December 2021

MAKING SPACE SAFE AND SUSTAINABLE

ISSF
INTERNATIONAL SPACE SAFETY FOUNDATION

PARIS PEACE FORUM
de PARIS sur la PAIX

PRESENTATION TO PARIS PEACE FORUM

VISION, PROPOSALS AND INITIATIVES OF THE INTERNATIONAL ASSOCIATION FOR THE ADVANCEMENT OF SPACE SAFETY TO ORGANIZE AND REGULATE OUTER SPACE

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MAKING SPACE SAFE AND SUSTAINABLE IAASS VISION, PROPOSALS, AND INITIATIVES INTRODUCTION

Since its establishment in 2004, the International Association for the Advancement of Space Safety (IAASS) has been working on developing and promoting its vision of making Space safe and sustainable.

The IAASS defines space safety, including long-term sustainability, as six intertwined risk management areas. In some areas, like safety of human onboard, risks are managed (mainly) by design, while in other areas, like space traffic, by operational procedures. The relevant stakeholders can be national, international, or global.

The cornerstone of international space law is the Outer Space Treaty of 1967. At the time of the treaty signature, space missions were rare and only USA and USSR, engaged in the Cold War, were pursuing substantial space programs from science to remote sensing, meteorology, and human spaceflight.

The Outer Space Treaty is essentially focused on the enunciation of top principles limiting the perimeter of actions in space of a country. Except for cooperation on astronauts rescue and consultations on unique hazardous situations, should the need arise, the treaty does not foresee a permanent forum for definition and harmonization of implementing rules and for operational coordination. Furthermore, accidents are addressed solely in terms of liability. Neither standard rules nor procedures are mandated for safety risk management, accidents prevention, and environment protection. Only later, in 2007 and 2019 respectively, the UN General Assembly endorsed non-binding guidelines for debris mitigation and long-term sustainability of doubtful effectiveness.

Safety and Security are the two sides of the same medal and need to be addressed concurrently. At the time of Outer Space Treaty signature, space security was mainly concerned about anti-ballistic missile and anti-satellite weapons. The signature of the ABM (Anti-Ballistic Missile) treaty in 1972 between USA and USSR and the moratorium first of ASAT tests initiated by USSR, and later the US congressional constraints on the funding and testing of ASAT weapons created a relatively stable and secure space environment. The USA withdrawal in 2002 from the ABM treaty, on consideration of emerging threats from rogue states and terrorism, inevitably sparked an arm race in space with Russia and China, which is still ongoing and gaining momentum with development and proliferation of new ASAT capabilities and hypersonic weapons. The uncontrolled growth of space debris due to ASAT tests, and the difficulty of establishing a civil STM (Space Traffic Management) regime due to the presence of military assets in orbit are major roadblocks to a safe and sustainable space.

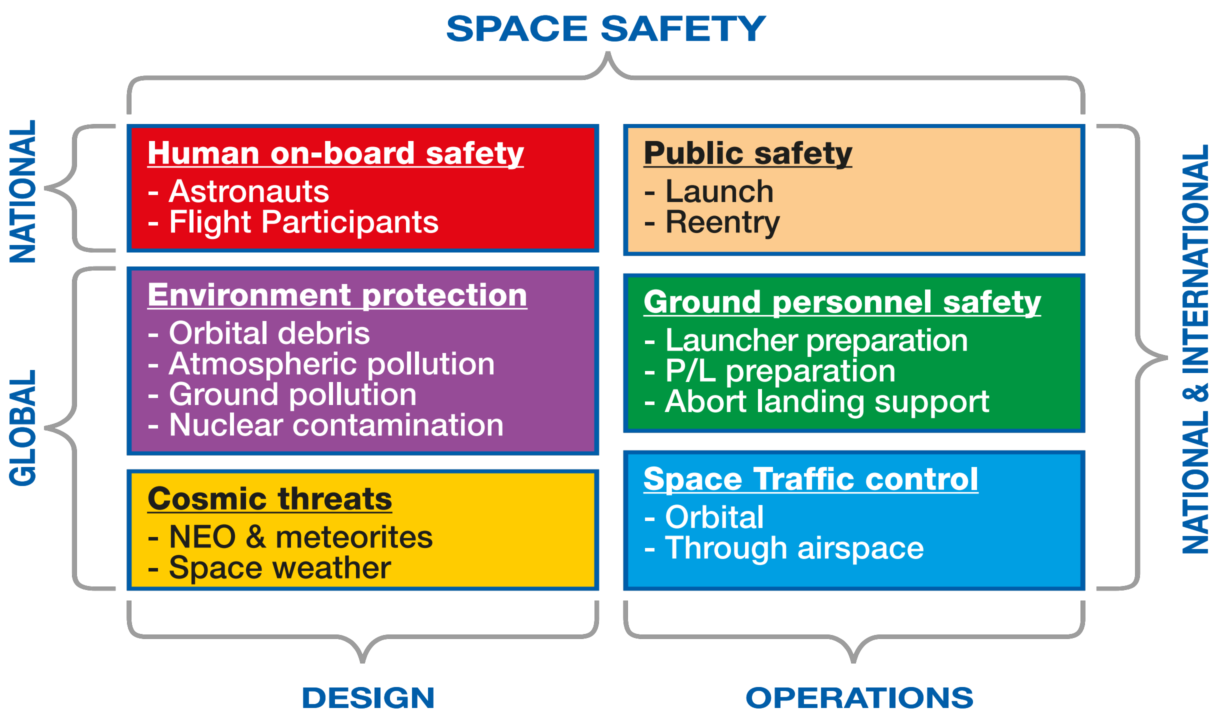


Fig. (1) Space safety risk areas

IAASS VISION, PROPOSALS AND INITIATIVES

1 THE IAASS MANIFESTO

The IAASS has proposed to supplement the Outer Space Treaty with the following safety and environmental protection principles:

1. **Ensure that citizens of all nations are equally protected from the risks posed by over-flying space systems and objects during launch and re-entry operations;**
2. **Ensure that space systems are developed, built and operated according to common minimum ground and flight safety rules which reflect the status of knowledge and the accumulated experience of all space-faring nations;**
3. **Seek to prevent collisions or interference with other aerospace systems during launch, on-orbit operation, and re-entry;**
4. **Ensure the protection of the ground, air and on-orbit environments from chemical, radioactive and debris contamination related to space operations;**
5. **Ensure that mutual aid provisions for space mission safety emergencies are progressively agreed, developed and made accessible without restriction anywhere on the Earth and in Outer Space.**

(Annex 1)

2 THE ISSUE OF AIRSPACE AND OUTER SPACE DELIMITATION

A major issue that was left undetermined by the Outer Space Treaty is the legal delimitation between Airspace and Outer Space. As a consequence, the boundary of national airspace sovereignty is currently undetermined, which creates major uncertainties about the applicable international law in the border region in view of the growing interest for commercial and military operations of high-altitude platforms, suborbital vehicles, and hypersonic weapons. The IAASS has proposed to solve the issue by establishing an intermediate region tentatively called "Near-Space" (18 km – 160 km), subjected to the jurisdiction but not sovereignty of the underlying country. The IAASS proposal including a study draft "Convention for Near Space" has been submitted to the United Nations COPUOS and will be presented at the 2022 sessions of the Legal Subcommittee.

(Annex 2)

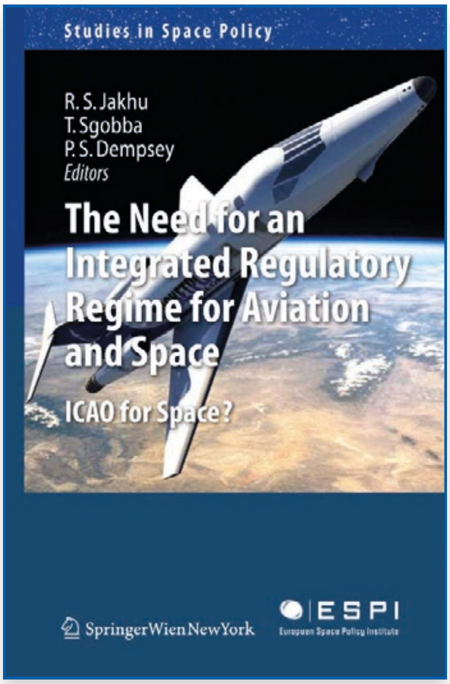
3 AN INTERNATIONAL ORGANIZATION FOR SPACE SAFETY AND TRAFFIC MANAGEMENT

The Outer Space Treaty leaves a number of points open or ill defined, however the major weakness is the lack of any mechanism for its enforcement and for operational coordination. Currently, there is no organization that has the mandate of regulating space to give practical implementation to the Outer Space principles. The Space Treaty's developer, the United Nations Office for Outer Space Affairs (UNOOSA), does not possess the structural, operational, and legal means needed to regulate space activities. Existing organizations like ISO (International Organization for Standardization) and consortia developing voluntary industrial consensus standards for space operations lack on one side the authority and practical means to enforce compliance with their standards, and on the other side are ill suited to take over the peculiar governmental responsibility of establishing safety and sustainability policies and rules missing in the Outer Space Treaty. Given this, the creation of a dedicated space organization affiliated to the United Nations is necessary.

The obstacles to the establishment of such organization are multiple. The first and possibly the major one comes from the US Space Policy of 2006 (never effectively reversed) against any new space safety and security agreement, which states that *"The United States will oppose the development of new legal regimes or other restrictions that seek to prohibit or limit U.S. access to or use of space. Proposed arms control agreements or restrictions must not impair the rights of the United States to conduct research, development, testing, and operations or other activities in space for U.S. national interests".* The other obstacle is the lack of EU engagement in space regulatory matters. Europe has no unified space legislation for space operations and lacks centralized organizations for space safety and traffic management like those available to European aviation through EASA and EUROCONTROL. Finally, Russia and China lack proven leadership in promoting and driving the establishment of global institutions.

In 2006 the IAASS and the McGill University of Montreal, Institute of Air and Space Law (IASL), initiated a study on the establishment of an international organization for space safety and traffic management on the model of the ICAO (International Civil Aviation Organization), an agency of the United Nations. What made the ICAO model particularly attractive was its “semi-binding” legal framework, which could hopefully win the US support. The ICAO Convention of 1944 established the new organization called ICAO with ample power in coordinating and harmonizing internationally civil aviation rules but without supranational final authority. The ICAO Convention is made in two parts: the body of the convention and the annexes. The convention body establishes the organization structure, responsibilities, and operations, while the annexes, called SARP (Standards and Recommended Practices), are the harmonized regulations, which are left to the organization to further develop and manage as the need arises.

The IAASS/McGill study team report entitled “The Need for an Integrated Regulatory Regime for Aviation and space - An ICAO for Space?” confirmed the suitability of the ICAO model to regulate civil/commercial space activities. It also recommended instead of creating a new organization to extend the aviation ICAO Convention to include space activities. The supporting rationale for such extension was that nowadays key elements of the aviation safety-critical infrastructure (navigation, communication, meteorology) are space-based and that a large portion of the space bound and returning traffic takes place through the international airspace under the ICAO jurisdiction. Furthermore, some emerging mode of transportation like point-to-point (suborbital) vehicles would operate in future through both airspace and outer space, while airports could double as spaceports. Finally, the study team considered that space weather and re-entering space debris represent risks also for aviation and would benefit being managed from a single institution.



Fig, (2) The final report of the IAASS/McGill “ICAO for Space” study team was published in 2011 by Springer under the sponsorship of the European Space Policy Institute (ESPI)

The preliminary report of the IAASS/McGill “ICAO for Space” study was discussed informally in 2007 at the 2nd IAASS international space safety conference in Chicago with the participation of experts from various space agencies, including Brian O’Connor at the time NASA Chief Safety & Mission Assurance. Considering the length and complications of the process to modify the ICAO Convention, Brian O’Connor proposed a bottom-up approach through the subscription of an inter-governmental MoU for developing international space safety and sustainability standards. The IAASS took the task of drafting the MoU ***(Annex 3)***. NASA discussed the draft MoU with FAA/AST (the Office in charge of regulating space launches and reentries in US) and jointly forwarded the draft MoU to the US Department of State. In 2008 the US DoS responded negatively ***(Annex 4)*** stating that the proposed MoU for an international space safety standardization cooperation was deemed not necessary at that time. Since then, there has been no indication of a change of policy by the US DoS.

 # 4
THE SPACE SAFETY INSTITUTE

Apart the role that a “Space ICAO” would hopefully play in future in harmonizing national policies and regulations, and in integrating and coordinating traffic management services, countries’ regulatory bodies are and will continue in any case to be responsible for levying and enforcing national regulations. Nowadays, faced to the rapid increase of commercial space activities, some regulatory bodies suffer from a lack of adequate human resources. The issue is further compounded by an on-going transition from prescriptive rules to performance rules, which aims to provide more freedom to innovate to developers and to allow wider use of automation. The relevant design process is said to move from rules-based design to risk-based design because the use of performance rules requires a supporting risk analysis.

Prescriptive safety rules specify design requirements, such as materials to be used, how a requirement is to be achieved, or how an item is to be fabricated or tested, such that the item can be considered safe. A prescriptive safety rule is an explicitly required design solution for an implicit safety goal. Instead, performance rules specify the safety goal (i.e., acceptable level of safety) but leave the concrete measures to achieve that outcome up to the discretion of the designer. By focusing on the outcome, performance rules give to developers flexibility and make it possible to find the lowest cost means to achieve compliance. Performance safety rules can generally accommodate technological change and the emergence of new technology driven hazards in ways that prescriptive standards cannot. However, compliance verification for performance rules is orders of magnitude more complex.

While objective evidence of compliance with prescriptive rules can be assessed by an inspector, assessing compliance with performance rules

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<tr><th></th><th>COMPANY</th><th>SAFETY INSTITUTE</th><th>REGULATORY BODY</th><th>INT. ORG</th></tr>
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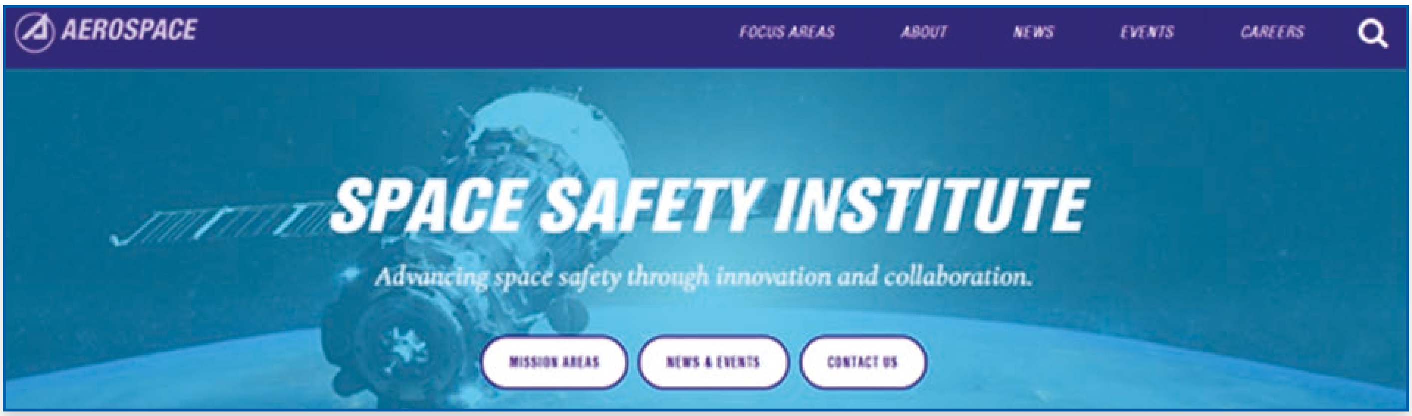
Fig. (3) The role of the Space Safety Institute

necessitates an independent multi-disciplinary review team with design and operations skills and competences equal or even better than those of the project team, because they have to analyze and validate the proposed design as meeting the safety goals. We can say that measures to evaluate and ensure conformity with performance rules are of as much or more significance than the standards themselves. In other words, for performance-based regulations the technically challenging task is not the production of the standard but compliance verification. Exactly the opposite of what happens with prescriptive rules. How can national space regulatory bodies acquire and maintain the support of most current technical and scientific skilled resources needed to move from rules-based certification to risk-based certification? The IAASS answer is that regulatory bodies should establish independent support organizations, a Space Safety Institute, in which experts from industry, academy and from regulators themselves can evaluate and validate within multidisciplinary teams the developer's proposed design solutions. Apart from a small core team, such organization would make use of temporary staff seconded from permanent mother organizations (manufacturers, operators, universities, etc.) for the duration of a specific project or certification activity.

