# Manifesto for a Safe and Sustainable Outer Space

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## CHALLENGES IN SPACE SAFETY



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# "MANIFESTO FOR A SAFE AND SUSTAINABLE OUTER SPACE"

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The human adventure in space is now more than a half century old. A total of about 6000 liftoffs have taken place and some 500 people have flown into space, but in the process a number of fatalities have occurred—both in space and on the ground. Furthermore, space traffic is becoming chaotic and the orbital environment is increasingly polluted by debris. The Technical Committees of the IAASS have spent a great deal of time to develop a "Manifesto" to express the goals and objectives that all space faring countries should collectively embrace to ensure that in future the space adventure will not be brought to a sudden halt by unacceptable risks. This newly launched "Manifesto for Safe and Sustainable Outer Space", as presented at the end of this article encapsulates the urgent appeal, by concerned space safety scientists, technicians, and legal experts that make up the IAASS, to policy makers and stakeholders around the globe to build consensus around a shared vision of a safe and sustainable space. Over time this Manifesto may be refined and augmented but the six objectives of the Manifesto represent a good starting point for an overdue debate on organizing outer space as a precious global asset.

**Keywords:** "*Manifesto for Safe and Sustainable Outer Space*", Space Fatalities, Commercial Space Transportation, Definition of Space Safety, Zone of Space Exploitation, Space Exploration, Space Debris, International Civil Aviation Organization (ICAO), International Association for the Advancement of Space Safety (IAASS)

## 1. SUMMARY

Safety of space missions refers to the safety of the general public (on ground, in air and at sea), launch range personnel, and humans on board. Space safety also encompasses the safeguard of valuable assets such as ground facilities (e.g., launch pads), space systems on orbit (e.g., space station, telecommunications satellites, etc.) and the safeguard of space, air and ground environment.

As commercial operations expand in the region of outer space up to and including geostationary orbits, it is clear that a formalized and globally agreed framework of space safety standards and procedures is essential for assuring safety and long-term sustainability of space activities. Such regulatory framework should be guided by six basic principles which the International Association for the Advancement of Space Safety (IAASS) has enunciated in the *Manifesto for a Safe and Sustainable Outer Space* for the consideration of policy-makers worldwide. This Manifesto is shown on page 2 of this article. In parallel due consideration should be given to the establishment of a suitable organizational set up at national and international level to carry on the implementation of the above principles.

## 2. THE NEW SPACE AGE

Early space programs were conducted almost exclusively by a few governments for military and civil purposes with little involvement by the private sector. Gradually, commercial uses of space began to develop as a global industry in particular in the field of satellite telecommunications first and launchers and global utilities later. Today, space can be considered divided in two functional regions: the region of space-exploitation and the region of space-exploration. Exploitation means *making productive use*, while exploration means, *travelling (over new territory) for adventure, discovery or investigation.* Currently we can almost identify a physical borderline in space (because of debris dissemination) between the two regions to lay 200 km above the geostationary (geosynchronous) altitude. Thus, the region, or zone for space exploitation, from the sea level to 36,200 kilometres in space is now used mainly of commercial and military strategic interest.

However, this zone is getting increasingly crowded—not only by active satellites but by space debris. On the other hand, the literally "boundless" region beyond 36,200 kilometres is currently for reserved for space exploration activities and thus is mainly of scientific interest. While the space exploration activities can be considered somehow covered by the existing space treaties, the safety of operations in the space-exploitation-region still needs to be regulated on an international level. In fact, just as international waters and airspace have traditionally been shared by government and commercial operators within an international regulatory framework, space exploitation operations are evolving in a similar fashion and have similar regulatory needs.

