risk that operators cannot adequately mitigate without appropriate communications.

- Occasionally, GEO satellites are not operated at their assigned location. For example, during launch, when relocating to a new orbital location, or during decommissioning, commercial satellites routinely transit the operating space of other satellites. During these periods, data sharing between operators is essential. Today, such data sharing is conducted in an ad hoc manner, and there is currently no standardized agreement among operators on the content, format and distribution protocols for data sharing. Where adjacent operators have routine interactions, more permanent agreements may exist between operators.

- Spacecraft anomalies can result in temporary or permanent, and partial or complete loss of control of a satellite which may cause the satellite to drift form its assigned orbital locations. Typically, these anomalies occur suddenly, precluding advance communication. Nevertheless, in situations where an uncontrolled satellite might drift outside of its nominal orbital location, some type of notification protocol would be appropriate, and this should include governmental spacecraft.

- Space debris can pose a threat to operational spacecraft. Satellite operators are concerned about non-functional spacecraft, other forms of man-made space debris and naturally occurring meteoroids.

    - Man-made Space Debris - The 2007 update to the IADC guidelines on space debris mitigation – specifically the section on the use of disposal orbits – have made an important contribution to the establishment of pragmatic international “best practices” for reducing man-made debris. The results of recent decommissioning activities show a clear increase in the implementation of these guidelines. This change of trend is a clear common success and represents an important improvement in communication and cooperation between the international organizations, national authorities and operators.

    - Meteoroids - The impact of a meteoroid, of most probable sizes in the sub-mm domain, can have mission-compromising effects on a satellite. It is currently very difficult to detect or implement measures to avoid such risks, except for general measures that play on statistical distribution and relative orientations or increase of shielding.

3.1.3 Present situation

Operators require precise information to manage their satellite fleets. Because they are constantly tracking their own satellites, it is easy to maintain an accurate catalogue of current information on their own assets. Experience has demonstrated that communication and coordination with other operators is the most effective means to reduce the probability of collisions.

To determine the approximate position of other space objects, operators have several choices: (1) obtain information directly from other operators; (2) check the public databases of two line element (TLE) lists maintained by the US Air Force and others; or (3) rely on third party services. Operators routinely track their own satellites, allowing them to create a highly accurate ephemeris of current location, velocity, and planned manoeuvres.[6] Commercial operators that share adjacent orbital locations will often develop highly interactive data exchange practices that are used in the event of a close conjunction, where, for example, one satellite is expected to enter the station-keeping volume of another. In addition, in case of need, operators provide additional notification to other operators known to be affected during special procedures such as satellite relocation fly-bys and transfer orbit operations. These notifications usually consist of the latest orbital information[7] near term manoeuvre plans and contact information for further discussion. Exchange of information is impossible between operators if the position, or even the existence, of other spacecraft is not known.

Exchange of satellite data is complicated because no single information exchange protocol exists. As a result, communication can lack coordination, can be time consuming, and can be imprecise. Operators who routinely coordinate and share information with one another develop information sharing arrangements. Since there is no single standard used to manage satellite fleets or to represent the position of an object in space, operators use different protocols for sharing information (e.g., e-mail, phone, and private Internet exchange or public posting on operator web sites) and for representing the status and position of their fleets (see Annex 3). Today, commercial operators must be prepared to accommodate the practices of other operators by negotiating individual agreements or by maintaining redundant information sharing protocols. Once an operator obtains the data regarding another system, usually the information must be translated into a compatible format. Some operators write their own software tools for monitoring and predicting close approach, either using TLEs or the orbit information provided by the other operator, while others contract with third parties for this service. It is at the discretion of each spacecraft operator to maintain "space situational awareness" with respect to their fleet and for developing the tools necessary to exchange information with other commercial operators.

Today, commercial satellite operators maintain timely and valuable information on hundreds of satellites and a comprehensive picture of the global RF environment.[8] However, commercial satellite operators have not deployed the costly electro-optical and radar sensors that would be necessary to obtain precise information on the location of other satellites, drifting objects, and natural and artificial space debris. Instead, operators utilize data resulting from electro-optical and radar observations publicly provided by the US Government through its Commercial and

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[6] Precise orbital data are also relevant to the effective management of the radio frequency spectrum. Commercial products can locate a transmitter causing harmful interference by using precise satellite location information from adjacent operators.

[7] This refers to the date and time reference, orbit data presentation, the reference and coordinate system. For further discussion, see Annex 3.

[8] Precise orbital data are also relevant to the effective management of the radio frequency spectrum. Commercial products such as TLS (transmitter location system) or Glowlink can be used to track interference from unknown sources. Experience shown that using orbital and manoeuvre information from other operators greatly reduces the time required to track down the source of interference.

Foreign Entities (CFE) program.[9] More recently, a growing number of governments and entities, including Russia, France, Australia, and the European Space Agency have begun collecting information on the space environment and have expressed some interest in sharing this information with commercial operators.

For most satellite operators, information on objects (other than their own spacecraft) is typically derived from the basic Two Line Element sets (TLEs) made available through the US Air Force' CFE program.[10] The United States Department of Defense is in the process of transitioning the CFE Program from a pilot program under the U.S. Air Force to an operational program under US Strategic Command. Operators sometimes use the basic TLEs provided by CFE to calculate first-order conjunction assessments. Potential conjunctions identified through this process can then be further refined using additional data, gathered from a variety of sources. Additionally, the operational CFE program offers a conjunction assessment service using more refined data and models. Operators need to enter into an agreement with US Strategic Command to benefit from this service and other value-added services.

Sharing information, such as planned manoeuvre data, is a key element of the operational CFE program. In addition to the uncertainties of the TLE data, operators also do not have a source of current and reliable manoeuvre information for active spacecraft. Manoeuvre information is necessary, in addition to location information, to properly predict the ephemeris for active spacecraft even though the results of a manoeuvre may also contain a certain degree of uncertainty. This uncertainty may not be resolved until the first post-manoeuvre orbital assessment. Even with good communication between operators or the best available data, manoeuvre dates and time may change. Developing a method to share timely and accurate manoeuvre data when necessary is a challenge shared by both governments and commercial operators.

Man-made objects (intact payloads, rocket bodies or mission-related objects, or fragments thereof), meteoroids, and solar activity all pose potentially serious issues for the health and integrity of satellites. In March 2009, there were over 19,000 objects tracked by the USA Space Surveillance Network (SSN). This system tracks objects larger than 5 to 10 cm in LEO, and larger than 30 cm to 1 meter in GEO. During the same period, the ESA MASTER model estimated the number of objects larger that 1cm across all orbit regimes at 606,000.

The present collision risk with man-made objects is still low in GEO. Nevertheless, prevention measures, such as prudent decommissioning activities and tracking mechanisms, need to continue. Collision with man-made space debris or operational payloads can only be avoided if these are accurately tracked in advance. At present, an operator cannot use the data available to reliably predict all close-approaches.

Within the next decade, many more actors are expected to exploit space for commercial, scientific, humanitarian, and governmental purposes. Therefore it is essential that the world's governments provide leadership on space management issues today in order to protect the space activities of tomorrow. Bad decisions and

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[9] See: http//www.space-track.org/perl/login.pl. This site provides access to satellite orbital data received from the U.S. Department of Defense and is the same data that was previously provided by the NASA Orbital Information Group (OIG).

[10] See: http://www.space-track.org/perl/login.pl

short-term thinking will create problems that will last for generations. Wise decisions and the careful management of our precious space resource will ensure that the tremendous benefits from the peaceful use and exploration of outer space are enjoyed by those who follow in our footsteps in the decades to come.

3.2 Operations in the MEO orbits

3.2.1 Introduction

The medium Earth orbit (MEO) region contains navigation satellite constellations, including GLONASS at an altitude of 19,130 km and GPS at an altitude of 20,182 km (semi-synchronous orbit, i.e., orbit period is approximately 12 hours). Galileo will be deployed at an altitude of 23,222 km. The Chinese COMPASS constellation is planned for an altitude of 21,500 km. The MEO region will also contain the disposed satellites and upper stages associated with the navigation constellations. In addition, the MEO region is transited by objects on Molniya and geosynchronous transfer orbits (GTO). The Molniya and GTO orbits contain many disposed objects and fragmentation debris. The European Space Agency MASTER (Meteoroid and Space Debris Terrestrial Environment) model predicts that there are some 200,000 objects of 1 cm or larger size with orbits passing through the MEO region. Typical collision velocities are lower than in LEO but are still about 5 km/sec on average. As a result, a collision with an object larger than 1 cm could cause severe damage to a spacecraft.

Debris mitigation guidelines, policy directives, and instructions within the U.S. government address end-of-life disposal of satellites and upper stages. As an example, the United States Government Orbital Debris Mitigation Standard Practices[11] recognizes storage or disposal orbits between LEO and MEO from 2,000 km altitude to at least 500 km below semi-synchronous orbit. The United States Strategic Command currently instructs in this same region that operators manoeuvre the satellite/booster/upper stage to an orbit with perigee altitude above 2,000 km and apogee altitude below 18,400 km (below GLONASS)[12]. For disposal between MEO and GEO, the satellite/booster/upper stage should be manoeuvred to an orbit that has either perigee altitude above 20,700 km and apogee altitude below 22,000 km (between GPS and Galileo), or perigee altitude above 25,200 km and apogee altitude below 34,800 km (between Galileo and GEO). These directives reflect a policy of debris prevention by avoiding collisions between operating spacecraft and disposed objects since there is no atmospheric drag to cause re-entry as in the lower part of the LEO region.

Regarding compliance with these guidelines, GPS Block I satellites were left in the constellation altitude range because they were decommissioned before the disposal guidelines were published. On the other hand, compliance by GPS Block II satellites has generally not been difficult. With only a few exceptions, GPS Block II satellites have had adequate remaining propellant at end of life to raise perigee to altitudes between 900 and 1,320 km above the GPS reference orbit. The next generation of GPS satellites (Block IIF) has a requirement to raise perigee to 832 km above the GPS reference orbit.

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[11] Available from the NASA Orbital Debris Program Office website: http://orbitaldebris.jsc.nasa.gov/library/USG_OD_Standard_Practices.pdf

[12] Strategic Command Instruction 505-04, *Satellite Disposal Procedures*, 21 April 2006.

The upper stages for GPS Block I and II missions have remained on highly eccentric transfer orbits with perigees low enough for atmospheric drag to restrict orbital lifetime. The GPS satellites have used an integrated apogee kick motor to raise perigee and circularize the orbit. GPS Block IIF satellites will be directly inserted into the operational constellation by the Evolved Expendable Launch Vehicle (EELV). However, due to design restrictions, the upper stages will not be able to raise their perigees out of the altitude band of the operational GPS constellation to the recommended disposal regions. Therefore, unlike for boosted satellites, the upper stages will pose a near-term collision risk to the operational GPS satellites.

In addition, China's COMPASS system's planned altitude of 21,500 km is within the GPS disposal orbit. Analysis of the intra-graveyard dynamics is required to determine the collision risk posed to operational MEO satellites.

An important phenomenon that affects MEO disposal is the eccentricity growth of MEO disposal orbits. GPS disposal orbits can undergo significant eccentricity growth over a time frame of decades. The cause of this long-term eccentricity growth is a dynamical resonance condition resulting from the combined gravitational attraction of the Sun and Moon, the non-spherical gravity field of the Earth, and solar radiation pressure. The eccentricity growth depends on the initial elements of the disposal orbit. The ramification of eccentricity growth is discussed in the following section on risks.

3.2.2 Risks

While there are a large number of objects transiting through the MEO region, they spend a relatively small fraction of time near the navigation constellations, and therefore the risk posed by those objects to the navigation constellations is much lower than the risk posed by background objects to LEO and GEO operational spacecraft. The risk will increase as the number of debris objects on Molniya and GTO orbits increases with time. In addition, disposed GPS Block I satellites still orbit inside the constellation altitude range and pose a collision risk to operational GPS satellites. As a result, the GPS ground segment monitors close approaches between operational satellites and tracked background objects. Regarding GLONASS, disposed satellites and upper stages have been left inside the GLONASS constellation altitude range and pose a collision risk to operational GLONASS satellites.

An important consideration for close approach monitoring and collision avoidance is that the tracking accuracy for background objects passing through the MEO constellations is limited. The associated tracking error is well below 1 km. The avoidance manoeuvres will thus have to be performed for close approaches within 1 km in order to be effective. Avoidance manoeuvres would result in satellite outages and therefore cause interference with the navigational performance of the constellation. Hence, a significant number of close approaches would pose a constellation performance interference risk.

Due to disposal orbit eccentricity growth, disposed satellites will not remain confined to the specified disposal regions and will eventually re-enter the MEO constellation altitude ranges and pose a collision risk to operational satellites. Eccentricity growth will also affect the collision risk that will be posed by the GPS Block IIF upper stages to the MEO constellations.

3.2.3 Present Situation

For GPS satellites, current operational practice is to minimize initial disposal orbit eccentricity in order to slow down eccentricity growth and maximally delay re-entry into the constellation. However, continuing this practice in the future will eventually cause the intra-graveyard collision risk to grow much larger than the collision risk posed to operational MEO satellites. As a result, development of improved yet realistic disposal procedures will continue. It is planned to investigate alternative MEO disposal strategies that do not minimize initial eccentricity in order to reduce intra-graveyard collision risk. Both intra-graveyard collision risk and constellation close approach frequency will be quantified for these strategies.

For GPS Block IIF upper stages, collision risk and close approach frequency assessments are being performed as launch vehicle performance predictions are updated. Options involving modification of the propellant blow-down sequence are still being analysed.

The Inter-Agency Space Debris Coordination Committee (IADC) serves as a forum for exchange of information on spacecraft disposal. Beyond this information exchange, it is clear that some coordination of End of Life disposal procedures specific to the MEO orbits will need to be developed between the operators of GNSS constellations (see Section 7, recommendations).