In 2020 the IAASS advanced the proposal to establish in the US of a Space Safety Institute aimed initially to support commercial human spaceflight. The concept was reviewed by a team of top experts and confirmed as valid. Based on the IAASS proposal, The Aerospace Corporation, the largest US aerospace Federally Funded Research and Development Center (FFRDC) has launched the Space Safety Institute and extended the scope to cover also space debris, launch and re-entry safety, and cybersecurity. (see separate document)

#5 AN INTERNATIONAL PUBLIC-PRIVATE PARTNERSHIP FOR SPACE DEBRIS REMOVAL

Studies performed by major space agencies have shown that a 'business as usual' scenario for space operations will lead to a progressive, uncontrolled increase of space debris in LEO



(Low Earth Orbits), with collisions becoming the primary debris source. The UN space debris mitigation measures can reduce the growth, assuming that they are duly implemented, which is not the case nowadays, but long-term space debris proliferation is still expected. Proliferation would continue even if all launch activities were halted, which is of course not doable, and if no further objects are added to the space environment (no debris release, no explosions). This is an indication that the population of large and massive objects (i.e., abandoned spacecraft and spent rocket upper stages) which is the source of most debris has reached a critical concentration in LEO. The programmed removal of those massive objects the so-called Active Debris Removal (ADR) is necessary to stabilize the growth of the space debris population.

There are major legal, political and financial challenges that presently prevent or pose difficulty to the conduct of ADR activities. There are three main issues in particular: ADR mission costs, development of potential dual-use technologies, and operator liabilities. Commercial initiatives or unilateral national programs are not cost-effective and raise suspicions about true intent. A study performed by IAASS in cooperation with the McGill University IASL, established that an international public-private partnership on the model of the early INTELSAT can solve most of the issues and launch the ADR industry. Such partnership would ensure a cost-effective business model by the development and re-use of standard vehicles configurations. Furthermore, free access to the relevant technologies by the partners would neutralize dual-use concerns. The IAASS proposal also includes a legal instrument that would commit the participating governments to annual quotas of °national° debris removals. Finally, a role is foreseen for insurance companies to insure the removal of new systems in case of failure, while financial means for the removal of old systems would be obtained through a "space garbage" tax levied on final users of space-based services. Don Kessler, father of space debris science, stated about the IAASS proposal *"I believe it is an interesting framework that may get around many of the policy and legal issues that any single government agency or private company would encounter"*.

(Annex 5)

6 SPACE DEBRIS RISK FOR AVIATION

The risk that an airplane is hit by a meteoroid or space debris, assumed to be very remote, has never been precisely quantified. In 2007, an aircraft from Chilean LAN Airlines flying from Santiago to Auckland (NZ) spotted burning objects falling from the sky in front of and behind the aircraft. In January 2012, uncontrolled reentry of Russia's Phobos-Grunt spacecraft resulted in a request by Russia to EUROCONTROL to close the European airspace above Europe for two hours. Despite increasing efforts to accurately predict space debris reentry, the exact time and location of reentry is still very uncertain. Partially, this is due to a skipping effect uncontrolled spacecraft experience as they enter the atmosphere at a shallow angle due to natural decay. The effect depends on atmospheric density variations and winds and is very difficult to model. The trajectory and the overall location of surviving fragments can be precisely predicted only when

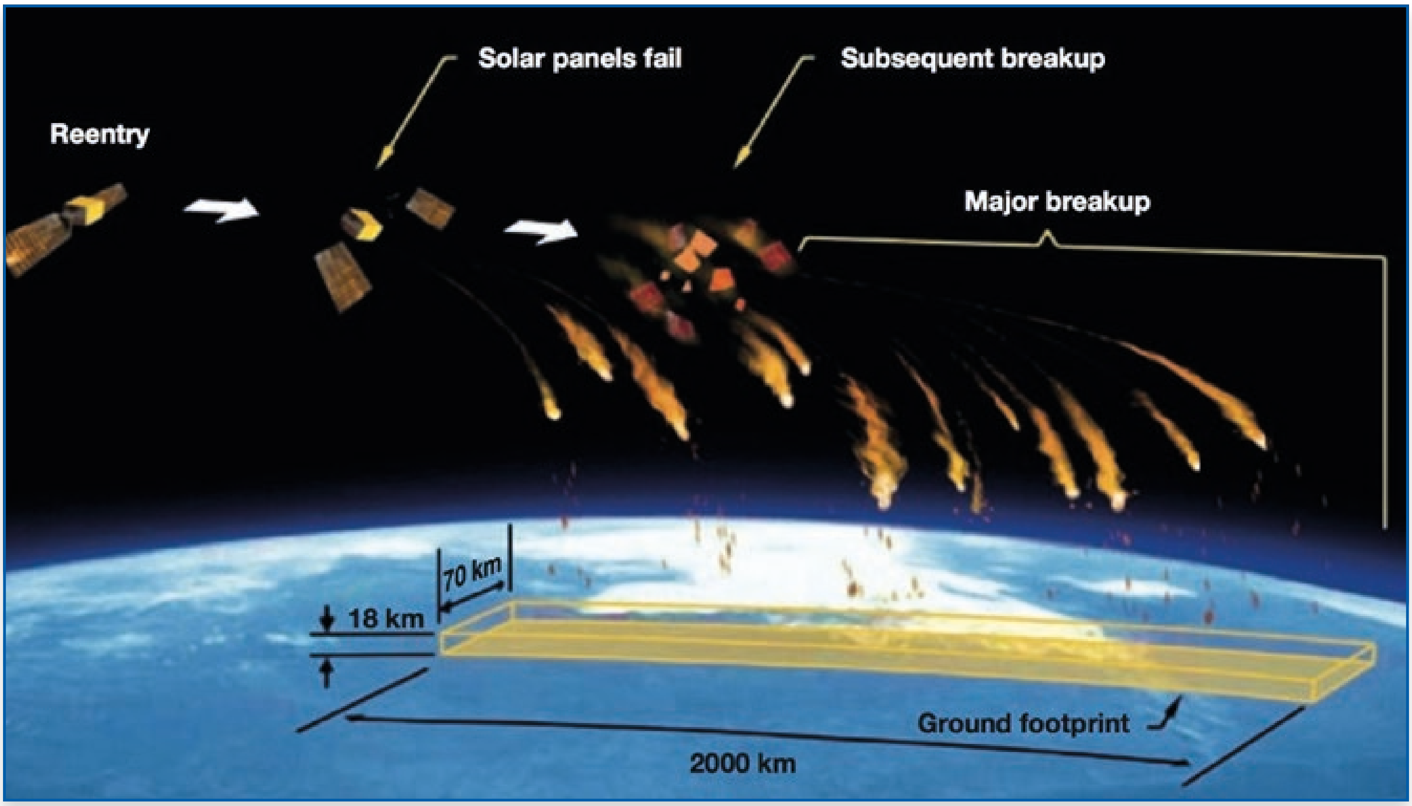


Fig. (4) Uncontrolled reentry breakup and ground footprint (dimensions show typical order of magnitude of hazardous volume) the bouncing ends and atmospheric reentry starts, but by then the time to impact with ground or to reach airspace becomes very short.

Even small space debris represent a source of risk for aviation, due to relative speed and construction. A collision with relatively small fragments has an intrinsic high potential for multiple casualties. Current vulnerability models show that an impact anywhere on an airliner with debris of mass above 300 grams would produce a catastrophic failure, meaning all people on board would be killed. The problem will be exacerbated by three factors: a) the deployment of large satellites constellations in LEO; b) the current acceptable risk level of 1x10-4 per event, established when space debris re-entries were a rare event; c) the scarce knowledge of small space debris generation and demise during re-entry.

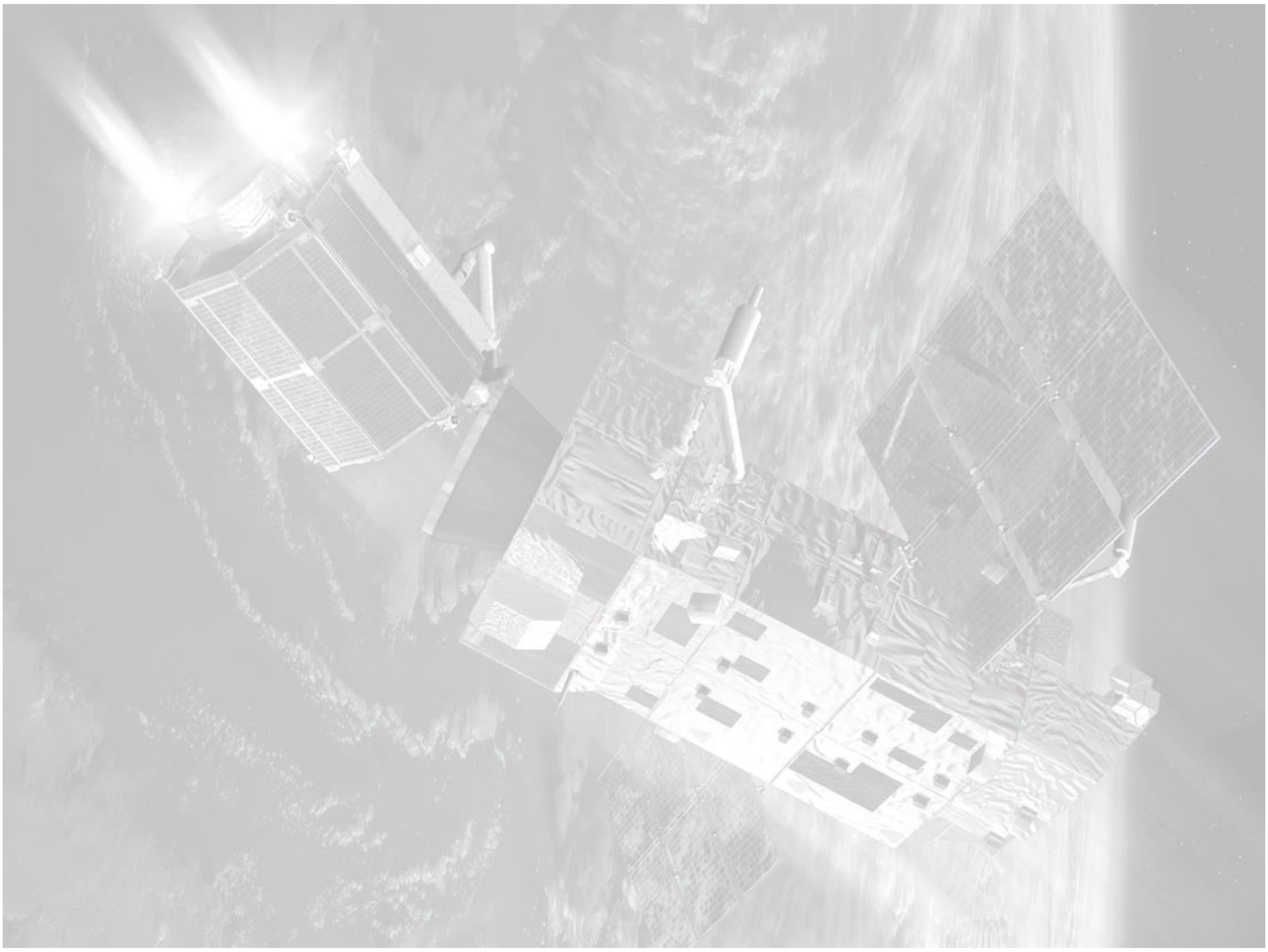
Although there are a number of methodologies and tools to assess the risk for the public on ground due to a reentering space debris event, there is nothing available for assessing the risk for aviation, and the combined space debris and meteoroids fluxes. The annual risk for passengers due to an airplane being hit by reentering space debris or by a meteoroid has never been quantified with any detail or precision. In addition, there are no methodologies for real-time risk assessment that can be used by air traffic control authorities and civil protection organizations to activate emergency plans for impending reentries. The IAASS is promoting the development of an advanced tool that will enable assessment of the risk to aviation due to reentering space debris and meteorites. The tool is called ADMIRE for **A**viation (Space) **D**ebris and **M**eteorites **I**ntegrated **R**isk **E**valuation. ADMIRE is aimed to the following applications:

1) Estimate of annual integrated debris and meteorites impact risk for aviation (globally, and locally for regions of highest air traffic),

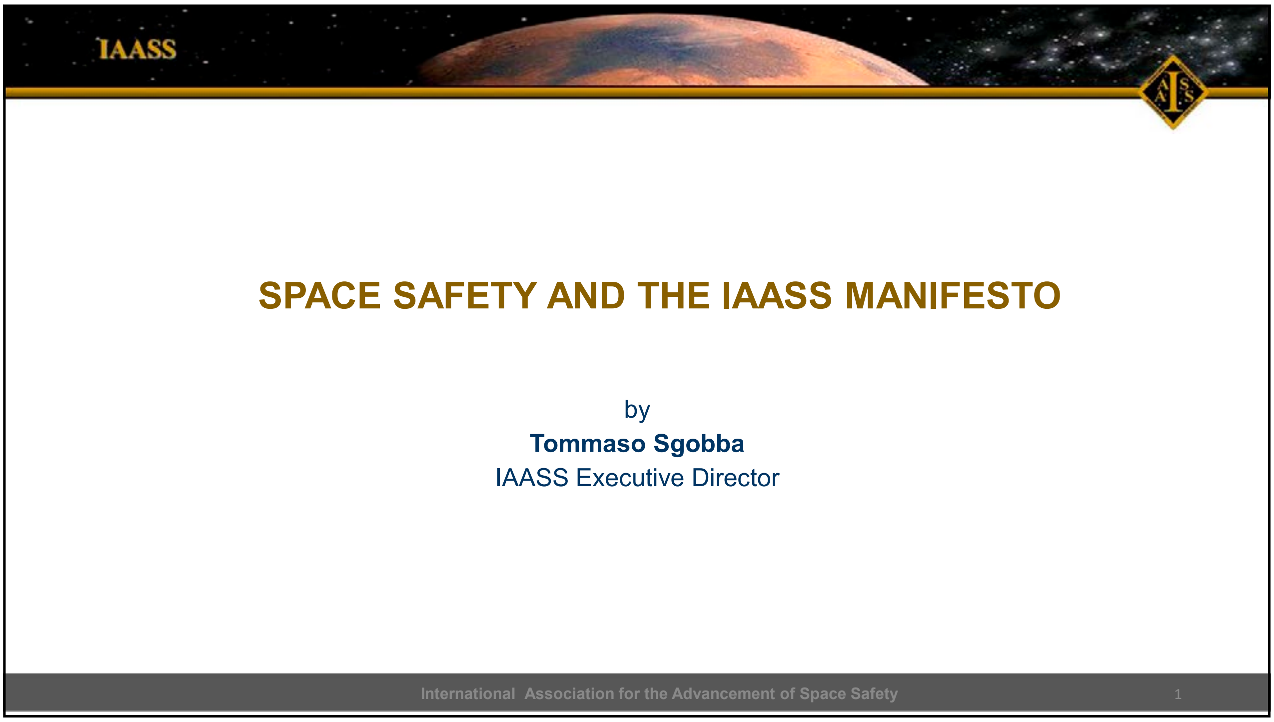
2) Assessment of new space systems compliance with reentry risk safety requirements, taking into account densities and vulnerabilities of ground population and aviation traffic;

3) Real-time risk management of space debris reentries in support of decision making by civil protection and air traffic control authorities.

