4 Current questions regarding fair and responsible use of space – summarising introduction

Niklas Hedman

The first session of the Workshop reviewed overarching topics on the role of States and other actors in meeting common challenges to sustainable space governance. In determining the meaning of fair and responsible use of outer space in its broader perspective, the session addressed both civil and military use of outer space and focused its attention on the overall role of space-faring nations and emerging space nations in advancing international cooperation in space activities. The session comprised the following speakers: Peter Martinez on Fair and responsible uses of space: a perspective from an emerging space country"; Theresa Hitchens on "Peaceful use of outer space vs. militarisation: cost–benefit analysis"; Fernand Alby on "The space debris environment and its impacts"; and Giovanni Gasparini on "Space Situational Awareness: an Overview".

Peter Martinez in his presentation pointed to the large number of countries that lacked means to take full advantage of the application of space science and technology, and stressed the need for stronger involvement of all countries in efforts to enhance international cooperation in space activities. Theresa Hitchens made an analysis of military, economic and social benefits of space activities, and expressed that, given the increased population of space debris, which posed a real threat to both military and civil satellites, including commercial satellites and consequently to commercial interests, and the risk of conflict escalation and increased tension, there was indeed a high price to pay for "weaponisation" of outer space. Fernand Alby, who made an analysis of the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space in comparison with the debris mitigation guidelines of the IADC and other mechanisms, presented the view that in order to prevent future creation of space debris in orbit, there was a need for a stronger international regulatory regime with compulsory mechanisms. Giovanni Gasparini addressed Space Situational Awareness (SSA) as mechanisms to provide better knowledge and understanding of space assets and space-based systems in orbit, and the potential role such mechanisms, predominantly security-driven tools, could play for future information sharing and confidence building.

The discussions, following the four presentations, focused to a large extent on the role of emerging space nations and developing countries in current and future international cooperation. In view of changes in the geopolitical landscape over the past 50 years and the increase of actors in the space field, including from private and commercial sector, the need to better integrate different stakeholders, both governmental and non-governmental, and to better promote the access to space-based data was acknowledged. A need for a holistic approach in terms of protecting the Earth environment and space environment was determined, and through international cooperation there was a need for achieving better fairness and responsibility in space activities. The common use of outer space for peaceful purposes and the avoidance of allowing outer space become a theatre of war and conflict was emphasised. The strengthening of existing legal regimes and the need for enhanced application and implementation of key legal instruments were mentioned as important factors to achieve fair and responsible conduct of space activities. Likewise, in view of greater knowledge and awareness of the fragility of the space environment and the need for enhanced sustainability, there was a need to develop further mechanisms and regulatory frameworks for the protection of the space and planetary environment. The usefulness of looking more closely into different tools for the management of space activities, such as SSA mechanisms, and to strive for broader participation and application involving developing countries was also stressed.

4.1 Fair and responsible uses of space: a perspective from an emerging space country

Peter Martinez

Abstract

This paper examines the different notions of "fair and responsible" uses of space from the perspective of advanced and emerging space nations. For emerging space nations, access to space applications to support human and environmental security constitutes an important element in their understanding of "fair and responsible" uses of space. Space applications also support social development though provision of services and through supporting improved governance. The rapid evolution of the space arena means that there are now many more actors and many more possibilities for cooperation open to emerging space nations than in earlier years. This, too, raises issues of the "fair and responsible" use of space for both advanced and emerging users of the space environment. The paper ends with a brief reflection on whether the notion of "fair and responsible" use of space applies to space exploration from the perspective of developing countries.

4.1.1. Introduction

If one were to ask a number of people what they understood by the term "fair and responsible use of space", the answers would probably depend on the national origins of those answering. A person from an advanced space-faring nation might understand this term in the context of "space security" (which is in itself a term open to various interpretations), but essentially pertaining to issues *in space*. A person from a developing country without a space programme would have a very different view. To that person, "fair and responsible use of space" would pertain to issues *on the ground*, such as access to data or technology. The aim of this paper is to consider these two complementary sets of views in light of the rapidly changing international space arena.

When India established its national space programme in the early 1970s, it was with a clear view to using the unique perspective of space to address problems of national development, as so clearly elucidated in the following oft-quoted remarks by Vikram Sarabhai, the father of the Indian space programme:

> "*There are those who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned spacecraft. But we are convinced that if we are to play a meaningful role nationally and with the community of nations, we must be second to none in the application of advanced technologies to the problems of man and society, which we find in our country.*"

Sarabhai's comments were right on the mark. Today, space applications affect humanity and society in a major way, and among developing nations, India is a leader in the applications of space technology to societal development. Indeed, it could be said that space applications are now part of the plumbing of modern life, even in many developing countries without space programmes. So, what does the concept of "fair and responsible use of space" mean for emerging space countries, or, indeed, for countries that do not have space programmes?

In order to answer this question, we need to consider the particular needs and challenges facing developing countries in applying space technology, as well as the changing geopolitical context of space activities. This context today is very different (and changing rapidly) from what it was at the beginning of the Space Age. This different, changing context dictates that emerging space nations will follow a different trajectory of space development than that followed by the first space powers.

4.1.2. Space applications and the developing world

It is estimated that the world's population will reach about 9 billion people by the year 2050.[11] Almost all the population growth from the current 6.75 billion will take place in less developed countries. The growing population is placing growing pressure on the environment to meet adequately *all* the resource needs of *all* the Earth's inhabitants. This is a global challenge, not just one for developing nations, and space has the global reach to address it. Space applications support environmental security, disaster management and human security and form one of the cornerstones of the Information Society.

The space contributions to these areas are reviewed briefly in the following sections, with emphasis on their particular importance in the developing world.

4.1.2.1. Environmental security

It is a truism that the planet that matters most to us is the one we live on. This fact predicates the logics of the space programmes or space applications capabilities of developing nations. It also shapes their perceptions of what constitutes "fair and responsible" use of space.

Among a host of environmental issues, global climate change is currently a major political and scientific concern worldwide. Developing countries are particularly vulnerable to the effects of climate change. Space technology has played a significant role in establishing the scientific basis for determining that this is a real issue requiring collective and long-term action by the community of nations. There is now sufficient consensus that action is required, leading Governments to allocate resources to address these challenges and to enter into treaties that address policy areas of mutual concern.

Earth observation satellites support environmental security by providing global observations of many important environmental parameters. However, there is a need to address issues such as the lack of data consistency, fragmentation, gaps in coverage, as well as data accessibility and interoperability challenges. Programmes such as the Global Earth Observation System of Systems (GEOSS) and Europe's Global Monitoring for Environment and Security (GMES) have started to address these data-related challenges.

There is another way that Earth observation satellites support environmental security, and that is through supporting the development and implementation of environmental treaties. This occurs throughout the whole treaty cycle. In the pre-negotiation phase, satellites can be used as an agenda-setting aid by providing global data that help us to identify and quantify the extent and magnitude of the problem. In the negotiation phase, satellite data can be used for assessments of the status quo and for target setting. In the implementation phase, satellites support monitoring and reporting requirements (e.g., as stipulated in the Kyoto Protocol). Satellite data can support treaty enforcement at national and international level in matters such as compliance verification and dispute resolution. A more detailed consideration of the role of satellites in supporting environmental treaties is given by Peter.[12]

Much work has been done by many actors to promote the usage of space applications for development. Despite this, there are still a large number of countries that lack the means to take full advantage of space applications benefits for environmental security. There are several reasons for this:

(a) *Earth observation applications on environmental issues are in the nature of a "public good" activity.* Such activities are normally undertaken by governments, but governments in developing countries often lack the resources and expertise to tackle the issue. Since there is no commercial incentive to develop applications locally, industry does not play a role, and hence the potential benefits are not realised.
(b) *Affordable, timely, appropriate and complete data are often not available.* The cost of data access can be prohibitive for developing countries, or the necessary data are simply not available.
(c) *The challenge of operationalisation.* The space community is replete with examples of successful pilot projects by space agencies that demonstrate the utility of space applications to environmental issues. However, it is very difficult to convert these projects into *operational* programmes.

With regard to (a) and (b), initiatives such as GEOSS and GMES are starting to address some of these issues. With regard to (c), I believe that there needs to be a closer engagement with the development sector to get space into the mainstream of development aid thinking. Often space is regarded as "too high-tech" for developing nations and is not seen as a development tool, in the same way as providing pumps or trucks, or building roads. Space is part of modern infrastructure for enabling the information society, just as the traditional infrastructure of roads, railways and harbours enabled the industrial society. Seen in this light, the development aid sector might be prepared to work more closely with the space sector to help build up the modern infrastructure of developing countries. This could involve the private sectors in developed and developing countries, thus addressing issue (a) above as well. Indeed, such an approach could contribute to a more "fair and responsible" use of space by the developed space-faring nations to address global environmental security concerns to the benefit of all nations. In so doing, it would de facto create more equitable access to space benefits for all nations.

4.1.2.2. Space applications for disaster management

If there is one area where the different types of space applications complement each other perfectly, then it is in the area of disaster management. Space applications can be used in all phases of the disaster management cycle – from risk assessment, through the acute disaster phase and the recovery phase afterwards. Because of the humanitarian aspect of disaster management, this is perhaps the area with the best examples of equitable access to the benefits of space.

The challenge to successful implementation of space-based disaster management can be summarised as the need to deliver:

- the right information;
- in the right form;
- to the right people;
- in the right place;
- at the right time.

Space tools can address each of the links in this chain, but in practice this is a complex challenge to overcome. The reason for this is that it is not the technology per se that is the problem, but rather the interface between the space community, who are comfortable with space tools, and the disaster management community, who are not familiar with these tools. In order to make full use of space-based disaster management tools, ways must be found to integrate space more effectively into intuitive, easy-to-use tools for responders on the ground. This could be accomplished through exploiting existing interfaces known widely to non-space users (e.g., Google Earth). Responders also require training in the use of even "simple" space tools. For example, responders were issued with satellite phones during the hurricane Katrina disaster. Many problems were experienced by first-time users unfamiliar with this technology; e.g., trying to make calls from locations where no satellite signals could be received, or thinking that the satellite phones could overcome disrupted terrestrial mobile services, and so on.

The International Charter on Space and Major Disasters has proven to be an extremely positive step for securing urgently required imagery of areas affected by disasters. Since January 2002, the Charter has been triggered 183 times for disasters on all populated continents. In spite of this, some nations still report "difficulty" in activating the Charter. This points to problems of coordination: the Charter coordinates capability in space, but it seems that coordination is lacking on the ground in the disaster management community in some countries. Simply put, the mechanism for triggering the Charter in those countries is not yet well known and established in their disaster management communities. This is perhaps one area where the UN-SPIDER initiative for coordinating space-based disaster management will be able to make a difference.

Instruments such as Charter and the new UN-SPIDER platform for space-based disaster management are examples of "fair and responsible" uses of space for the benefit of all mankind.

4.1.2.3. Space and social development

Satellite communication is a cornerstone of the global information society. It is also a potent enabler of development, especially in countries with poor fixed terrestrial communications infrastructure. The following are some of the activities enabled:

(a) *Tele-medicine/health and tele-education:* Tele-health services can help developing nations to inform their populations on a wide range of health issues (such as HIV/AIDS, avoidance of diseases such a cholera, etc.) and to overcome shortages of doctors in remote areas. Tele-education provides the means to overcome shortages of teachers and teaching materials in remote areas.

However, four elements all need to be in place for a successful operational implementation of such services. First, connectivity must be robust. The infrastructure and support system must be established (ground terminals, training, technical support). Second, the tele-education/health activities must be integrated with the local educational system (and curriculum!) and with the local medical services, respectively. Third, educators and medical personnel must be properly trained in the use of this technology. Fourth, there should be seamless integration of the distant and in situ health/education systems. These are all issues that must be resolved *on the ground*, not in space. Among developing nations, India provides perhaps the best examples of space systems that are fully integrated into a variety of areas, ranging from fisheries to agriculture, medicine and education.