3.3 Operations in the LEO orbits

3.3.1 Orbits of the manned space vehicles

For manned flight orbits, typically below 500 Km altitude, space debris mitigation measures are highly relevant due to crew safety implications. Operating the International Space Station, currently the only permanently manned orbital station operated in low Earth orbit, along with its myriad supply and transportation vehicles, requires close coordination among all the ISS partner space agencies, as well as their respective governments. Precise scheduling is necessary to manage the arrival, departure, landing and/or disposal of visiting vehicles, such that they do not negatively impact each other, the ISS, or any other vehicle operating in LEO. The ISS partnership also monitors space debris and occasionally maneuvers the ISS to avoid potential contact with space debris. In total, 8 evasive maneuvers were performed in the first 10 years of continuous operation of the ISS. Full and open communications has proven to be the key factor that allows for safe operation of the vehicle. Lessons learnt from the experience gained in operating the ISS should be directly applicable to future manned orbital stations.

As compared to earlier space stations the ISS releases considerably fewer mission related objects into space. A large share of the remnants generated through ISS operations are discarded by means of controlled, destructive re-entries of supply vehicles (Progress or ATV). In addition, in the recent past the ISS partners have developed an “ISS Jettison Policy” that allows to discard obsolete ISS hardware by jettison in an extra-vehicular activity (EVA). Procedures are defined such that (1) the residual lifetime of the released objects and their re-entry risk potential complies with international debris mitigation guidelines, and (2) the ISS safety, and the safety of its supply vehicles is not compromised.

3.3.2 Sun-Synchronous orbits

3.3.2.1 Introduction

On Sun-Synchronous orbits, a near-constant angle between the orbital plane and the Sun direction is maintained throughout the year. This particularity is very useful in the case of Earth observation satellites, because the same areas on the Earth surface can be observed at different dates under the same lighting conditions. The Sun-synchronism is obtained for slightly retrograde, near-polar orbits through a particular combination of altitude and inclination.

Most Earth observation missions operate on Sun-synchronous orbits at altitudes between 600 and 900 km. Today this part of the LEO space is the most crowded region, with the highest debris growth rates of any orbit, resulting in a doubling of the debris concentrations between 2004 and 2009. Beside numerous civilian and military satellites, many scientific spacecraft use this altitude range to fulfill their mission. Upper stages of launchers that were used to inject these satellites into orbit can also be found in this region. In addition, several fragmentation events, deliberate or accidental, contributed a large number of long-lived debris. While most fragmentations were due to explosions, there were also 4 confirmed, unintentional collisions between catalog objects, including the first collision between two large-size, intact objects (Iridium-33 and Cospms-2251 on Feb.10, 2009). All these collisions occurred between 700 and 1,000 km altitude, as a consequence of the high debris concentrations.

Long-term projections of the space debris environment indicate that within a few decades collisions between intact objects or fragments will start prevailing over explosions. The resulting increase in collision rates will be non-linear, possibly leading to a collisional cascading process (“Kessler syndrome”) in some orbit regimes. Simulations show that even in the absence of new launches, the number of objects in space will continue to increase, based on a latent in-orbit mass reservoir of about 5,800 tons, of which 40% reside in LEO, with up to 1,200 objects and 350 tons of mass per 50 km altitude bin, and up to 2,100 objects and 650 tons of mass per 1 deg inclination bin.

3.3.2.2 Risks

Due to the large number of LEO debris in all size regimes, a non-negligible risk of collision exists for satellites operating in this region. Because of the spacing in right ascension of the orbital planes of the many thousands of orbital debris and hundreds of spacecraft operating in the Sun-synchronous orbits, their orbits cross each other at the poles every revolution (about every 95 to 100 minutes) with a high relative velocity (average 10 to 14 Km/s).

Small impacts are observed on retrieved objects (e.g. solar panels of the Hubble space telescope, LDEF, MIR or ISS experiments), or on return vehicles such as the Space Shuttle. Due to the very high orbital velocities (around 8 km/s in LEO), and the even higher collision velocities, even a 1 mm particle can inflict serious damage to a spacecraft in case of impact on a critical component. The collision of an unprotected spacecraft with a 1 cm object would most probably lead to a mission loss, and the collision with a 10 cm object is expected to cause a catastrophic fragmentation, leading to a large amount of additional debris, some of which would again be capable of triggering further catastrophic break-ups. Of the 4 unintentional collisions between catalogued objects (all of them in the LEO region), the most recent one between Iridium-33 and Cosmos-2251 on Feb.10, 2009, at 790 km altitude, produced about 1,500 large, catalogued debris. This event is only surpassed by the effect of a China's ASAT test on its FengYun-1C satellite on Jan. 11, 2007, at 862 km altitude, which resulted in some 2,500 long-lived catalog objects. The collision risk for operational satellites on Sun-synchronous orbits has significantly increased (e.g. by about 100% for ESA's Envisat and ERS-2 satellites) as a result of the latter two events.

In order to conserve the LEO region at a safe level for space operations, mass removal is advised through natural orbit decay, direct de-orbit, or perigee lowering to a reduced-lifetime orbit. For large-size objects one can expect that 20% to 40% of the mass survive to ground impact. In most cases the re-entry will be at random, with no control of the impact footprint. The residual risk to the ground population, to air traffic, and to maritime traffic must be compliant with applicable rules of the launching state.

3.3.2.3 Present situation

The most effective debris mitigation measures are the implementation of end-of-life disposal maneuvers and the end-of-life passivation of spacecraft and orbital stages. The objective of passivation measures is a reduction of explosion fragments that dominate the current space debris environment. The objective of direct de-orbit maneuvers or orbit lifetime reduction maneuvers (to residual lifetimes of less than 25 years) is the removal of on-orbit mass to avoid long-term collisional cascading.

These debris mitigation measures can only be applied to a subset of the large-size objects, since most satellites and rocket upper stages were launched before the adoption of guidelines, and their design does not allow performing these operations. In any case the implementation of these measures is complex. The estimation of remaining fuel at end of life is inaccurate, and large uncertainties entail significant margins that reduce the effectiveness of the measure. In addition, operators are sometimes reluctant to interrupt the mission of an operational satellite and compromise mission objectives. Another difficulty results from the passivation activities. The release of propellants or pressurants produces a thrust that may cause adverse effects on the orbit and/or attitude. A dedicated passivation strategy needs to be implemented to optimize the end of life disposal maneuver, maintaining the necessary control of the attitude, the TM/TC links, and the power supply before switching off the spacecraft. These requirements incur a high reliability of the end-of-life disposal system, with corresponding implications on technologies and related cost.

Generally a direct de-orbiting of spacecraft and launcher upper stages is not possible due to the large amount of propellant required. Space Debris Mitigation Guidelines recommend lowering the orbit to be compliant with the 25-year rule. As a consequence the vehicle will remain on orbit for several years before reentering into the atmosphere in an uncontrolled manner. The surviving debris will reach the ground within a latitude band corresponding to the inclination of the orbit.

Some satellites do not have a propulsion system, because it is not required or even detrimental for their mission. This is the case for numerous micro- or nano-satellites. In order to be compliant with the 25-year rule these satellites should be injected into orbits of a sufficiently low altitude which depends on the area-to-mass ratio of the object, and on the atmospheric conditions as a function of the solar activity cycle. Drag augmentation through the deployment of appendices at the end-of-mission can allow for a higher operational altitude.

To reduce the risk of catastrophic collisions with catalog-size objects, some operators of satellites in Sun-synchronous orbits and other LEO regions, predict and monitor close approaches and perform avoidance maneuvers when necessary. This process is rather complex due to the unknown accuracy of orbit data for external customers of catalog service providers. In the absence of first-hand information on the available orbit data, conservative assumptions must be made on the orbit uncertainties. This leads to larger stand-off margins and thus to an increased false alarm rate, with adverse implications on the mission fuel budget and the mission objectives. The orbit ephemerides of operational spacecraft are mostly known with good accuracy. In order to reduce orbit uncertainties of the approaching object the operator has to perform tracking measurements using powerful radars that generally belong to defense organizations. Therefore, the implementation of such a collision monitoring process for LEO satellites is mostly limited to space agencies. It is generally not feasible for private operators. If an evasive maneuver is executed, the operational mission is often interrupted or compromised until a restituting maneuver is performed (e.g. to re-establish the ground-track repeat pattern). Avoidance maneuvers can significantly reduce the risk of catastrophic collisions with large, intact objects, which otherwise could contribute to the onset of collisional cascading. However, avoidance maneuvers cannot significantly improve the mission safety of an unprotected spacecraft, since the impact of an untrackable 1 cm object may already cause a mission termination, and the probability of such impacts is an order of magnitude higher than for trackable objects.

End of life operations (de-orbiting and passivation) should be systematically applied at the end of mission operations of all satellites and launchers in the LEO regime. This is the only feasible approach today to reduce the collision risk and to limit the debris growth. However, to maintain a long-term stability of the LEO debris environment, debris mitigation alone will be insufficient. It will need to be combined with debris remediation through retrieval or induced de-orbit of abandoned objects. Related technologies will need to be developed and deployed. They are costly and technologically demanding, but they would secure a space infrastructure that outweighs such costs by far.

3.4 Launch and Re-entry/Return Operations

A key element of the responsibility of a space-faring nation is to establish the technology and risk mitigation processes to protect life and property against falling rocket stages and consequences of launch failures, and against atmospheric re-entries of their upper stages and spacecraft.

Citizens of all nations should be equally protected from the risk of launch operations and re-entries. As matter of fact risk criteria do not exist, and the actual distribution of risk imparted to the general public on earth is completely unknown for the following reasons:

- First, only a few launch countries have published their launch and re-entries risk acceptance criteria and risk mitigation measures.

- Second, waivers for non compliances with safety requirements, when granted, are treated as confidential.

- Third, risk assessments (when performed) are on a launch-by-launch basis with no consideration for previous launches or planned launches worldwide.

There is no agency – national or international – that monitors and controls the cumulative risk imparted to over flown populations by launch and re-entry operations. A city may be placed at risk by launches from multiple launch sites without the launching nation and interested parties performing any coordinated effort to assure that the levels are tolerable.

3.4.1 Launch risk

Launch risk analyses typically include nominal debris generation events and failure analyses to identify how a launch vehicle will respond, followed by failure response analyses to define the types of malfunction trajectories the vehicles will fly. The vehicle loads are assessed along the malfunction trajectory to determine whether structural limits are exceeded. Vehicle position and velocity may be compared against abort criteria to assess whether the vehicle should be allowed to continue flight, terminate thrust, or be destroyed. Debris generating events then become the basis for assessing the flux of debris falling through the atmosphere and the impact probability densities. The debris involved may be screened by size, impact kinetic energy or other criteria to assess which fragments pose a threat to unsheltered people, people inside various types of shelters, people on ships and people in aircraft.

Other hazards associated with launch operations are explosive hazards, and toxic hazards generated by normal combustion and toxic releases from malfunctions.

Flight termination criteria are customarily designed based on the capability of the launching range safety system to limit the risk from a malfunctioning launch vehicle. Frequently, ranges assume they can reliably detect a malfunctioning launch vehicle and terminate its flight whenever good quality tracking data is available. This assumption is based on high-reliability designs customarily used for range safety systems. At present, however, there are no international design standards for range safety systems. Moreover, efforts to assure that the design standard does, in fact, achieve the intended reliability levels are rare.

Current practice often fails to properly address toxic hazards, explosive hazards, and hazards from fires. It is also inconsistent in addressing initiating events. Some launch and test ranges attempt to quantify risks from all debris generating events, including malfunctions of launch vehicles; others focus on planned events, such as jettisoning spent stages.

When assessing launch risks it is important to account for all exposed populations: people on land, people in boats and people in aircraft. Proper consideration must be given to the effect of sheltering on the risks. It is often assumed that neglecting sheltering will overestimate the risk. When sheltering is adequate to preclude fragment penetration, this assumption is valid. When fragments are capable of penetrating a structure or of causing its collapse, debris from the structure increases the threat to occupants.

Additional consideration must be given to the relationship of population groups to the launch. People directly involved in supporting launch operations may be expected to tolerate higher risk levels than uninvolved members of the general public. Typically, launch support personnel are confined to a region about the launch location within the territorial domain of the launching nation. As launch vehicles proceed downrange, they typically leave the territorial domain of the launching nation and begin to over-fly international waters and the territory of other nations.

3.4.2 Re-entry/return risk

In 1978, the Soviet Union reconnaissance satellite COSMOS 954 failed to separate its nuclear reactor core and boost it into a disposal orbit as planned. The reactor instead remained onboard the satellite in an orbit that decayed until it re-entered into the Earth atmosphere. The satellite crashed near the Great Slave Lake in Canada Northwest Territories spreading its radioactive fuel over a 124,000 km2 area. Recovery teams swept the area by foot for months. They were ultimately able to recover 12 large pieces which comprised only 1% of the reactor fuel. These pieces displayed a radioactivity up to 1.1 Sieverts per hour (a nuclear emergency is usually declared on ground at 500 micro-Sieverts per hour).

Another accident involving nuclear power had taken place in April 1964 due to the failure of a Thor Delta launcher. The spacecraft, US Navy Transit 5BN-3, carried a SNAP-9A radioisotope thermo-electric generator with 1 kg of radioactive plutonium-238 that was dispersed in the atmosphere during the re-entry.

On Wednesday, 21 February 2008, for the first time in history, an uncontrolled, re-entering satellite (USA 193) was shot down by a military missile for stated reasons of public safety while at an altitude of 247 km. The decision was taken at US presidential level. The malfunctioning satellite, an intelligence US satellite, carried 450 kg of highly toxic hydrazine in a titanium fuel tank. Similar tanks are known to have survived re-entry. It was expected that about 50% of the satellite mass would have survived re-entry, thus causing a public risk on ground.

Many non-functional satellites, spent launch vehicle upper stages, and other orbital debris do not remain in their orbits indefinitely, but gradually return to Earth. However, at low Earth orbit, it may take years or tens of years and at higher altitudes it can take hundreds or even thousands of years.

As a non-functional satellite, spent launch vehicle stage and other debris lose altitude they enter denser regions of the atmosphere, where friction with atmosphere at high velocity generates a tremendous amount of heat. As a result a major portion of the hardware will burn up but some components and parts can and do survive the re-entry heating.