(Annex 6)



Annex 1
SPACE SAFETY AND THE IAASS MANIFESTO



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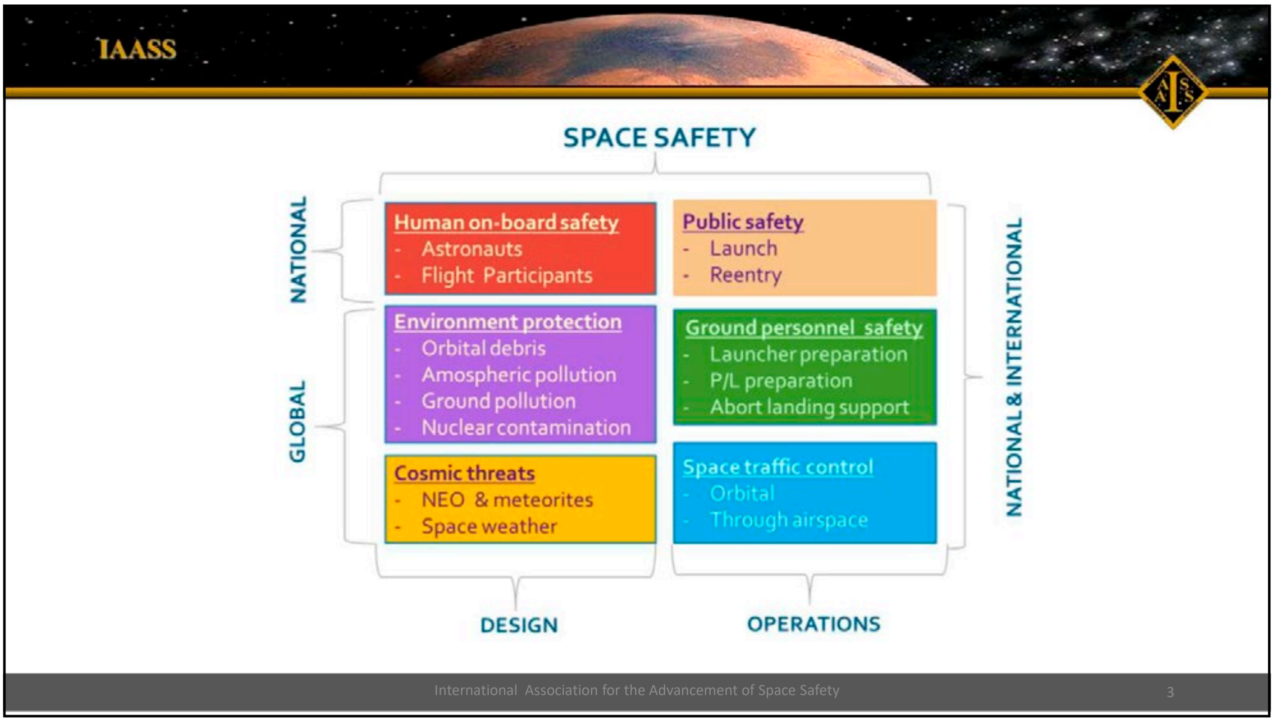

3

IAASS

IAASS Manifesto
for a Safe and Sustainable Space

1. ***Ensure that citizens of all nations are equally protected from the risks posed by over-flying space systems and objects during launch and re-entry operations;***
2. ***Ensure that space systems are developed, built and operated according to common minimum ground and flight safety rules which reflect the status of knowledge and the accumulated experience of all space-faring nations;***
3. ***Seek to prevent collisions or interference with other aerospace systems during launch, on-orbit operation, and re-entry;***
4. ***Ensure the protection of the ground, air and on-orbit environments from chemical, radioactive and debris contamination related to space operations;***
5. ***Ensure that mutual aid provisions for space mission safety emergencies are progressively agreed, developed and made accessible without restriction anywhere on the Earth and in Outer Space.***

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IAASS

#1
Ensure that citizens of all nations are equally protected from the risks posed by over-flying space systems and objects during launch and re-entry operations

Related issues:

a. Legal regime uncertainty due to lack of internationally agreed delimitation between airspace and outerspace.
b. Acceptable risk levels (if any) defined on event basis, and unilaterally established by the country performing launch and re-entry operations.
c. Lack of internationally agreed standard methods for launch and re-entry risk assessment.
d. Overflown countries often unaware of risk, and unable to control the cumulative annual risk in case of multiple overflying rockets.
e. Launch and re-entry risk assessments usually not including risk for public traveling by air.
f. Re-entry alert services available only in some countries (e.g. EU Re-entry Analysis Service), and covering only risk on ground.
g. Quantitative vs. qualitative (FT) performance requirements for system safety functions (e.g. FTS, re-entry functions).

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IAASS

#1.a
Legal regime uncertainty due to lack of internationally agreed delimitation of airspace/outerspace

A study of IAASS and McGill University IASL has proposed the insertion of an intermediate space region, Near-Space, between 18 km and 160 km with a mixed legal regime.

According to the IAASS/McGill proposal, the Near-Space legal regime would be as follows:

a) innocent passage (civil/commercial space activities) would be allowed, but the safety risk for overflown population should comply with international norms.
b) The economic exploitation of Near-Space (e.g. operation of pseudo-satellites) should be the exclusive prerogative of the country underneath.
c) Overflights for non-civil/commercial purposes (e.g. ICBM tests) would require authorization by overflown countries.

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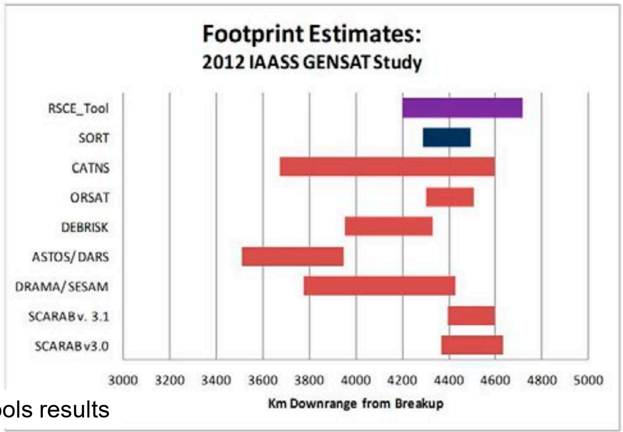
IAASS

#1.c
Lack of internationally agreed standard methods for launch and re-entry risk assessment.

	SCARAB v3.0	SCARAB v. 3.1	DRAMA/ SESAM	ASTOS/ DARS	DEBRISK	ORSAT	CATNS
Fragmentation altitude	77.2	74.8	78	78	78	78	~74
Number of fragments	6	5	30	15	23	21	26
Surviving mass	41	124.5	71.4	73	58.7	47.2	159.7
Surviving mass (%)	10	30	18.2	18.7	14.5	12	37.7
Casualty area (m^2)	5.3	5.28	33.4	14.1	18.2	15.3	29.4
Range (min-heel) (km)	4368	4395	3777	3510	3955	4301	3985
Range (max-toe) (km)	4631	4597	4430	4411	4332	4509	4604
Footprint length (km)	263	202	652	438	377	208	619



IAASS L&R Committee study comparing re-entry tools results

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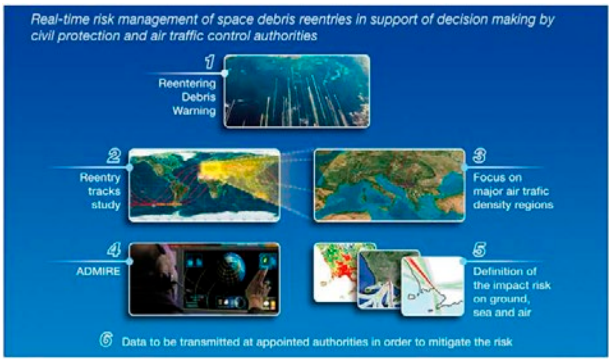
IAASS

#1.e
Risk assessments usually not including risk for public traveling by air.
 # 1.f
Re-entry alert services available only in some countries (e.g. EU Re-entry Analysis Service), and covering only risk on ground.

Currently, approximately 70% of re-entries of intact objects are uncontrolled, ±50% of the returning mass, (i.e. 100 tons/year). On average, there is one spacecraft or rocket body uncontrolled re-entry every week.

Small fragments are not modelled and many may survive. A fragment with mass > 300gm is catastrophic for an airliner.

With the introduction of space-based internet services the LEO population may increase up to 40 times! within a decade.



The IAASS "ADMIRE" Project for Aviation Space Debris Safety

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IAASS

#2

Ensure that space systems are developed, built and operated according to common minimum ground and flight safety rules which reflect the status of knowledge and the accumulated experience of all space-faring nations;

IAASS promotes the development of international performance-based space safety standards for the design and operations of space systems.

They should be mandatory whenever there are risk on foreign people, either on ground (including at international spaceport), on board (international participants), or travelling by air.

IAASS

#3

Seek to prevent collisions or interference with other aerospace systems during launch, on-orbit operation, and re-entry;

The IAASS promotes the principles of:

- Separating military Space Situational Awareness (SSA) from civil Space Traffic Management (STM).
- Enlarging national launch authority mandates (e.g. FAA-AST) to include commercial on-orbit and beyond-earth-orbit space operations licensing, and civil/commercial STM services.
- ICAO to Integrate Air Traffic Management and Space Traffic Management in a single international system (also in view of growing air-launches from the international airspace)

The IAASS promotes international research and professional exchange in the field of STM:

- Member of the Advisory Board of the IAA Study Group 5.15 on "*Space Traffic Management - Towards a Roadmap for Implementation*", 2018
- IAASS Space Traffic Management Working Group.

IAASS

#4
Ensure the protection of the ground, air and on-orbit environments from chemical, radioactive and debris contamination related to space operations

- For the protection of the orbital environment, tree main issues need to be addressed:
  - Ban ASAT weapons, development, test, stockage, and use
  - Enforce prevention of space debris creation
  - Enforce removal of space debris
- Confrontation vs. cooperation: China seems to have developed full ASAT capabilities up to MEO, HEO and GEO. Confrontation may lead to irreversible degradation of the orbital environment. A minimum of cooperation is beneficial and truly necessary. IAASS supports the *International Code of Conduct for Outer Space Activities,* a non-legally binding, voluntary international instrument aimed at building norms of responsible behavior in space activities.
- Institute for Prevention and Control of Space Debris (IPCSD). The IAASS has proposed the establishment (on commercial basis) of the IPCSD to certify compliance with ISO 24113 "Space debris mitigation requirements" and provide support to commercial entities during development and operations.

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IAASS

#4
Ensure the protection of the ground, air and on-orbit environments from chemical, radioactive and debris contamination related to space operations – CONT'D

The IAASS developed a proposal, in cooperation with McGill University Institute of Air and Space Law, for an international regulatory framework for:

1) Ensuring that future satellites and rocket stages are no longer abandoned, voluntarily or accidentally, on-orbit at the end of their mission;
2) Facilitating active debris removal by establishing an international/intergovernmental organization to conducting Active Debris Removal (ADR) on the model of INTELSAT.

On one hand the launching state of a space object that later becomes a debris must have the primary responsibility for its removal, and the other hand removal systems development and operational costs can be minimized through international cooperation, thus avoiding liability issues, and defeating by international dissemination of technologies, the concern about acquisition of military advantage due development and deployment of new potential dual systems.

"I believe it is an interesting framework that may get around many of the policy and legal issues that any single government agency or private company would encounter" – Don Kessler 8 Feb. 2011

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IAASS

#5
Ensure that mutual aid provisions for space mission safety emergencies are progressively agreed, developed and made accessible without restriction anywhere on the Earth and in Outer Space.

- The US Congress is very much wary about China intention in space but has always encouraged NASA for the last 30 years to seek cooperation in space rescue matters.
- Also the perspective of multiple national and international Moon bases/missions goes in the direction of promoting cooperation with China and other countries on rescue. Even direct communication between Moon bases and/or with EVA suited astronauts of different countries in case of emergency would be impossible without systems interoperability.
- The IAASS is promoting the development of International Search & Rescue capabilities in space similar to those existing in civil fields (ICAO, IMO) and also in the military community (International Submarine Escape and Rescue Liaison Office - ISMERLO).

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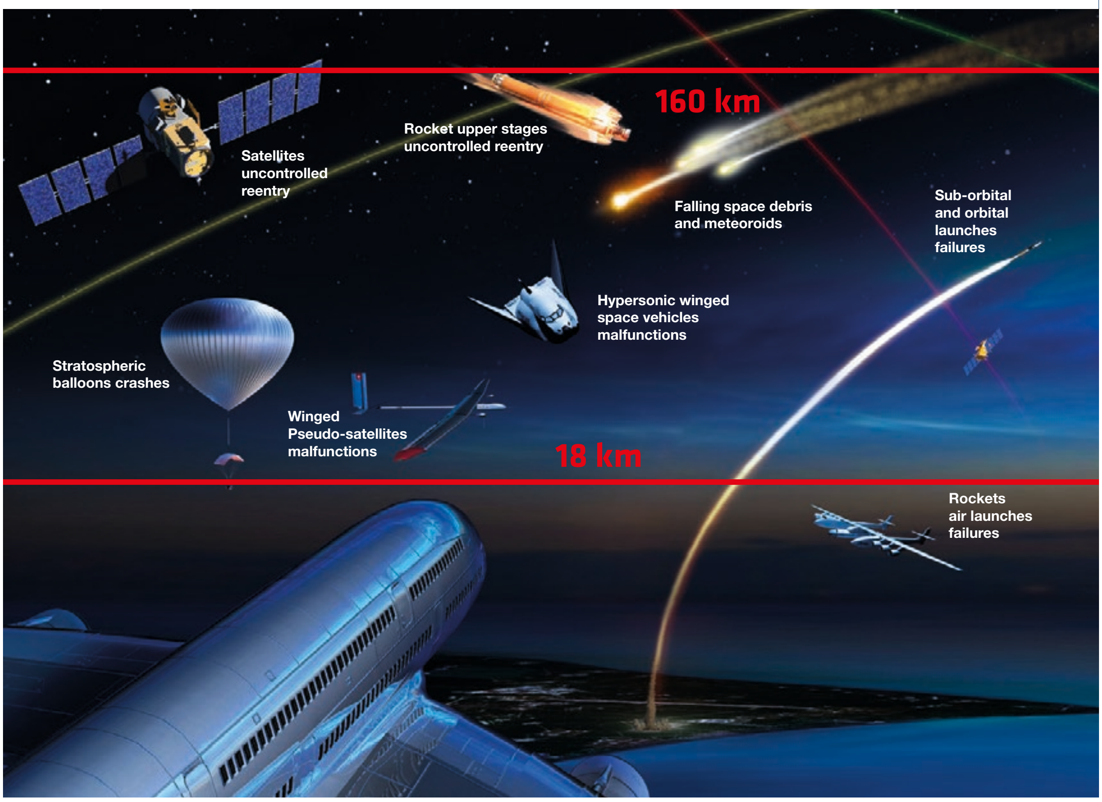
Annex 2

NEAR SPACE
THE QUEST FOR A NEW LEGAL FRONTIER

IAASSSR26032020

INTERNATIONAL ASSOCIATION
FOR THE ADVANCEMENT OF
SPACE SAFETY



Near Space - The Quest for a New Legal Frontier

Introduction

While it's common knowledge that sovereignty of a state extends to its airspace,[1] it is not quite clear where vertically the limit is. Furthermore, while it is accepted that the use and exploration of outer space is the province of all mankind,[2] thus excluding any claims of national appropriation,[3] it is unclear from which lowest end of the Earth's atmosphere such a claim applies.

Even though much activity has taken place in outer space in the past sixty years,[4] it is only recently that the upper layers of the atmosphere have caught the interest of business, and military commands. Suborbital flights, in particular, but also high-altitudinal platforms[5] and stratospheric balloons[6] are some of the systems aimed to exploit the region's capabilities. The region is also environmentally sensitive to the projected increase of rocket launches, destructive re-entries, and suborbital flights because of the effects of some rocket exhaust chemicals on ozone layer depletion, and of the concern that particles generated can by absorption and reflection change the amount of solar energy injected in to the atmosphere.[7-8] Legally however, it is an indistinct region where it is not clear whether the operations that take place are covered by aviation or space conventions and treaties[9], in particular with reference to the freedom of overflight that applies to space orbital operations.

Referred to by different authors by various names, this region is called Near Space for the purpose of this paper and is tentatively defined as extending from airspace Flight Level 600, approximately 18 km,[10] the practical upper limit of airspace, to 160 km above sea level,[11] the practical lower perigee for an orbiting satellite.