(b) *Improved governance:* Satellite communication can also be used to "bring government to the people". For example, people in rural communities without government offices can access government information and submit forms electronically ("e-filing") without the expense of travelling to cities to submit applications for identity documents, birth certificates, pension payments, etc. This technology has also been used in South Africa to link the people in remote isolated communities to their elected representatives in Parliament, over a 1000 km away.

With regard to "fair and responsible" use of space in the domain of satellite communications, the dominant issue for the developing countries is access to spectrum and orbital slots in geostationary orbit. Every year, developing countries

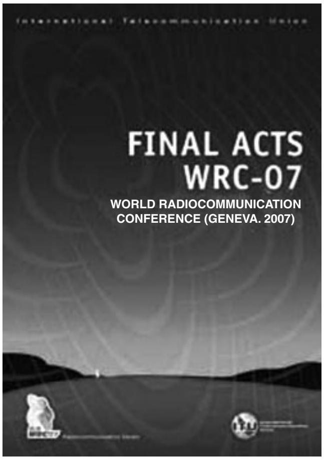

Fig. 1. *2007 World Radiocommunication Conference (source: ITU).*

in COPUOS reiterate this view and point out that there is a difference between the ideal "paper" situation and the situation in practice in geostationary orbit.

In the developing world the C band is widely used, partly because there is a well-established infrastructure in place, but also because of the cloud-penetrating ability of C-band radio frequencies. But there is growing pressure on the C band from military and civilian users. In the 2007 World Radiocommunication Conference the satellite communications operators led a strong lobby against a push by the terrestrial mobile technology operators to use the C band. The Congress voted to safeguard the C band for satellite users, essentially affirming the view that this is a "fair and responsible" use of space (Figure 1).

4.1.3. The evolving space arena

4.1.3.1. From prestige-driven space age to information-driven space age

The space arena was shaped historically by the cold war context in which it developed and was driven by rivalry (political, military, economic) between the two key actors, the USA and the USSR. The principal driver was international prestige for their two competing economic and political systems. The early Space Age was marked by competition, rather than cooperation, and space was seen as a platform for projecting national power. Cooperation in space activities was therefore mostly intra-bloc, with a few notable exceptions, like the Apollo-Soyuz Test Project.

We are now in a second Space Age, which is driven by *information* as a commodity. This period began with the end of the Cold War and is characterised by the use of space technology to provide information for security and prosperity. This period has seen the emergence of the commercial space sector as a major player, both in terms of the space industry and terrestrial industries based on assets in space. The former includes the large space contractors and the many smaller companies that form part of the global space system supply chains. The latter includes the communications and broadcast satellite operators, the GNSS industry and an emerging Earth observation data distribution industry (along the lines of Google Earth). Together, these industrial groups have allowed the emergence of global utilities, such as satellite navigation/timekeeping, communications and Earth observation, bringing the benefits of space applications directly to many millions of individual users.

4.1.3.2. Growth in number and diversity of actors

There are now many more actors in the space arena than in the first two decades of the Space Age. By 2005, there were 36 national space agencies (on all continents).[13] By 2007, 10 actors had demonstrated independent orbital launch capability and 47 States had launched civilian satellites, either independently or in cooperation with others.[14]

In the early days of the Space Age, the actors in the space arena were all States and their national space agencies. However, there is now a much more diverse set of actors. Industry has become a major player in terms of enabling new actors to enter the arena. Non-governmental organisations (NGOs) are also playing a significant role in allowing new actors to enter the arena. This is especially so in the case of international professional organisations, such as the IAF, the IAA, COSPAR and others. These NGOs provide a forum to bring together a diverse set of actors in an informal setting to discuss matters of mutual interest in a way that may not be possible in inter-governmental organisations.

The appearance of more actors and a higher level of activity in space means that there will be more pressure on available orbital and spectrum resources, more pressure on the space environment and consequently a greater need for coordination. On the other hand, it also means easier access to space data and services from a variety of sources. Established and emerging space nations and non-space nations will all have different views on what constitutes “fair and responsible” uses of outer space. These matters will have to be debated in global space fora to reach a common understanding and to define accepted rules of conduct.

4.1.3.3. Increasing reliance on space capability by the military in more countries

An increasing number of States are making military use of the full range of space applications. To date, 14 States have launched dedicated military satellites and as more countries enter the space arena, it is likely that their militaries will follow. The military also makes use of commercially available data (e.g., Earth observation) and services (e.g., communications) to supplement their own capabilities.

There is also a trend to integrate military and civilian applications into dual-use satellites. This makes sense from a technological perspective since there is no intrinsic difference in the technologies required by civilian and military users. The only difference is in the applications. Such dual-use systems are also attractive for emerging space nations, which may not have the resources to develop separate military and civilian space programmes.

However, there are also some disadvantages to combining civilian and military functions on a single satellite. Dual-use satellites can become potential targets in conflict situations and they could also be an impediment to cooperation or commercialisation if the military partner is sensitive about the technical details or orbital parameters becoming widely known.

4.1.3.4. Changing patterns of cooperation

In the early days of the Space Age, international cooperation was mostly intra-bloc, with few exceptions. With the growth in the number of space-faring countries, there is now a much wider spectrum of possibilities for cooperation.

A number of regional cooperation structures have emerged over the past 20 years. These structures have arisen from initiatives by the leading space countries in each region, acting as aggregators to promote the application of space technology throughout their region. In the Asia-Pacific region, two regional structures have emerged, the Asia-Pacific Space Cooperation Organisation (APSCO), under the leadership of China, and the Asia-Pacific Regional Space Agency Forum (APR-SAF), under the leadership of Japan. The principal regional cooperation structure in the Latin American region is the Space Conference of the Americas. Beginning in 2005, the African region started the African Leadership Conference on Space Science and Technology for Sustainable Development. The latter two regional conferences aim to raise awareness and the political profile of space among the governments of the region and have yet to establish operational space programmes. The Asia-Pacific entities have made somewhat more progress in this regard: APSCO is working towards a constellation of small satellites for environmental monitoring and disaster management, while APRSAF has implemented the Sentinel Asia programme for satellite-aided disaster management.

Fig. 2. *Second meeting of the interim Council of APSCO (source: CNSA).*

Fig. 3. *15th Session of APRSAF in December 2008 (source: JAXA).*

Another development is the growth in South–South collaborations among the intermediate and emerging space countries. An example of this is the China–Brazil CBERS cooperation in the development and operation of Earth observation satellites.

The established space-faring nations have very extensive cooperation programmes, and are also seeking to cooperate with intermediate and emerging space countries. Of course, cooperation is often driven by objectives such as strengthening strategic alliances, or using space to boost national prestige and regional influence, or to promote and sustain space industrial capabilities. All of these drivers lead in some cases to a sort of "competition to cooperate" with emerging space countries (Figures 2 and 3).

4.1.3.5. Rise of global utilities

The use of space technology is no longer the preserve of space experts. The development of intuitive, easy-to-use interfaces has seen enormous take-up of satellite broadcasting, communication and GNSS services by the general public. The take-up of Earth observation has been slower, but is developing at a rapid pace, as more intuitive interfaces (such as Google Earth) become available.

The easier access to space data and services has created greater demand for such data and services, thus fuelling the growth of profitable distribution channels. In the past, space agencies established entities to sell on a commercial basis data or services from agency-owned satellites. These operators soon realised that direct distribution space networks could generate large profits, so they started to acquire and operate their own space systems. Examples of this are satellite communications companies (such as Luxembourg-based SES Global) and more recently in the Earth observation domain the Google Earth partnership with GeoEye for acquiring its own data. The market for space data and services is now being shaped more and more by the entities operating the distribution channels to end users, rather than the providers of the space capabilities. Information distributors are now *owners* of space systems and are shaping user demand to create new markets for space-derived/delivered information.

The ready availability of ever-higher resolution imagery, satellite communication services and GNSS signals can promote as well as harm human security. From a space security perspective, military and security bodies will resist these developments, particularly in regard to imagery distribution, but the growing number of actors and the enormous reach of the internet will make it impossible to enforce restrictions indefinitely. Governments will have to face up to international public scrutiny and will no longer have a monopoly on the acquisition or interpretation of imagery. Already, there are a number of NGOs and news organisations that have made use of satellite imagery to document human rights abuses. This is surely an example of "fair and responsible" use of space.

4.1.3.6. Role of commercial space actors

The private sector is becoming an enabler of new space programmes. As of January 2008, 47 civilian entities had accessed space.[15] Quite a number of those did so with assistance of the commercial sector. The established Big Players in Europe and (to a lesser extent) North America are seeking emerging markets outside of their regions. Some are more constrained than others by regulatory barriers concerning technology transfer, such as the United States' International Traffic in Arms Regulations (ITAR). China and India are more recent entrants into the commercial space arena and can offer access to space or complete space systems delivered to orbit for emerging space countries. An example of this is the Nigerian communications satellite NigcomSat-1 built and launched for Nigeria by China's Great Wall Industry Corporation. In some cases, these actors are partnering with established large European players to offer "bundled" and/or "ITAR-free" services. In future, the personal spaceflight market will also provide space access opportunities to emerging nations.

Industry is starting to play a catalytic role in establishing international cooperation. An example of this is the Disaster Management Constellation, a cooperative project among Algeria, China, Nigeria, Turkey, and the UK in which Surrey Satellite Technologies Limited has played a catalytic and leading role.

If the history of human exploration and settlement is anything to go by, in future wealth will be created in space as well as on Earth. The commercial sector is today paving the way for these future developments, which will give rise to another set of debates on what constitutes "fair and responsible" uses of space. The history of the 1979 Moon Agreement, or, indeed, the 1982 United Nations Convention on the Law of the Sea, both with references to the Moon or the deep seabed and their resources as "the common heritage of mankind", shows that this will not be an easy debate.

4.1.3.7. Growing interest in space exploration in a country marks transition from emerging to intermediate space power status

Some emerging and intermediate space nations are beginning to adopt a view of space that goes beyond its purely utilitarian applications, providing an impetus for others to follow. There is a growing interest in manned spaceflight by countries that have not had this capability in the past. China has demonstrated human spaceflight capability and India is well on the way to doing so. This has given rise to other actors in the Asia-Pacific region initiating human spaceflight programmes, such as Korea and Malaysia, which have current astronaut development programmes taking advantage of flight opportunities offered by other nations. On the African continent, Nigeria has indicated an intention to do likewise in future. The burgeoning space tourism industry will provide more flight opportunities, not only for astronauts, but also for lofting small satellites or for performing scientific research in microgravity.

4.1.4. Preserving the space environment through "fair and responsible" use

4.1.4.1. Security on Earth underpinned by security in space

More and more, security on Earth is linked to security in space. As more States become actors in the space arena, the orbital environment will become a more crowded and complex environment in which to operate. To date, 29 States have demonstrated sub-orbital launch capability and 11 have demonstrated orbital launch capability. Security in space (just like security on Earth's roadways) will rely on the orderly and predictable behaviour of all users.

Perhaps the aspect of space security that is of most immediate concern to emerging space nations is that of preserving the Earth's orbital environment as a safe area in which to operate satellites, free from risk of disruption by space debris. This is an area in which the emerging space countries have a direct and critical contribution to make to "fair and responsible" use of space.

Space debris poses a serious threat to the space activities of developing countries, which may not be able to replace assets lost on orbit. The threat of impacts by debris will drive up development and insurance costs. The loss of an active spacecraft to debris impact may erode political support for space programmes in developing nations – operating satellites may be perceived to be too risky to justify the expected benefits of investment.

Because of the greater number of operational space systems in orbit, and the large and growing debris population, emerging space nations do not have the luxury of repeating the lessons learnt by the more established space nations in the early days of the Space Age. Emerging space nations should therefore take a number of steps to ensure that they are "fair and responsible" users of space. Such steps include:

- Developing space situational awareness capabilities, linked to those of other countries.
- Choosing launch service providers carefully and responsibly to minimise the chances of adding to the debris population.
- Adopting debris mitigation standards modelled on COPUOS/IADC voluntary guidelines, to be applied in the development and licensing of satellites, and in the selection of domestic and international component suppliers and launch service providers.