It is very difficult to predict where debris from a randomly re-entering satellite will hit Earth. Over the last 40 years, more than 1,400 metric tons of materials are believed to have survived re-entry. The largest object to re-enter was the Russian Mir Space Station, which weighed 120 metric tons.

Currently it is considered that such risk, although low and comparable to that of the population leaving in close proximity of an airport, would not be accepted as inevitable by the general public and an accident would badly expose the launching nation.

Currently, there are 32 defunct nuclear reactors circling the Earth as well as 13 reactor fuel cores and at least eight radio-thermal generators (RTGs). RTGs had been used nine times in space missions in low Earth orbits up to 1972, and twice in geostationary orbits up to 1976. Since 1969 another 14 reactors have been used on lunar and interplanetary missions. The total mass of RTG nuclear fuel in Earth orbit today is on the order of 150kg. Another form of nuclear power sources used in space activities are nuclear reactors. Most reactors were on board Soviet Union radar reconnaissance satellites (RORSATs) launched between 1965 and 1988. The total mass of uranium-235 reactor fuel in orbit is on the order of 1,000 kg.

Finally returning space vehicles may also constitute a risk in case of malfunction. Following the Space Shuttle Columbia accident investigation the FAA funded a more detailed aircraft risk analysis that used the actual records of aviation activity at the time of the accident. That study found that the probability of an impact by Columbia debris to commercial aircraft in the vicinity was at least one in a thousand, and the chance of an impact to general aviation was at least one in a hundred. In consideration also of the projected development of the space tourism industry making use of suborbital return vehicles, the FAA Office of Commercial Space Transportation is developing a SATMS-DST (Space and Air Traffic Management System - Decision Support Tools) that will be used as a real-time tool in the event of a catastrophic event like the Columbia accident to identify how to re-direct aircraft around a space vehicle debris hazard area.

Section 4 – Managing the electromagnetic spectrum

4.1 Electromagnetic Spectrum Management at the International Level

4.1.1 Basic principles

During the last 45 years, from the Administrative Radio Conference in 1963 and up to and including the 2007 World Radio communication Conference in Geneva (WRC-07), many International Telecommunication Union (ITU) conferences have addressed the regulation of spectrum/orbit usage by stations of the space radio communication services. The ITU Member States have established a legal regime, which is codified through the ITU Constitution, Convention and Radio Regulations.

These instruments contain the main principles and lay down the specific regulations governing the following major elements:

- frequency spectrum allocations to different categories of radio communication services and Earth Exploration Satellite (EES) services;
- rights and obligations of Member administrations in obtaining access to the spectrum/orbit resources;
- international recognition of these rights by recording frequency assignments and, as appropriate, orbital positions used or intended to be used in the Master International Frequency Register.

The above regulations are based, in part, on the main principles of efficient use of and equitable access to the spectrum/orbit resources laid down in No. 196 of the ITU Constitution (Article 44), which stipulates that:

"In using frequency bands for radio services, Members shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations, so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries".

As indicated in the above provision, further detailed regulations and procedures governing orbit/spectrum use are contained in the Radio Regulations (RR), which is a binding international treaty (No. 31 of the ITU Constitution).

Although the ITU RR so established constitute thus an independent legal regime, several of its major principles take account of those embedded in various United Nations (UN) Declarations and Treaties. The most important UN Treaty which was taken as a basis for ITU space related regulations is the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 20.01.1967" (The Outer Space Treaty).

Article 2 of the Outer Space Treaty provides that outer space (to contrast with air space which is under national sovereignty) "is not subject to national appropriation by claim of sovereignty, by means of use or occupation or by any other means." Article 1 provides in relevant part that outer space shall be free for exploitation and use by all States… ". Nobody owns thus any orbital position but everybody can use this resource under certain circumstances. Another important element of the UN treaties is that States retain jurisdiction and control over registered objects that they launched into outer space (Outer Space Treaty, article VIII, Registration Convention, article II). Moreover, Article VI of the Outer Space Treaty provides that the activities of non-governmental entities in outer space "shall require authorization and continuing supervision by the appropriate State Party to the Treaty." States are thus obliged to establish appropriate supervision and control mechanisms on space networks.

4.1.2 Procedures

In the process of establishing ITU's space-related regulations, emphasis was laid from the outset on **efficient, rational and cost-effective utilization**. This concept was implemented through a "first come, first served" procedure. This procedure ("coordination before use") is based on the principle that international recognition for the use of a satellite position and associated frequencies is acquired through negotiations with the **administrations concerned** and by actual usage. If applied correctly (i.e. to cover genuine requirements), the procedure offers a means of achieving efficient spectrum/orbit management; it serves to fill the gaps in the orbit as needs arise and results, in principle, in a homogeneous orbital distribution of operational satellites. On the basis of the RR, and in the frequency bands where this concept is applied, Member State administrations designate the volume of orbit/spectrum resources that is required to satisfy their actual requirements. It then falls to the national administrations to assign frequencies and orbital positions, to apply the appropriate procedures (international coordination and recording) for the space segment and earth stations of their (governmental, public and private) networks, and to assume continuing responsibility for the networks.

The progressive exploitation of the orbit/frequency resources and the resulting likelihood of congestion of the geostationary-satellite orbit prompted ITU Member countries to consider more and more seriously the question of **equitable access** in respect of the orbit/spectrum resources. This resulted in the establishment (and introduction into the ITU regulatory regime) of frequency/orbital position a-priori plans in which a certain amount of frequency spectrum is set aside **for future use by all countries**, particularly those which are not in a position, at that time, to make use of these resources. These plans, in which each country has a predetermined orbital position associated with the right to use, at any time, of a certain amount of frequency spectrum, together with the associated procedures, guarantee for each country equitable access to the spectrum/orbit resources, thereby safeguarding their basic rights. Such plans govern a considerable part of the frequency usage of the most resource-demanding radio communication services.

During the last 45 years, the regulatory framework has been constantly adapted to changing circumstances and has achieved the necessary flexibility in satisfying the two major, but not always compatible, requirements of efficiency and equity. With the dramatic development in telecommunication services, increasing demand for spectrum/orbit usage for practically all space communication services has been observed. This increase is attributable to many factors. These include not only technological progress, but also political, social and structural changes around the world and their impact on the liberalization of telecommunication services, the introduction of non geostationary-satellite orbit (non-GSO) satellite systems for commercial communications, growing market orientation, the change in the way this widening market is shared between private and State-owned service providers and the general globalization and commercialization of communication systems.

4.1.3 Regulations applying to the use of frequencies and orbits by satellite networks

The specific procedures setting out the rights and obligations of the administrations in the domain of orbit/spectrum management and providing means to achieve an acceptable radio communications interference environment have been laid down by successive WRCs on the basis of, among other factors, the two main principles referred to above: efficient use and equitable access. In order to put these principles into effect, two major mechanisms for the sharing of orbit and spectrum resources have been developed and implemented:

- *A priori* planning procedures which include:
  - the Allotment Plan for the fixed-satellite service using part of the 4/6 and 10 11/12 13 GHz frequency bands contained in Appendix 30B;
  - the Plan for the broadcasting-satellite service in the frequency band 11.7-2.7 GHz (Appendix 30) and the associated Plan for feeder links in the 14 GHz and 17 GHz frequency bands (Appendix 30A).
- Coordination procedures which include:
  - geostationary-satellite networks (in all services and frequency bands) and non-geostationary-satellite networks in certain frequency bands governed by the No. 9.11A procedure, which are subject to advance publication and coordination procedures;

- other non-geostationary-satellite networks (all pertinent services and certain frequency bands), for which only the advance publication procedure is required before notification.

The procedures applied to the space services reflect the above main principles.

4.1.3.1 Procedures applying to non-planned services

The procedures applying to non-planned services are based on the principle of "first come, first served". Successful coordination of space networks or earth stations paves the way to the international recognition of the use of frequencies by these networks/stations and the recording of the frequencies in the Master International Frequency Register (MIFR).

All coordination procedures are consolidated in one single article of the Radio Regulations, namely Article 9 "Procedure for effecting coordination with or obtaining agreement of other administrations". Associated with Article 9 are also Appendix 4, which specifies the various data that must be furnished in the different steps of the procedures, and Appendix 5, which contains criteria for identification of administrations with which coordination is to be effected or agreement sought. The provisions detailing the requirement for notification of frequency assignments are basically specified in Article 11 of the Radio Regulations.

The relevant provisions involve three basic steps:

• *advance publication (Section I, Article 9)*, to inform all administrations of any planned satellite system using a geostationary or a non-geostationary satellite and of its general description.

• *coordination (Section II, Article 9)*, which is a formal regulatory obligation both for an administration seeking to assign a frequency assignment to its network and for an administration whose existing or planned services may be affected by that assignment. An agreement arising from this coordination confers certain rights and imposes certain obligations on the administrations concerned.

• *notification/recording (Article 11)*, which is the final regulatory step for recording of the frequency assignments into the Master International Frequency Register (MIFR).

Article **6 (CS 37)** of the Constitution of the Union provides, among other things, that all members are bound to abide by the Constitution and Convention and the Administrative Regulations in all telecommunication offices and stations established or operated by them which are capable of causing harmful interference to the radio services of other countries. See also Article 45 (CS197, CS 198).

4.1.3.2 Assignment or Allotment Plans

Appendices 30, 30A and 30B to the Radio Regulations contain plans for the broadcasting-satellite and the fixed-satellite services. These plans were established with a view to guaranteeing equitable access to the GSO by all countries. The plans contain orbital positions, a certain frequency spectrum and a service area, which normally covers only the country's territory. The plan entries are associated with a set of technical parameters in accordance with which a specific satellite network may be implemented. The plans also contain implementation procedures for those modified requirements, which were not foreseeable at the moment of the establishment of the plans.

4.1.3.3 Sustainment of Space System Radio frequency Environment

An important aspect to the sustainability of space activities is the need to preserve a stable spectrum environment in frequency bands used by space systems. Given the weak signal nature of most space-based radio communications systems, they are particularly susceptible to interference caused by other radio services and applications. In particular, Article 4 of the ITU Radio Regulations addresses the need for protecting the operation of radio communications systems that are used to provide safety services, such as the Radio Navigation-Satellite Service (RNSS), and many space-faring nations cooperate on preserving and sustaining the radio frequency environment in which these and other space-based radio communications systems operate.

4.1.3.4 Sustainable use of radio frequencies for earth exploration services

Besides the use of satellites for telecommunications, broadcasting and navigation, other spectrum uses, such as for radio astronomy observations and earth observation, require special consideration to ensure their continued viability. This is because they rely to a large extent on passive measurements, which are extremely sensitive to interference because of the weakness of the natural signal. Moreover, these measurements have to be made at particular wavelengths defined with reference to the absorption spectrum of atmospheric constituents; these wavelengths are determined by the Physics and are thus an irreplaceable natural resource.

These applications, referred to by the ITU as “Earth Exploration Satellite Services” (EESS) are increasingly important since space-based observation are currently the dominant source of input information to Numerical Weather Prediction models, which are supporting weather forecasting and related disaster warning on an operational basis, and to global climate change monitoring and investigation, which is the basis for assessing climate change scenarios and adaptation plans.

These aspects have been reviewed by WMO and the ITU in a joint Handbook on “Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction “(2008).

4.2 Electromagnetic Spectrum Management at the National Level

In addition to the international regulatory framework of the ITU, ITU Member States have in place national legislation, policies and regulations for the management of the electromagnetic spectrum used by Radio communications services including the frequency bands allocated for use by space systems.

Countries have enacted various Acts or other forms of legislation which govern the use of the Radio spectrum and are premised on the compliance with the International Radio Regulations as those countries are treaty bound by the ITU Radio Regulations.

Although spectrum use is guided by the Radio Regulations, countries are free to set their own national policies regarding the specific use of shared frequency bands. Policies may be formulated to favour one co-primary use over another to best serve national interests while still operating within the confines of the Radio Regulations. One country, for example may have a policy that favours the development of High

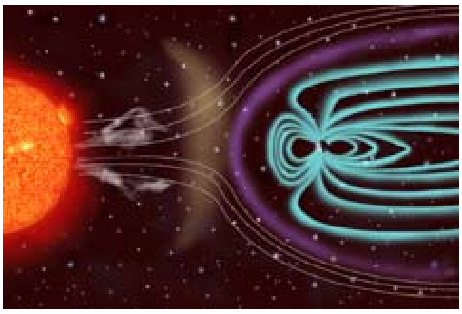
Density Fixed Satellite Services (HDFSS) in a band that has a co-primary allocation with the fixed service in the ITU Region to which that country belongs. That country may operate space-Earth links at power flux density (pfd) limits in excess of those in Article 21 of the Radio Regulations over its own territory but would respect the limits over the territories of other countries whose permission it has not obtained to exceed the limits. At the same time, the earth stations in the country favouring HDFSS in the shared band may have to operate with a level of protection guaranteed by only a pfd level at the border between it and a neighbouring country rather than by the more traditional case-by-case coordination between co-primary services.

Recommendations of the ITU-R, the application of which is on a voluntary basis, are also used by some countries as a means to facilitate the orderly development of space services within their respective jurisdiction. In addition, ITU-R Recommendations are often used as a technical basis for bi-lateral and multilateral negotiations and coordination agreements. Often, these Recommendations are incorporated in whole or in part into the domestic regulations governing the use of spectrum by both earth and space segment within the space services.

Common to all countries is the process of registering the intent to use frequencies and the notification process with the ITU. While each country may have a different internal process for applying for or requesting the right or to be authorized to use spectrum in the form of a licence, such as a comparative evaluation process or spectrum auctions, all countries are required to submit such intent through their regulator to the ITU in accordance with the process associated with the particular type of service. For example, unplanned FSS services would use the submission and notification processes associated with Articles 9 and 11 of the Radio Regulations and would be subject to the regulatory deadlines associated with those processes. In the "first come-first served" nature of the Article 9 and 11 process, the right to use the frequency bands carries with it the obligation of the country applying to successfully coordinate its space services with all other potentially affected space services of other countries that had earlier indicated the intent to use the frequencies using the same ITU process. Associated with the international submission and notification process of space services are filing fees which are set by the ITU. Countries have the right to pass on these fees either directly or indirectly to holders of the licenses to use the spectrum in accordance with their differing policies and objectives. The objectives of countries in setting licensing fees may range from that of simple cost recovery to revenue generation and it may vary by the type of service, the frequency band and the demand for that type of service. Finally, enforcement authority of compliance with the ITU regulations rests with the regulatory authority of each individual country.