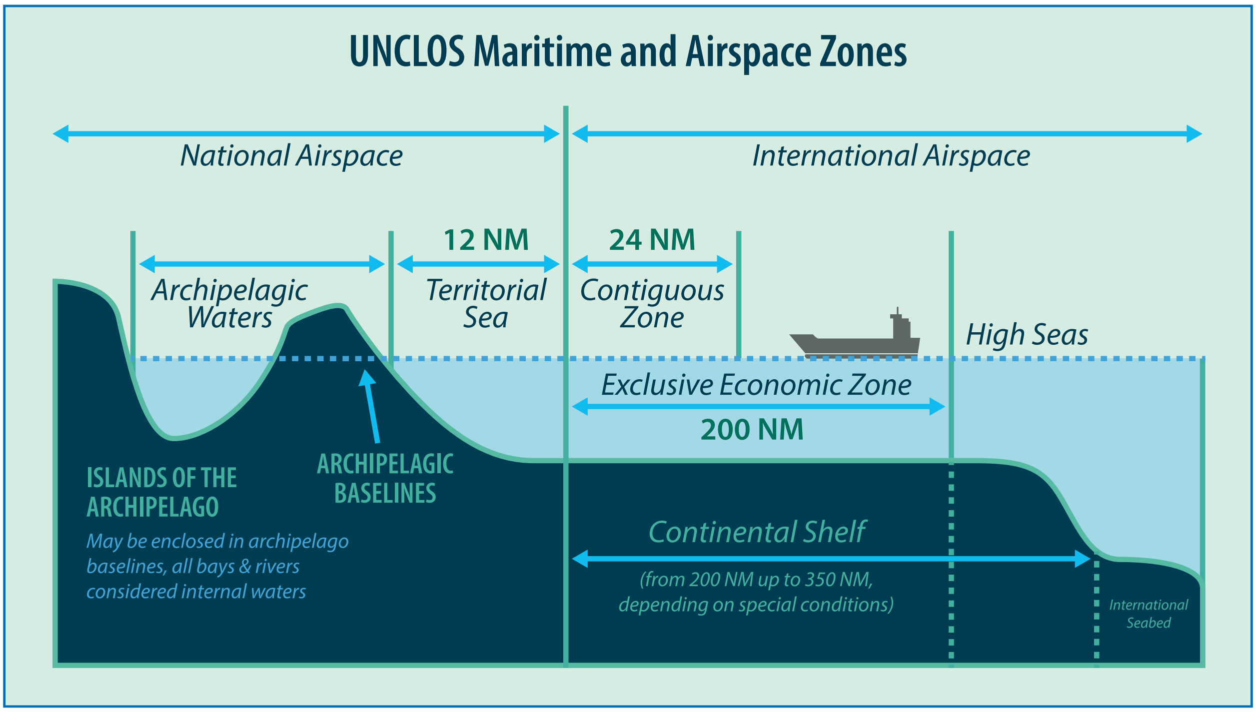
The UNCOPOUS legal subcommittee has been preoccupied with the issue of delimitation of airspace and outer space since the beginning of public interest for suborbital space tourism.[12] The debate has been revived between "spatialist" and "functionalist" approach - that is, whether a flying object should be considered an aircraft or spacecraft[13] based on where it operates or on its function[14] respectively. The Von Karman line at 100 km,[15] a theoretical line above which aerodynamic attitude control of a rocket is no longer possible, has been one contender as spatialist demarcation line.[16] It has been recently endorsed in United States as defining the sphere of competences of the Air Force and of the newly established Space Force.[17] Space legislations in Australia,[18] Denmark[19] and Kazakhstan[20] have also demarcated the beginning of space at 100 km. In any case, spurred by the interest for suborbital space tourism[21], and for possible future point-to-point hypersonic and suborbital transportation, the debate about the legal regime applicable to those vehicles and operations is still very much open. It seemed pertinent to many of those involved that there should be such a border line defining where state sovereignty ends and outer space extraterritorial regime begins. However, there have been few authors, (discussed in more detail below) who have questioned the idea of such an abrupt end to state sovereignty. They have proposed an intermediate region in which state sovereignty is reduced rather than coming to an abrupt end. The aims are on one side to prevent that overflight safety risk of foreign population due to launch, re-entry, and point-to-point operations are managed unilaterally without international harmonization, and on the other side to recognize the economic (and military) interest of the subjacent State to control stationary or quasi-stationary overflying operations. The proposed intermediate region is what we call in this paper Near Space. Some authors have proposed to call it "protozone"[22], which is a bit misleading term because in ancient Greek protos (πρῶτος) means *first in time*, or to call it Exclusive Economic Utilization Space[23], which does not reflect the safety/security issues.

While defining an extra legal regime might be seen as a complication and perhaps limiting business innovation, in the case of suborbital flights and other stratospheric activity, it actually would serve the urpose to enhance business growth by unequivocally establishing the applicable legal regime.[24] The absence of a univocal legal regime for liability is keeping business sceptical.

Originally an IAASS proposal to UNCOPUOS inspired by the law of the sea there have been several studies to refine the concept of such new legal frontier of Near Space.[25] Most notably, the work of Joseph Pelton,[26] Ram Jakhu,[27] Paul Stephen Dempsey and Maria Manoli,[28] and more recently of Hao Liu and Fabio Tronchetti.[29]

The Law of the Sea Analogy

For a long time, under the law of the sea, there only existed the territorial sea and the international waters.[30] However a two-fold problem was identified - firstly there was the issue of safety and security of the coastal state,[31] secondly there were various economic resources in the



areas adjacent to the territorial waters, which were being misused by belonging to the global commons of international waters.[32] To solve those problems greater responsibility and benefits, were ascribed to the coastal states with creation of Continental Shelf, Contiguous Zone and Exclusive Economic Zone (EEZ).[33] Contiguous Zone is the zone, extending from 24 nautical miles from the coast,[34] in which the coastal States can impose 'its customs, fiscal, immigration or sanitary laws'.[35] The EEZ on the other hand In the EEZ, the coastal state is awarded sovereign rights over the natural resources in the zone for the purposes of '...exploring and exploiting, conserving and managing the natural resources, whether living or non-living'.[36] These rights also have the corresponding obligation to 'conserve the resources, utilise them, and cooperate with other countries to those ends'.[37]

Proposal for a Legal Regime for Near Space

The issue of demarcation between airspace and outer space is strictly connected to overflight and territorial sovereignty. Generally, rockets fly straight up vertically only for few seconds at launch. Then, having cleared the launch pad, the rocket performs a pitch over maneuver thus climbing to space with an angle that varies.[38] Currently, rockets overflight risk of foreign territories is covered only in terms of liability by space treaties. The issue was debated at the beginning of the space activities and then left undecided for decades until it was resumed at the start of development of winged vehicles for commercial suborbital spaceflight. An interesting (official) summary of the early debate is in the excerpt here below from the U.S. Congress hearings in 1966 of the NASA Administrator J. Webb as part the NASA authorization for 1967[39]:

"Question 6. Mr. Webb, has NASA prepared any reports on the legal problems of air space and outer space? All countries exercise the right of overflight in orbit. Does the United States consider it has that same right during the preorbital phase of the flight? What is the policy of the United States on overflight of foreign lands during the preorbital flight phase (launch phase)?
Answer:… The term "overflight" means flight through the air space of a subjacent state. In fact, NASA space vehicles do not traverse foreign territory, short of an abort situation, until the space vehicle has attained a height of at least 200,000 feet (over 35 miles), again with the possible exception of Grand Bahama. Although no precise definition of where outer space begins and the air space ends has been agreed upon, there would be little contest that 200,000 feet (over 35 miles) is in outer space. Since the principle that outer space is free for exploration and use by all and is not subject to national appropriation(or national sovereignty, jurisdiction, or control) has been unanimously adopted at the U.N., no agreement from a subjacent state is required before its territory can be traversed by a space vehicle in outer space. The abort

or orbital decay situation where fragments might enter a subjacent state's airspace and impact the Earth gives rise to two questions currently the subject of negotiation before the U.N. (the Legal Subcommittee of the Outer Space Committee). One question relates to liability for damage caused by the return of objects launched into outer space, the other involves the obligation to return such objects."

In near future, there will be various kind of systems, like suborbital vehicles, that will make frequent use of Near Space or reside over there, which further complicate the safety issue of safety of overflight by space bound and returning systems. Clearly it is the underlying State that has the greatest economic and safety and security interest in controlling he Near Space above its territory. Thus, a specific legal regime for Near Space is needed. This legal regime should centre around limited sovereignty[40] but full jurisdiction[41] of the underlying State. The new legal regime would hope to illuminate how the conscious economic exploitation of Near Space can lead to greater sharing of economic and environmental benefits with the public at large.[42]

This paper takes a step further the work of the academicians cited above by drafting a "Convention on Regulation of Near Space" here below as a strawman to support further analysis and discussion.

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3. Article 2, *Outer Space Treaty*, 1967.
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10. Hao Liu & Fabio Tronchetti, "Regulating Near-Space Activities: Using the Precedent of the Exclusive Economic Zone as a Model?", *Ocean Development & International Law*, (2019), at p. 91 https://doi.org/10.1080/00908320.2018.1548452. New Zealand has enacted The Outer Space and High-Altitude Activities Act, 2017 which defines high-altitude as flight level 600.

11. 160 km is the IAASS Draft Convention limit. Paul Stephen Dempsey puts the limits of Near Space at 120 km, Paul Stephen Dempsey and Maria Manoli, Sub-Orbital Flights and the Delimitation of Airspace vis-a-vis Outer Space, *Annals of Air and Space Law*, Vol. XLII, 2017, 197, p. 236; Hao Liu, *Supra* note 9 demarcate Near Space at 100 km.

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13. For a discussion of the spatialist approach see Paul Stephen Dempsey and Maria Manoli, *Supra* note 10, at p. 216.

14. For a discussion about the functionalist approach see Paul Stephen Dempsey and Maria Manoli, *Supra* note 10, at p. 206.

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24. *Supra* note 9, p. 543.

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27. Ram Jakhu and Joseph Pelton (eds.), *Global Space Governance: An International Study* (Springer, Montreal, 2017), p. 243.

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the Sea (Brill Nijhoff, Leiden, 2015), p. 265.

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33. UN Convention on the Law of the Sea, 1982.

34. Article 33, UN Convention on the Law of the Sea, 1982.

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36. Article 56, UN Convention on Law of the Sea, 1982.

37. *Supra* note 29, p. 5.

38. https://en.wikipedia.org/wiki/Gravity_turn (last viewed March 23, 2020).

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41. *Supra* note 15 at p. 134.

42. An example is that of Norway, which has benefitted significantly from the creation of an EEZ, Alf Håkon Hoel, "The Performance of Exclusive Economic Zones - The Case of Norway" in *Supra* note 29, p. 33.

IAASS STUDY DRAFT
Convention on the Regulation of Near Space

A Convention to establish Near Space in international air and space law

CONTENTS

PREAMBLE

The States party to this Convention:

Recalling the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 1967, the Convention on International Liability for Damage Caused by Space Objects, 1972, the Convention on Registration of Objects Launched into Outer Space, 1974 and the Chicago Convention, 1944.

Recognising the need to define a legal demarcation between air space and outer space.

Acknowledging the projected increase of emerging stratospheric and suborbital activities, by means of suborbital vehicles, high altitudinal platforms, hypersonic aircrafts, pseudo-satellites, and stratospheric balloons.

Recognizing that national airspace functionally has not been legislated beyond 400,000 feet level and that there is a need for harmonious national legislations to ensure the safety of operations above that level, including space bound and returning traffic.

Recognising the need of ensuring freedom of access to space for all nations of the world, and equity in the exploitation of upcoming stratospheric and suborbital technologies.

Recognising that the re-entry phase of space objects through the upper layers of the atmosphere, can pose a risk for aviation traffic underneath and the environment, and that the density of the upper layers of the atmosphere is subjected to wide diurnal, seasonal and geographical variations.

Understanding that the demarcation between air space and outer space is improved by providing for a transition region of partial national sovereignty, instead of a simple border line.

Understanding that harmonious regulations at national level for the transition region between air space and outer space would encourage the economic development and ensure safety of operations.

Have agreed as follows:

...

PART I
INTRODUCTION

Article 1
Scope

States party to the Convention hereunder specify the use of near space for civil and commercial purposes of space exploration and scientific research.

Article 2
Definitions

Aero-space Object means 'any object created for operation in Near Space, including suborbital vehicle'.

The Convention refers to 'the IASS Study Draft Convention on Near Space'.

Underlying State is 'the State above whose territory, territorial sea, contiguous zone or exclusive economic zone the Near Space is being referred'. In case of an overlap of territory Underlying the Near Space, the rules relating to territorial demarcation provided under law of the sea shall be referred to.

Damage means and includes 'loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organizations'

Suborbital Flight is 'a rocket-powered flight up to any altitude during which the vehicle does not reach orbital velocity.'

PART II
NEAR SPACE DELIMITATION

Article 3
Definition of Near Space

Near space is a region above and adjacent to the national airspace, subject to the specific legal regime provided under this Convention. The rights and jurisdiction of the Underlying State and the rights and freedoms of other States are governed by the relevant provisions of this Convention.

Article 4
Delimitation of Near Space

Near Space extends from 18 km above sea level up to 160 km above sea level.

Article 5
Breadth of Near Space above an Underlying State

Near Space belonging to a State extends over the territory, territorial sea, contiguous zone and exclusive economic zone of a State. In case of an overlap of territory Underlying the Near Space, the rules relating to territorial demarcation provided under United Nations Convention on the Law of the Sea, 1982 shall be referred to.

Article 6
Territorial Status of Near Space

Near Space is not part of the territory of a State.

Article 7
Near Space is not part of National Airspace

Near space is not part of the national airspace but a separate legal entity. The provisions under the Chicago Convention, 1944 apply to near space only when specifically mentioned.

Article 8
Near Space is not part of Outer Space

Near Space is not part of outer space, thus it is not governed by Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 1967.

PART III
RIGHTS OF UNDERLYING STATE IN NEAR SPACE

Article 9
Non-Permissible Activities

States Parties to the Treat undertake to not place in Near Space of their territory or the territory of another State any objects carrying nuclear weapons or any other kinds of weapons of mass destruction.

Article 10
State Sovereignty in Airspace not Compromised

Nothing contained in this Convention, undermines Article 1 of the Chicago Convention, 1944 dealing with the sovereignty of a State in its national airspace.

Article 11
Jurisdiction of the Underlying State

The jurisdiction of a State extends to Near Space above its territory, territorial seas, contiguous zone and exclusive economic zone.

Article 12
Jurisdiction over the High Seas

Over the high seas, the jurisdiction over Near Space is to be exercised by the International Civil Aviation Organisation.

Article 13
Distinction between Domestic and International Near Space Activities

In case where an Aero-space Object starts and ends its journey entirely within the territory of one State, it is known as a domestic Near Space activity. Any activity that is not domestic shall be termed as international Near Space activity.

Provided where an Aero-space Object lands at high seas and is transported to the territory of a State, it shall be considered a domestic near space activity.

Article 14
Underlying State to have a Right to Use and Administer

State Underlying Near Space shall have a right to use and administer the Near Space to the exclusion of other States party to the Convention.

Article 15
Freedoms in Near Space

The States party to the Convention will have the following freedoms in the Near Space of other State parties –

a. innocent passage for civil and/or commercial activities to be freely allowed, provided that the safety measure for the mitigation of risk for over-flown population comply with internationally agreed standards and recommended practices.

b. Over-flights not falling within sub-clause (a) above shall require authorization by the overflown countries.

Article 16
Right of Stationary or Hovering Objects

States party to the Convention shall have the right to allow placement of stationary or hovering Aero-space Objects in the Near Space above their territory or with the permission of the Underlying State in the Near Space of another State.

PART IV
PRIVATE ACTIVITIES IN NEAR SPACE

Article 17
Control over Private Actors

Private activities in the Near Space are encouraged. Each Contracting State however shall be required to take appropriate measures to prohibit the deliberate use of any Aero-space Object registered in that State or operated by an operator, who has his principal place of business or permanent residence in that State, for any purpose inconsistent with the aims of the Convention.

Article 18
Conditions for Inclusion of Operator

States party to the Convention are required to create national rules, regulations and procedures to specify conditions for the inclusion of the operator of an Aero-space Object in Near Space activities.

Each Contracting State is required to take appropriate measures to prohibit the deliberate use of any Aero-space Object registered in that State or operated by an operator who has his principal place of business or permanent residence in that State, for any purpose inconsistent with the aims of the Convention.

Article 19
Licensing of Objects Operated in Near Space

The Underlying State has a duty of continued supervision and authorisation of activities in its Near Space.