4.1.4.2. International cooperation as a means to preserve space security

One of the best means to enhance space security is to promote cooperation among the established and emerging space powers. Although bilateral cooperation is the favoured mode of cooperation among space agencies, large networks for collaboration (e.g., the Group on Earth Observation or the Global Exploration Strategy) lead to greater transparency and build confidence, mitigating mistrust and uncertainty as more countries gain access to space.

The established international legal regime for outer space activities (Table 1) provides another basis to promote transparency and responsible uses of outer space. The first four outer space treaties listed in the Table provide a basis for ensuring sustainable, equitable and secure access to space for current and future users of space. However, many States still have not acceded to these four treaties, including some COPUOS Member States. The fifth Treaty, the Moon Agreement, which

Tab. 1: *United Nations Outer Space Treaties.*

Treaty	Year	Ratifications
Outer Space Treaty	1967	98
Rescue Agreement	1968	91
Liability Convention	1972	87
Registration Convention	1975	48
Moon Agreement	1979	12

Source: United Nations Office for Outer Space Affairs.

attempted to deal with the notion of sharing the benefits of resource exploitation on the Moon, does not enjoy wide support among the leading space powers. Almost all of the ratifications of this Treaty are by countries not involved in lunar exploration. I will return to the issue of space exploration and developing countries in the last section of this paper.

The Outer Space Treaty, Rescue Convention and Liability Convention are all premised, to a certain extent, on the ability of States to identify the launching or responsible State for a given space object. The Registration convention makes provision for the identification of launching States with responsibilities for certain space objects. Out of 5734 payloads launched as of January 2008, 282 were not registered, and in recent years the trend of non-registration has been growing.[16] This should be a cause for concern to all space-faring nations.

While there is broad acceptance among States for the need to discuss "rules of the road" in the space arena, different States have different views concerning the implementation of such rules. Some States advocate non-binding, voluntary measures to address space security issues; others insist on a binding, treaty-based approach. Since the principal international space law-making body, COPUOS, operates on the basis of consensus, the effect of such disagreement could be to block progress on various fronts.

4.1.5. What about space exploration?

Through space exploration humanity is taking its first tentative steps from its cradle on Earth into the universe as a space-faring species. The immense public interest in international focus periods such as World Space Week in many developing countries with no space programmes demonstrates that people everywhere are excited by space exploration. So, what role is there, if any, for developing countries in the space exploration enterprise? In answering this question, we can recall that Article 1 of the Outer Space Treaty of 1967 reads as follows:

> "*The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.*"

It is interesting to note that space exploration is no longer the exclusive preserve of just a few major space powers. Some intermediate space powers and even some non-governmental entities (e.g., the Google Lunar X Prize and the International Lunar Observatory Association) are becoming active participants in the space exploration enterprise too. The appearance of these new actors potentially provides some new opportunities for emerging space nations to engage in the exploration enterprise.[17]

With more countries becoming involved in space exploration, it is clear that some form of coordination would benefit all stakeholders in the exploration enterprise. The Global Space Exploration Strategy[18] was adopted by the space agencies of 14 countries in May 2007. The Strategy is based on the premise of our common human destiny in space, as evinced in the opening remark of Chapter 1 of the strategy: "Space exploration is essential to humanity's future". In the closing remarks of Theme 4: A Global Partnership, the document states: "It [the strategy] is inclusive; the goal is to expand the opportunity for participation in space exploration to all nations and their citizens". However, the document does not address *how* to expand the opportunity for participation by developing nations, nor does it point to a process for doing so.

I would argue that, in its present form, the Global Space Exploration strategy is really an international strategy, not a global one. The word "global" is defined to mean "of or relating to the whole Earth". Yet, there were no agencies from Africa or Latin America listed among the organisations involved in drafting this document. Indeed, one would be hard pressed to find any emerging space nations represented among the countries that have developed this document. This lack of representation by a significant fraction of the world is reflected in the content of the document. In the 25-page document the phrase "developing world" occurs only once in a mention of a portable TB diagnostic tool developed as a spin-off of Mars exploration. The word "Africa" appears twice in the document in a reference to humans emerging from "ancient Africa".

So, is this an issue of "fair and responsible" use of space? I would argue that it is, because the "global" exploration enterprise seems to be leaving the developing world behind. For these countries, participation, even at a very modest level would have enormous national impact. Firstly, it would provide an opportunity for the scientific community in these countries to participate in a cutting-edge endeavour. Secondly, and perhaps more importantly, it would generally promote science and mathematics education in those countries, thus raising the general level of science and mathematics literacy. Some consideration should be given to creating mechanisms that would allow emerging space actors and even interested non-space-faring countries some opportunities to participate in the collective human adventure of space exploration, so that it becomes truly a global endeavour. Perhaps the main benefit of promoting a truly global space exploration agenda is that it would strengthen international cooperation in the peaceful use and exploration of outer space, thereby promoting a globally shared notion of the fair and responsible uses of outer space.

[11] United Nations. World Population Prospects: The 2004 Revision Highlight. United Nations Publication ESA/P/WP.193: Department of Economic and Social Affairs, Population Division. New York, United Nations, 2005.
[12] Peter, Nicolas. "The Use of Remote Sensing to Support the Application of Multilateral Environmental Agreements." Space Policy 20.3 (2004): 189–196.
[13] Peter, Nicolas. "The Changing Geopolitics of Space Activities." Space Policy 22.2 (2006): 100–109.
[14] Spacesecurity.org. Space Security 2008. Waterloo: Spacesecurity.org, 2008.
[15] Ibid.
[16] Ibid.
[17] Noumenia Project Team. Noumenia – Building on the Google Lunar X Prize: Recommendations for Future Activities on the Moon and Beyond. Strasbourg: International Space University, 2008.
[18] "Global Space Exploration Strategy: A Framework for Coordination." 31 May 2007. JAXA Press Release. 16 Mar. 2009. http://www.jaxa.jp/press/2007/05/20070531_ges_e.html.

4.2 Peaceful uses of outer space vs. militarisation: a cost–benefit analysis

Theresa Hitchens

4.2.1. Introduction

While questions regarding the future security of space often pit military uses against civilian – or “peaceful” – uses, reality is much more complicated. The world has benefited both from the militarisation of space and from progress in civil and commercial uses. Put simply, the use of space provides military (and thus security), economic and societal benefits.

Nor can the military and civil space spheres be easily separated. This is because space is a special environment, dominated by the laws of physics. Thus, both military and civilian assets in space must use similar orbits to accomplish different, but fundamentally similar, missions – such as Earth observation and communications. Further, due to the continued high costs of getting to orbit, many satellites, both those owned by commercial entities and those owned by governments, serve dual functions: providing services to both national militaries and civil society.

In addition, orbital assets face the same basic set of threats to their functionality and survivability from what is a fundamentally harsh environment. Space debris, solar flares, radio frequency interference all can create serious, or deadly, problems for satellites and spacecraft. For example, space debris – which is widely recognised as a growing problem because of the enormous damage it can wreak upon space craft upon impact – does not discriminate between military and civil satellites, or between satellites owned by one nation or another.

Finally, analyses of future space security often focus on the use of space by nation states – thus driving any debate down to the narrow concerns of national security. This often results in “zero sum game” thinking; i.e., the construct that one nation’s gains in space capability, be it military or civil, results in a loss for another nation’s security. But framing the debate in this manner misses a critical point: outer space is the ultimate globalised environment. Not only do about 50 nation states own and/or operate satellites, but also independent actors such as multinational firms, universities, academic consortia and even non-governmental organisations are increasingly active in either operating satellites or utilising data from them in novel (and non-state-centric) ways.

The bottom line is that actions by any one space sector, or even by any single space operator, affect all others. In particular, this raises questions regarding the trade-offs between actions that may improve military capabilities, but actually threaten civil and/or commercial capabilities.

4.2.1.1. Space is militarised but not weaponised

Another key factor in weighing how future uses of space will affect the security and sustainability of space operations is the fact that while the space environment can be said to be "militarised", it has not yet been "weaponised". That is, many nations and groups of nations use space for military purposes, but no nation has deployed dedicated weapons in space, or those designed to destroy satellites. This distinction is crucial. Arguably, the history of restraint among the world's space-faring powers regarding space warfare has allowed the rapid development of space activities that benefit humankind, in both the economic and scientific arenas. This is because the advent of anti-satellite (ASAT) and/or space-based weapons – and thus the subsequent threat of warfare in space – would dramatically increase the risks to spacecraft of all kinds – thus quite probably increasing the already high "costs of entry" for civil and commercial players.

Unfortunately, this situation may be changing due to improved technology, reductions in the cost of building and operating satellites and the increased perception of the military value of satellites among potential combatants. Evidence of this creeping trend towards weaponisation, after decades of relative quiescence in military space competition, includes: the Chinese testing of an ASAT weapon in January 2007; the U.S. decision to "shoot down" an ailing spy satellite in February 2008 using modified missile defence technology along with the strengthened U.S. doctrine of "space control";[19] and open debate in countries such as India, Israel and Russia about the potential value of ASATs and/or space-based weapon systems.

So, the central question to be addressed by this paper is more aptly: what are the costs vs. benefits for the sustainable and secure use of space by all stakeholders (military, civil and commercial) of increased militarisation and weaponisation of space? To answer this question, one first must review the benefits of space usage to the military, economic and civil society sectors; then consider the costs of increased militarisation and/or weaponisation to all three sectors.

4.2.2. Military benefits

It cannot be denied that outer space has been militarised since the dawn of the space age. During the Cold War, the Soviet Union and the United States actively, if often secretly, engaged in research and development of ASATs, space-based weapons and war fighting concepts that would utilise space as the proverbial "high ground" of battle. While the superpowers' interest in the potential of space warfare eventually ceded to concerns about the possible affect of space-related weapons on the arguably more important nuclear balance between the two sides, both Russia and the United States have continued to pursue separate military space programmes designed to enhance both strategic goals such as deterrence and performance on the battlefield. Meanwhile, many other nations have entered the fray: China, France, Germany, Italy, Israel, Spain and the United Kingdom all have, to a greater or lesser extent, dedicated military space assets. India, Japan, Iran and North Korea have similar potential, and some apparent interest in pursuing such a course.

Interestingly, in the recent past most military space programmes were dedicated to "strategic" purposes: missile and nuclear warning, intelligence gathering and verification of treaties and agreements (whether bilateral or multilateral) and communications. However, since the 1990s, military usage of space has shifted towards applications designed to enhance tactical operations on the battlefield. For example, the Global Positioning System (GPS) satellite navigation system is

A Space Enabled Reconnaissance-Strike Complex: The New American Way of War

KTO, 1991	Unguided	245,000	92%
(Desert Storm): 37 Days	Laser/EO-guided	20,450	8%
1 Mbps/5K Forces			
Serbia, 1999	Unguided	16,000	66%
(Allied Force)	Laser/EO-guided	7000	31%
78 Days; 24.5 Mbps/5K	GPS-guided	700	3%
Afghanistan, 2001-02	Unguided	9000	41%
(Enduring Freedom)	Laser/EO-guided	6000	27%
90 Days; 68.2 Mbps/5K	GPS-guided	7000	32%
Iraq, 2003	Unguided	9251	32%
(Iraqi Freedom)	Guided	19,948	68%
29 Days; 51.1 Mbps/5K			

Fig. 4. *Power Point Chart (courtesy of Lt. Col. (ret.) Peter Hays). Legend: KTO, Kuwaiti Theatre of Operations; EO, electro-optical; Mpbs, megabits; 5 K, bandwidth usage per 5000 troops.*[20]

increasingly used by the U.S. military to guide so-called "smart bombs" with greatly increased accuracy over older munitions using only inertial guidance systems, as well as for tracking U.S. forces (down to the individual soldier level) in the field (Figure 4).