Section 5 — Space weather and threats from other natural causes

5.1 — Space weather



Everyone is familiar with changes in the weather on Earth. However, "weather" also occurs in space. Just as it affects weather on Earth, the sun can produce dramatic effects in the space environment surrounding the Earth. "Space weather" — the collective term used to describe variations in the Sun-Earth environment, mainly originating from solar activity — is of increasing importance in our technology dependent society. Space Weather is particularly important for our society as its economy is more and more based on satellite radio navigation and telecommunications largely perturbed by space weather. Our social and economic wellbeing is dependent upon certain critical infrastructures, power, water, communications, transportations, financial transactions, and our ability to continue to provide vital government services in the presence of disasters, whether man-made or natural.

What is "Space Weather?"

Space Weather has been defined as the set of conditions describing the variable state of the interplanetary environment. Since these conditions depend mainly on perturbations originating from the sun, research into space weather consists for a large part of the study, observation and forecasting of solar activity, and their effect on the solar wind, magnetosphere and ionosphere. Solar activity impacts the Earth through three different sources: electromagnetic radiation, high-energy particles and bulky plasma flows (solar wind and superimposed coronal mass ejections).

- **Solar wind** is a continuous outflow of electrified gas (or plasma) from the solar surface. It blows constantly past the Earth at a typical speed of 1.5 million km/h. The magnetic field that surrounds our planet deflects the solar wind, but sometimes explosive events on the sun — known as **Coronal Mass Ejections** (CMEs) — hurl large amounts of charged particles toward the Earth at speeds of more than eight million km/h.

• This results in **geomagnetic storms** that distort the protective magnetic field and can dramatically affect the Earth and its upper atmosphere.

- The **magnetosphere** is the region of space above the atmosphere that is under the direct influence of Earth's magnetic field. It is bounded on the solar side by the magnetopause.
- The **ionosphere** is the region of Earth's atmosphere that extends from about 50 to 300 km above the surface of the planet and is made up of multiple layers dominated by electrically charged (or ionized) atoms.

During a geomagnetic storm, the ionosphere can be severely altered and in turn affect the near Earth environment. The resultant changes in ion density (sometimes called ionospheric storms) can persist for more than a day after a period of high geomagnetic activity.

• The most direct impact of the Sun on the Earth is through the **solar radiation** (sunlight) that heats the Earth's atmosphere and surface. During periods of high solar activity, the amount of energy emitted in high-energy radiation (extreme ultraviolet and X-ray) can increase by several orders of magnitude due to **solar flares**.

• Through various mechanisms, particles can be accelerated to near-relativistic speeds by solar flares and CME shock fronts. These charged **high-energy particles** may reach the Earth's environment depending on the structure of the interplanetary magnetic field.

"Space Weather" Impacts

A number of man-made and natural systems are affected by space weather. This includes satellites, astronauts, aircraft, communication and navigation systems, power grids and pipelines.

This text only deals with the impact of space weather on human space activities.

Satellites: Space weather will exert effects on spacecraft that vary according to the orbit and the position of the satellite and are caused by the changing nature of the Sun. While satellites can be designed to avoid the many problems in the space environment, most of the new satellites have been designed to meet other criteria: principally small and light, therefore easier and cheaper to launch.

A satellite is susceptible to many ills from many sources. While only some of them are caused by space weather, many types of spacecraft anomalies can be caused by various aspects of space environment. The total damage suffered by satellites due to space weather effects is hard to quantify but is probably very significant.

• *Electrical Charging*

One of the most common anomalies caused by radiation hazards is spacecraft or satellite electrical charging. Charging can be produced three ways.

- By an object's motion through a medium containing charged particles (called "wake charging"), which is a significant problem for large objects like the Space Shuttle or a space station.
- Directed particle bombardment, as occurs during geomagnetic storms and proton events.

- Solar illumination, which causes electrons to escape from an object's surface (called the "photoelectric effect").

The impact of each phenomenon is strongly influenced by variations in an object's shape and the materials used in its construction. An electrostatic discharge can produce spurious circuit switching; degradation or failure of electronic components, thermal coatings, and solar cells; or false sensor readings. In extreme cases, a satellite's life span can be significantly reduced, necessitating an unplanned launch of a replacement satellite. An electrical charge can be deposited either on the surface or deep within an object, resulting in two types of charging:

- *Surface charging* – low energy electrons attach to the spacecraft causing different charges on parts of the spacecraft leading to an electrical arc discharge on the surface. Solar illumination and wake charging are surface charging phenomena.
- *Deep dielectric charging* – high energy electrons penetrate through the shielding of the spacecraft and build up in dielectric insulators and conductors such as coax cable. A charge can build up until it reaches a breakdown point of that particular dielectric and an electrical discharge occurs. The higher the energy of the bombarding particles, the deeper the charge can be placed.

Normally electrical charging will not (in itself) cause an electrical upset or damage. It will deposit an electrostatic charge which will stay on the vehicle (for perhaps many hours) until some triggering mechanism causes a discharge or arcing. Such mechanisms include a change in particle environment, a change in solar illumination (like moving from eclipse to sunlit), or on-board vehicle activity.

• *Single Event Upsets (SEUs)*

SEUs are caused by very high energy particles that penetrate the shielding and hit memory devices, causing memory changes and physical damage. The high energy particles have two sources: cosmic rays, which are a slow steady flux of high energy, sometimes of heavy particles and (2) solar proton emissions of very large fluxes from solar flares.

In fact, a single proton or cosmic ray can (by itself) deposit enough charge to cause an electrical upset (circuit switch, spurious command, or memory change or loss) or serious physical damage to on-board computers or other components.

Hence these occurrences are called "single event upsets." SEUs are very random, almost unpredictable events. They can occur at any time during the 11-year Solar Cycle. In fact, SEUs are actually most common near Solar Minimum, when the Interplanetary Magnetic Field emanating from the sun is weak and unable to provide the Earth much shielding from cosmic rays originating outside the Solar System.

- *Radiation Damage: Total Dose Effects*

  Radiation from galactic cosmic rays and solar proton events can cause cumulative radiation damage, such as results when solar panels decrease the voltage they can generate as the damage accumulates.

  Despite all engineering efforts, satellites are still quite susceptible to the charged particle environment; in fact, with the newer microelectronics and lower voltages, it will actually be easier to cause electrical upsets than on the older, simpler vehicles. While the components are built to withstand the harsh environment, they can fail after repeated exposure to large storms. Both low and high earth-orbiting spacecraft and satellites are subject radiation hazards.

- *Spacecraft Drag and Orbital Tracking*

  Ultraviolet flux from the Sun and disturbances in the Earth's magnetic field combine to heat the upper atmosphere and lead to the decay of lower Earth orbiting satellites, causing an earlier re-entry into the Earth atmosphere. Satellites affected by atmospheric drag may require costly orbit maintenance manoeuvres.

  Long-term predictions of when a satellite re-enters tend to be error-prone. A classic example was the premature loss of Skylab. Solar activity was so severe, for such an extended period, that Skylab re-entered before a planned Space Shuttle rescue mission was ready to launch.

- *Disorienting magnetic fluctuations and discharges*

  Some spacecraft that use the Earth's magnetic field to help control their attitude can lose orientation during a geomagnetic storm. Many satellites rely on electro-optical sensors to maintain their orientation in space. These sensors lock onto certain patterns in the background stars and use them to achieve precise pointing accuracy.

  High energy particles can actually release flashes of light in such devices as star trackers, charge couple devices (CCDs), and optical devices.

  They can cause misorientation in the star tracking devices or misreadings in sensors, causing the satellite to lose attitude lock with respect to the Earth. Directional communications antenna, sensors, and solar cell panels would then fail to see their intended targets. The result may be loss of communications with the satellite; loss of satellite power; and, in extreme cases, loss of the satellite due to drained batteries.

  (Gradual star sensor degradation can also occur under constant radiation exposure.) Disorientation occurs primarily on geosynchronous or polar-orbiting satellites when solar activity is high.

Astronauts: space weather conditions can be hazardous to humans in space. Astronauts are normally well protected by the shelter of their space vehicle. However, when they venture outside their protective environment, they are vulnerable to high doses of particles or radiation. This is particularly relevant in the context of the use of the International Space Station and of the advent of renewed manned lunar exploration and interplanetary space travel such as the missions to Mars.

Communication Systems: The Earth's ionosphere is important for a wide range of communication systems. Unfortunately, solar flares and other space weather phenomena can upset the composition of this layer causing communication disruptions at all frequencies. During an ionospheric storm, some radio frequencies are absorbed and others are reflected, leading to rapidly fluctuating signals and unexpected propagation paths. This may lead to disruption of ground-to-satellite communication when aligned with the satellite and the ground antenna. This problem lasts only for the duration of the alignment.

Navigation Systems: Space Weather effects on Global Navigation Satellite Systems (GNSS) such as GPS, GLONASS and Galileo are the main limitation to the accuracy and reliability of most of the positioning applications based on GNSS. In practice, real-time GNSS applications are mainly affected by the ionospheric plasma variability, which depends on Space Weather conditions. During severe ionospheric storms (often due to geomagnetic storms), the plasma variability can induce “out of tolerance” errors in the measured positions or even lead to the impossibility to measure (accurate) positions in real time.

5.2 : Other natural causes

Apart from man-made objects (see chapter 3), particles of natural origin pass through Earth orbit regions used by space operators. At any time, about 3 tons of meteoroid mass is distributed across the regimes of LEO, MEO and GEO. This is roughly 0.5% of the mass of man-made objects residing in the same volume. Meteoroids are of cometary or asteroidal origin. They are most abundant at sizes of 100 to 200 µm, travelling at velocities of up to 72 km/s, with most probable values around 20 km/s. With regard to in-orbit collision flux for the densely populated LEO and GEO regions, meteoroid contributions are only of similar magnitude as debris flux at sub-mm sizes. Hence, the resulting risk of loosing a mission is normally considerable lower than for space debris. Most of the meteoroid collisions originate from a non-directional back-ground flux (more than 90% of the total). A smaller contribution comes from seasonally recurring meteoroid streams which are associated with some Earth-crossing comet trails and appear to originate from a fixed position on the celestial sphere (the “radiant”) that is mostly used as a name-tag of the meteoroid stream (e.g. the “Perseides”). The stream contributions may, for a very limited time period (typically hours) exceed the background flux by several orders of magnitude. In such instances, it is advisable to delay extra-vehicular activities, or to minimize the spacecraft cross-section with respect to the radiant direction. However, the cumulated risk due to a meteoroid storm is generally outweighed by a few extra days of background flux.

Section 6 - Which international mechanisms to improve the safety and security of space activities?

When discussing possible new international mechanisms to ensure the safety and security of space activities over the long term, the first step is to review the existing ones.

6.1 Space Debris

With respect to space debris, the IADC has done a great job over more than 15 years and is to be commended for the quality of its work, including the extremely useful "awareness raising activities" it has conducted which raised the space debris issue to the level of decision makers worldwide.

Clearly, IADC should be encouraged to continue its mission. An open question is if and how commercial satellite operators could be included in its deliberations. It is suggested that the IADC should consider how to interact with the community of commercial operators, for example through an approach similar to the one adopted by ITU to involve the telecommunication industry.

Along the same line, the UNCOPUOS Scientific and Technical Sub-Committee (STSC) should continue its monitoring of the space debris situation and, when needed, propose recommended adaptations or evolutions to the UN COPUOS Space Debris Mitigation Guidelines adopted in 2007. In parallel the COPUOS Legal Subcommittee has been tasked to examine the implementation of the Space Debris Guidelines at national levels. The Legal Subcommittee should be encouraged to propose to the Plenary Committee possible clarifications that may be needed or otherwise beneficial to the implementation of the guidelines in national mechanisms.

6.2 Information Exchange to Improve Space Situational Awareness

As more states or regional groups of nations are building space situational awareness systems to collect knowledge of the space environment and of the space situation, mechanisms for routine data exchange on space object catalogs, space weather information and meteorites need to be set in place. In any data exchange, two objectives should be considered:

- optimize the sharing of information of common interest to all in order to ensure the safety of space assets;
- protect information which is commercially sensitive or needs to be protected for national security purposes.

Going further, it might be useful to consider setting up a system of alerts relying on a continuous assessment of the space situation based on the sharing of data and crosschecking of relevant information.

6.2.1 Concerning the production and distribution of space weather information, the World Meteorological Organization (WMO) Executive Council agreed in June 2008 that WMO should support international coordination in this area. In April 2009, the 14th session of the WMO Commission for Basic Systems (CBS) recommended the establishment of an Inter-Programme Coordination Team on Space Weather (ICTSW), including experts from the CBS and from the WMO Commission on Aeronautical Meteorology, with the following Terms of Reference:

(a) Standardization and enhancement of Space Weather data exchange and delivery through the WMO Information System (WIS);

(b) Harmonized definition of end-products and services, including e.g. quality assurance guidelines and emergency warning procedures, in interaction with aviation and other major application sectors;

(c) Integration of Space Weather observations, through review of space- and surface-based observation requirements, harmonization of sensor specifications, monitoring plans for Space Weather observation;

(d) Encouraging the dialogue between the research and operational Space Weather communities.

Bearing in mind WMO's experience with cooperation, standardization, and ensuring the interoperability of global operational systems for weather and climate information, this decision to engage in space weather is a significant step forward. The practical implementation of this decision will be watched with interest by all space operators.

6.2.2 As for space traffic and satellite orbital parameters, the US Government has been providing information on satellite locations via its website – www.space-track.org. The US Government is now pursuing a program for Commercial & Foreign Entities (CFE) which would provide conjunction assessment and other services to non-US Government entities. The CFE program makes data available that operators can use to estimate the likelihood of collision or other interference, but this data may not comprehensive enough for collision avoidance manoeuvre decisions. The CFE program might be expanded to include specific close approach predictions to operators.