The underlying State shall determine the registration, certification, licensing, astronaut licensing, insurance and operational requirements of Aero-space Objects whose operator is a permanent resident of the said State or has its principal place of business in the State.

Article 20
Terms for Deployment of Aero-space Objects

The deployment of Aero-space Objects in Near Space shall be agreed to upon between the Underlying State and the operator, prior to commencement of operation.

Article 21
Aero-space Objects of Foreign Operators

Underlying State shall prescribe rules to provide for the Aero-space Objects of foreign operators to operate within its Near Space. Procedures relating to prior notification, approval and duration of deployment in the foreign Near Space shall be prescribed.

In case of a perceived threat to the national safety or security of the Underlying State the permission for deployment of a foreign Aero-space Object shall be denied.

Article 22
Liability

In case of damage to the uninvolved public, the operator of the Aero-space Object shall be absolutely liable to a limit to be specified, unless there is proof of gross negligence on the part of the claimant.

PART V
MISCELLANEOUS

Article 23
Principles Governing State Action in Near Space

States party to the Convention agree to provide to the extent feasible universal access, highest degree of safety and security, uniformity of standards and international cooperation in the activities relating to their respective Near Space.

Article 24
Protection of Life and Property on Surface

With respect to activities in the Near Space, necessary measures shall be taken to ensure effective protection of human life and property on the surface of the Earth and in the airspace. To this end the State parties shall adopt appropriate rules, regulations and procedures to supplement existing national regulations.

Article 25
Uncontrolled Destructive Re-entry

The States party to the Convention agree to international coordination, under the supervision of International Civil Aviation Organisation, to provide for rules and principles to mitigate the risk of uncontrolled destructive re-entry of space objects through the Near Space above the international airspace.

Article 26
Traffic Management of Near Space

Traffic management of Near Space is to be integrated with the existing air traffic management by the International Civil Aviation Organisation.

States party to the Convention are obliged to develop and de-classify technologies needed to position objects at Near Space levels.

Article 27
Settlement of Disputes

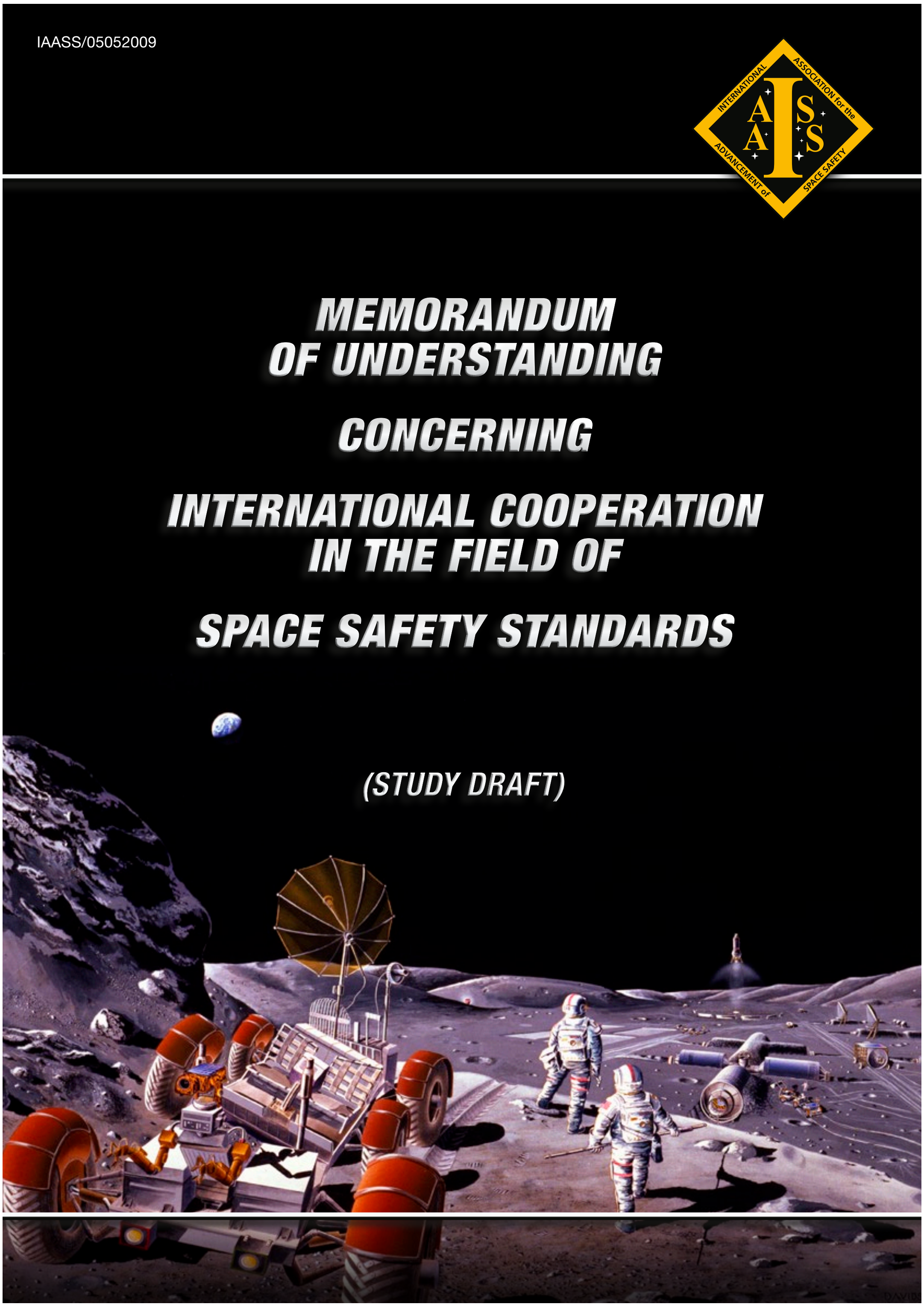
Any dispute resulting from the application of this Convention shall be resolved through the established procedures for the peaceful settlement of disputes.

Article 28
Environmental Pollution

All States party to the Convention shall take necessary measures to reduce environmental pollution in Near Space and shall adopt appropriate rules, regulations, and procedures for the same. States parties shall also invest the resources to investigate technologies for mitigating pollution due to civil and commercial activities in Near Space.

Annex 3

MEMORANDUM OF UNDERSTANDING CONCERNING INTERNATIONAL COOPERATION IN THE FIELD OF SPACE SAFETY STANDARDS



Background

The international space community has identified the rapid international commercialization of space, in particular in the field of telecommunication, navigation and launch services, as an important and positive step to the continual global and national economic growth. Recent interest and actions from the private sector in the field of commercial human spaceflight illustrates the widening range of financial commitments, and business risks the private sector is willing to make in space. Though there is great promise about the further commercial potentials of space for the world economy, safety and on-orbit environmental risks are very real and growing, but there is no international cooperative effort to balance the multiple commercial interests in space with internationally agreed and nationally enforceable safety regulations.

The space treaties provide generic principles for the use of space but no implementing rules. They were produced at the early time of space programs when two countries, U.S. and Soviet Union locked in the Cold-War atmosphere, had a governmental monopoly in space with no much presence of the private and commercial sector. The space treaties were therefore conceived for the purpose of defining the overall limits applicable to each nation space activities and not to facilitate and promote commercial and civil international cooperation

The International Standards Organization (ISO) is the only international body that has attempted so far to develop some space safety guidelines (i.e. voluntary standards) for global use, in particular in the field of space debris. They are in any case not endorsed by most of the national space regulatory bodies. To better focus the discussion on this point we need to clarify that in general the standards can be divided in policy standards (usually referred to as policy requirements, *doctrine*, or rules) and industrial or technical standards. The former are in the case of safety those defining the acceptable level of risk and mitigation strategies on the basis of technical as well as non-technical considerations of various kinds (including economic effectiveness). The latter instead define essentially the state of art and best technical practices (design solutions, engineering methods, etc.). The ISO institutional mission is to develop industrial standards, such to facilitate international commerce, and not to set up safety policies, which are a government responsibility.

However, some important national bodies (e.g., USAF, CNES, NASA, FAA) have developed a number of space safety standards which are the natural reference for any international harmonization effort.

It should be further noted that the awareness about the need for international coordination in the field of space safety is growing very fast. For example, there are two important passages in the NASA Authorization Act – 2008 (H.R. 6063), signed into law on October 15, 2008, in the sections related to space traffic management and crew rescue. In Sec.1102, SPACE TRAFFIC MANAGEMENT, NASA is instructed to initiate an international coordination in that field. In fact it is stated that: *"(a) In General- As more nations acquire the capabilities for launching payloads into outer space, there is an increasing need for a framework under which information intended to promote safe access into outer space, operations in outer space, and return from outer space to Earth free from physical or radio-frequency interference can be shared among those nations.(b) Discussions- The Administrator, in consultation with other appropriate agencies of the Federal Government, shall initiate discussions with the appropriate representatives of other spacefaring nations with the goal of determining an appropriate framework under which information intended to promote safe access into outer space, operations in outer space, and return from outer space to Earth free from physical or radio-frequency interference can be shared among those nations."*

In Sect. 406, EXPLORATION CREW RESCUE, it is further stated that: *"In order to maximize the ability to rescue astronauts whose space vehicles have become disabled, the Administrator shall enter into discussions with the appropriate representatives of spacefaring nations who have or plan to have crew transportation systems capable of orbital flight or flight beyond low Earth orbit for the purpose of agreeing on a common docking system standard".*

The final aim of this MOU is to provide a mechanism for the international coordination of national space safety policies and rules pertaining to those space safety risk issues that are international in nature and that can be effectively mitigated only through international cooperation. The parties subscribing this MOU would adopt the resulting voluntary rules and commit to their use as the main/preferred reference for their own national regulations. Furthermore they would jointly review the adequacy of industrial standards, issued by specialized standardization bodies such as ISO, in view of recommending their use (recommended practices).

In addition, the scope of this MOU includes the development of "optional" space safety technical standards for some specific areas for which two or more subscribing parties have an interest to harmonize their standards (e.g., to remove unwanted barriers to space commerce, or in view of international programs).

Article 1
Purpose and Objectives

1.1 The purpose of this Memorandum of Understanding (MOU) is to establish arrangements between Subscribing Parties (SP) for a genuinely open and as wide as possible international partnership in developing civil and commercial space safety policy standards to: a) ensure safe access to, use of, and transit through outerspace by all countries, and b) to safeguard the functional and physical integrity of any space object operating therein.

1.2 The objectives of this MOU are in line with international law, and are specifically to:

a) provide the basis for cooperation between Subscribing Parties and establish roles and responsibilities.

b) establish the management structure an interfaces necessary to ensure effective planning, funding and coordination.

c) provide a general description of the civil and commercial standards within the scope of this MOU and the main groupings comprising it.

Article 2
Standards Groupings

Under this MOU five coordinated groupings of policy standards will be established and maintained:

I) Public Safety Risk of Space Missions. Standards dealing with public safety risk management, including launch and re-entry operations, safe use of NPS (Nuclear Power Sources), health hazard in proximity of launch sites, as well as interfaces between airspace and outerspace bound traffic.

II) Ground Processing of Commercial Space Vehicles and Payloads. Standards establishing general design and operations safety requirements for ground processing of Commercial Space Vehicles and Payloads at international spaceports, including certification of ground personnel.

III) On-orbit Space Traffic Management. Standards establishing exchange of space situational awareness data and operational traffic management rules to prevent on orbit physical and functional interferences between functional spacecraft, and to prevent collision with orbital debris.

IV) Space Debris. Standards establishing international standards for mitigation and remediation of space debris. [*Note: On-going voluntary standardisation efforts within ISO would be duly taken into consideration*].

V) On-Orbit Safe & Rescue and Servicing. Standards establishing international rendezvous and docking requirements and minimum systems interoperability requirements, for on-orbit safe & rescue and servicing operations. It includes also requirements for interoperability of EVA (extra-vehicular activity) suits.

Article 3
Organization

2.1 The top body for guiding and co-ordinating all aspects of this standardisation activity is a Steering Board, called **International Space Safety Board** (ISSB). Each Subscribing Party shall have one representative as member of the Steering Board. The Steering Board can invite qualified observers to attend their meetings.

The Steering Board is supported by sub-boards dealing with specific areas of standardisation:

- The **Public Space Safety Board** (PSSB), for standards dealing with public safety risk management of space missions.
- The **Ground Space Safety Board** (GSSB), for standards dealing with ground processing safety risk management of space systems.
- The **Space Traffic Management Board** (STMB), for standards dealing with space traffic management and space situational awareness.
- The **Space Debris Standardization Board** (SDSB) for standards dealing with space debris mitigation and remediation standards.

Note: no overlapping with the IADC (Inter-Agency Space Debris Coordination Committee) which in accordance with their Term of Reference has the primary purpose to exchange information on space debris research activities between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities and to identify debris mitigation options.

- The **Safe and Rescue Board** (SRB), for standards dealing with interoperability of on-orbit safe & rescue systems and servicing systems.

Finally, the **Secretariat** under the lead of a Secretary shall provide the overall management function.

The Steering Board nominates members and chairs of the Sub-Boards on the basis of proven knowledge and experience in the specific field. Each Sub-Board nominates experts to be the members and chairs of each Working Group to which the development/review of one or more standards is assigned.

The Steering Board decisions are taken on the basis of unanimity. The decisions of the Sub-Boards and Working Groups can be either by unanimity or by a qualified 2/3 majority. In the latter case the Sub-Board and Working Groups decisions will need to be ratified by a decision of the Steering Board.

2.2 International Space Safety Steering Board – Terms of reference

The Steering Board is the international body responsible for the overall coordination of the space safety standardisation efforts. It is responsible for:

- establishing a four years strategic implementation plan, including funding profile and sources, and submitting it to the approval of the Head Representatives of the Subscribing Parties at dedicated meetings.
- approving the annual budget prepared by the Secretary
- deciding, on the basis of Sub-Board assessment and recommendation, when a standard has been approved by a Working Group with only a 2/3 majority decision.

- nominating members and chairs of the Sub- Boards

The Steering Board Chair and the Sub-Boards Chairs will be elected at unanimity by the Steering Board members for a period of four years, which can be renewed for two times.

2.3 Secretariat – Terms of reference

The Secretariat under the lead of the Secretary provides the overall management support function to the Steering Board and its subordinate Boards and Working Groups. It is responsible for:

- detailed annual planning of the standardisation activities;
- issuing of operating procedures;
- monitoring the progress of working groups activities;
- publishing the standards;
- maintaining the website of the organisation;
- issuing a detailed annual report to the Sub-Boards concerning the status of Working Group activities including updating of the annual planning and recommendations for future work;
- ensure performance of all administrative duties.

2.4 Sub-Boards – Terms of reference

The Sub-Board is responsible for the overall coordination of the standardisation efforts of the Working Groups for their assigned grouping. It is responsible for:

- providing to the Steering Board input for the four years strategic implementation plan;
- approving the detailed annual plan prepared by the Secretariat;
- providing assessment and recommendation to the Steering Board when a standard has been approved by a working group with only a 2/3 majority decision;

- nominating members and chairs of the Working Group (after confirmation of sponsorship availability by the relevant Subscribing Party (see article 4);
- issuing an annual summary report to the Steering Board concerning the status of activities and future direction.

Article 4
Funding

Funding is provided directly and indirectly by the Subscribing Parties.

The directs funds are those provided to the International Space Safety Standardization Organization to cover all costs of running the Secretariat, including staff, office rentals, etc. Such costs are evenly shared among the Subscribing Parties.

The indirect funds are those that the Subscribing Parties will internally allocate to sponsor the participation of their nationals (staff, contractors, consultants, etc.) to the standardisation activities, including travel costs.

Article 5
Transitional Rules

4.1 Initial Standards Baseline

Each Subscribing Party will propose an initial list of candidate international space safety standards among those already formally issued in the past by the Subscribing Party as national standards.

The Sub-Boards will determine if overlaps exists between Subscribing Parties standards lists and initiate working groups with the participation only of members and chairs sponsored by the Subscribing Parties of the overlapping standards. Observers from other Subscribing Parties can attend the meetings, but not vote. Each resulting standard will be baselined as international standard by the relevant Sub-Board.

If no overlap exists and only a single national standard exists, the national standard will be automatically adopted as international standards, save for text adaptations or reformulation necessary for the international use.

4.2 Initial Funding

The annual initial direct funds for operating the Secretariat are established to be (TBD).