Increased bandwidth for communications has led to a revolution in the amount of data that can be transmitted to commanders and forces in the field, including detailed imagery – the quality of which has improved greatly in the last two decades. Weather satellites further allow advanced planning in a way that would have been impossible in the Second World War.

In sum, space now provides huge tactical advantages to militaries who can harness it: improved battlefield awareness; 24/7 connectivity; rapid mobility; rapid and accurate strike capability; and fewer casualties, both to one's own military personnel as well within the civilian population.

There also are arguably new tactical advantages to be gained from the advent of ASATs and space-based weapons. ASAT weapons could eliminate some of the battlefield advantages provided by satellites illuminated above, as well as complicate long-range strike capabilities and make an attack more risky for the attacker. Further, some ASAT technologies – particularly ground-based kinetic energy (hit-to-kill) missiles – are already available and are relatively low cost compared to the price tag of space assets themselves. Space-based weapons (to target satellites, missiles or ground facilities) potentially provide global reach and 24/7 access to targets. They would further complicate the use of ground-based ASATs by an enemy, thus potentially reducing risks to one's own space assets. Therefore, it isn't difficult to understand why some military commanders are interested in such capabilities.

4.2.3. Economic benefits

It is obvious that the development of space as a commercial sector has brought economic benefits (as well as societal benefits, to be discussed below) to both those nations and companies operating satellites, as well as to the global public at large. What is actually harder to do is to quantify both the size of commercial space economy and specify the benefits resulting from that economic activity. This is largely because no nation state or global institution actually runs the traditional numbers on space commerce that are calculated annually for other economic sectors such as agriculture or the auto industry. Even the United States, which has the largest space economy (including military spending, spending by civil agencies such as NASA and the National Oceanic and Atmospheric Administration and commercial activity), keeps no statistics quantifying either the size of the military space budget, nor does it compile the basic facts about commercial space activities, services and benefits. According to a recent study by the non-governmental group Economists for Peace & Security: "The lack of reliable economic indicators represents an important gap in our knowledge abut the space economy and is a major impediment in the making of rational space policy."[21]

While some space-related industry groups and international institutions attempt to compile annual or semi-annual statistics, their methodologies differ as do their source materials. However, what can be seen from the statistics that exist is that space is a big business, and getting bigger every day. There are about 899 active satellites in orbit, with 390 owned by commercial firms or consortia and another 283 civil/non-military government-owned.[22] (That is, about two-thirds of the working satellites are not military owned/operated.) The Space Foundation, a U.S.-based non-profit dedicated to promoting the space industry, estimates that international revenue from government and commercial ventures at 251 billion U.S. dollars in 2007, up 11% from 2006.[23] The Organisation for Economic Cooperation and Development (OECD) estimated the global employment in 2006 in space industry manufacturing alone (with space services such as GPS receivers being the largest industry sector) at 120,000.[24] The U.S. Federal Aviation Administration (FAA), which is increasingly interested in commercial space activities, recently found that in 2006 commercial space transportation generated 139.3 billion U.S. dollars in economic activity and 729,000 U.S.-based jobs.[25]

There are also enormous indirect benefits to the global economy from the use of space, which are equally difficult to quantify. For example, the growth in global commerce spurred by the Internet as well as the emergence of the Internet-based economy. GPS – developed and operated by the U.S. Air Force – also has been crucial in enabling near-instantaneous financial transactions, improvements in the efficiency of air, ground and sea transportation, as well as better utilities management. The worldwide communications networks enabled by satellites have spurred globalisation of many industries and with that economic development, including in the poorest nations. Remote sensing – capabilities that also have their origins in military research – has enabled increased production of agricultural products. These economic benefits, in turn, lead to benefits to human society around the globe.

4.2.4. Civil society benefits

Examples of the benefits to civil society from the use of space are legion. They include the creation of jobs, in both developed and under-developed nations; weather prediction and disaster warning; disaster monitoring and response;

tele-education and tele-medicine for remote, poverty-stricken areas; communications in otherwise under-developed regions; climate change monitoring; refugee monitoring and assistance; documenting and monitoring wars and resulting crimes against civilians; resource management; improved scientific knowledge of

Angaba closeup before attack (source: eyesondarfur).

Angaba closeup after attack (source: eyesondarfur).

the Earth, the solar system and the universe; and increased international cooperation. As in the commercial sector, GPS is of particular importance for many civil society applications – as most computer operations rely on GPS clocks. Thus, it must be remembered that technological progress spearheaded by militaries often, and particularly in this case, spin off to other sectors of human activity.

Again, these benefits are next to impossible to quantify, but they are nonetheless tangible. For example, in recent years with the increased availability and thus reduction in costs of satellite imagery, non-governmental agencies such as Amnesty International have been tracking and documenting atrocities such as the ongoing genocide in Darfur.[26] The advent of tele-medicine has helped hundreds of thousands of patients from the poorest parts of India to the Australian Outback to rural Appalachia in the United States.

4.2.5. Costs to militaries of increasing militarisation/ weaponisation

While many nations have recognised the benefits that space assets can provide for military activities and capabilities, there are also costs inherent in embracing military architectures that rely heavily on space.

Most obvious is the fact that developing, building, launching and operating satellites remain expensive. Launch costs for the past two decades have hovered between 6000 and 17,000 euros per kilogram (depending on payload weight, size of rocket and the desired orbit). Indeed, according to commercial satellite operators, launch costs have actually gone up by about 50% over the past few years despite long-standing government and industry efforts to reduce them. Further, military satellites traditionally are large: 3–5+ metric tons each. Finally, satellite lifetimes are limited: 7–15 years – meaning recurring costs in replacing them.

Less obvious is the fact that reliance on satellites creates vulnerabilities for military operations. Satellites and spacecraft are fragile assets, vulnerable to damage from any number of threats – from space debris to ASATs. For example, NASA has had to replace at least 80 windshields on the Space Shuttle since the dawn of the programme due to impacts with debris.[27] Even the Hubble telescope has been damaged by debris, with one such collision resulting in a 1 cm hole in one of its gain antennas (Figure 5).[28]

They are also quite difficult to protect. Shielding against impacts by anything larger than 1 cm in diameter is quite simply impossible. Satellites travel is predictable orbits, and can be tracked – and if enough assets are dedicated to it, targeted (particularly those in low-Earth orbit which are relatively easy to reach

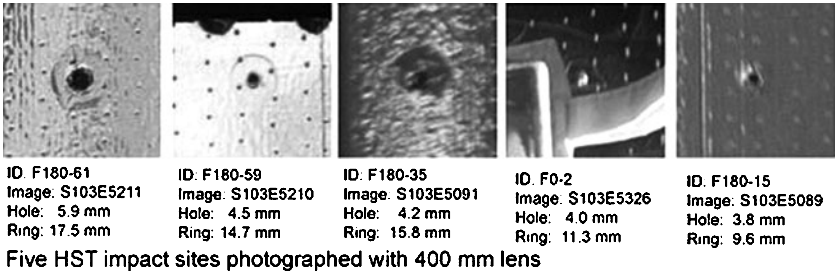

Fig. 5. *Holes in hubble telescope (source: NASA/JSC).*

using terrestrial-based missiles). Finally, the rapid diffusion of technology (ironically made possible by satellites!) means that advantages over potential adversaries are hard to maintain – thus ensuring that 'arms racing' in space is almost inevitable.

The spread of technologies applicable to ASATs has further increased the risks to military satellites. As satellites become more accessible as targets, the problem of reliance on them for critical military capabilities becomes more acute. The creation of dangerous debris from hit-to-kill ASATs – one of the most easily available methods for "killing" a satellite – adds to the threat picture. Finally, the potential use of ASATs in a conflict raises the likelihood of rapid conflict escalation, perhaps even up to the use of nuclear weapons.

And while space-based weapons might provide some advantages to achieving particular military missions, they would be expensive – and for many military missions the cost/benefit ratio wise other means of attack is negligible if not actually negative. Of course, space-based weapons are also just as vulnerable as other satellites. Perhaps most insidiously, the deployment by one nation of space-based weapons would increase incentives for others to develop means to target space-based objects, thus increasing the risks to all objects on orbit (including non-military) since it is fiendishly difficult to discriminate a space-based weapon from a perfectly benign satellite.

4.2.6. Commercial costs of increased militarisation/ weaponisation

The cost for development and production of a typical commercial communication satellite (according to operators) is between 140 million U.S. dollars and 180 million U.S. dollars (108 million to 139 million euros), and the launch adds another 120 million U.S. dollars to 140 million U.S. dollars (93 million to 108 million euros). Obviously, the loss of any one satellite due to acts of war would be a loss of this investment plus the loss of planned business revenue.

Unfortunately, the actual impacts of increased risks caused by further militarisation or weaponisation of space could be felt by commercial and civil operators even before any “shots were fired” in space.

A first, and well documented, impact of increased militarisation of space is restrictions on trade in space-related technologies that can hamper the ability of commercial companies to do business in an extremely globalised market. This dilemma is most obvious in the United States, where the subjection of commercial space technology exports to the International Traffic in Arms Regulations (ITAR) severely limits the transfer of technology and know-how. Under ITAR rules, if a non-U.S. firm buys any U.S.-made space-related systems or even parts, its future exports also become subject to U.S. export control. This is particularly problematic for trade with China, as China is the primary subject of U.S. export control concern in space – and the reason ITAR rules were slapped on space technologies in 1999.[29]

Space industry representatives and supporters of new space ventures such as tourism – from the American Institute of Aeronautics and Astronautics (AIAA) to the Space Foundation – have all slammed the ITAR regime as unworkable, and as reducing U.S. market share dramatically over the past decade.[30] Charles Huettner, executive director of the Aerospace States Association, said in July 2008, “ITAR has led to increased global competition and is a significant impediment to the U.S. space industry’s ability to market to foreign buyers resulting in decreased sales and competitiveness”.[31] Of increasing worry to U.S. satellite manufacturers is the successful move by European companies EADS and Thales Alenia Space to market “ITAR-free” satellites and large subsystems such as motors, even if they are more expensive than those made with U.S. components – with some efforts to develop European-only critical space components even being funded by the European Space Agency (ESA).[32]

Not so obvious is the pressure increased militarisation or weaponisation may place on operators who must weigh enormous investment costs against the likelihood of loss. In particular, insurance for launch and initial on-orbit operations increases this price tag by 8–10% currently, and that percent would of course go up in an environment considered more risky by insurance companies.