### 2.1 MILITARY SPACE EXPLOITATION

At the beginning of the space era, both the United States and the former Soviet Union developed and implemented programs that were more military in nature than civilian or scientific. The heritage of the current International Space Station and other civilian systems can be traced back to military programs. Space military programs were also precursors of all satellites applications from imagery to navigation, telecommunications and me-

## MANIFESTO FOR SAFE AND SUSTAINABLE OUTER SPACE

**(AS INITIALLY ADOPTED IN OCTOBER 2009)**

The International Association for the Advancement of Space Safety (IAASS) expresses serious concern about the safety and sustainability of civil and commercial space activities and calls upon all nations to actively cooperate with determination and goodwill to enhance access to and promote the safe use of outer space for the benefit of present and future human generations by committing to:

i. Equally protect the citizens of all nations from the risks posed by launching, over-flying, and re-entering of space systems;

ii. Develop, build and operate space systems in accordance with common ground and flight safety rules, procedures and standards based on the status of knowledge and the accumulated experience of all space-faring nations;

iii. Establish international traffic control rules for launch, on-orbit and re-entry operations to prevent collisions or interference with other space systems and with air traffic;

iv. Protect the ground, air and space environments from chemical, radioactive and debris contamination related to space operations;

v. Ban intentional destruction of any on-orbit space system or other harmful activities that pose safety and environmental risks; and

vi. Establish mutual aid provisions for space mission emergencies.

teorology. The overhead reconnaissance by satellites was very soon accepted as legitimate means for confidence building and information exchange. By 1967, the year of coming into force of the Outer Space Treaty which established the principle of peaceful use of outer space, military satellites (e.g., for communications and navigation, detection of nuclear explosions in space, missile launchings and weather monitoring) were already an integral and irreplaceable part of the defence systems of both the US and the USSR. In the 1990s, space became a key component of military planning. The Persian Gulf War Desert Storm of 1991 was later described as the first 'space war'; since it was the first time that the full range of military space assets were used for actual fighting.

The interest for military use of space was and remains strong, and will become even stronger as national security will depend more and more on space based systems. Such strategic interest, of course, spurs debates and policies about assets protection and in turn "space superiority" and "space control". In this respect a debate has been raging for several years about limiting space militarization to the current balance of applications and to forbid the deployment of space-based weapons.

In any case, military commands have an overall interest in transparent space operations as a way of preventing military incidents, and are becoming increasingly anxious about their capability to determine the nature (commercial or military) of satellites on-orbit as their population and miniaturization increase. They are even pondering the development of joint standards for station-keeping so that one military is not alarmed by a sudden manoeuvre of the other's satellite that was intended as station keeping, not as the beginning of an attack. It is therefore important to underline that an international civil regulatory framework for the space-exploitation-region might well be acceptable to many (military) parties because of the above need for transparency and because of the common general interest in safeguarding the space environment.

### 2.2 Commercial Space Exploitation

From an economic standpoint, space commerce has been important for several years and space-derived annual revenue exceeded $250 billion in 2008 according to the annual report of The Space Foundation [1]. This is primarily due to the extensive expansion of traditional sector of telecommunication satellite services. New commercial fields are emerging such as space-based navigation systems (e.g. GPS of the U.S., GLONASS of Russia, Galileo of the EU, Beidou of China, Quasi-Zenith Satellite System of Japan, IRNSS of India, etc.), integrated global remote sensing and space-tourism. Navigation systems may soon become the second pillar of space commerce. But apart from the capability to generate revenue and profits, commercial space-based systems have a strategic importance as catalyst for further and faster economic and social progress on a global scale.

From a safety regulatory perspective, the most important development was in the field of commercial launch services. In the main market, the United States, space transportation was initially an area of government monopoly. In the early 1980's difficulties in meeting an increasing demand, the phasing out use of unmanned expendable launch vehicles (ELVs) and the failure of the Space Shuttle to both reduce cost and increase launch frequencies eventually created a substantial commercial transportation market. In time the European commercial consortium Arianespace took a large share of this market as well as in other parts of the world. Later, the fall of the Soviet Union allowed a number of Russian and Ukrainian companies to enter the launch services market sometimes in joint venture with their western counterparts. In addition, Japan, China and India also entered the commercial launch market, while South Korea and Brazil will join them soon.