4.3 Seat of the Secretariat

The Secretariat will be registered as non-profit organization with seat in (TBD).

Annex 4

US DoS RESPONDED NEGATIVELY

United States Department of State

Bureau of Oceans and International Environmental and Scientific Affairs

Washington, D.C. 20520

September 24, 2008

Mr. Tommaso Sgobba
President, International Association for the Advancement of Space Safety
Postbus 127
2200AC Noordwijk
The Netherlands

Dear Mr. Sgobba:

At the request of the Federal Aviation Administration's Office of Commercial Space Transportation, the Department of State has reviewed the International Association for the Advancement of Space Safety's (IAASS) proposed "Memorandum of Understanding Concerning Cooperation on Civil and Commercial Space Safety Standards" (the "MoU proposal") Although we believe that the space safety profession can greatly benefit from the international collaboration of space safety practitioners in organizations such as IAASS, the United States Government does not believe that a set of international space safety standards of the type in the IAASS MoU proposal is necessary at this time.

International cooperation is a fundamental element of the space policies of the United States and other responsible space-faring nations. The United States has been a leading supporter of international cooperation to mitigate orbital debris and to preserve the space environment for future generations.

In this regard, the United States has been pleased to support a recent initiative by the Government of France to establish an informal working group that brings together experts from the public and private space sectors to explore additional measures to ensure the long-term sustainability of space activities. The next meeting of this group will take place in the United Kingdom on October 3, on the margins of the 59th Annual International Astronautics Congress in Glasgow, Scotland. As this informal working group develops consensus on specific measures, the results may be forwarded to the United Nations Committee on the Peaceful Uses of Outer Space for consideration as part of a set of "Best Practice Guidelines" for safe space operations. We understand that you have been in contact with the Chair of this working group, Gerard Brachet, and that IAASS participation in this activity would be welcomed.

The U.S. also supports a joint United Nations IAEA/COPUOS Joint Experts Group (JEG) that is developing a safety framework for use of nuclear power sources (NPS) in outer space. A NASA expert, on behalf of the JEG, will be giving a presentation on their efforts at the upcoming IAASS conference in Rome.

Although we cannot offer our support to your specific proposal, U.S. Government officials and experts will continue to participate in IAASS events such as the Conference on Space Flight Safety, October 21-23, 2008, as appropriate. If you have any questions please feel free to contact me call me at +1-202-663-2398.

Sincerely,

Kenneth D. Hodgkins
Director,
Office of Space and Advanced Technology

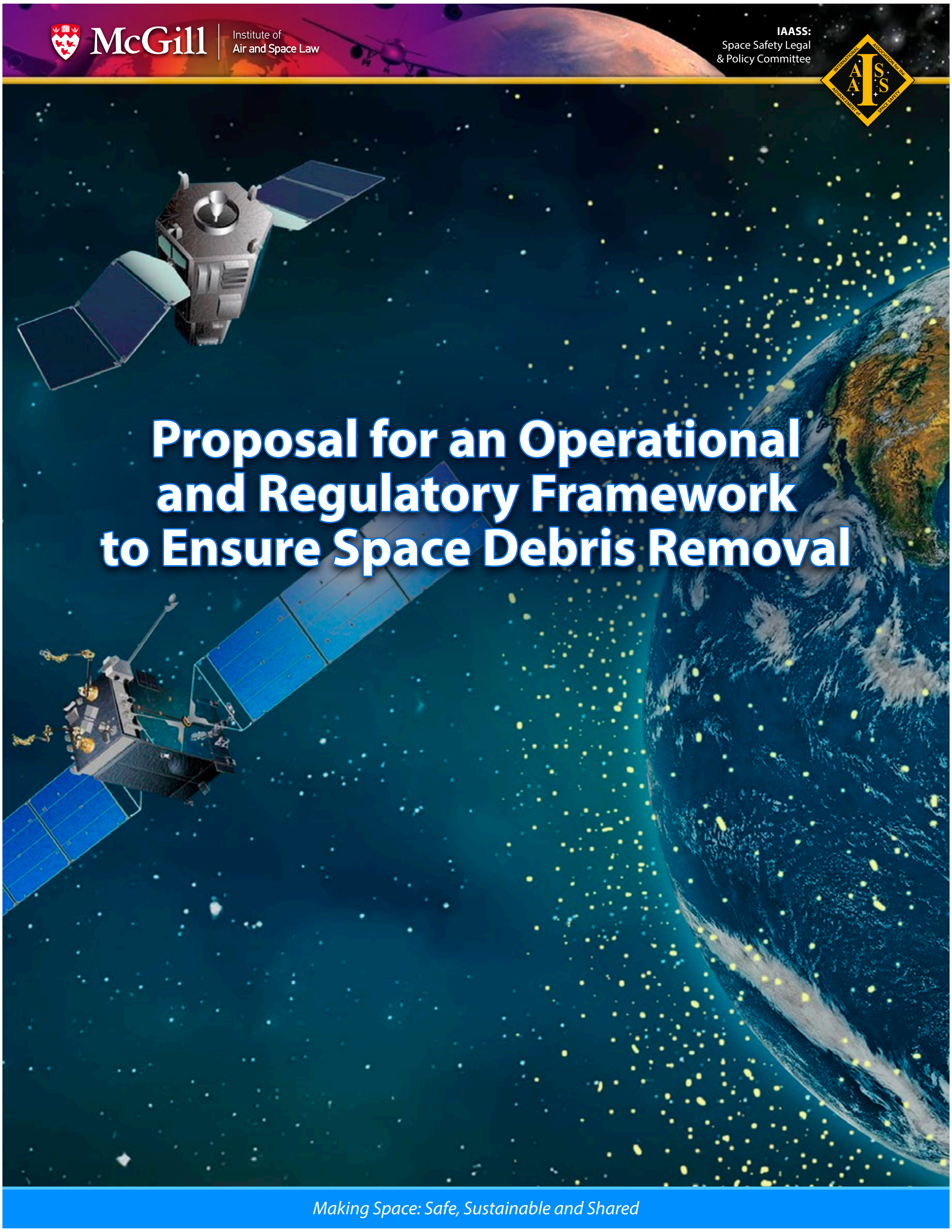
Cc:

Dr. George C. Nield, Associate Administrator for Commercial Space Transportation, Federal Aviation Administration

Mr. Bryan O'Connor, Chief of Safety and Mission Assurance, National Aeronautics and Space Administration

Annex 5

PROPOSAL FOR AN OPERATIONAL AND REGULATORY FRAMEWORK TO ENSURE SPACE DEBRIS REMOVAL



Proposal for an Operational and Regulatory Framework to Ensure Space Debris Removal

There are major legal, political and financial challenges that presently prevent or pose difficulty to the conduct of active debris removal (ADR) activities. Commercial initiatives or unilateral national programs are not enough. International cooperation among all stakeholders following proven models is needed.

PROPOSAL KEY ELEMENTS

A study conducted by the McGill University and IAASS (International Association for the Advancement of Space Safety), in brief called "Assured Debris Removal", has developed the operational and regulatory key elements for making space debris removal feasible. The elements are:

1) Establishment of an inter-governmental organization on the model of the early INTELSAT to procure the development, deployment/operations and commercialization of satellites for space debris removal. This organization could later transition to a private corporation (as INTELSAT did). (We tentatively refer to such organization by calling it INREMSAT for International Debris Removal Satellite).

2) INREMSAT Subscribing Governments would concurrently commit, through the signature of a separate legal instrument (treaty or agreement), to procure on commercial basis the removal of a number of existing "big" space debris (dead satellites and spent upper stages) created by their national space missions or by the commercial space activities of their nationals. Criteria for selection will be agreed but the ultimate decision will be with each country. Countries not participating to the INREMSAT consortium would be also invited to join such treaty/agreement.

3) A country which commits to the removal of (its own) space debris would be allowed (by the WTO?) to impose a national "space-garbage-collection" tax. Such tax would be levied on the final users of space-based commercial services available in the country.

4) Space-faring countries would make changes to their national space licensing rules by introducing an "assured removal" clause as prerequisite to obtain a license to launch/operate a satellite, by means of national or foreign launcher. Such clause would apply to both the satellite and the upper stage of the launcher used for the launch. Specifically, the "assured removal" clause would require that the operator demonstrates that either the systems in question have capability (and plans) to perform autonomously at the end-of-life/mission a safe controlled re-entry or removal to a graveyard orbit, or that they have contracted INREMSAT or similar commercial service provider for such activity. Furthermore, the operator would be required to take an insurance policy in case a failure/malfunction prevents performing the initially foreseen autonomous disposal. The insurance company would then procure and cover the cost of the relevant disposal service.

THE INTELSAT STORY

With the advent of satellite communication technology in the early 1960's, the United States government led an effort to establish a global system for satellite communications. Preliminary negotiations were held in 1962 with, and at the instigation of the governments of, the United Kingdom and Canada. Subsequently, European countries and other nations joined the negotiations. The negotiations eventually culminated in the adoption of the Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System signed by Governments at Washington on August 20, 1964 (Interim Agreement), and the agreement signed on August 20, 1964, by Governments or telecommunications entities designated by Governments, pursuant to the provisions of the Interim Agreement (Special Agreement). These instruments marked the birth of INTELSAT in 1964: a multinational organization established initially to provide the space segment of a global satellite communications system. In 1971, the 1964 instruments were respectively superseded by the Agreement relating to the International Telecommunications Satellite Organization “INTELSAT” (Intelsat Agreement) and the Operating Agreement relating to the International Telecommunications Satellite Organization “INTELSAT” (Intelsat Operating Agreement). As such, INTELSAT was formally established in 1971.

The Intelsat Agreement itself was a multilateral treaty that could only be signed by States. However, under the provisions of the Intelsat Agreement, each State Party was required to sign or to designate a public or private telecommunications entity to sign the Operating Agreement. Thus, membership in INTELSAT was thereby opened to private sector telecommunications entities from States Parties to the Intelsat Agreement. The original INTELSAT may be conceived as a group of public and private joint venturers, combining their technical and financial resources to establish and operate facilities which each participant intended to use to provide services within its defined market area. Each participant therefore obtained the technical, economic, and even political, benefits flowing from a common cooperative effort. Private sector involvement and participation in the scheme could only be achieved by virtue of the two instrument approach.

The Intelsat Agreement clearly set out the scope of activities of the organization, the financial principles upon which its activities would be funded as well as the structure of the organization among many other things. With regard to the structure of the organization, the following four organs were established: (1) the Assembly of the Parties; (2) the Meeting of Signatories; (3) the Board of Governors; and, (4) an Executive organ responsible to the Board of Governors. Despite the fact that the Intelsat Agreement spelt out the role to be performed by each of these four organs, it would seem that in practice there were significant overlaps (and redundancies) between the roles respectively performed by the Assembly of the Parties and the Meeting of Signatories.

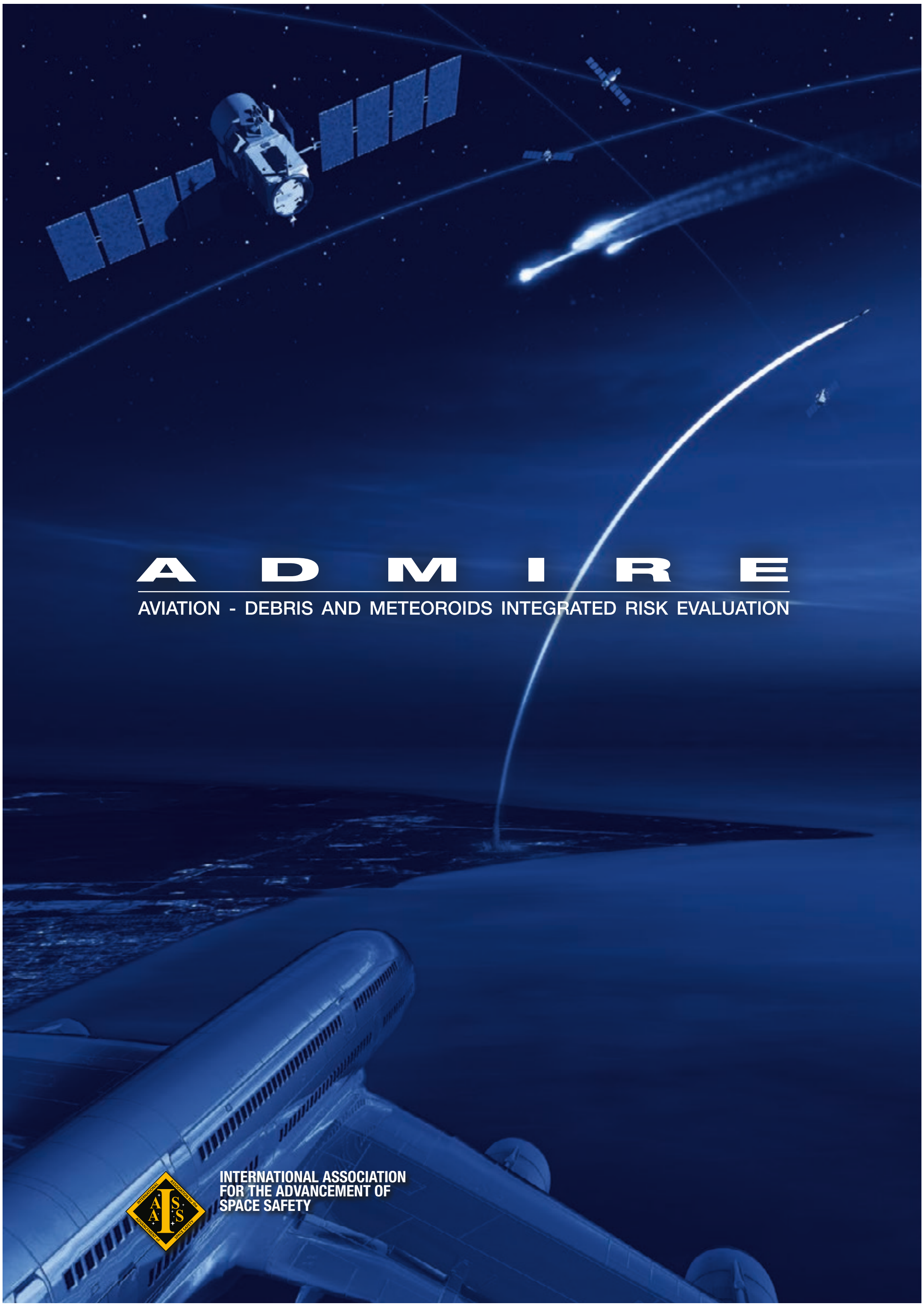
The Operating Agreement on the other hand set out the rights and obligations of each signatory thereto, including the obligation to make financial contributions to INTELSAT, the basis and modalities for determining investment shares in the organization, the utilization of charges and revenues and many others. The establishment of principles for determining investment and ownership shares, and setting specific investment percentages [in INTELSAT] presented one of the more thorny problems for negotiation. The determination of investment shares had to be predicated on a principle with which all or most of the participants could agree; one which was pertinent to the nature and purpose of the venture; which minimized or eliminated strictly political consideration; and, which objectively reflected the potential use of the system by the respective participants. Failing agreement on a rational and objective standard, the negotiation would have floundered. The principle agreed upon was that each signatory to the Operating Agreement would have an investment share in the organization proportional to its use of the INTELSAT space segment during the six month period immediately preceding the date of determination of investment shares. After 30 years of successful operations, INTELSAT was transformed from an international organization into a private company in 2001.

CONCLUSION

In essence, the INTELSAT scheme allowed for governments, public and private telecommunications entities to collaborate in a hitherto unprecedented manner to provide global satellite communications infrastructure and services reaching all corners of the earth and providing mutual benefit to all participants. Although this occurred during an era of increased international cooperation within the framework of the ITU, it nevertheless provides several lessons worthy of emulation and capable of adaptation to meet the current space debris scenario. First, it is clear that ADR activities can only be successfully and economically conducted in an environment of increased cooperation between governments acting in close collaboration with each other as well as public and private space operators. The adoption of a two instrument approach (as was done in the case of the original INTELSAT) for the establishment of a regulatory regime and an international organization for ADR activities would no doubt facilitate the conduct of such activities. The use of a concept similar to the investment shares concept of the Intelsat Operating Agreement to fund the activities of the international organization proposed for ADR activities would also enhance its financial position.