Most worrisome to commercial operators is the spectre of space warfare where not only are their own satellites targets (as many commercial satellites provide services to militaries and thus might be considered fair game in a fire-fight), but also where the combatants are using kinetic energy ASATs that create enormous amounts of debris. Even the destruction of a handful of large military satellites in low-Earth orbit could result in increases to the debris population that could render entire orbital bands unusable, or impassable, by spacecraft (Figure 6).[33]

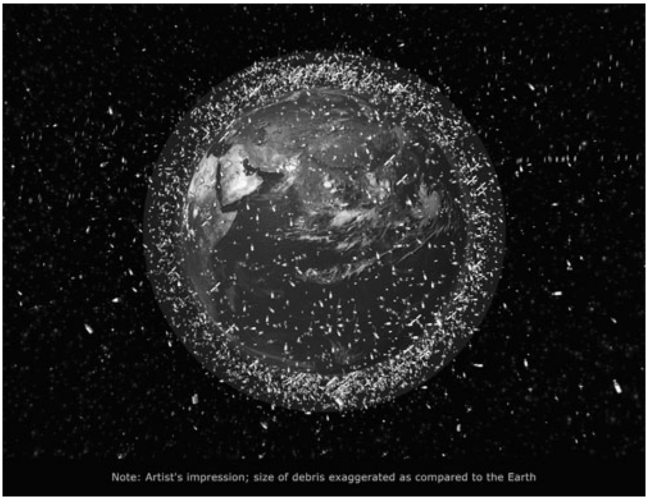

Fig. 6. *Current debris objects in LEO (source: courtesy, ESA).*

According to space market analyst Marco Cacéres of Teal Group;

> "*About the last thing that the satellite market needs now is the uncertainty that will accompany any moves to start blowing up objects in space or arming military satellites with protective countermeasures. The added debris problem is bad enough. An ASAT weapons race will have the effect of increasing the financial risk of any satellite programme, and undoubtedly be felt most within the commercial market through decreased investor confidence and (or) higher insurance rates*".[34]

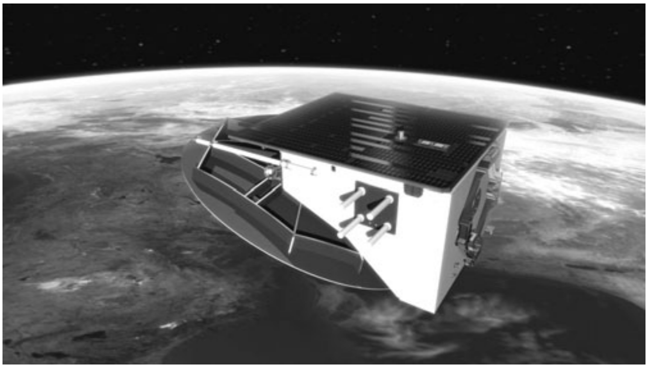

Fig. 7. *SAR-Lupe Illustration (source: courtesy, OHB System).*

Finally, another factor that comes into play is the willingness of militaries to utilise the services of commercial providers if the space environment is considered a militarily contested arena. More and more nations seem to be moving towards dedicated military satellites, with the most recent example Germany's SAR-Lupe radar satellite constellation commissioned by the German military on 4 December 2008 (Figure 7).[35]

In another example, the U.S. Defence Department decided in September 2008 to buy two new imagery satellites, dubbed BASIC for Broad Area Space-Based Imagery Collection, with capabilities no better than that provided by commercial companies GeoEye and Digital Globe, due to concerns about "ownership" and "control" of the satellites and image gathering.[36] That plan, however, was shot down by Congress due to concern that it violated presidential policy regarding government use of commercial capabilities where feasible as well as the likely price tag.[37] Considering that the U.S. military since 2005 has been the main consumer of commercial satellite communications, accounting for about 90% of overall revenues,[38] and more than half the market for commercial imagery comes from government contracts,[39] movement by militaries to procure more dedicated capabilities could affect the commercial market in a negative manner.

4.2.7. Costs to civil society of increased militarisation/weaponisation

Perhaps the least quantifiable, but most serious, cost to civil society should the trend towards greater militarisation and weaponisation of space continue would be the increase in tensions among the world's space powers regarding space capabilities. Fears that other nations might gain military advantage would likely dampen political will for international cooperation – which is becoming increasingly vital in areas such as disaster and climate monitoring. Cooperation on space exploration would also be affected.

Indeed, the U.S. ITAR rules already have undercut efforts by NASA to forge strong space science and exploration partnerships, and engendered considerable hostility among European civil space agencies. A key example of how ITAR can actually sabotage civil collaboration was NASA's failed 2005 Demonstration of Autonomous Rendezvous Technology (DART) mission, involving a small satellite designed to closely orbit another satellite. NASA's "mishap report" on the mission highlighted the fact that "perceived restrictions" under ITAR resulted in "insufficient technical communication between the project and the international vendor" in part led to a lack of understanding of the spacecraft's parameters and the mission risks.[40]

ITAR also was blamed for complicating NASA's collaboration with Europe on the Automated Transfer Vehicle for the International Space Station, causing NASA Administrator Michael Griffin to write to U.S. Secretary of State Condoleezza Rice in April 2007 seeking relief from the regulations.[41] Indeed, some European scientists were prohibited from using the computers in NASA's Mars Exploration Rover science operation facility, even though they were supposed to be developing computer command and control software for the instruments ESA had built and provided to the mission.[42]

The situation could only get worse if military tensions are heightened and concerns about protecting national technical advantages rise. Further, deployment of space weapons would almost inevitably exacerbate those negative trends.[43]

The balance of government investment in military wise civil space programmes is also a potential problem if nation states become more focused on military uses of space assets. While relatively few nations currently maintain separate military and civil space programmes (chiefly, the United States, Russia and France), the trend towards integrating space capabilities with military forces – a trend that is spreading far and wide even to traditionally pacifistic nations such as Japan – inevitably will lead to internal battles for resources. For example, in the United States, NASA's budget has remained essentially stagnant over the last decade, while known military space spending has been growing especially in the past few years. While determining actual national security space spending in the United States is nearly impossible due to vague reporting, the multiplicity of agencies and military services with space-related budgets, and classification. But by at least one estimate, national security space spending jumped from about 20 billion U.S. dollars in fiscal year 2005 to about 30 billion U.S. dollars in fiscal year 2008.[44]

As with commercial vendors, civil government agencies also have to weigh the potential risks with the costs and benefits of developing and deploying on-orbit assets. A riskier environment caused by increased tensions, and the advent of space-related weaponry, would certainly raise the bar for agencies (and parliaments) weighing public investments in satellites and spacecraft.

In a similar vein, the advent of hostilities in space as part of traditional warfare would place civil space assets and services at dire risk – especially if debris-creating weapons were involved. This is not a trivial concern, given the reliance of modern societies on space-enabled capabilities.

4.2.8. Conclusions

Although much more detailed study would be required to complete a detailed and quantified cost–benefit analysis of increased militarisation and weaponisation of space, several conclusions can be drawn from even this cursory overview.

First, growing interest of militaries around the world in capturing the benefits of space-enabled operations – of which there are many – threatens to raise tensions among space-faring powers.

Second, increased military tensions in space will lead (and in some cases already is leading) capable nations into consideration of the potential advantages of ASATs and space-based weaponry, and the potential development and deployment of such weapons.

Third, trade-offs (in budgets and risk levels) between military advantages and commercial/civil disadvantages will be required if these first two trends continue. That is, commercial and civil space efforts almost inevitably will suffer from increased investments in military space capabilities and the subsequent increase in tensions and risks.

Fourth, space weaponisation and/or space warfare – especially if destructive weapons are involved – would increase the risks to all space assets and operations, whether military, civil or commercial.

Finally, and most importantly, it is almost impossible not to conclude that the costs of space warfare would exceed any benefits – since any benefits would be only short-term tactical military benefits whereas costs would be long-term and affect all sectors of human space activity.

Thus, it behoves space powers to move cautiously in the military space sphere and to undertake efforts to develop holistic national space strategies that take into account the interlocking nature of military, civil and commercial space activities. Balance and prudence will be necessary watchwords if the space environment is to remain sustainable and secure for use by future generations.

---

[19] The 2006 U.S. National Space Strategy details a historically robust concept of 'space control' that stakes out U.S. rights to 'freedom of action' in space as well as claims a U.S. right to: "dissuade or deter others from either impeding those rights or developing capabilities intended to do so; take those actions necessary to protect its space capabilities; respond to interference; and deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests". See: White House Office of Science and Technology Policy "U.S. National Space Policy". 2006. 4 Nov. 2009. http://www.ostp.gov/galleries/default-file/Unclassified%20National%20Space%20Policy%20–%20FINAL.pdf.

[20] Sources for Figure 1 include: Central Air Forces. "Operation Iraqi Freedom: By the Numbers." Presentation. Prince Sultan Air Base, Saudi Arabia. 30 April 2003; Lambeth, Benjamin S. The Transformation of American Airpower. Ithaca: Cornell University Press, 2000; and Cohen, Eliot A. Gulf War Air Power Survey, Summary Report. Washington, D.C.: Government Printing Office, 1993.

[21] Kaufman, Richard, Hertzfeld, Henry, and Jeffrey Lewis. Space, Security and the Economy. Washington, D.C.: Economists for Peace & Security, September 2008: 4.

[22] Union of Concerned Scientists. UCS Satellite Database. 6 June 2008. http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/ucs-satellite-database.html.
[23] Space Foundation. The Space Report 2009. Colorado Springs, CO: Space Foundation, 2009: 6.
[24] Kaufman, Richard, Hertzfeld, Henry, and Jeffrey Lewis. Space, Security and the Economy. Washington, D.C.: Economists for Peace & Security, September 2008: 8.
[25] Federal Aviation Administration. The Economic Impact of Commercial Space Transportation on the US Economy. Washington, D.C.: FAA. April 2008: 1.
[26] Amnesty International website. Eyes on Darfur. 4 Nov. 2009. http://www.eyesondarfur.org/satellite.html.
[27] Atkinson, Nancy. "Space Debris Illustrated: The Problem in Pictures." 11 April 2008. Universe Today. 4 Nov. 2009. http://www.universetoday.com/2008/04/11/space-debris-illustrated-the-problem-in-pictures.
[28] Lepisto, Christine. "Shocking Space Debris Images." 20 April 2008. Treehugger. 4 Nov. 2009. http://www.treehugger.com/files/2008/04/shocking-space-debris-images.php.
[29] Secure World Foundation website. International Traffic in Arms Regulations (ITAR) Factsheet. Last updated September 2008. 4 Nov. 2009. http://www.secureworldfoundation.org/siteadmin/images/files/file_229.pdfm.
[30] See: "ITAR and the U.S. Space Industry." September 2008. Space Foundation. 4 Nov. 2009. http://www.spacefoundation.org/docs/SpaceFoundation_ITAR.pdf; and Messier, Doug. "AIAA Supports Loosening of U.S. ITAR Export Regulations." 11 Mar. 2008. Parabolic Arc. 4 Nov. 2009. http://www.parabolicarc.com/2008/03/11/aiaa-supports-loosening-of-us-itar-export-regulations/.
[31] Kuslolek, Richard. "ITAR Dilemma: Finding the Balance Between Regulation And Profit" 1 July 2008. Satellite Today. http://www.satellitetoday.com/military/homelandsecurity/23649.html.
[32] Brown, Peter J. "Engaging China in Space Part 2: US Firms Tired of Being Shut Out." 4 Dec. 2008. Asia Times. 4 Nov. 2009. http://www.atimes.com/atimes/China/JL04Ad01.html.
[33] Wright, David. "Space Debris." Physics Today 60.10: 35–40.
[34] Cáceres, Marco. "Market Impact Brief: China's ASAT Weapons Test." January 2007. Teal Group Corp. Arlington, VA.
[35] "Germany Commissions First Spy Satellite", 4 Dec. 2008. Deutsche Welle DW-World. 4 Nov. 2009. http://www.dw-world.de/dw/article/0,,3849862,00.html.
[36] Shalal-Esa, Andrea. "U.S. Approves Plan for 2 Commercial Image Satellites." 10 Sept. 2008. Reuters. 4 Nov. 2009. http://www.reuters.com/article/reutersEdge/idUSN1045748920080910.
[37] Gardener, David W. "Congress Cuts BASIC Satellite Imaging Program." 21 Oct. 2008. Information Week. http://www.informationweek.com/news/showArticle.jhtml?articleID=211300121.
[38] "Market to Generate $7.8 Billion in Satellite Communications Revenue Through 2010." 15 Mar. 2005. Northern Sky Research Press Release. 4 Nov. 2009. http://www.spaceref.com/news/viewpr.html?pid=16401.
[39] Eisler, Peter. "Global Security: The Sky's Unblinking Eyes." 9 Nov.2008. USA Today. 4 Nov. 2009. http://www.technewsworld.com/story/65090.html?wlc=1229102384.
[40] NASA. NESC Review of Demonstration of Autonomous Rendezvous Technology (DART) Mission Mishap Investigation Board Review (MIB). NASA Engineering and Safety Center Report: Demonstration of Autonomous Rendezvous Technology Mishap Review Board. Doc. No. RP-06-119, Version 1.0. December 2006: 31.
[41] Berger, Brian and Peter B. de Selding. "ITAR Complicates Preparations for New Station Supply Vehicle." Space News 11 Apr. 2007.
[42] Lakdawalla, Emily. "A Backlog of 400 Emails: ESA and NASA; MGS Failure; Iapetus; Saturn's D Ring." 25 July 2007. The Planetary Society Blog, The Planetary Society. 4 Nov. 2009. http://www.planetary.org/blog/article/00001044/.
[43] Assembly of the Western European Union. Weapons in Space. Fifty-Second Session. Document A/1932 of 21 June 2006. Paris: WEU: 7.
[44] Kaufman, Richard, Hertzfeld, Henry, and Jeffrey Lewis. Space, Security and the Economy. Washington, D.C.: Economists for Peace & Security, September 2008: 10–16.