Several commercial operators have formed an informal process whereby each provides high-accuracy orbit ephemeredes for its own satellites and this information is combined with publicly available information from the US Space Surveillance Network to predict interference with other satellites and space debris.[13] The Aerospace Corporation piloted a similar approach a few years back, and the MIT Lincoln Labs has provided support to a limited number of operators for several years.

Another proposal calls for the establishment of an international non-profit clearinghouse dedicated to providing such services[14]. The organization would acquire orbit ephemeris data from satellite operators, combine this with tracking data provided by member governments and private tracking organizations, and provide member operators with warnings of pending close approaches of tracked objects and other interference events. The clearinghouse would also provide, with the approval of the data providers, information to governments on the locations and manoeuvre plans of member satellites. Governments would use this information to predict and avoid conflicts with government-owned satellites. A board of directors would govern the non-profit, with board members representing participating governments and private satellite operators.

Such a clearinghouse could evolve to provide additional services to both government and satellite operators. Governments need information on whether satellites licensed in their jurisdictions are being operated and disposed in accordance with established requirements and agreements. Satellite operators need assistance in coordinating manoeuvres with neighbouring and affected operators. The clearinghouse could provide this type of data to governments and assistance to operators. The clearinghouse could also help assure that satellites are registered in

[13] Chan, J. and DalBello, R., " Data Sharing to Improve Close Approach Monitoring And Safety of Flight," 3rd IAASS Conference, Rome, Italy, 2008.

[14] Ailor, W.H., "Moving Forward on Space Traffic Control," 3rd IAASS Conference, Rome, Italy, 2008.

accordance with the 1967 UN Outer Space Treaty as complemented by the 1975 UN Registration Convention.

RECOMMENDATION

Mechanisms and organizational options for providing space traffic services to all space operators, including the establishment of an international clearinghouse to provide such services, should be investigated.

Section 7 – Conclusions and recommendations

7.1 Compliance with and Promotion of Treaties, Conventions and Other Commitments Relating to Outer Space Activities

The core treaties governing the use of outer space, in particular the Outer Space Treaty and the Registration Convention, have served States parties well over many decades. Under the legal framework of these treaties, use of outer space by nations, international organizations and, now, private entities, has flourished. As a result, space technology and services contribute immeasurably to economic growth and improvements in the quality of life around the world. However, many States have not yet acceded to those treaties, including some members of UNCOPUOS.

International organizations also have an important role to play in the strengthening of the legal framework applicable to space activities; they can consider steps they can take to encourage their members to adhere to the four core outer space treaties, as well as to declare their acceptation of the treaties' provisions, so as to bring their activities within the framework of international space law.

The outer space treaties were drawn up in full awareness of the possibility of international organizations to conduct space activities. Indeed, several of the treaties contain mechanisms to permit international intergovernmental organizations that conduct space activities to do so within the framework of the treaties. Each of the Treaties contains provisions specific to international intergovernmental organizations.

Several extremely important international intergovernmental organizations are not operating within the treaties because not enough of their members have become parties to them. As the framework established by the treaties is an important and beneficial one for the global conduct of space activities, it is desirable for international organizations to conduct their space activities under the coverage of these significant instruments.

The existing outer space treaties underpin international space cooperation and make clear that it is to be carried out for the benefit and in the interest of all States. The orderly conduct of space activities is beneficial to all States. Wide acceptance by States of the responsibilities contained in the treaties would guarantee broad international cooperation in the scientific and legal aspects of space activities.

As an important contributing factor in the long-term sustainability of space activities, all States and international organizations involved in outer space activities should be encouraged to ratify and implement the space law instruments adopted in the framework of the United Nations. And further, States that have accepted those instruments should continue to look at the sufficiency of their respective national laws to implement them.

Increasing the number of States or international organizations that accede to, or formally agree to abide by the treaties, will strengthen the international legal regime governing the conduct of outer space activities.

Implementation by States and international organizations of existing legal instruments and relevant UN Declarations, Principles, Recommendations and Guidelines will be an important step to strengthen and to further develop the international legal regime governing the conduct of outer space activities and will also serve as an important contributing factor in the long-term sustainability of space activities.

7.2 Common Communication and Data Standards

One impediment to the effective exchange of data among space operators is that fact that there are no universal protocols for space communications and data. While commonality has been achieved to some degree by segments of the space community, e.g., among a number of government space agencies, and separately, among some commercial operators, broader acceptance and use of standard protocols can be achieved and contribute to greater sustainability of space operations in the long term. Greater acceptance and use of communication and data standards developed by the Consultative Committee for Space Data Systems (CCSDS) should be strongly pursued. The CCSDS was founded in 1982 by major government space agencies, and it presently consists of communications experts from 28 nations who meet regularly to develop standards related to space communications and data systems.

The standards developed by CCSDS are provided to the International Standards Organization (ISO) for further promulgation as ISO standards. The goal of CCSDS is to enhance government and commercial interoperability and cross-support, while also reducing risk. To date, more than 400 space missions have chosen to fly with CCSDS-developed standards for communications and data systems. Greater use of CCSDS and/or ISO standards for space operations will ultimately reduce risk for space operations. More information on CCSDS can be found at web site http://public.ccsds.org.

7.3 Other recommendations

A number of rather specific recommendations have been collected during the course of development of this document. They have not been discussed in any depth.

They are reflected here only as a matter of record.

A/ Suggested recommendations for operations in and near the GEO orbit.

- A1. – Unpublished spacecraft.

Operators who do not publicly disclose the location of their satellites assume a higher burden of safe and responsible operations than other operators since most operators possess accurate information on only their own satellites and lack internal, comprehensive space surveillance facilities. Some possible solutions to reduce risk include:

- Publish the list of all operators, including those of governments or agencies, in a database and a list of points of contact in each of those organizations to ensure effective coordination during non-nominal operations.

- Encourage all operators to provide to other GEO operators information on the location, as well as timing and other relevant information related to any planned manoeuvres of their satellites including, in particular, (i) transfer orbit mission operations and periods of relocation, (ii) cases where satellites of different GEO operators share a control window *(or station-keeping box as was previously used in this document)*, and (iii) satellite anomalies causing the satellite to enter the control windows of other satellites. Operators who elect not to provide this information, e.g., for government security reasons, should take exceptional care in the operation of their satellites and ensure they have sufficient data on the identity, location, and intentions of nearby satellites of other operators.

▪ A2.- Collocation of spacecraft by different operator entities

Cases in which spacecraft of different operators share a station keeping box present special risks that can be mitigated if the operators establish a coordinated collocation strategy that can be monitored by data exchanges and communications. Alternatively, operators can enter into an ad-hoc arrangement to locate their respective spacecraft in adjacent windows and establish procedures to exchange information in case of spacecraft anomalies or relocation. The operators need to have the freedom to select their preferred method of operation.

▪ A3.- Space debris

Presently, the Two Line Elements (TLEs) remain the only public source of information for tracking decommissioned spacecraft, and this data is not comprehensive enough for collision avoidance purposes. While the number of objects in the GEO arc crossing the orbits of active spacecraft is not high, it remains very important to avoid risks by reducing GEO intersections.

The only way to further reduce the risks associated with close approaches in this domain is to increase the scope of data and their accuracy in existing or new databases by means of tracking systems and orbit determination processes of traceable accuracies, and through international cooperation among the various international tracking agencies and operators. It is proposed to explore this possibility with the relevant international/national agencies.

Efforts should continue to coordinate and promulgate debris mitigation strategies including safe disposal of non-functioning and obsolete orbital assets, and the notification, characterization and tracking of unintended space debris creation. Further, mechanisms should be further explored to coordinate the tracking of hazardous space objects, and to coordinate alert processes for those who are operating spacecraft.

▪ A4.- Transgression of station keeping box or orbit relocations:

This happens when a spacecraft enters in the station keeping box of another operator due to a spacecraft anomaly or due to relocation at a low drift rate for whatever reason. This is a rare situation although it requires measures to reduce any possible risk. Spacecraft crossing the station keeping box of other operators are more frequent during LEOP operations. The proposed solutions are:

- Establish a data exchange mechanism among the operators, to be used when such events occur. This mechanism could involve exchanging information to be defined in a commonly agreed format and reference system to be recommended. Such a data center (Center) could be a collaborative effort among interested satellite operators using automated tools to improve the quality and sharing of operational information and analyses (Data), resulting in safer, more efficient operations. Members would agree to timely contribution of high-quality information about specified aspects of their satellite operations to the Center that may be used as agreed by other Members. The Center could provide (i) and up-to-date repository of operational information including a list of Points of Contact; (ii) certain automated analysis services, such as orbital conjunction warnings and assessments; and (iii) other services including to non-members or the public as agreed by its Members. The Center could be designed to provide accurate, reliable information operating on a continuous basis for the use of its Members. The Center could operate internationally, supported financially by its Members on the basis of an equitable cost-sharing model.

- Encourage operators in GEO to establish best practices associated with relocations to avoid passing through windows of other spacecraft except in case of short arcs, anomalies and other special circumstances. In the event that passing through the control window of another operator is essential, operators should be encouraged to follow best practices such as coordination with potentially affected operators.

- Establish a decision mechanism such that the spacecraft entering inside the known control window of another operator (Approached Satellite) bears the responsibility to manoeuvre to avoid the Approached Satellite except in case of anomaly, in which case an ad-hoc mechanism should be developed and promulgated by operators. *(Buying insurance for satellites is highly desired and insurance providers may be able to factor this into their risk, so rather than trying to police this type of event, it might be addressed by getting insurers involved.)*[15]

▪ A5. - Finally, it is desirable that the international guidelines are further improved to ease their implementation by the operators:

- There is a diversity of guidelines and issuing organizations. These are not always well harmonized. The IADC is the most recognized organization and its guidelines are considered as the reference to follow for newly launched satellites. National legislation may take priority over any international guideline but it is desirable that such legislation conform to the already existing best-practices and guidelines.

- Difficulties with guidelines that may have a negative influence on the assets of the operators, such as requiring retention of enough propellants at End of Service Life and use probability levels to ensure that a certain distance is reached. Consider requiring satellite manufacturers to provide satellites that contain better onboard capabilities to measure propellant levels. This would in turn allow operators to better determine the time of End-of-Service Life, thereby saving fuel as well as

[15] Comment: It is not immediately obvious that this approach is superior to an approach based on shared responsibility, which tends to facilitate coordination to a greater degree than a priority regime.

increasing the probability of achieving minimum IADC disposal altitude above GEO.

- All agencies should evolve towards the use of the IADC definition for a safe GEO disposal orbit.

- Common tools provided by national/international agencies to make long-term propagations would be an appropriate support for the operator's community in order to calculate the most appropriate graveyard orbit that avoids a perigee re-entry into the so called "GEO protected region" for a verifiable period (e.g. 100 years).

B/ Preliminary recommendations specific to operations in LEO orbits:

- B1- Explore the use of new technologies to reduce orbital lifetime to the maximum extent possible.

- B2- The choice of the operational orbit should be done considering the density of objects in this region together with the overall collision risk during the whole mission. Minor modifications of the orbit could reduce the risks for active satellites and the production of debris. Data collection and sharing is essential to implementing this measure.

- B3- A collision avoidance process is recommended for operators having access to sufficient and accurate information. Collision avoidance during the launch phase is complex due to relatively large uncertainties on launch vehicle trajectory but essential, particularly for manned vehicles.

- B4- The most efficient mitigation measures are limitation of orbital lifetime and passivation: in low Earth orbits, all satellites and launcher upper stages should be compliant with the 25-year rule, as specified by the IADC and some other organizations. A shorter lifetime, when feasible, would be useful to reduce the risks.

- B5- Explosions are the main source of debris in LEO today. A low probability of accidental explosions should be ensured through design and safe operations during the operational lifetime, and through passivation after end of mission. Deliberate fragmentation should be forbidden or performed, when absolutely necessary, at very low altitude in order to reduce to the maximum extent possible the orbital lifetime of the corresponding debris.

- B6- Very small satellites (cubesats, nano- or pico-satellites) represent a particular risk in the future: these satellites generally have no propulsion capacity and will be launched in clusters, which may lead to a rapid increase of the in-orbit population. In addition, due to their very small size they may be difficult to be tracked and catalogued by space surveillance systems. Their use should be limited to the very low altitudes leading to a short natural orbit lifetime, of less than the 25 years.

C/ Preliminary recommendations specific to operation in the MEO orbits:

- C1- The operators of satellites in Medium Earth Orbits (MEO) should define in common the best end of life option for the satellites and upper stages in this region. The long term stability of MEO end-of-life disposal should be analysed in order to avoid satellites or the upper stages of one operator interfering with the operational satellites of the other operators.

D/ General recommendation on cooperation between Government Space authorities and commercial satellite operators:

Except for the national legislations that are binding, the respect of guidelines will be better ensured if all the actors are willing to participate and if the methods that are put in place are pragmatic and easy to accept. The cooperation among the national and international organizations that are in charge of developing the guidelines and the community of commercial spacecraft operators is necessary in order to ensure the common interest.

- D1- For the benefit of all parties it is desirable that such cooperation increases among the government organizations and private sectors in the form of regular forums.

ANNEX 1

Background information and status of national regulations on Space Debris mitigation

The American Institute of Aeronautics and Astronautics (AIAA) issued the first position paper on space debris in 1981 [ref]. Since that time, many organizations have come to recognize the potential threat posed by orbital debris and the need to take action to curb the growth in its population, most notably the Inter-Agency Space Debris Coordination Committee (IADC) and the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS).

A. The IADC

The IADC is a forum of national or international space agencies that coordinate their activities related to the issues of man-made debris and natural meteoroids in space. The primary purpose of the IADC is to exchange information on space debris research activities among member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing co-operative activities, and to identify debris mitigation options. One of the IADC's activities is to recommend debris mitigation measures, with an emphasis on cost-effectiveness, which can be considered during planning and design of spacecraft and launch vehicles in order to minimize or eliminate generation of debris during operations. The "IADC Space Debris Mitigation Guidelines", reflecting the fundamental mitigation elements of a series of existing practices, standards, codes and handbooks, were formally adopted in October 2002. Two years later, a companion document, entitled "Support to the IADC Space Debris Mitigation Guidelines", was generated to provide technical background, rationale and guidance for implementation of the IADC Guidelines.