Annex 6

ADMIRE
AVIATION - DEBRIS AND METEOROIDS INTEGRATED RISK EVALUATION



ADMIRE
AVIATION - DEBRIS AND METEOROIDS INTEGRATED RISK EVALUATION

Airplanes vulnerability to small fragments

Small space fragments (space debris and meteorites) represent a source of risk for aviation. Due to relative speed and construction, a collision with relatively small fragments, although assumed very remote, has an intrinsic high potential for multiple casualties.

Current vulnerability models showed that an impact anywhere on a commercial aviation transport with debris of mass above 300 grams would produce a catastrophic failure, meaning all people on board would be killed.

The reentering space debris flux is better known than reentering meteorite flux and, although the space debris reentry risk is lower, it is in the same order of magnitude than meteorites' one.

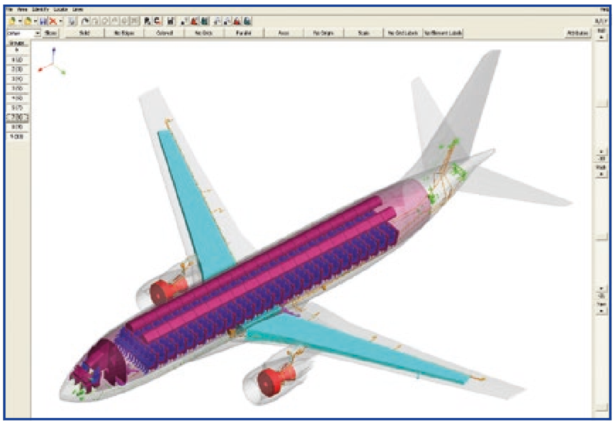


Figure 1 - Computer Model of a Commercial Transport Aircraft Used to Assess Debris Impact. (Source: Space Safety Magazine)

It has been estimated that:

Object	Number/Year > 100g	Total Mass (tons)
Meteorites	13,680	53
Space Debris	2,267	40

Table 1 - Objects entering the atmosphere.

Air traffic density is another fundamental variable in assessing aircraft risk to small fragments, especially in the regions where the air traffic is higher and it must take carefully into account the different types of aircraft in service.

Although there are a number of methodologies and tools to assess the risk for the public on ground due to a reentering space debris event, there is nothing available for assessing the risk for aviation, and the combined space debris and meteoroids fluxes. The annual risk for passengers due to an airplane being hit by reentering space debris or by a meteoroid has never been quantified with any detail or precision. In addition, there are no methodologies for real-time risk assessment that can be used by air traffic control authorities and civil protection organizations to activate emergency plans for impending reentries.

The **International Association for the Advancement of Space Safety (IAASS)** has gathered a pool of industry, agency, and independent experts with the aim of developing an advanced tool that will enable assessment of the risk to aviation due to reentering space debris and meteorites.

The tool is called **ADMIRE** for *Aviation - (Space) Debris and Meteorites Integrated Risk Evaluation.*

Figure 2 - Global air traffic paths. The image clearly shows that Europe, US, East China and Japan are regions where the air traffic density is heightened (Credits: Micheal Markieta / Arup)

ADMIRE
AVIATION - DEBRIS AND METEOROIDS INTEGRATED RISK EVALUATION

Background

Space Debris

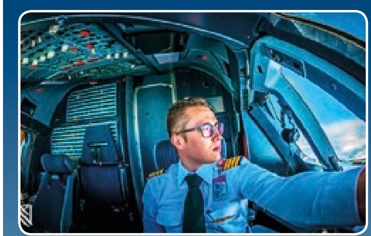
Space debris are manmade objects in orbit around the Earth, which no longer serve a useful purpose. The U.S. Space Surveillance Network regularly tracks and maintains in its catalogue an estimated 21,000 items in orbit, which includes objects larger than approximately five to ten centimetres in low Earth orbit (LEO) and 30 cm to 1 m at geostationary altitudes (GEO). Only 6% of the orbital population represents operational satellites, while the remaining 94% objects is attributed to space debris (decommissioned satellites, spent upper stages, mission-related objects and fragments) [1]. Unlike GEO, space debris in LEO experience a certain amount of atmospheric drag, which causes them to gradually spiral down towards Earth, the decay duration depends on the object's altitude, area-to-mass ratio and solar activity.

Size	Detection	Number	Mass fraction
> 10 cm	Can be tracked	~ 14,000	> 95%
1-10 cm	Only partially tracked	~ 370,000	< 5%
< 1 cm	Not tracked	> 10 million	

Table 2 - Number of tracked and non-tracked debris in LEO [2] [3]

Meteorites

About $30x10^6$ to $40x10^6$ kg of outer space matter are intercepted each year by our planet. Most of this material vaporizes when it goes through the atmosphere. The meteorites (objects that reach the ground) are divided into two categories: micrometeorites between 30 and 500 µm in size and meteorites. The annual mass of micrometeorites that reach the surface of the Earth is today estimated at about 6,000 metric tons. These micrometeorites have a very low unit mass and are thus of no danger to people on the surface of the Earth. About 40,000 meteorites per year, in the range between 10 g and 1,000 kg, hit the Earth. Meteorites of a mass greater than 1,000 kg are even rarer: the frequency for meteorites of 10 tons reaching the Earth is about one per year. Beyond that size, large meteoroids can cause local or regional disasters.



On 27 March 2007, wreckage from Russian Progress 23P cargo was spotted by Lan Chile (LAN Airlines) in an Airbus A340, which was travelling between Santiago, Chile, and Auckland, New Zealand, carrying 270 passengers. The pilot estimated the debris was within 8 km of the aircraft, and he reported hearing the sonic boom as it passed. The assistant secretary of the Australian and International Pilots Association, Captain Steven Anderson, who flies for Qantas, said that based on the details of the report, the debris could have caused catastrophic consequences had it actually struck the aircraft.

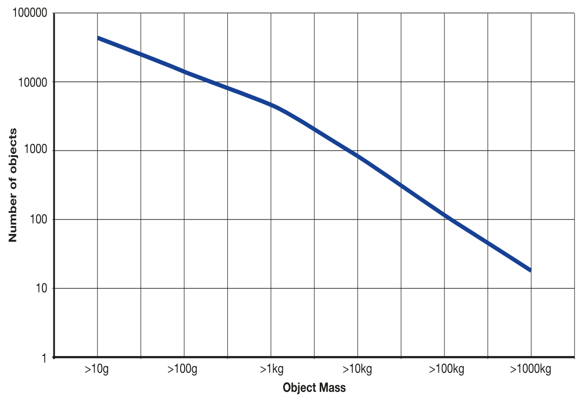


Figure 3 - Annual cumulative meteorite flux.

This type of phenomenon, given its probability and the serious consequences involved cannot be compared to the risks of debris from man-made objects reentry. Meteorites annual flow including masses between 10 g and 1,000 kg is estimated at 53,800 kg. The main danger caused by falling meteorites or debris is due to their kinetic energy and their impact's surface on the ground, which themselves depend on their number and characteristics: mass, dimension, shape. Current estimates of the frequency of falling meteorites as a function of their mass is shown in Figure 3. These values are based on the analysis of meteorites found on accumulation sites on the one hand and on the analysis of data recorded by observation cameras on the other hand.

While going through the atmosphere, meteoroids undergo mechanical and thermal stress, due to aerodynamic heating and drag, which most often leads to them breaking up. It is estimated that, on average, a reentering object produces five fragments that are counted as meteorites. Meteorites are classified according to their composition: stone meteorites (chondrites) and metal meteorites (iron ferrites). For the scope of this study, most of the meteorites (more than 96% for masses less than 10 kg) are chondrites whose mass per unit volume is about 3,400 kg/m^3. Given the relatively low masses of meteorites in the range of 10 g to 1,000 kg, they are efficiently broken by the atmosphere and reach the ground at a speed corresponding to terminal velocity.

1 European Space Agency, "Space Debris" [2009] http://www.esa.int/About_Us/ESA_Publications/ESA_BR-274_i_Space_Debris_i.
2 C. Liou & N.L. Johnson; Instability of the present LEO satellite populations; Advances in Space Research, Vol. 41, Issue 7, 2008, Pages 1046-1053
3 Brian Weeden; The Current Space Debris Situation; Global Security Program; 2010 Beijing Space Debris Mitigation Workshop, October 2010

ADMIRE
AVIATION - DEBRIS AND METEOROIDS INTEGRATED RISK EVALUATION

The Shuttle Columbia Disaster and its Heritage

The disintegration of the Shuttle Columbia on February 1, 2003 was a watershed moment in the history of reentry safety. It highlighted the need to select vehicle reentry trajectories that minimize the risk to ground populations and the need to take measures to keep air traffic away from falling debris. The Columbia accident initiated a chain of events that demonstrated the need for a deliberate, integrated, and international approach to public safety during reentry operations, particularly for the management of air traffic and space operations.

The Shuttle Columbia failure began at about 60 km of altitude and led to a “progressive breakup” in which primary structural failure was followed by smaller pieces continuing to shed off of larger pieces during the fall. Large pieces (landing gear, turbo pumps, etc.) had high ballistic coefficients (defined as the ratio of an object’s mass to its drag coefficient times reference area), making them less susceptible to wind and drag.

Thus, they fell quickly, reaching the ground within three to five minutes. While there is no protection from these fragments, they comprise a very small part of the total debris field. Smaller pieces (thermal tiles, fragments of the cargo bay doors, etc.) had low ballistic coefficients, and became entrained in the wind as they fell. Some developed a small amount of lift as they fell, and as a result, these pieces took about 40 minutes to reach the ground. While small and light, some of these pieces were large enough to substantially damage aircraft. Still smaller pieces (similar to confetti) that are assumed to be harmless to aircraft remained airborne for over two hours.

The Columbia accident showed that a Shuttle failure during reentry could produce risks to aircraft that exceed these values by several orders of magnitude. Prior to this accident, neither the FAA nor NASA took active precautions to protect uninvolved aircraft from the potential hazards of Shuttle debris during a planned reentry.

As a result, in the 40 minutes required for the majority of the debris from Columbia to fall to the Earth’s surface, as many as nine civil aircraft flew through the falling debris. Although no damage was reported to any of those aircraft, a study conducted by ACTA, Inc. of Torrance, CA showed, using data retrieved from the accident investigation, that the probability of one of these aircraft being struck by a piece of falling debris could have been as high as 0.1 (1 in 10) to 0.003 (3 in 1,000). The analysis used the current models, which assumed that any impact anywhere on a commercial transport with debris of mass above 300 grams would produce a catastrophic accident: all people on board are killed. Those practices were captured at that time in RCC 321-07 “Common Risk Criteria for the National Ranges,” published by the Range Commanders Council (RCC), which provided a vulnerability model for the commercial transport class.

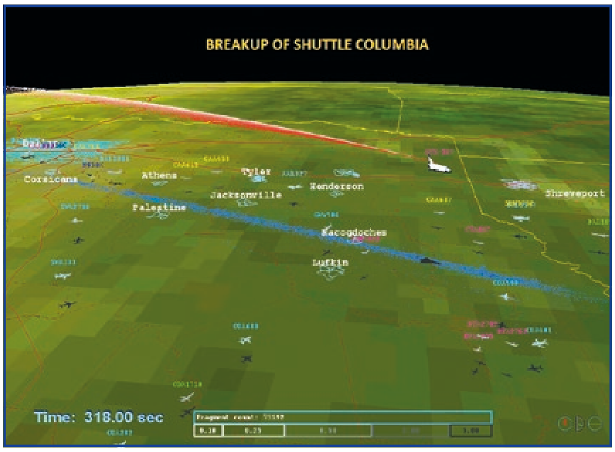
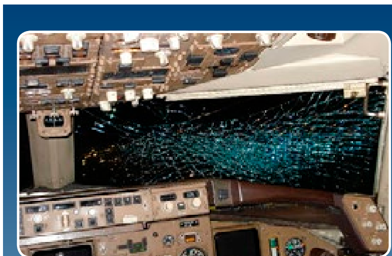


Figure 4 - Air traffic during the catastrophic reentry of Shuttle Columbia. The airliners were not aware of falling fragments and risked collision.



A Chinese passenger plane was forced to make an emergency landing after the exterior glass of the cockpit window was cracked by an unidentified flying object at 9,600-meters (31,500 feet). The object collided with the Boeing 757-200 passenger plane on December 19 on a flight from Beijing to Wuhan, capital of central Hubei province, an edition of the newspaper seen in Beijing on Wednesday said. The plane which belonged to a Hubei subsidiary of China’s Southern Airlines, made a successful emergency landing at Beijing’s Capital International Airport. *©Reuters Limited 1996*

After FAA executives were briefed about the potential for aircraft impacts during the Columbia accident, the FAA established procedures to be used as a real-time tactical tool in the event of a Columbia-like accident to identify how to redirect aircraft around space vehicle debris. The tool developed for the purpose was called the Shuttle Hazard Area to Aircraft Calculator (SHAAC). SHAAC used a simplified Shuttle debris catalogue to predict the size and location of the aircraft hazard area, or debris footprint, for each Shuttle state vector. Such a hazard area predicts the extent of the airspace that should contain all the falling debris potentially hazardous to aircraft if the Shuttle were to break apart at the time, position, and velocity associated with the input state vector. In addition to a Shuttle trajectory file, SHAAC imported forecasted wind data from the National Oceanic and Atmospheric Administration (NOAA), incorporating an uncertainty factor to account for forecasting uncertainty.

The SHAAC output a set of four coordinate pairs for each hazard area that formed a box defining the airspace containing the falling fragments.

The Shuttle retired from service in 2011, but in the near future an increasing number of commercial space transportation systems will carry out routine suborbital operations, launches to orbit, and orbital reentries. Across this range of vehicles, the available reaction time between space vehicle breakup and entry of debris into the National Air Space (NAS) can range from zero (if the vehicle is in the air traffic environment at the time of the failure) to upwards of 90 minutes (if the vehicle is nearly in space and at orbital speed at the time of failure).

Air Traffic Operators will require dependable information and procedures to cope with the sudden onset of such an event and with the short lead-time that will be available until debris enters the airspace. To address those operational needs, FAA has been working on a systematic, standardized space vehicle debris threat management process that can be applied to the variety of space vehicles that will eventually operate in the NAS. ▸▸

4 NASA, https://solarsystem.nasa.gov

ADMIRE
AVIATION - DEBRIS AND METEOROIDS INTEGRATED RISK EVALUATION

Controlled versus Uncontrolled Reentry

The procedures established after the Shuttle Columbia accident to clear the airspace in case of a space vehicle breakup are only feasible for controlled reentries such as those typically performed for crewed missions, or at the end of mission by the cargo vehicles that ferry spare parts, consumables, and other items to the International Space Station. In such cases specific manoeuvres are planned either to bring the vehicle intact to a preplanned location, at sea or on ground, or to place the debris field, following fragmentation/explosion, away from inhabited areas, like into the SPOUA (South Pacific Uninhabited Area). Unfortunately, most reentries are uncontrolled. Figure 5 is a simple illustration of the breakup process for an uncontrolled reentry.

Uncontrolled reentries occur as the atmosphere slowly drags an orbiting object deeper into the atmosphere. Moving at over 7 km/sec, the object begins to heat as it encounters increasingly significant atmospheric density below the reentry interface altitude of about 120 km. The heating increases as gravity and drag lower the altitude, and eventually low melting point materials reach a condition where they fail. Heating on the primary object and on released fragments continues to increase, and aerodynamic deceleration loads also begin to build. Aluminium structures have been observed to fail consistently at approximately 78 km altitude, causing a catastrophic breakup of the object. This major breakup phenomenon near 78 km altitude is remarkably independent of vehicle attitude and rates, diameter, shape, and entry flight path angle in between –0.3° and –1.5°. High heating rates and aerodynamic forces that produce thermal melting, thermal fragmentation and mechanical fracture during reentry are the primary causes of the various external destruction events.

Destruction may also be introduced by internal components of the space system like propellant tanks with residual fuel. Pressurization of the tanks by heating may exceed the critical burst level and the release explosive gases may lead to an explosive destruction of the space system.