4.3 The space debris environment and its impacts

Fernand Alby

4.3.1. The situation in orbit

The problem of space debris first arose on 4 October 1957. On that date, the Soviet Union placed the very first artificial satellite in orbit around the Earth using a Semyorka rocket. This rocket's final stage (6500 kg) and protective fairing (100 kg) remained in the same orbit as Sputnik (84 kg), so in fact the 'functional' payload was little over a mere 1% of the total mass injected into orbit. Moreover, this 1% operated for just 21 days before re-entering the atmosphere 92 days later: the "functional" 1% of the injected mass had thus been debris for three quarters of its orbital lifetime.

Since then, space activities have developed considerably and the population of objects in orbit has not stopped growing: human activity has led to the proliferation in space of a huge number of objects of all sizes. Recent calculations estimate around 12,000 objects measuring over 10 cm in size, 200,000 objects between 1 and 10 cm and 35,000,000 objects between 0.1 and 1 cm. Particles measuring less than 0.1 cm are even more abundant. For almost any size of object in space, man-made pollution now represents a greater risk than the meteors found in the "natural" space environment.

These objects derive from a number of sources (see Figure 8):

- Operational satellites, which number around 600, and satellites at the end of their lifetime that remain in orbit around the Earth.
- Upper stages of launchers that have been used to place these satellites in orbit.
- Operational debris, objects intentionally released during a mission: casings needed to protect instruments during the launch phase, mounting systems for solar panels or antennas before their deployment in orbit, release mechanisms, straps, etc.
- Fragmentation debris: debris produced after a collision between an object in orbit and space debris or meteorites. Also, debris resulting from spacecraft accidentally or intentionally exploding.

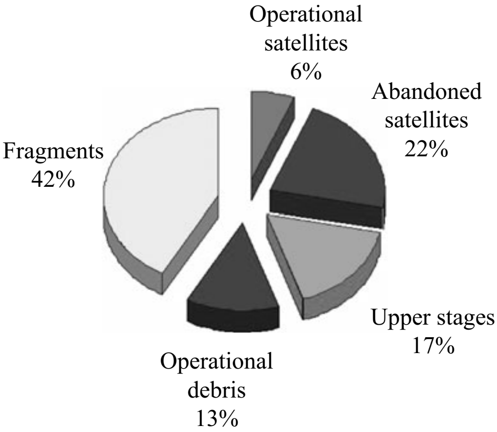

Fig. 8. *Debris' categories: main object categories in orbit (source: CNES).*

- Propellant residues: solid propellant motors that are used to carry out orbit transfers, particularly between a transfer orbit and geostationary orbit, release small alumina particles during thrust. This problem is especially critical at the end of the thrust when combustion becomes unstable and slag measuring several centimetres may be ejected into space.
- Ageing of materials in space. The space environment is extremely hostile to acute temperature changes in areas exposed to shade then sunlight, atomic oxygen, ultraviolet rays, etc. This ageing leads to large quantities of debris being produced (photoelectric cells becoming detached, heat shield covers flaking, paintwork peeling off, etc.).

There are other, more anecdotal sources of debris, which can also have a significant impact on the population of objects in orbit:

– In 1961 and 1963 the U.S. Air Force planned to release several million copper needles (Westford Needles) into orbit at an altitude of around 3000 km, as part of the Midas 4 and Midas 6 experiments. The objective was to create a ring of dipoles around the Earth that could be used as a passive reflector for military communications. Only the second experiment was partially successful. These needles then formed into clusters: 65 of these clusters could be observed from the ground even as late as 1998.
– In the 1980s the Soviet Union operated nuclear-powered RORSAT ocean reconnaissance satellites. At the end of their mission, their nuclear reactor cores were re-orbited at altitudes between 900 and 1000 km to allow their radioactivity to decrease before they fell back into the atmosphere. Leaks in the cooling

circuits were observed on 16 of these satellites, which resulted in thousands of droplets of liquid sodium and potassium being released into orbit. These droplets measure between 1 mm and a few centimetres.

Since 1957 the growth in the number of objects catalogued over time (those objects that can be monitored from the ground) has been more or less constant: they are increasing in number by around 220 per year. Future growth will depend essentially on the number of launches and the number of objects placed into orbit by each launch: over the last few years the number of launches has dropped, mainly due to a decline in activity in Russia, although other factors have had the opposite effect. Plans for constellations involving several dozen, or even several hundred satellites, have raised fears of a rapid increase in population. These projects are currently on hold but another potential risk is beginning to emerge with the development of “small” satellites (micro, nano and pico satellites) that could be launched in clusters by a single launcher. Another significant factor is the effectiveness of mitigation measures, which are being applied with increasing frequency. Anti-satellite tests such as the destruction of Fengyun 1 C in January 2007 and USA 193 in February 2008 have, of course, a negative impact on the environment. The consequences are particularly important when these tests are conducted at a relative high altitude (case of Fengyun 1 C at 850 km) that leads to a large number of debris having a very long orbital lifetime.

With large enough objects (those typically measuring 10 cm in low orbit and between 0.5 m and 1 m in geostationary orbit), the name, origin, and orbit parameters of each one are catalogued, enabling their trajectories to be predicted. These objects are regularly observed by radars in low orbit and telescopes in higher or geostationary orbits. The American SSN (Space Surveillance Network) has thus been able to compile a catalogue of around 12,000 objects. Smaller objects can also be observed, but as their trajectory cannot be calculated, it is impossible to find them again later. Their observation only provides statistical information on the number and size of objects to be obtained. Lastly, very small objects (dust) cannot be detected using ground-based facilities. Satellite-borne detectors are used to measure flows of small particles. Post-flight analysis of control surfaces exposed to the space environment then brought back to Earth after a mission have also provided a wealth of information on the number, artificial or natural origin, and mass of particles encountered. This was the case, for instance, with the solar panels from the Hubble telescope that were recovered in orbit on several occasions, and with various surfaces fitted to the space stations (International Space Station (ISS) or MIR) and to dedicated vessels such as the Long Duration Exposure Facility (LDEF). It was also the case with the Space Shuttle, which undergoes a detailed inspection after every flight.

The distribution of debris in space is not uniform, but obviously its concentration is greater in "useful" orbits where human activity is greatest, particularly in the geostationary orbit where most of the telecommunications satellites are found and in low orbits between 600 and 1500 km that correspond to many Earth observation missions.

The orbital lifetime of these objects is limited by the influence of the atmosphere. Atmospheric density diminishes more or less exponentially as altitude increases and the residual atmosphere found in low orbits has a decelerating effect on objects in orbit. The consequence of this deceleration is to lower an object's altitude and therefore increase atmospheric friction, which eventually results in objects falling back down to Earth. For example, at the altitude of the ISS (around 350 km), an object's lifespan is just a few months, which requires manoeuvres to be carried out regularly to compensate for this effect. However, this phenomenon only affects objects in low orbits: even at SPOT's altitude (800 km) the lifespan is of the order of one or two centuries. In higher orbits, lifespan can be measured in millennia or tens of millennia. With elliptical orbits, such as the transfer orbits which are used to reach geostationary orbit, an object's lifespan depends essentially on its perigee altitude: for a perigee altitude of 200 km the orbital lifetime ranges from a few months to a few years. A perigee altitude above 600 km results in orbital lifetimes measuring in the millennia. Lastly, in geostationary orbit, where there is no trace of any atmosphere, lifespan has no limits on a human scale.

4.3.2. Risks in orbit and on the ground

Obviously, this debris does pose a risk in the event of a collision with operational satellites. In orbit, these objects move at relative speeds of as much as 15–20 km/s. At these rates, even small particles have considerable kinetic energy: there is currently no shielding that can resist objects measuring more than 1 or 2 cm.

Impacts caused by small pieces of debris can be seen on any surface that has spent time in space and been brought back to Earth. For example, impacts were noted on the Shuttle Endeavour after flight STS 118 in August 2007: a perforation measuring 8×6 mm was observed on a radiator panel. The astronauts themselves have been able to observe damage to the ISS during their spacewalks (e.g., a torn thermal cover was discovered on the Zarya module in June 2007). With the Space Shuttle, the post-flight inspection leads to an average of one window per mission being replaced due to impact damage.

These data have made it possible to calculate that, statistically, the ISS may be struck by an object measuring over 1 cm every 71 years and that the Hubble telescope, during its theoretical 17-year lifespan, has a 4% chance of experiencing

Tab. 2: *Average time between two debris impacts in low orbit on a satellite measuring 100 m² (source: ESA).*

Altitude (km)	Debris measuring 0.1 mm (days)	Debris measuring 1 mm (years)	Debris measuring 1 cm (years)	Debris measuring 10 cm (years)
400	10	3	885	12,900
780	1.5	1	155	1190
1500	1.6	1.6	270	1590

the same kind of impact. Table 2 gives the average time between two debris impacts on a 100 m^2 satellite according to its altitude and the size of the particles (see Table 2).

The consequences of these collisions depend on the impact site: on a satellite, perforation of a solar panel, an antenna or even a wall is generally of no importance. However, a high-speed impact between a small object and a fuel tank or an electronic unit could result in the satellite being lost.

The first official collision in space between catalogued objects took place on 24 July 1996, when debris from the in-orbit explosion of the third stage of Ariane flight V16 severed the stabilisation mast on the Cerise microsatellite (Figure 9). Two other collisions between catalogued objects were subsequently revealed: a collision on 17 January 2005 between a stage of the American Thor launcher and a fragment from a Chinese CZ-4 launcher stage and a collision between the Russian Cosmos 1934 navigation satellite and debris from the Cosmos 926 satellite, which occurred in December 1991 but was only identified in 2005. Unfortunately, the

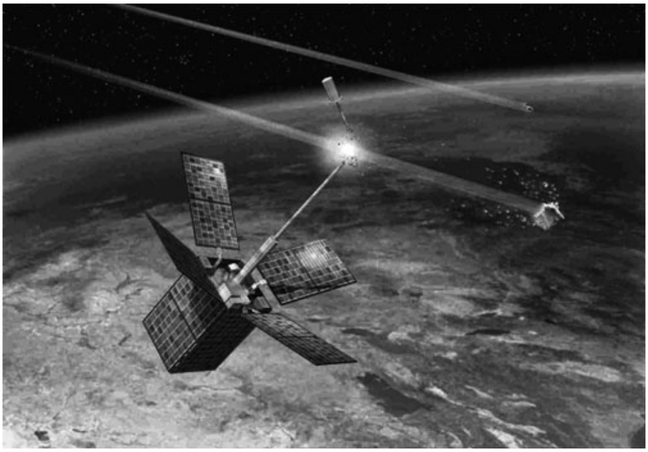

Fig. 9. *"Debris' collision Artist's view" (source: CNES).*

likelihood of this kind of event occurring will increase in the future due to the growth in the population of objects orbiting the Earth.

At the moment, objects measuring between 1 and 10 cm represent the greatest danger as shielding is unable to stop them and it is impossible for satellites to avoid them because they are too small to be tracked from the ground.