These IADC Guidelines address:

- The minimization of the potential for on-orbit breakups, namely:
    - Minimizing post mission break-ups resulting from stored energy
    - Minimizing break-ups during operational phases
    - Avoidance of intentional destruction and other harmful activities
- Post Mission Disposal, applicable to:
    - Geosynchronous region
    - Objects passing through the LEO Region
    - Other Orbits
- Prevention of On-Orbit Collisions

The 2002 IADC Guidelines were updated in 2007 and their current status can be found at http://www.iadc-online.org.

B. United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)

Since UN COPUOS published its Technical Report on Space Debris in 1999 (A/AC.105/720, later known as the "Rex Report"), there has been a general understanding that the current space debris environment poses a risk to spacecraft in

Earth orbit. UNCOPUOS also recognized that as the population of debris continues to grow, the probability of collisions that could lead to potential damage will consequently increase. Accordingly, UNCOPUOS acknowledged that the prompt implementation of appropriate debris mitigation measures is a prudent and necessary step towards preserving the outer space environment for future generations, and recognized the benefit of a set of high level qualitative guidelines, having wider acceptance among the global space community. A Working Group on Space Debris was established in 2003, under the auspices of the Scientific and Technical Subcommittee of COPUOS, to develop a set of recommended guidelines based on the technical content and the basic definitions of the IADC space debris mitigation guidelines, taking into consideration the existing United Nations treaties and principles on outer space.

In order to involve as many spacecraft and orbital stage operators as possible, the applicability of these UNCOPUOS Guidelines was extended not only to newly designed space systems but also, where possible, to existing ones. A number of constraints were also established to achieve consensus within the STSC Working Group, the STSC and UNCOPUOS, namely, the UNCOPUOS Guidelines: were based on, and not to be more technically stringent than, the IADC Mitigation Guidelines; allow exceptions on a case by case basis because of mission objectives or cost effectiveness; and are not be legally binding.

The Working Group on Space Debris submitted a first proposal to UNCOPUOS in June 2005, which was then agreed in February 2006. One year later, having secured consensus at a national level, the proposed Guidelines document [ref document A/AC.105/C.1/L.284] was accepted by the Scientific and Technical Subcommittee with minor comments, and in June 2007 COPUOS endorsed the “Space Debris Mitigation Guidelines”, putting it as an annex to its report to the UN General Assembly, which itself endorsed the document at the end of 2007 [Resolution A/RES/62/217 dated 10 January 2008].

C. ISO:

In order to implement the IADC, ITU and UN Space Debris mitigation guidelines in an operative standard way, the ISO – the International Organization for Standardization – set up an Orbital Debris Coordination Working Group (ODCWG) in 2003 to transform these guidelines into a set of measurable and verifiable requirements.

The ISO standards prescribe requirements that have been derived in large part from internationally-agreed guidelines such as those published by the IADC. They also capture industry best practice and specify definite actions to be taken by satellite manufacturers and operators to achieve compliance.

Such requirements are thought specifically to cover the need of standardization for those Countries which does not already have set up and implemented any national legislation to enforce the UN treaties and UN mitigation guidelines. This latter are therefore encouraged to comply with the international agreements in order not to endanger or constrain existing and future space systems and missions.

The ISO TC20/SC14 Orbital Debris Co-ordination working group established in 2001, develops both top-level standard, which comprises all of the high-level debris mitigation requirements and lower level standards, which contain detailed procedures and practices for implementing the requirements.

Specifically the ODC Working Group target is to perform the following tasks:

- Develop a plan for the preparation of ISO debris mitigation standards
- Coordinate the development of debris mitigation standards among the other C20/SC14 working groups
- Establish and maintain external liaisons with organizations involved in debris mitigation (e.g. IADC, UNCOPUOS, and IAA).

The highest level debris mitigation requirements are contained in a top-level standard designated “ISO 24113: Space Systems – Space Debris Mitigation” which provides the main interface for the user, bridging between the primary debris mitigation requirements and the lower-level implementation standards that will ensure compliance. Also this ISO 24113 standard defines the primary space debris mitigation requirements applicable over the life cycle of a space system. It covers all elements of unmanned space systems launched into or passing through near-Earth space, including launch vehicle orbital stages, operating spacecraft, and any objects released as part of normal operations or disposal actions.

The purpose of the high level standards is to avoid the intentional release of debris into Earth orbit during normal operations, avoid break-ups in Earth orbit, and remove spacecraft and launch vehicle orbital stages from high-value orbital regions after end of mission.

Many of the high level requirements concern the removal of spacecraft or launch vehicle orbital stages from the GEO and LEO regions after end of mission. In the standard both of these regions are considered as protected with regard to the generation of space debris. This is necessary to ensure the safe and sustainable use of these high-value, high-utility regions in the future.

Other ISO standards documents are:

- ISO 26872: Space Systems – Disposal of Satellites Operating at Geosynchronous Altitude
- ISO 23339: Space Systems – Unmanned Spacecraft – Estimating the Mass of Remaining Usable Propellant
- ISO 27852: Space Systems – Determining Orbit Lifetime
- ISO 11233: Space Systems – Orbit Determination and Estimation
- ISO 27875: Space Systems – R e-entry Risk Management for Unmanned Spacecraft and Launch Vehicle Orbital Stages
- ISO 11227 : Space Systems – Test Procedures to Evaluate Spacecraft Material Ejecta upon Hypervelocity Impact

Detailed procedures and practices for complying with the high-level requirements are contained in a set of lower level implementation standards.

Once published, the standards will undergo periodic systematic reviews to ensure they remain up-to-date and usable by industry.

D. National Mechanisms/ Implementation

D1. United States

In 1995 NASA was the first space agency in the world to issue a comprehensive set of orbital debris mitigation procedures [NASA Safety Standards (NSS) 1740.14 - based on NASA Management Instruction (NMI) 1700.8, "Policy to Limit Orbital Debris Generation," which was issued in April of 1993]. Subsequently, a U.S. interagency working group led by NASA and the US Department of Defense developed a work plan to study the debris environment and to work with U.S. government agencies and other space faring nations and international organizations to design and adopt guidelines to minimize orbital debris. In 1997, this working group created a set of U.S. Government Orbital Debris Mitigation Standard Practices [ref]. Based on the NASA standard procedures for limiting debris, these standard practices were intended for government-operated or -procured space systems, including satellites as well as launch vehicles. The US interagency group also shared the standard practices with the aerospace industry to encourage voluntary compliance. At the agency level, NASA procedures currently require that each program and project conduct a formal assessment of the potential to generate orbital debris during deployment, mission operations, and after the mission has been terminated. The accompanying standards for implementation are consistent with the objectives of the U.S. National Space Policy [ref], the U.S. Government Orbital Debris Mitigation Standard Practices [ref], the Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines, and the Space Debris Mitigation guidelines of the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. NASA-Standard (NASA-STD) 8719.14 released in 2007 [ref] updates the original NASA Safety Standard (NSS) 1740.14 developed in 1995. The NASA Standard establishes requirements for (1) limiting the generation of orbital debris, (2) assessing the risk of collision with existing space debris, (3) assessing the potential of space structures to impact the surface of the Earth, and (4) assessing and limiting the risk associated with the end of mission of a space object. This NASA Standard is applicable to all objects launched into space in which NASA has lead involvement and control or has partial involvement with control over design or operations via U.S. internal or international partnership agreements, including the launch vehicle. NASA Handbook 8719.14 was published in 2008 to provide detailed background material in support of the NASA Standard.

The U.S. Department of Transportation, through its Federal Aviation Administration (FAA), addresses mitigation of space debris via licensing regulations for commercial space launches and re-entries. These regulations, based on U.S. Government Orbital Debris Standard Practices, cover licenses for the launch of expendable and reusable launch vehicles, and re-entry vehicles. The FAA can also evaluate payloads and their potential hazards under a Payload Review if the payload is regulated by the FAA, the U.S. Federal Communications Commission (FCC) or the National Oceanic and Atmospheric Administration, or owned or operated by the U.S. Government.

The U.S. FCC licenses radio-frequency use by satellites (other than U.S. government satellites). The FCC began to address space debris mitigation issues in the 1990s, first on a case-by-case basis, and then through the adoption of debris mitigation rules for new services. In 2004, the FCC adopted a comprehensive set of debris mitigation regulations, based on the NASA Safety Standard, the U.S. Government Orbital Debris Mitigation Practices, and the IADC Space Debris Mitigation Guidelines. The FCC regulations require applicants for FCC licenses to disclose their plans for debris mitigation. The regulations require all satellites to "passivate" at end of their life, by removing stored energy sources on the satellite. The regulations also require disposal of geostationary satellites to an orbit consistent with the IADC guidelines (with an exception for satellites launched prior to March 18, 2002).

D2. Canada

In Canada, orbital space debris mitigation is addressed through the terms and conditions of licences granted to satellite operators under the Radio communication Act. The Minister of Industry through the Canadian Department of Industry has the authority to fix the terms and conditions of such licences. As well, the Remote Sensing Space Systems Act which came into effect in 2007, also sets requirements for the disposal of remote sensing satellites as a condition of granting a licence to satellite operators.

In regard to debris mitigation for geostationary satellites - the satellite, at the end of its life, shall be removed from the geostationary satellite orbit region in a manner consistent with Recommendation ITU-R S.1003 Environmental Protection of the Geostationary Satellite Orbit;

For non-geostationary satellites - the licensee, at the end of-life of the satellite, must implement space debris mitigation measures in accordance with best industry practices so as to minimize adverse effects on the orbital environment.

In addition to the ITU recommendation noted above, Canada also considers other voluntary international guidelines on the mitigation of orbital debris including the 2007 Inter-Agency Space Debris Coordination Committee (IADC) and United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and requires applicants to provide a debris mitigation plan which is consistent with these guidelines. Canada, through Industry Canada intends to develop and consult on a more comprehensive approach for space debris mitigation in the near future.

The Canadian Space Agency (CSA) also assists the Minister of Industry to coordinate the space policies and programs of the Government of Canada. The CSA is currently setting up a working group, namely the **CSA Orbital Debris Working Group (CSA-ODWG)**. The purpose of the group is to share technical information and know-how in the area of Orbital Space Debris. These include (but are not limited to) debris damage mitigation technologies implemented through novel spacecraft technical designs, debris detection and collision avoidance measures.

The CSA-ODWG will pursue the following objectives:

1. To identify and encourage targeted R&D in orbital debris & mitigation measures.

2. To identify and encourage development of orbital debris detection and collision avoidance techniques & technologies.

3. To promote S&T collaboration across Canada and with our international partners.

4. Increase the S&T knowledge and awareness of Orbital Debris in the Space community.

5. To establish and maintain technical liaison with our international partners (NASA, ESA-ESTEC, ESOC, CNES, JAXA, ASI, BNSC, IADC, NORAD (SSN), etc. in order to represent the interests of CSA-ODWG.

Membership of CSA-ODWG is open to Canadian academia, including researchers and post doctoral fellows and graduate students, the government S&T community, and the industry S&T organizations which are interested in the area. The CSA-ODWG may invite international participants to contribute to discussion at the technical level.

D3. France

Regulatory activities for space debris first began in France in 1997, when a working group was formed to produce a CNES 'standard' for this field. The resulting draft document, which was based on the existing NASA standard, led to the publication in 1999 of the Exigences de Sécurité - Débris Spatiaux (Space Debris-Safety Requirements) document [ref MPM-51-00-12]. CNES then proposed to its European space agency partners (ASI, BNSC, DLR and ESA) that they work together to prepare a European document based on the CNES standard. To this end, the European Space Debris Mitigation Standard Working Group (EDMS-WG) was set up. The document drafted by the EDMS-WG was first discussed internally by each participating agency, then with the major spacecraft manufacturers and operators in Europe. June 2004 saw the publication of the resulting “European Code of Conduct for Space Debris Mitigation” [European Code of Conduct for Space Debris Mitigation, issue 2.0 of 14/9/2007]. This Code of Conduct is applicable to all new CNES projects, and is recommended for projects under development and satellites already in orbit. The conditions of application are specified in the note "Modalités de prise en compte par les projets orbitaux du code de conduite pour les débris spatiaux" ("Procedures to be applied by orbital projects in accordance with the code of conduct for space debris") [28 June 2004]. Since 1999, CNES has been systematically applying the directives on space debris that resulted first from the CNES standard and subsequently from the European Code of Conduct. France is currently preparing national space legislation [Loi no 2008-518 relative aux opérations spatiales (3 June 2008)] that would enable constraints to be imposed in terms of protection of the environment, property and people. To this end, requirements covering space debris will be introduced in the technical regulations that will accompany the legislation.

D4. United Kingdom

The Outer Space Act 1986 (OSA) [ref] is the legal basis for the regulation of activities in outer space (including the launch and operation of space objects) carried out by persons connected with the United Kingdom (UK). The Act ensures compliance with UK obligations under the international conventions covering the use of outer space to which the UK is a signatory. Under the legislation of the OSA, a licence shall not be granted unless the licensing authority is satisfied that the activities will not jeopardize public health or the safety of persons or property, will be consistent with the international obligations of the United Kingdom, and will not impair the national security of the United Kingdom. Further operations should be conducted in such a way as to prevent the contamination of outer space or adverse changes in the environment of the Earth, and to avoid interference with activities of others in the peaceful exploration and use of outer space. The qualitative and quantitative criteria used for licence evaluation are based on standards and practices employed by a variety of formal bodies. In developing the technical evaluation framework to reflect space debris mitigation issues, the particular issues of physical interference and contamination referred to in the Outer Space Act are employed. Although the problem of space debris was not recognized when the OSA was enacted in 1986, the Act is flexible enough to allow interpretation to cover this aspect in the technical evaluation. Thus “physical interference” is used to address probability of collision with other objects in orbit and “contamination” to address safe disposal at end of life. As regards the actual measures that are used to evaluate a licence application, use is made of the growing number of guidelines, codes and standards that are being developed to deal with space debris mitigation. The IADC Space Debris Mitigation Guidelines, the European Code of Conduct on Space Debris Mitigation, and the UN Space Debris Mitigation Guidelines provide qualitative and quantitative measures that are used to assess compliance of licence applicants’ proposed activities and measures with recognized “best practice” within the community.