Items made from materials with relatively low melting points, such as aluminium, typically fail first, releasing fragments that generally decelerate further and follow their own trajectories. Major fragments such as electronics boxes, propellant and pressurization tanks, and other components are released. Deceleration loads build to seven or more times the acceleration of gravity, potentially causing additional failures due to inertial loads. Each object is heated further until its velocity drops to the point where the heating and loads diminish. At this point, the original orbiting object has been broken into a number of smaller fragments, each falling independently. Much of the structure of the original object, typically aluminium, has melted away; objects made of high melting point materials like titanium, glass, and steel often survive to impact. Some objects made of low melting point materials can survive to impact because they were released very early in the trajectory and decelerated quickly or they were shielded from much of the reentry heating by other objects.

There are competing effects that complicate the prediction of whether a given object will survive to impact or demise. However, reentry heating rates are approximately proportional to the velocity cubed and inversely related to the radius of curvature. Thus, small objects released early often demise, unless they have low enough density to slow down rapidly.

The "footprint" is the area where debris hazards are predicted to occur given a reentry break-up. A typical footprint for a reentering spacecraft of 5,000 kg or more is approximately 2,000 km long, contained within 35 km of the original ground track as illustrated in Figure 4. For a reentering launch stage, a typical footprint length is between 100 and 400 km. The major reentry breakup process takes place over a ~5 minute period. Objects that survive the reentry environment continue to decelerate and most will approach a terminal velocity proportional to the square root of their ballistic coefficient at about 18 km. From this point, the surviving fragments fall nearly vertically, with their trajectory blown by winds and some additional dispersion potentially due to lift.

According to The Aerospace Corporation, there are about 100 large man-made space objects that reenter the Earth's atmosphere randomly each year and then fragment and explode during reentry. Current forecasts of the time and location of such uncontrolled reentries may have errors of several thousand kilometres and are available only minutes before reentry. Consequently, air traffic controllers cannot issue specific "Notice To Airmen" (NOTAMs) on impending reentries. NOTAMs are effective only when mission planners can provide a specific time and location in advance, as in the case of controlled reentries. In conclusion, air traffic is subjected to an annual total flux of reentering space debris and meteoroids whose collision risk is not generally controllable and has been never quantified.

In addition to large objects, there are several thousand of smaller space debris, results of on-orbit fragmentations due to explosions or collisions that reenter annually. Very little is known about them in terms of further fragmentation or demise.

Dr. Russell Patera of The Aerospace Corporation analysed the risk from falling space debris to passengers aboard commercial aircraft using statistical data and information associated with different commercial aircrafts. The analysis was carried out only for flights within, from and to US in 2006. Patera's work computer the risk for aircraft from a typical flux of space debris with a realistic distribution of inclinations. According to Patera's estimation the annual risk for aviation due to space debris is 3×10^{-4}.

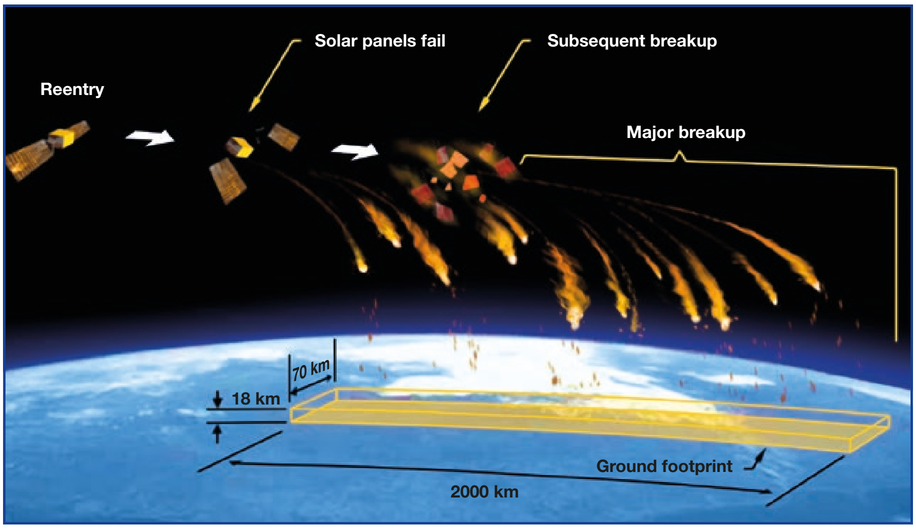


Figure 5 - Dimensions of airspace affected by a spacecraft reentry event.

A D M I R E
AVIATION - DEBRIS AND METEOROIDS INTEGRATED RISK EVALUATION

Unpredictability of impact location for uncontrolled reentries and real-time risk assessment

The US Air Force maintains a catalogue of objects in Earth orbit that is updated periodically with new radar and optical observations and can be used to estimate when an object will reenter. Because of uncertainties in the atmospheric density and the orientation and dynamics of the reentering body, reentry prediction using this tracking data have an error of approximately 10 percent in time; that is, if an object is observed and an accurate orbit based on that observation is computed one hour prior to reentry, there is a ±6 minute error in that prediction. Since this object is traveling at orbital speed (~7.6 km/second), this error translates to an uncertainty in the reentry point of approximately ±2740 km, as Fig. 6 illustrates (this is likely an optimistic scenario—without special tasking, good estimates of final orbits are generally not computed within one hour of reentry).

The uncertainty in the impact zone can be reduced substantially if the object is observed at the primary breakup altitude. If an object is observed before breakup, no major debris has yet been released, so the predicted impact zone must include uncertainties in the atmosphere, vehicle dynamics, etc., for the remaining time before breakup.

After breakup, there is uncertainty as to whether the observed object is at the toe or heel of the debris footprint, and since the objective is to produce a ground impact zone that will contain the debris with a high level of confidence, the possible ground area affected is larger than the actual debris footprint. For these reasons, the observation altitude that produces an affected area that is closest to the actual debris footprint length is the altitude where the object experiences the primary breakup event.

Thus, the best predictions of the airspace to be affected by debris are made if the object is observed during the actual reentry and the prediction is based on trajectory data obtained at the breakup altitude.

From the point of view of the risk evaluation from the airspace to the ground, an uncontrolled satellite can renter anywhere on a large portion of the Earth surface, putting all the locations within the latitude band defined by the orbit inclination into the risk zone. Considering that a reentering satellite in nearly circular orbit completes a full revolution around the Earth in just less than 90 min, even a few days before orbital decay a reentry window still includes many revolutions, overflying most of the planet. Due to the very fast velocity of a low Earth satellite, a relatively small uncertainty in time translates into huge along-track distance uncertainties.

Usually, the final reentry forecasts issued during the last hour or minutes preceding the actual reentry are based on a 2-3 hours old state vector, due to an unavoidable communication and processing delay between the orbit determination epoch and the release of the corresponding reentry prediction. Therefore, the predictions issued immediately before reentry maintain a typical along-track uncertainty of half an orbit. However, even though the final reentry uncertainty window is in practice quite spatially extended along-track, the possible impact time of the satellite fragments at a given sub-satellite location may be computed with reasonable accuracy. This allows, for any sub-satellite location included in the reentry window, to define a risk time window. In other words, for each sub-satellite location included in the reentry window, the debris impact is possible, but not certain; however, in each place, the possible impact may occur only during a specific risk time window, which can be therefore used to plan risk mitigation measures on the ground and in the overhead airspace.

If the attention is focused on a quite compact and small area of the planet, it is possible to produce additional information useful for the civil protection authorities.

In this case, the relevant question for any meaningful planning is if *given a certain uncertainty window, where and when a reentering satellite fragment might cross the national airspace and what is the probability that the fragment will hit the ground?*

The reply to this question comes from the simulation of all possible reentries over an area of interest, included in the global reentry uncertainty window, also taking into account satellite fragmentation. For example and using Italy as an area of interest, starting 2-3 days before the satellite decay from orbit, the nominal predicted trajectory is slightly modified, through small changes of the ballistic parameter, in order to obtain simulated reentries over the involved area in the time interval corresponding to the current uncertainty window. The ground tracks found in this way are much more stable and less affected by the uncertainties.

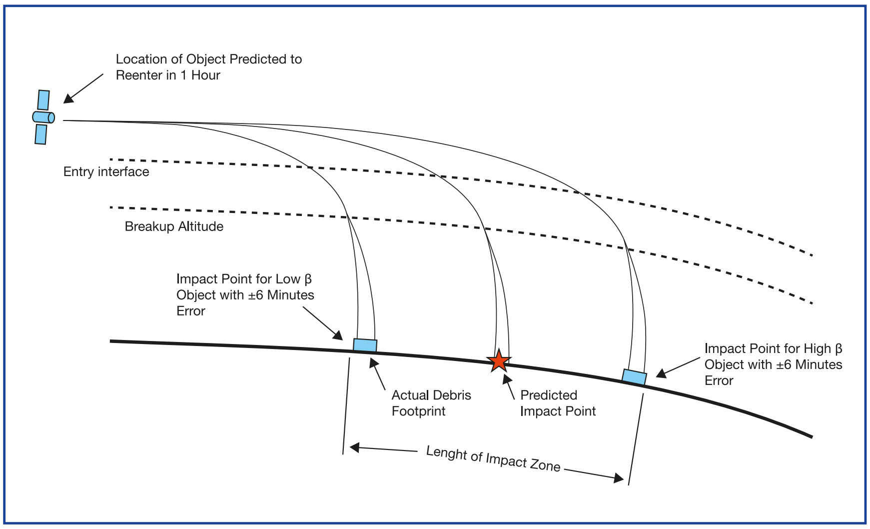


Figure 6 - Possible downrange impact points from observation prior to breakup

Successively, the nominal impact times and ground tracks are integrated with a small time dispersion to account for initial conditions variability, a larger time dispersion of tens of minutes to account for the different flight times of fragments with distinct ballistic properties (including small particles not dangerous on the ground, but possibly representing a hazard for aircraft crossing the affected airspace), and a cross-track safety margin to account for the expected dispersion of the fragments and the trajectory residual uncertainties. Applying this method, ot has been found that ISTI-CNR (Italian Council of Research) for the Italian territory the "risk" time windows typically have an amplitude of about 30-40 minutes, including the airspace crossing from an altitude around 10 km to ground impact [5].

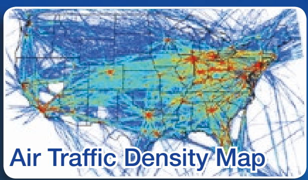
[5] L. Anselmo, C. Pardini "Satellite reentry predictions for the Italian civil protection authorities" Acta Astronautica 87 (2013) 163–181

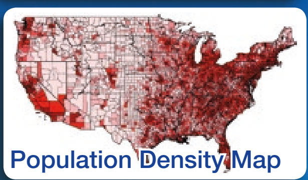
A D M I R E
AVIATION - DEBRIS AND METEOROIDS INTEGRATED RISK EVALUATION

ADMIRE Applications

1) Estimate of annual integrated debris and meteorites impact risk for aviation (globally,and locally for regions of highest air traffic).
2) Assessment of new space systems compliance with applicable reentry risk safety requirements, taking into account densities and vulnerabilities of ground population and aviation traffic.
3) Real-time risk management of space debris reentries in support of decision making by civil protection and air traffic control authorities.

Estimate of annual integrated debris and meteorites impact risk for aviation (globally and locally for regions of highest air traffic)

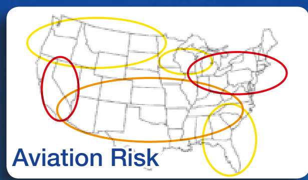




Flux of Space Debris

Flux of Meteorites

INPUT



OUTPUT

The estimation of the annual risk for aviation provides with a complete set of information necessary to manufacturers in order to elaborate solutions to mitigate the risk for the aircraft in case of impact with a reentering object. Moreover, the determination of the total reentering flux gives insurance companies precise information that would help setting new risk occurrences in order to develop a more complete coverage of the risk for the aviation and liability of space assets.

Assessment of new space systems compliance with applicable reentry risk safety requirements, taking into account densities and vulnerabilities of ground population and aviation traffic

New Space Systems

Fragmentation Model (Input)

Air Traffic Density

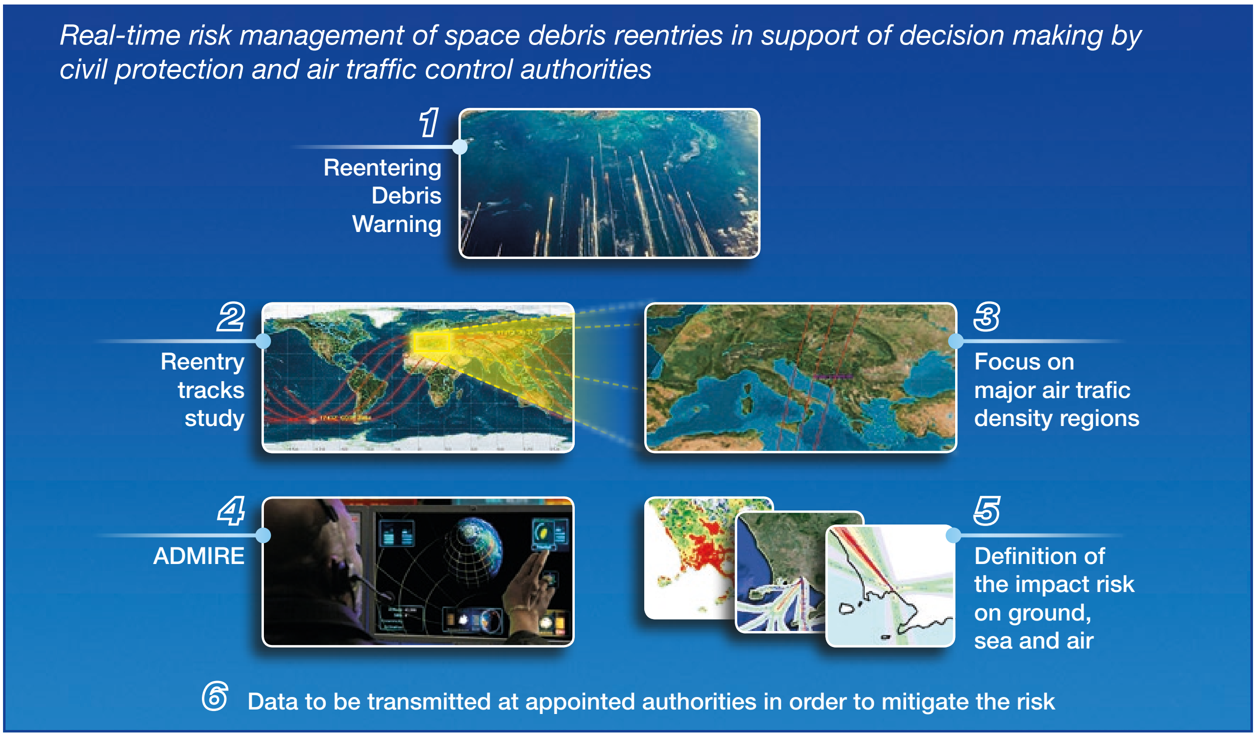
Population's Density on Ground

Assessment of compliance with applicable reentry risk safety requirements

ADMIRE provides new space systems with information necessary for the compliance with current and future reentry safety requirements, considering not only the density of the population on ground, but also the aviation traffic as a separate value.

ADMIRE

AVIATION - DEBRIS AND METEOROIDS INTEGRATED RISK EVALUATION



Finally, ADMIRE, integrating space debris reentry predictions and up-to-date aviation traffic density maps, will be a fundamental tool for civil protection and air traffic control authorities to assess the reentry risk due to manmade objects in order to make safe and quick decisions to prevent accidents.

Study Logic

WP PM-IAASS *Project Management*

Phase 0		Phase A/B	Phase C/D
		WP ASTOS *Air Traffic Density Modelling*	
WP 0 *State of the Art*		WP HTG *Fragmentation and Survivability*	WP ACTA *ADMIRE Annual Risk Report*
WP 0.1 - ACTA *Reentry Risk*	WP 0.2 - ASTOS *Air Traffic Density Map*	WP CNES *Meteoroids*	WP ACTA *ADMIRE Individual Event Risk Assessment Module*
WP 0.3 - ACTA *Aircraft Vulnerability*	WP 0.4 - CNES *Meteoroids*	WP ACTA *Aircraft Vulnerability*	WP ACTA *ADMIRE Real-Time Risk Assessment Module*
WP 0.5 - PAUL WILDE *Space Debris*	WP 0.6 - HTG *Fragmentation*	WP ISTI-CNR *Real-Time Risk Assessment*	
WP 0.7 - CNES *Fragmentation*	WP 0.8 - ACTA *Patera's Methodology*		

Partners

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