Space debris is also a potential hazard on the ground: objects in low orbit are slowed down by the residual atmosphere and eventually fall back to Earth. Most of these materials disintegrate during re-entry because of the extremely high temperatures but some elements can survive these conditions and reach the ground. For example, with the MIR space station, whose mass in orbit was 140 tons, Russian specialists estimated that 20% of its mass would survive as debris, representing an excessive risk. The decision was therefore taken to conduct a controlled re-entry to ensure that the debris fell over the South Pacific. There are two kinds of re-entry. With uncontrolled re-entries, an object falls anywhere within the latitudes corresponding to its orbit inclination. When the risk to inhabitants is too great, a controlled re-entry must be conducted. One or more manoeuvres are needed to ensure that the object falls in a precise place (i.e. the ocean) in order to minimise the risks. In general, agencies consider the level of acceptable risk to be around 10^{-4}, or a few 10^{-4} (probability of there being a victim during the operation). When the risk is below this threshold, a natural uncontrolled re-entry is acceptable. However, if the risk should exceed this threshold, controlled de-orbiting is essential to bring the level of risk back down.

Currently, one to two catalogued objects fall back down to Earth each week and pieces from these objects are regularly recovered from the ground: some of these (helium tanks, fuel tanks, engine combustion chambers, etc.) may be masses weighing several dozen kilograms. To date, no casualties have been reported as a result of falling space debris.

4.3.3. The solutions

4.3.3.1. Evaluation of the available solutions

To deal with a situation which is of growing concern, there are four potential solutions: clean up space to reduce the amount of debris, use shielding to protect objects from impacts, avoid debris and reduce production of debris (prevention). We shall see that the first three solutions do not work, or work only partly, and therefore the only answer is prevention.

First, the solutions that do not work. There is no way to clean up orbits by eliminating debris. Because of the high speeds at which orbiting objects move (several km/s), any capture system such as the “butterfly net”, absorbent foam, etc., would simply result in the intercepting system and the debris disintegrating upon collision. Ground-based destruction systems based on powerful lasers have also been considered. Apart from the fact that their feasibility is far from proven (power needed, pointing accuracy, uncertainty about the trajectory of the debris), the experts agree that it would be better to have one intact object in orbit that can be tracked from the ground than hundreds or even thousands of smaller pieces of potentially dangerous debris.

Another alternative would be to recover debris in orbit using a vessel such as the Space Shuttle. This kind of solution would require a certain number of technical problems to be overcome, for example how to perform a rendezvous with an uncooperative object, probably rotating, with an uncontrolled attitude; then how to grasp it and secure this potentially dangerous object (perhaps containing residual fuel and thus representing an explosion hazard) in the cargo bay; and then how to carry out atmospheric re-entry with such a cargo. Besides, the Shuttle’s capabilities are limited to altitudes below around 600 km and slightly inclined orbits. Furthermore, after completing its first rendezvous, it would be out of the question, due to the available fuel, to modify its trajectory plan and seek another object located in a different orbit. Under these conditions, the cost of such a mission to retrieve a single piece of debris, or a few pieces of debris located in adjacent orbits, would seem exorbitant.

Some partial solutions are available. It is possible to protect spacecraft using shielding. However, given the speeds in orbit and the corresponding energy, no shield is able to stop particles measuring more than 1 or 2 cm. Moreover, shields add significantly to a spacecraft’s mass, so their use is currently reserved for permanently-crewed space stations.

Another partial solution consists in avoiding collisions when the debris’ trajectory is well understood: avoidance is theoretically feasible whenever there is a risk of collision with catalogued debris. The process is still difficult, however, because the catalogues are not sufficiently accurate and radar facilities must also be used to reduce uncertainty and limit false alarms. Furthermore, it has to be possible to detect the collision several days in advance to have time to carry out the necessary analyses, conduct measurements, confirm the risk and take any decision. It also generally requires the mission to be interrupted until the satellite has returned to its initial orbit. This process is indispensable for manned vessels such as the ISS or the Space Shuttle. For example, on the ISS such close surveillance led to the following eight avoidance manoeuvres being conducted:

- 27-Oct.-1999 ISS-Pegasus Rocket Body
- 30-Sept.-2000 ISS-Vostok Rocket Body

- 10-Feb.-2001 ISS-Space Shuttle Elektron 1 Debris
- 14-Mar.-2001 ISS-Space Shuttle ISS/Shuttle Debris
- 15-Dec.-2001 ISS-Kosmos Rocket Body
- 16-May-2002 ISS-Kosmos Rocket Body
- 30-May-2003 ISS-Megsat
- 28-Aug.-2008 ISS-Cosmos 2421 debris

It should also be noted that surveillance potentially leading to avoidance manoeuvres is being implemented more and more with reference to satellite control (e.g., CNES currently has 15 satellites under surveillance).

The only solution that can be applied immediately, therefore, is prevention: this means no longer creating any space debris, or creating as little as possible. These measures aim to reduce or stabilise the rate of population growth of objects in orbit.

4.3.3.2. Prevention measures

Priority is given to applying these measures to the two most crowded and hence most polluted zones in space (see Figure 10):

- The low orbit zone: altitudes below 2000 km,
- The geostationary zone: a corridor extending ±200 km each side of geostationary altitude and limited to ±15° of inclination.

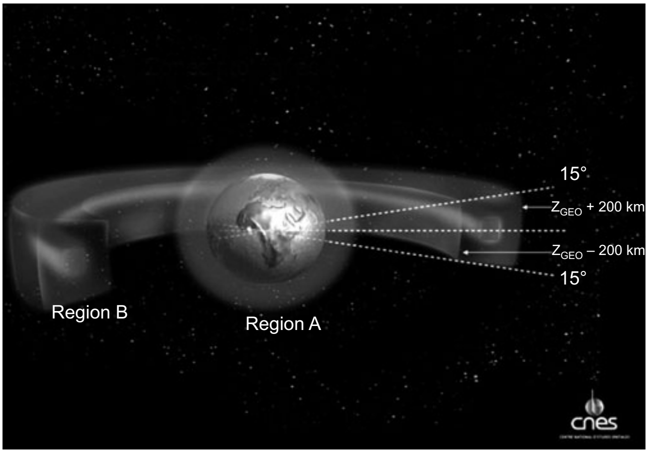

Fig. 10. *Zones where the measures will take place: protected regions in space (source: CNES).*

4.3.3.2.1. Principles of the measures

The prevention measures can be summarised according to four major principles:

- Do not intentionally release objects into space: covers, hoods, straps, springs and fastening mechanisms used during launch must all be “trapped”, i.e. they must remain fixed to the satellite and must no longer be abandoned in orbit as was often the case before. Pyrotechnic cutting must be performed cleanly and the debris created by rupturing materials must be captured. Solid propellant motors used for positioning operations can also be a significant source of debris: some models release particles throughout combustion, particularly at the end of combustion with the low-speed ejection of particles measuring around a centimetre, which remain in orbit.
- Reduce the probability of explosions in orbit: the fragmentation of a spacecraft in orbit leads to a huge amount of debris of all sizes being created and in-orbit fragmentation thus represents the main source of debris. This constraint is generally taken into account by the designer and the operator during the mission to ensure the necessary reliability. However, once the mission has been completed, this constraint disappears and the operator must take special measures to avoid any subsequent explosion of the satellite or launcher that it will be abandoning in orbit. These operations, known as passivation, consist in reducing all sources of on-board power: by emptying fuel tanks, opening pressurised gas tanks, discharging batteries, etc.
- End-of-life manoeuvres: the aim of these measures is to remove the decommissioned vessel from protected regions. In low orbit the generally accepted requirement is the 25-year rule: no vessel may remain more than 25 years in the protected region after its operational mission has ended. This can be accomplished in a number of ways including: direct (controlled) de-orbiting, indirect de-orbiting (lowering the perigee so that atmospheric friction causes the object to fall back to Earth in less than 25 years), moving the vessel up above the protected region, or using another spacecraft to recover it. In geostationary orbit, this solution is impractical due to the region’s remoteness from Earth. The recommended solution is thus to transfer the vessel into a “graveyard” orbit located 200 km above geostationary orbit, where it can no longer obstruct the protected region. After the de-orbiting or re-orbiting manoeuvres have been completed, the vessel must be passivated to avoid any subsequent risk of explosion.
- Prevention of in-orbit collisions: a collision between two vessels would generate a massive amount of debris. This risk can be decreased by the choice of mission orbit (choosing a relatively unpopulated orbit), the choice of launch time with regard to launch-related risks, and by conducting in-

orbit avoidance manoeuvres. Employing the latter two measures is only possible if the operator has enough information to calculate the collision risks, which is generally not the case: the catalogue of objects in space published by the United States only contains data on some of the objects over a certain size and the precision of these data is somewhat inadequate. The operator therefore needs access to other facilities (i.e. military) in order to accomplish this function.

4.3.3.2.2. Constraints

Clearly these prevention measures represent additional constraints – and therefore extra costs – to designers and operators of launchers and satellites:

– Additional mass and increased complexity due to the extra equipment required for conducting passivation: valves, tubing, nozzles, pyrotechnics, etc.
– Inability to select the optimal injection orbit from a performance point of view in order to comply with the 25-year rule, need to re-ignite a launcher stage, etc.
– Shortening of the operational lifespan because of the mass of fuel needed to conduct end-of-life manoeuvres (and even more so because end-of-life uncertainties may require safety margins to be added to avoid running out of fuel).
– Cost of the operations themselves: teams of operators and specialists at the control centre, network of stations needed for the TM/TC link.
– Use of materials that do not generate debris when they age.
– Difficult decision-making with regard to terminating the mission in order to conduct end-of-life manoeuvres: the operator will wish to prolong the profitable use of its satellite as much as possible.

These prevention measures therefore require additional immediate expense on the part of the operators without any obvious benefit to them. Implementation of these measures has a long-term effect that concerns the entire community. Operators must therefore be encouraged (compelled) to apply these measures; however, because space activity is developed in a context of economic competition, each country, or each agency, cannot impose these (sometimes considerable) constraints if other competitors do not follow suit. For this reason, the issue needs to be debated on an international level and a consensus needs to be reached between all the stakeholders.

4.3.3.3. Regulatory provisions

For more than 15 years the issue of space debris has been raised by various authorities and numerous documents have been written. These include the following:

- The ITU (International Telecommunication Union): ITU-RS-1003 Recommendation on GEO disposal (re-orbiting geostationary satellites at the end of their mission).
- Space agencies: NASA standards first, CNES standards in 1999.
- Network of centres (ASI, BNSC, CNES, DLR and ESA): publication of the European Code of Conduct for Space Debris Mitigation in 2004.
- The IADC (Inter Agency Space Debris Coordination Committee): publication of IADC Space Debris Mitigation Guidelines in October 2002.
- The Scientific and Technical Sub-Committee (STSC) of COPUOS (Committee on the Peaceful Uses of Outer Space) published the UNCOPUOS Space Debris Mitigation Guidelines in 2007.
- Standards organisations such as ISO have developed standards on space debris.
- Countries have set up national regulatory provisions in the form of licence systems (USA, UK) or laws (France).

These documents have been developed to respond to immediate requirements and the situation may seem somewhat confusing to an outside observer bewildered by their number and respective roles.

Fortunately, despite having been written by different groups, these documents are technically consistent: the members of these groups almost all belong to the

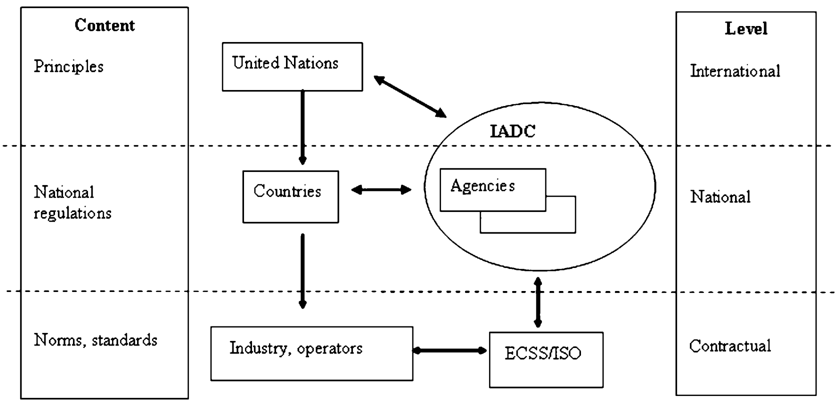

Fig. 11. *Summary of the situation: principles of the regulatory documentation (source: CNES).*

IADC and consistency has been maintained by the group of IADC experts who played a key role in the process.