In the field of space transportation a new industry appears to be emerging. This is the enterprise sometimes called space-tourism or space adventures. This type of efforts was perhaps considered an area of serious undertaking ever since the successful *SpaceShipOne* sub-orbital test flights in 2004. There have been to date over 25 different concepts and vehicles under development of which 8 foresee horizontal take-off and landing capabilities. It should be noted that suborbital vehicles currently under development are largely based on mature technologies and proven operations concepts which are about 40 years old.

Nowadays the challenges are costs reduction and safety improvement. Many believe, however, that cost reduction currently acts as the most important driver in current design efforts. The first commercial—but still experimental—sub-orbital flights are expected to take place in 2010 and will be operated by the British company Virgin-Galactic. Concurrently, plans are also underway to plan, build and operate commercial spaceports in a number of places around the world. In addition to several such "spaceports" in the U.S. progress has been made in this direction in such locations as Barcelona, Dubai, Singapore and Sweden. When this "industry" is put into perspective, the sub-orbital space tourism enterprises may have little to do with space and much with Earth. Vehicles with sub-orbital flight capabilities have in fact the potential to be used at a later date for hypersonic point-to-point international travel, giving possibly rise (sooner than later) to "hypersonic-flight tourism". This, however, would also give rise to new environmental concerns as well.

For obvious reason of much higher complexity and cost, large scale orbital tourism developments are far behind. Orbital space tourism became reality in April 2001, through the use of Russian government vehicles and related infrastructure. Since then six space tourists have travelled on a Russian Soyuz spacecraft, which docked with the International Space Station (ISS). The 2006 saw a key milestone with the launch of an unmanned commercial demonstrator, the inflatable orbiting space station Genesis I, privately developed by Bigelow Inc. on quite solid bases of previous NASA research and patents. In 2007 the larger Genesis II launch followed.

Finally, NASA launched the demonstration phase of the Commercial Orbital Transportation Services program, with the final goal to contract with one or more space transport firms to deliver a given amount of cargo to the International Space Station each year. Eventually this may also include transportation and return of crew members and possibly private passengers if NASA chooses to exercise certain options to continue the development of commercial space transport capability to orbit.

### 2.3 Airspace and Space-Exploitation-Region Integration

The international airspace traffic control above oceans and high seas is very important not only for the safety of aviation global operations but also for the safety of space launch and re-entry operations. Major spaceports and launch sites are generally located close to the ocean coastline for the obvious safety reason of fast clearing inhabited areas. In some cases launches even take place directly from modified, self-propelled, ocean oil-drilling platforms, called ocean-going mobile launch facilities. These platforms because of their equatorial location can provide the most direct route to geosynchronous or "Clarke" orbit and maximum lift capacity. Spacecraft re-entry trajectories are selected as much as possible with similar criteria, and all controlled destructive re-entries are all aimed to the oceans.

States possess complete and exclusive sovereignty over their national airspace, which is defined as the atmospheric zone directly above their landmass and "territorial sea", which extends 12 nautical miles from the coast. Beyond that line, the airspace is defined as "international airspace" and does not belong to any one country. The Convention on International Civil Aviation of 1944 (Chicago Convention) placed international airspace under the authority of the International Civil Aviation Organization (ICAO). The ICAO delegates who are responsible for the provision of air traffic control services in this airspace to various countries is based generally upon geographic proximity and the availability of the required resources.

As aviation and space traffic continue to grow, ICAO has an increasing primary responsibility and duty of promoting innovative strategies to ensure the safety of the "integrated" air and space traffic in the international airspace, which is where air and outer space-related traffic mostly interact. In the future civil aviation will make more use of space-based systems for traffic management, approach and landing. Such systems are currently under development and make use of Global Navigation Satellite System (GNSS), like the American Global Positioning Satellite (GPS) System, plus various precision augmentation systems, and position broadcasting capabilities. Also in the case of rockets launches there is a forthcoming transition from ground based radar to GPS applications of safety (flight termination) systems. Such systems support one of the most important safety responsibilities of the launch range safety officer. This duty is to monitor the track of launch vehicles during flight and, in case of malfunction and risk for the public, to terminate the flight.