D5. Germany

The authority for defining the top level objectives for Germany’s space activities lies with the Bundesministerium für Wirtschaft und Technologie (BMWi, Federal Ministry of Economics and Technology). The German Space Programme is implemented and managed by the Deutsches Zentrum für Luft und Raumfahrt DLR (German Aerospace Centre) in its capacity as Germany’s space agency. The legal framework is given by the Delegation of Space Activities Act (Raumfahrtaufgaben-Übertragungsgesetz). DLR policy requires for each contractor the implementation of a PA programme, including space debris mitigation, throughout all project phases. The standards of the European Cooperation for Space Standardization (ECSS) set the benchmark for the necessary PA activities required by the German Space Agency Quality Management System. Since 2004, Germany has imposed requirements based on the European Code of Conduct which was signed by DLR in this year. Starting in 2007 an integrated approach for the conversion of Space Debris Mitigation Guidelines into an implementation mechanism has been developed within the PA requirements tailoring as part of a multiple stage process starting with a Request for Proposal and leading to the PA Controlling of the relevant project. The European Code of Conduct on Space Debris Mitigation forms the input for this Safety-part of the PA requirements and assesses compliance with both the IADC Space Debris Mitigation Guidelines and the UN Space Debris Mitigation Guidelines. Verifiability and practicability of the requirements to be considered during development, production, and operation of a space system are currently under review taking into account the aspect of maintaining the competitiveness of the German Space Industry as well.

D6. Italy

In Italy, national mechanisms are carried out under the Italian Space Agency (ASI) umbrella. At the moment, as ASI is the main body which develops and launches satellites, the verification of design, launch and operation of satellites made by national industries, is conducted by ASI personnel. The ASI General Director signed the European Code of Conduct in 2003. Now this document is applicable for each contract assigned at the national level. Compliance with the Code of Conduct is determined during the technical reviews of the design of new satellites and launchers and for their developing phases. In general, industry recognizes the need for and value for such mitigation practices and consequently good compliance is found. A further step could be performed at the national level, in order to ensure a proper control of all private or other organizational Italian entities that launch or operate their satellite.

D7. ESA

In April 2008, the Director General of the European Space Agency (ESA), in confirming his endorsement of the European Code of Conduct for Space Debris Mitigation, approved a document “Requirements for Space Debris Mitigation for ESA Projects” to aid implementation of the Code of Conduct to ESA programmes, making it an applicable standard for all new launchers, satellites and manned systems procured by the Agency. These requirements on “Space Debris Mitigation for ESA Projects” define a minimum set of requirements for the limitation of space debris, in particular within the LEO and GEO protected regions, and a minimum set of risk reduction measures in the case of re-entries of space systems or their components in the Earth’s atmosphere.

D8. Russian Federation

Since the early 1990s Russia actively participates in all actions concerning space debris. The official activity of the Inter-Agency Space Debris Coordination Committee (IADC) was started in Moscow in 1993 when the IADC Terms of Reference have been adopted and today the IADC is the leading international technical expert on space debris. The Federal Space Agency of the Russian Federation (Roscosmos) carries out the coordinated branch policy on space debris mitigation. Roscosmos takes part in all sessions of the IADC and of the ISO space debris working group. Every year Roscosmos presents a comprehensive report about its activity on debris mitigation to the Scientific and Technical Subcommittee (STSC) of UNCOPUOS.

In 1999 the Branch Standard OST 134-1022-99, “Near-Earth Space, Model of spatial - temporary distribution of density of Space Debris”, had come into force. In 2000 the second Branch Standard, OST 134-1023-2000 "Space Technology Items, General Requirements for Mitigation of Space Debris Population", had come into force. The standard requirements are similar to the best practices of other organizations and agencies - IADC members and are obligatory for all activities by the order of Roscosmos. In 2003 the third Branch Standard, OST 134-1031-2003 “Space Technology Items, General Requirements on Spacecraft Shielding Against Space Debris and Meteoroids”, had come into force.

Roscosmos has participated actively in preparing the “IADC Space Debris Mitigation Guidelines” (2002) and the “UNCOPUOS Space Debris Mitigation Guidelines” (2007). In 2008 the President of Russian Federation approved “The Keystones of the Russian Federation Space Policy up to 2020 and beyond”. The “…ecological safety of space activity, implementation of technologies and the designs minimizing production of space debris at launch and operation of spacecraft and orbital stations” were determined as the high priority issues in this document. Since January 1, 2009 the new Russian National Standard GOST R 52925-2008 “General Requirements to Spacecraft and Orbital Stages on Space Debris

Mitigation" has come into force. The requirements of the Standard should be applied to new designed and updated space vehicles of different type: civil, science, commercial, military and manned missions. Application of the Standard requirements spreads to all stages of life cycle of space vehicles: design, manufacturing, launch, operation and disposal. The requirements of the Standard are fully in line with the UN Mitigation Guidelines. A number of actions under Roscosmos authority may be recognized as the best debris mitigation practices all over the world. Among them, the controlled re-entry of the "Mir" orbital station of 120 tons in mass when the worldwide community was highly concerned about the danger it represented for the population and for property on the Earth' surface. Another example is the successful disposal in March 2006 (in accordance with the IADC rules) of the emergency spacecraft "Express AM - 11" by using of correction and orientation engines. It should be recalled also the annual successful practices (five to six times per year) by the TSNIIMASH Mission Control Center in splashing down of the "Progress" cargo vehicles and in soft landing of the manned vehicles "Soyuz-TM" to restricted on-ground areas that are used in service of the International Space Station (ISS). Another excellent example of international cooperation in space between Russian and US specialists (TSNIIMASH and NASA Mission Control Centers) is the safety assurance of the ISS crew and of the ISS as a whole.

D9. Japan

JAXA, the main body of the space activities in Japan, established its Space Debris Mitigation Standard in Oct.2003, based on the NASDA document (NASDA-STD-18) established in Mar.1996. Japan has been the member of the IADC since Feb.1992 and contributed to establish the IADC Mitigation Guideline and also the UN Mitigation Guideline, cooperated with the members of the IADC and those of the ST Sub-committee of the UNCOPUOS.

It has been revised to the present one, JMR-003A, in parallel with the establishment of the IADC and UN Mitigation Guideline and, therefore, is compatible with those ones.

The principles of the Standard of JAXA are:

1. Preventing the on –orbit break-ups of the space systems.

2. Transferring a spacecraft which has completed its mission in GEO, into higher orbit.

3. Reducing the stay time of the orbital stage in the GTO.

4. Minimizing the number of objects released in the orbit in the nominal operational phase.

5. Reducing the stay time of the spacecraft in the LEO (less than 25 years).

6. Avoidance of the on-orbit collision.

Standard also requested to assess the re-entry risk of impact of the survived objects at the atmospheric re-entry.

JAXA has applied this Standard to its own projects and reviewed its status of the application at the System Safety Review Board in the progress of the system design and the development.

Other national entities and industries have referred this Standard for their space activities.

D10. India

The national mechanism and implementation of space debris mitigation measures for Indian Satellites and Launch Vehicles is done by Indian Space Research Organisation (ISRO). The final stages of Indian launch vehicles are passivated at the end of useful mission to avoid any further break-up of the stage. The ISRO's communication satellites in GSO are designed with adequate propellant margins for re-orbiting to a higher orbit at the end of their useful life. The strategy is implemented on a case-by-case basis consistent with national requirements. Propulsion systems, by design, are built as integrated systems with the spacecraft bus and payload. The propulsion system is not separated in orbit. Since these are liquid propulsion systems, the ejecta do not contain any solid particles. Also the batteries of spacecrafts are safed in order to prevent an orbit explosion. As a member of UNCOPUOUS and through ISRO's membership in IADC, India is contributing significantly to the international efforts and activities in the field of space debris.

ANNEX 2

Status of international Space Surveillance Systems and of mechanisms for sharing information

Annex 2.1: The Air Force TLE system

The task of locating and tracking active spacecraft and space debris is a technically challenging and expensive activity. Currently, the US Strategic Command's Joint Space Operations Center (JSPOC) plays a key role internationally in tracking, and reporting on, man-made objects in orbit. The JSPOC receives on-orbit positional data from the Space Surveillance Network, which is composed of both optical and radar sensors throughout the world. This allows the JSPOC to attempt to maintain accurate data on every man-made object currently in orbit. Today the JSPOC is tracking more than 19,000 objects in space.

Because of the relatively imprecise nature of the TLE data, the US Air Force established the "Space Support Request (SSR) Process" for granting operators access to information that goes beyond the basic TLEs. Through the SSR Process, operators can request additional information (the Special Perturbation, or SP, data) on specific 'close approach' situations. Although helpful, it is cumbersome to rely on the SSR Process as an operational tool because it requires advance notice, which is often impossible in emergency situations. In addition, conjunction events often require close cooperation and interactive communication. Today, the SSR Process relies primarily on email as a method of communication and the US Government does not guarantee the rapid turnaround necessary in most cases.

Annex 2.2: Status of space surveillance systems in operation in Europe

2.2.1 France:

The French space surveillance system is operated by the French Air Force and provides on a routine basis a catalogue of more than 2200 of objects in low Earth orbit. The system is based on the GRAVES bi-static radar. Objects flying through the field of view of this sensor are detected and the corresponding orbital parameters are estimated. This catalogue is used by CNES in complement to the US SSN TLEs to perform conjunction assessment for the French satellites operating in low Earth orbits. In case of collision risk, additional accurate tracking measurements are requested from the French MoD tracking radars or from the German TIRA radar. In addition to these facilities, the two TAROT optical telescopes, located in South East France and in Northern Chile, are used to detect and track objects in the geostationary orbit.

2.2.2 Germany

The German FGAN Research Institute for High Frequency Physics and Radar Techniques (FHR), division Radar Techniques for Space Reconnaissance (RWA), operates the Tracking and Imaging Radar (TIRA) system which serves as the central experimental facility for the development and investigation of radar techniques for the detection and reconnaissance of objects in space, and to a certain degree of air targets. The capabilities are established through high resolution in range and Doppler frequency, by radar image generation and interpretation, polarimetric techniques and others.

The TIRA system gains radar data at 22.5 cm (L-band) and 1.8 cm (Ku-band) wavelengths.

These form the data basis for the development of image and feature based classification and identification algorithms. Based on radar data of space objects and techniques developed at RWA, characteristic target features like orbital elements, intrinsic motion parameters, orbital lifetime, target shape and size, ballistic coefficient, mass and material properties can be determined. TIRA consists of three major subsystems, the antenna system with a 34 m parabolic reflector movable in azimuth and elevation, a narrow band, fully coherent monopulse tracking radar of high pulse power at L-band (1,333 GHz) frequency, and a wide band (currently 800 MHz) imaging radar at Ku-band frequency (16.7 MHz), allowing high target resolution.

2.2.3 Italy:

This paragraph describes the monitoring capability of the Italian Space Agency. Italy has developed since 2002 the capability of monitoring space debris using both optical and radar means mainly to support the IADC monitoring campaigns.

Optical Sensors:

The Italian Space debris Observatory (called SpaDe), allows optical observations campaign in HEO and GEO. It consists of:

a) Two optical tubes of 400 mm diameter Modified Cassegrain, with a focal ratio of f/1.8 and Baker-Schmidt with a diameter of 300 mm and a focal ratio of f/2.8.

b) A tracking system, realized by a Paramount GT 1100 ME commercial mount capable to rotate with a maximum angular velocity of 5 deg/s in right ascension and 7 deg/s in declination. And

c) The CCD camera is a FLI Proline 16803 with a Kodak Kaf 16803 sensor. This CCD permits to achieve a field of view of about 2.6 deg for the Baker-Schmidt and about 3 deg for the Modified Cassegrain.

The SpaDe observatory is semi-transportable and manufactured in a dome easily transportable, even by car.

It is now assembled in Collepardo. All the orbiting objects are automatically detected and identified with a proper software capable to automatically process and store all images of an observation campaign.

Radar Sensors:

The Italian sensors are receiving VLBI stations of 32m located in Medicina or Noto (see chart). The designed system is a complex system (with high computation capability and FPGA) that works in piggy-back mode as a back-end of a radar bistatic configuration. The facility belongs to the INAF Institute of Radio Astronomy IRA-INAF and allows as much as 300/day observations of dimension and velocity determination of object by their radar echoes.

There is also an interferometric system belonging to the ISAC-CNR to monitor small artificial debris and meteoroids as they enter into high atmosphere. The facilities are located in Bologna, Lecce and Modra and are capable to locate debris iteration (by ionization) with high atmosphere.

2.2.4 Switzerland:

The main Swiss contribution to space surveillance is provided by the Astronomical Institute of the University of Bern (AIUB) which has a long experience in optical observation and orbit determination. The AIUB operates two telescopes in Zimmerwald near Bern and is able to detect objects in high-altitude orbits, determines their orbital parameters and maintain a catalog. This know-how and the related data permit the AIUB to take part in European and international cooperations in the fields of space surveillance and NEOs. The AIUB is also in charge of optical observations with the ESA telescope in Tenerife (Spain) and determination of objects orbital parameters.

2.2.5 United Kingdom:

The United Kingdom hosts a number of space surveillance capabilities ranging from radars through to optical systems. The mission of the RAF Fylingdales radar system is "to provide an uninterrupted ballistic missile warning and space surveillance service". Although the primary role of the Fylingdales system is related to ballistic missile early warning, its secondary mission is to contribute to the Allied Space Surveillance Network, and supports UK forces worldwide through its Satellite Warning Service. The Solid State Phased Array Radar (SSPAR) at Fylingales consists of a 3-sided truncated pyramid about 40m high. Each face is approximately 28m in diameter and contains an array of 2,560 transmit/receive modules, each with a circularly polarized antenna, giving an overall mean power output from the 3 faces of approximately 2.5 Mega Watts. Fylingdales is the only 3-faced BMEWS radar in the world, providing a full 360º of cover. The SSPAR can keep track of many hundreds of space objects per minute out to a range of 3000 nautical miles. The Starbrook space surveillance sensor is an optical surveying system which uses a 10cm aperture telescope with a 10 megapixel CCD to deliver a 10 degree by 6 degree field of view. Starbrook is installed at a UK Facility in Cyprus and is used to service a number of UK government military and civil programmes. In addition there are a number of systems in the UK capable of supporting space surveillance such as the 25m radar antenna at Chilbolton.