In the near future a number of safety critical aviation systems, from traffic control to high resolution weather forecasts and digital aviation communications will be based in space. This means that aviation safety will heavily depend upon the integrity and reliability of space based systems and services. In addition certain advanced technologies will precipitate a merging of interests. For example, terrestrial weather forecasts are essential also for space system safety during launch and re-entry, only recently has the aviation community become interested and indeed concerned about the dissemination of space weather forecasts and planning of related operational responses. Space weather is a collective term for radiation from a number of varying conditions on the sun plus galactic cosmic rays that have potential serious effects on electronic systems and on human beings. Solar radiation storms also known as Solar Proton Events (SPE) can increase the risk of errors and failures not only for orbiting satellites but also for safety critical aircraft electronic equipment such as flight engine management computers, and especially aircraft flying on polar routes. New technologies and progress with micro-electronics will in future further increase such failure risk because of their higher sensitivity to radiation.

Finally, the upcoming trend to operate hybrid systems (so called aero-spacecraft) from dual ground infrastructure (airport/spaceports) would ultimately seem to require a well integrated international regulatory framework both for flightworthiness certification and ground operations.

## 3. THE SPACE SAFETY RISK INTERNATIONAL DIMENSION

Since the beginning of human spaceflight 18 astronauts and cosmonauts have lost their lives in flight, which is about 4% of the total number of people who have travelled to space. An additional four have been killed on the ground during training. To date there have been an additional 200 people killed by rocket explosions during ground testing and processing, launch preparations and actual launches. And of those flight and ground accidents 35 causalities have come since the beginning of the 21st century.

In the last 10 years there have been at least six launches that were terminated by the launch range safety officer to prevent risk to the public. Several more cases have involved incidents whereby launchers did not manage to make it to orbit and crashed back to Earth. In fact, public risk criteria do not exist, and the actual distribution of annual risk imparted to the general public on Earth by space activities is completely unknown for the following reasons. First, only a few space faring countries have published their launch and re-entries risk acceptance criteria and risk mitigation measures. Secondly, waivers for non compliances with launch/re-entry safety requirements, when granted, are treated as confidential. Thirdly, risk assessments (when performed) are on a launch-by-launch (or re-entry-by-re-entry) basis with no consideration for previous launches/re-entries or planned launches/re-entries worldwide in the same year.

There is no single agency – national or international – that monitors and controls the ***cumulative*** risk imparted to over flown populations by launch and re-entry operations. A foreign city may be placed at risk by launches from multiple launch sites without the launching nations and interested parties performing any coordinated effort to assure that the risk levels are acceptable. Furthermore, debris generated during uncontrolled or off-nominal re-entries could cause casualties in the air (as well as at sea) which are generally not taken into account in the risk assessment models. For example, the Shuttle Columbia accident posed a serious risk locally to civil aviation due to falling debris. After the accident, the risk in the affected airspace was estimated to be in the order of 1/1000 for commercial airlines and 1/100 for general aviation [2]. (Afterwards new emergency procedures for the US airspace were put in place by FAA in coordination with NASA).

Environmental accidents such as failures leading to dispersal of radioactive material also have occurred. As of September 2009, there have been ten such cases. These incidents include the plutonium payload on board the Apollo 13 lunar module jettisoned at re-entry that ended up in the Pacific Ocean near New Zealand. Another case is the 31 kilograms of Uranium-235 that was spread over Canada's Northwest Territories when the Russian Cosmos 954 came back to Earth in 1978. The most recent accident of this kind was in 1996 when the Russian MARS 96 satellite disintegrated over Chile and released its plutonium payload that has never been located. There have also been several instances of severe ground chemical contamination as well. A Russian launcher failure occurred as recently as September 2007. This launch failure contaminated a large swath of agricultural land with some 200 metric tons of toxic rocket fuel.