2.2.6 European Space Agency:

ESA has been maintaining their DISCOS database (Database and Information System Characterizing Objects in Space) since the early 1990ies. DISCOS serves as a single-source reference for information on launch details, ownership, orbit histories, physical properties, and mission descriptions of more than 34,000 objects tracked since Sputnik-1 (including 5.7 million orbit records in total). A bilateral agreement with NASA guarantees a continuous flow of two-line element (TLE) orbit data for all unclassified objects tracked by the US Space Surveillance Network (SSN). DISCOS constitutes a reliable source of space object data that is frequently used ESA-internally and by a large number of external customers. Data products include information on in-orbit fragmentation events, in-orbit solid rocket motor firing events, details on launch vehicles and launch sites, visibility forecasts for catalog objects from user specified positions, and re-entry forecasts. Out of the 14,000 unclassified objects currently tracked by the US Space Surveillance Network, about 8% can be attributed to GEO, 19% are on MEO and highly eccentric orbits, and the remaining 73% are in the LEO regime.

ESA's Space Debris Office operates a 1m Zeiss telescope used for the detection and survey of objects at geostationary altitudes. The telescope implements Ritchey-Crétien optics with one degree FOV, and a CCD camera with a liquid nitrogen cooled 2 x 2 mosaic of 2k x 2k CCD chips. It can detect and track objects in GEO up to magnitudes of +19 to +21 (i.e. down to 15 cm in size). During GEO observation campaigns, typically 75% of all detections are new objects, which are not contained in the USSTRATCOM Catalog.

The European Space Agency is presently setting up a Space Situational Awareness (SSA) Preparatory Program, following a decision by the ESA Ministerial Council in Nov. 2008. By 2013 this Preparatory Program shall provide SSA precursor services in the areas of survey & tracking, space weather, and near-Earth objects (NEO). The different SSA application areas will initially be based on a federation of data sources, including data from European sensors. At a later stage the European SSA system is intended for autonomous operations, at least in the field of survey & tracking. The sensor principles (radar and optical) to be used for different orbit altitude regimes are currently under investigation. The sensor network, data products, and data distribution policy will be defined to match customer requirements, security constraints, available technology, and affordability.

ANNEX 3

Annexes to Section 3 on space operations

ANNEX 3.1

Operations in the GEO Orbit - Private Initiatives – The Data Center

In response to the shortcoming of the current TLE-based CFE program and the recognition that better inter-operator communication is desirable in and of itself, some spacecraft operators have recently begun a broad dialogue on how to best ensure information-sharing within the satellite communication industry. One proposal currently being discussed in the international operators' community is the "Data Center". As conceptualized, the Data Center would be an interactive repository for commercial satellite orbital, maneuver and frequency information. Satellite operators would routinely deposit their fleet information into the Data Center and retrieve information from other member operators when necessary. The Data Center would allow operators to augment existing Two Line Element (TLE) data with precision orbit data and manoeuvre plans from the operator's fleets. The Data Center would also:

- Perform data conversion and reformatting tasks allowing operators to share orbital element and/or ephemeris data in different formats
- Adopt common usage and definition of terminologies
- Develop common operational protocols for handling routine and emergency situations
- Exchange operator personnel contact information and protocol in advance of need

If the Data Center were to gain acceptance, it could perform additional functions, such as the close approach monitoring tasks currently being conducted by some operators. In this phase, US Government provided TLE data could be augmented by the more precise data available from the operators. This would improve the accuracy of the Center's conjunction monitoring and could provide a standardized way for operator's to share information with governments. In the early stages, information on non-operational space objects would still be supplemented by TLE data from the Air Force CFE program and/or other government programs. Governmental support would still be required when precise information is needed to resolve close approaches and avoidance maneuver planning.

In summary, the principal goal of the Data Center would be to promote safety in space operations by encouraging coordination and communication among commercial operators. The Data Center could also serve as a means to facilitate communication between operators and governments. Details on the implementation of the Data Center, services to be provided, usage policies, structure of the organization and by-laws have yet to be determined and would require agreements with the member operators at the creation the organization. The development of a Data Center could provide new visibility and awareness of the geostationary orbit and allow all spacecraft to be flown in a safer manner and reduce the likelihood of an accidental international incident in space.

ANNEX 3.2

Orbital Data Formats

1. - Coordinate systems:

• True: Position of the referred to element for the specified date/epoch. With respect to an inertial position, the true of date/epoch is obtained by a rotation that includes precession and nutation.

• Mean: Position of the referred to element after averaging out the nutation component. With respect to an inertial position, the mean of date/epoch is obtained by a rotation that includes only precession.

• Date/epoch: Reference time for an event. Epoch refers normally to the processing start of a certain batch of data whilst date refers to the time stamped on each individual observation or event.

The typically geocentric coordinate systems are:

- J2000.0 Þ Mean Equator and Equinox of 2000/01/01.
- J1950.0 Þ Mean Equator and Equinox of 1950/01/01.
- Mean-of-date Þ Mean Equator and Equinox of date.
- True-of-date Þ True Equator and Equinox of date.
- QMOD Þ Mean-of-date with a simplified nutation model.
- TEME Þ True Equator and (projected) Mean Equinox of date.
- VEIS (or G50) Þ True Equator and (projected) True Equinox of 1950.0
- Earth-Fixed

2. - Time References

UTC (Universal Time Coordinated) is the standard reference:

- Piece-wise continuous (leap-seconds introduced)
- Follows Earth rotation within ±0.9 sec
- It is the time shown by clocks (also called GMT)

Formats:

- ISO Standard: YYYY/MM/DD hh:mm:ss
- Julian Day: Number of days since 01/01/4713 BC
- Modified Julian Day 1950 (MJD1950)
- Modified Julian Day 2000 (MJD2000)
- JD = MJD1950 + 2433282.5 = MJD2000 + 2451544.5

3. - Presentation of Orbital data:

Keplerian elements:

- A: Semi-major axis (km)

- E: Eccentricity
- i: Inclination (degrees)
- Ω: Right Ascension of Ascending node (degrees)
- w: Argument of perigee (degrees)
- ν: True anomaly (degrees)
- Effective mass to cross section ratio (kg/m2).

Note: for GEO orbits the true anomaly is often replaced by the geodetic longitude: λ: Longitude (degrees)

Two line elements:

- TLEs. Definition can be found in many sources, e.g. CelesTrak
- n: mean motion (revs/day) is used instead of semi-major axis
- M: mean anomaly (degrees) is used instead of true anomaly

Cartesian elements:

X, Y, Z, Xdot, Ydot, Zdot (km).

Note: Only osculating elements should be used to avoid difficulties to transform mean elements into osculating elements.

ANNEX 3.3

Regulation of commercial suborbital flights

The nascent commercial personal space flight market presents a challenge to regulators with regard to the potential certification and licensing of the flight vehicles and their use (both within and outside the atmosphere), from the perspective of the operator, the "space flight participants", and third parties that might be affected by the operations.

Approach

The duration of a sub-orbital flight is likely to last much less than an hour whereas an orbital flight might be expected to be measured in days. From launch to re-entry, the space flight participant will pass through a number of atmospheric, altitude and aerodynamic flow regimes. It is important for ease of implementation and future evolution, that any new licensing regime seek to address the whole life-cycle of a mission, whether it be orbital or sub-orbital. For this reason, the approach proposed here is to derive a comprehensive approach to the regulation of commercial space flights, encompassing all elements of the mission(s) outlined above.

In addressing the regulation of commercial space flights at this time, there is a strong argument that government should not apply the same stringent safety measures appropriate to a more mature transportation markets, and even the established expendable launch vehicle market. Like any other business, space tourism is expected to develop progressively, starting with a relatively small-scale and high-priced "pioneering phase", the scale of activity growing, and prices falling as the technology and market matures. It is envisaged that space tourism will become a mass-market business, much like aviation today. It is therefore argued that governments and licensing authorities should adopt a similar phased approach to regulation of such activities to facilitate rather than stifle the development of the industry.

Government, and in particular its regulatory function, is more effective when it works in partnership with industry. Consultation is an important tool but due to the rapidly evolving nature and variety of both the flight technology and market associated with space tourism, it is important that the implementation of regulatory oversight involves the developers, manufacturers and operators when setting performance and evaluation criteria for their respective systems, i.e. there is unlikely to be a “standard” system or approach as is found in the aviation industry.

The USA/FAA Approach as a Model

The current “best practice” for dealing with the regulation of space tourism exists in the United States of America in the form of the Commercial Space Launch Amendments Act (CSLAA) of 2004. Adopting this approach as the model for dealing with space tourism activities has a number of advantages:

- national industries are free to compete on equal terms with other leading players (i.e. the national space licensing regime should not apply a greater regulatory burden on its industry than that exists already elsewhere)
- Space tourism by its nature, and likely development, is international and hence regulatory regimes which are consistent across nations and thereby have the potential to be multi-lateral in nature are likely to facilitate the development of the industry

The basic tenet of US regulations for space flight participants is the concept of informed consent. An operator is required to inform space flight participants of the risks of space travel generally and the risks of space travel in the operator’s vehicle in particular. They are obliged to tell the passenger that the US government has not certified the vehicle as safe for carrying flight crew or space flight passengers.

When US Congress gave the Department of Transportation/Federal Aviation Administration authority for regulating private human space flight under the Commercial Space Launch Amendments Act (CSLAA) of 2004, it took a phased regulatory approach to allow this new industry to thrive. Its view was that regulations should evolve over time as the industry matures. Until December 2012, the primary responsibility of the FAA under the CSLAA is to protect the uninvolved public by licensing the launch (or re-entry) event. Unlike commercial passenger aviation, the FAA does not certify commercial space launch or re-entry vehicles.

The space flight participants, or passengers will be informed of the risks in writing about the launch and re-entry, provided the safety record and data related to the vehicle they are flying on, and give written consent to the operator.

An operator must successfully verify the integrated performance of a vehicle's hardware and any software in an operational flight environment before allowing any space flight participant on board. Verification must include flight testing. The regulations also establish requirements for crew notification, medical qualifications and training, as well as requirements governing environmental control and life support systems.

Launch vehicle operators are required to provide certain safety-related information against criteria identified by the FAA as to what an operator must do to conduct a licensed launch with a human on board. In addition, launch operators are required to inform passengers of the risks of space travel generally and the risks of space travel in the operator's vehicle in particular.

A Space Flight Participant must provide written informed consent. The FAA regulations also include training and general security requirements for Space Flight Participants.

The CSLAA requires that a space flight participant be informed of the risks of going on a launch or re-entry vehicle, and specifies that the Department of Transportation (FAA) may issue regulations requiring space flight participants to undergo an appropriate physical examination. To date, the FAA has decided against prescribing specific medical requirements for space flight participants. Instead of establishing space flight participant medical requirements, the FAA issued guidelines recommending that space flight participants obtain an evaluation of their medical history to determine whether a physical examination might be appropriate. The guidelines recommend that a space flight participant provide a medical history to a physician experienced or trained in the concepts of aerospace medicine. The physician would determine whether the space flight participant should undergo an appropriate physical examination before boarding a vehicle destined for space flight. Guidance for the medical assessment of space flight participants was provided by the FAA's Office of Aerospace Medicine and the FAA's Civil Aerospace Medical Institute.

The FAA's Human Space Flight (HSF) rule requires each crew member to complete training on how to carry out his or her role on board or on the ground so that the vehicle will not harm the public. The crew must train for his or her role in nominal and non-nominal conditions that include abort scenarios and emergency operations. An operator must train each space flight participant before flight on how to respond to emergency situations, including smoke, fire, loss of cabin pressure, and emergency exit. Without this training, a space flight participant might inadvertently interfere with the crew's ability to protect public safety. The HSF rule also requires that an operator implement security requirements to prevent any space flight participant from jeopardizing the safety of the flight crew or the public.

Current US regulation requires the crew and space flight passengers to enter into a reciprocal waiver of claims with the US government.

Appendix

FAA regulation in force in the United States

U.S. Department of Transportation

Federal Aviation Administration

Office of Commercial Space Transportation

July 22, 2008

Regulation of U.S. Suborbital Commercial Space Flights:

Background for Informal Consultations on Best Practices for Space Operations

In December 2004, the U.S. President signed the Commercial Space Launch Amendments Act (CSLAA) of 2004. The CSLAA makes the Federal Aviation Administration (FAA) responsible for regulating commercial human space flight. The law recognizes commercial human space flight as a fledgling industry which requires a phased approach to regulating standards, allowing for evolution as the industry matures. Prior to the CSLAA, the FAA already had the authority to regulate commercial suborbital expendable launch vehicles. The FAA's Office of Commercial Space Transportation implements 49 U.S.C. Subtitle IX, Chapter 701, which governs the regulation of commercial space launch and re-entry activities.

The FAA issued regulations in December 2006 establishing requirements for crew and space flight participants. The new rules, which became effective in February 2007, maintain the FAA's commitment to protect the safety of the public and call for measures that enable space flight participants to make informed decisions about their personal safety. Launch operators must inform passengers of the risks of space travel generally and risks of space travel in the operator's vehicle. The regulations also include training and general security requirements for space flight participants, establish requirements for crew notification, medical qualifications and training, and establish requirements for environmental control and life support systems. The regulations impose financial responsibility and waiver of liability requirements as well. In addition, the regulations define a suborbital rocket and space flight participants.

The CSLAA also established an experimental permit regime as an option for reusable suborbital rockets for such purposes as testing, research and development, or crew training on a repeat basis. Under an FAA permit, a reusable suborbital launch vehicle may not be operated to carry property or space flight participants for compensation or hire.

The FAA continues to respond to the 2004 law and is developing advisory circulars and other guidance documents regarding commercial human space flight.