Today, launchers release substantial ozone depleting substances in the stratosphere. This amount is estimated to be larger than the entire annual use of CFC-based medical inhalers once in use and now banned by the Montreal Protocol. Other toxic substances from rocket launches are believe to find their way into water supplies in many parts of the world [3]

Another factor affecting safety and sustainability of space activities is debris left in space. Currently, there are about 800 operating satellites. However, there are over 17,000 tracked debris objects that are greater than 10 cm in size. New tracking systems with greater sensing precision will soon be able to follow the paths of some 30,000 space debris objects. Perhaps even more relevant there are now millions of hazardous bits of debris too small to monitor. Even a paint chip flying at orbital speeds can do major damage to a satellite or a Space Shuttle window. Orbital debris includes "dead" satellites, launcher upper stages, pieces of metal, blobs of liquid metal coolant that leaked from discarded space reactors, debris resulting from satellite explosions, optical lens covers, paint flakes, etc. Some of this material will remain in Earth orbit for hundreds or thousands of years and constitute a potential hazard for operational spacecraft because of the high relative velocities at impact.

Because there is no international legal obligation to ensure that inoperative spacecraft are removed from orbit, many operators do not care to safely dispose them off at the end of the useful lives (e.g. by de-orbiting), and all failed satellites are just abandoned. The latest example of the ensuing danger is the accident that occurred on February 10, 2009. This incident was when a defunct Cosmos-2251 satellite and an active commercial Iridium-33 satellite actually collided in space in low earth orbit (Leo). This caused the total destruction of both satellites and generated a cloud of new debris that jeopardized the entire Iridium constellation and other Leo constellation satellites.

Finally, the expanding human space-faring club (including China, next India and perhaps one day Europe and Japan), as well as emerging commercial human spaceflight all serve to raise the issue of establishing international safety standards. These standards could include interoperability standards for space systems, provisions to allow mutual aid in case of emergencies during ascent/descent, on-orbit, and even agreement on hazards posed by extraterrestrial bodies.

## 4. A MANIFESTO FOR ORGANIZING SPACE

As activities expand in the space-exploitation-region (i.e. up to 36,200 km) it seems increasingly clear that a formalized and globally agreed framework of space safety standards and procedures is needed to assure safety and long-term sustainability of space operations. Such a future regulatory framework of safety policies and standards should be guided by international commitment to basic guiding principles. The International Association for the Advancement of Space Safety (IAASS) has worked for over a year to develop six such basic principles that are now reflected in its recently published "Manifesto".

Actually the need goes beyond agreeing on universally accepted policies and standards—although this is an essential first step. The next step is for institutions to take responsibility for their implementation. Such an institutional structure could be in the form of a brand new organization—or the reasonable extension of the responsibilities of existing regulatory agencies at the national and/or international level.

For example, in the United States, where space transportation safety regulatory responsibilities are already assigned to a specialized office of the FAA (i.e. The Federal Aviation Administration-Office of Commercial Space Transportation (FAA-AST), the extension of that office's mandate to oversee and establish safety regulations and standards for all commercial space operations might be prudently considered. Parallel thought might extend to the European Aviation Safety Agency (EASA). Then there is also the logical progression of thought that would suggest that the International Civil Aviation Organization in Montreal, Canada might be provided with expanded responsibilities in this area [4].

**Author's Note 1:** The Manifesto is the result of the collective effort of the IAASS and, in particular, this effort was led by the IAASS Technical Committees. The opinions expressed in the document are those of the IAASS members involved in the document preparation and not necessarily those of their employers.

**Author's Note 2:** The International Association for the Advancement of Space Safety

The International Association for the Advancement of Space Safety (IAASS), was legally established on 16 April 2004 in the Netherlands. The IAASS is a non-profit professional organization dedicated to furthering international cooperation and scientific advancement in the field of space systems safety. The IAASS aims at promoting a New Safety Culture in space activities. For more information, visit the association website at http://www.iaass.org/. Also in the United States there is the International Space Safety Foundation that works closely with the IAASS. Its web site is: http://www.issfoundation.org

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