Today the situation is clearer and can be summarised as follows (see Figure 11):

- The IADC is the common reference for all these documents. The IADC Space Debris Mitigation Guidelines represent the consensus of the 11 main space agencies: ASI (Italy), BNSC (United Kingdom), CNES (France), CNSA (China), DLR (Germany), ESA (Europe), ISRO (India), JAXA (Japan), NASA (USA), NSAU (Ukraine) and ROSCOSMOS (Russia). The IADC defines the technical bases for the measures (described in Section 3.2.1) and studies their influence on the environment.
- The United Nations, via COPUOS, defines the major principles for the measures to be applied in space: the seven principles are described in document A/AC.105/C.1/L.284, which was approved by the United Nations General Assembly in November 2007 (Resolution A/RES/62/217). The UN requests all States to implement these principles through national legislation to make them applicable. This adds to concerns about documents already drafted by the UN (Outer Space Treaty of 1967 and the Convention of 1972) that assign liability to the launch State in the event of damage caused in orbit or on the ground. This implies that the State must have the means to control the space activities of its own citizens.
- These States therefore need national regulations in order to impose measures on their operators and manufacturers to protect the orbital environment. Initially, the national space agencies, which conduct most of the space activities in their own countries, developed their own internal rules (NASA standard, CNES standard and European Code of Conduct). Nowadays, with space activities being increasingly carried out by the private sector, the agencies' self-imposed rules need to be replaced by laws applying to all a particular State's citizens: this is the role of the licence systems and national laws covering space activities.
- Lastly, operators and manufacturers need to translate these rules into implementation standards that can be directly applied to projects: these standards must be clearly measurable, quantifiable and verifiable. This corresponds to the work currently being undertaken within ISO.

4.3.4. Summary

The main space agencies, particularly NASA, were very quick to recognise the new problem posed by the proliferation of space debris. Because of their dual role as perpetrator and victim of this pollution, they reacted by developing internal rules applicable to their own projects and aimed at reducing the production of debris. It quickly became obvious that international consensus was also needed for these measures and this led to the creation of the IADC: this inter-agency committee is now the sole reference in the field and the space agencies all apply the same measures. Nowadays, however, the agencies are no longer the only stakeholders in space: an increasing share of activities is being conducted by private manufacturers and operators who can sidestep the agencies' rules. In accordance with the United Nations Treaties, liability in the event of any damage in space falls on States. The subject was therefore added to the agenda of the United Nations Committee responsible for space affairs (COPUOS), which has led to the drafting of a high-level document, still based on the IADC reference, that lays out the major principles to be applied in space with regard to prevention of space debris. These principles must then be passed on through each State's legislative system to ensure that the activities of all stakeholders in space can be controlled.[45]

[45] The following references were used for this article: Alby, Fernand. "Implementation of Space Debris Mitigation Guidelines." Proceedings of the Fifty-sixth International Astronautical Congress, 17–21 Oct. 2005, Fukuoka, Japan. IAC-05-B6.3.08; Alby, Fernand. "SPOT-1 end of life disposition manœuvres." Advances in Space Research 35.7 (2005): 1335–1342; Johnson, Nicholas L. "Current characteristics and trends of the tracked satellite population in the human spaceflight regime." Proceedings of the Fifty-seventh International Astronautical Congress, 2–6 Oct. 2006, Valencia, Spain. IAC-06-B6.1.03.

4.4 Space situational awareness: an overview

Giovanni Gasparini and Valérie Miranda

4.4.1. Introduction

In the past 20 years we have experienced rapid growth in the launch of space assets by dozens of nations and operators, mostly for communications and entertainment (TV) purposes but also to provide increased services for the public in general (navigation systems for example) and for the military in particular. Hundreds of satellites, some of which are no longer operating, are crowding the most popular orbits (GEO, geostationary orbit, and some specific LEOs – low-Earth orbits), accompanied by thousands of debris travelling at speeds of kilometers per second, enough to transform even a very small (1 cm) piece of debris into a killer bullet for thin protective skins. It was only a matter of time before this unregulated system, recently put under further strain by the Chinese anti-satellite weapons (ASAT) test of 11th January 2007 that generated thousands of debris still remaining in orbit, was shaken by a potentially catastrophic event.[46] It eventually happened on 10 February 2009 when two satellites collided creating a "cloud" of thousands of debris potentially producing a chain effect along one of the most crowded LEO orbits. The impact was unforeseen despite both satellites being present in the U.S. space catalogue. If the commercial operator of one of the satellites (Iridium, which provides communications for the wider public and the Pentagon) had received timely information, it could have manoeuvred in order to avoid the dead Russian military satellite into which it crashed. This accident shows how little timely information we have as to the traffic in orbit and how important it is in economic, operational and strategic terms to improve the current situation. This article offers a general overview of the current situation regarding the availability of systems providing this precious information, focusing on the strategic value of space awareness systems, and discusses the implications of different approaches towards the establishment of a wider global SSA system.

4.4.2. Present SSA situation

The term "Space Situational Awareness" was coined by the U.S. Air Force. During the Second World War, the German and Allied Air Forces observed that most of the fighter pilots hit did not realise they were under enemy fire until their plane was destroyed. Similarly, later studies conducted by the U.S. Air Force (USAF) concluded that during the war in Korea and Vietnam, 80% of planes that were shot were completely unaware of what was happening. According to USAF experts, the main cause was a lack of "Situation Awareness" (SA), which thus proved essential to the fighter pilots' survival.[47] The concept of Situational Awareness was then used to refer to the space environment and appeared as such for the first time in the 2001 Report on Space by Donald Rumsfeld.[48]

As Laurence Nardon clearly explains in her "Space Situational Awareness and International Policy", SSA – in plain words, the ability to "see" what is going on in space – "can have different applications and can therefore serve different policy goals". In particular, "in the United States, SSA programmes monitor the threat from human-made objects: other satellites and space vessels, anti-satellite weapons (ASATs) as well as space debris".[49] Thus, as well stated by Theresa Hitchens, "SSA is the foundation stone underpinning all operations in space, required for ensuring that working satellites do not interfere with each other, debris tracking and collision avoidance, diagnosing an ailing satellite, and satellite protection and defence,[50] as well as for the more controversial Air Force mission of "offensive space control".[51] In the European context, however, SSA is defined in much wider terms, including 'the awareness of threats from asteroids, solar flares and other "astronomical threats"'.[52]

4.4.2.1. SSA in the United States

The United States is so far the only country that has developed a global SSA system,[53] the "Space Surveillance Network" (SSN). This is composed of ground-based radars and optical sensors located in 25 sites in the Northern hemisphere.[54] These sensors are grouped into three main categories: dedicated sensors, whose primary mission is space surveillance and which are owned by the Air Force Space Command; collateral sensors, initially conceived for missile warning and now used for space surveillance missions; and contributing sensors which provide data as part of the SSN but are owned by private contractors or by other branches of the U.S. government.

The SSN tracks space objects which are 10 cm in diameter or larger in both LEO and the higher geostationary orbit at an altitude of 36,000 km where telecommunications satellites operate. The space objects tracked consist of active and inactive satellites, spent rocket bodies and fragmentation.[55]

The enormous amount of data collected by SSN sensors[56] is then transmitted via satellite, ground wire, microwave and telephone to the Joint Space Operations Centre (JSpOC), which is part of the United States Strategic Command (USSTRATCOM). The JSpOC then fuses the SSN data with other sources to provide SSA for the U.S. military and other customers.[57]

In addition, data are regularly published and used free of charge worldwide by different users interested in tracking satellites and space debris.[58] In this regard it is important to underline that while published U.S. information includes data on the orbits of other nations' military hardware, it excludes data on sensitive U.S. defence satellites.[59]

Although it is a reference point for cataloguing satellites and space debris, the U.S. SSN has some limitations that are acknowledged by field experts and Department of Defence (DoD) officers. The former complain of low accuracy, incomplete information and a proprietary data format (the so-called two lines element);[60] the latter recognise that "U.S. SSA capabilities are less than adequate today [. . .] the sensors cannot consistently find small debris and have limited capability to find, track and characterise objects in high-altitude orbits".[61] It is therefore generally admitted that the U.S. should devote more resources to the enhancement of its SSA capabilities. This is particularly true if we consider the growing importance of space assets and the increasing U.S. reliance and dependency on them. Indeed, from Desert Storm to recent operations in Afghanistan and in Iraq, military interventions have increasingly depended on space capabilities as force multipliers. Furthermore, space assets have become essential to worldwide commerce and everyday life. To date, American supremacy in the space environment is still unchallenged but this is likely to change in the future and the proliferation of space capabilities as well as the emergence of new competitors (such as China, or Europe in the satellite navigation field) has to be taken into account.[62]

So far, U.S. space policy has focused on Space Force Enhancement (SFE), which provides combat support operations to improve the effectiveness military forces, and on Space Force Application (SFA)[63] that is mostly devoted to nuclear deterrence. However, considering the emerging threats to its space assets and the consequent need to ensure its control of space as well as space superiority, U.S. attention is now shifting towards the enhancement of Counterspace (CS) activities. These latter are defined as the "capabilities needed to attain and maintain a desired degree of space superiority by allowing friendly forces to exploit space capabilities while negating an adversary to do the same".[64] They are made up of three "pillars": SSA, Defensive Counterspace (DCS) and Offensive Counterspace (OCS).

Within the general framework of U.S. National Space Policy that was adopted by the Bush Administration in 2006, the Strategic Master Plan (SMP) of the Air Force Space Command well illustrates the three-phase process to enhance U.S. Counterspace capabilities over the next 15 years.

First, with respect to SSA which is considered to be the "permanent crucial enabler" for DCS and OCS, the SMP recognises the need to improve U.S. ability to "find, fix, track and provide characterisation data on near earth and deep space objects and events, as well as improving the ability to adequately process and analyse data from all space regimes and from all SSA sources".[65] Additionally, the U.S. should enhance its ability to distinguish man-made attack and other sources of anomalies from natural environmental effects. Finally, the SMP provides for the current SSN system to be modernised and complemented with various in-orbit telescopes as well as innovative detection systems on board future satellites.[66]

Second, as concerns Defensive Counterspace, in addition to current DCS techniques that now focus on hardening satellites against electronic jamming, further means (in-orbit manoeuvring capabilities, launch-on-demand capacities, satellites redundancy and smallsats constellations) should be available after 2018.[67]

Third, with regard to OCS capabilities, the aim is to negate adversary space services by creating reversible (deceive, deny, disrupt) or irreversible (degrade, destroy) effects. According to the Strategic Master Plan, these are the least urgent capability, to be dealt with only in the long term. Thus the Plan provides that by 2025 a range of means, including lasers and in-orbit ASATs, will be added to the electromagnetic pulse (EMP) jamming systems currently available, targeting all existing satellite systems.[68]

Overall, it seems that Space Situational Awareness in the U.S. serves mainly military purposes. However, there is no general consensus as to its specific use or final scope. According to some experts, SSA could be one of the measures at U.S. disposal for deterring future attacks against its satellites. As John Sheldon puts it, "effective deterrence is strengthened by the fact that Space Situational Awareness could potentially indicate the nature and origins of any attempted attack on a satellite".[69] In contrast, others such as Robert Butterworth observe that mere deterrent policies are not effective enough to reduce the vulnerability of U.S. space assets and recommend relying on defence measures: "defence can deter, but deterrence policies cannot defend. Defence can be tested and exercised; deterrence threats cannot: their efficacy depends on the perceptions and actions of a foreign government."[70] Butterworth further states that: "none of these (defence) measures requires anything in the way of space-based weaponry".[71]

The debate over the best way to protect American space capabilities and ensure U.S. control of space is thus part of a wider and heated discussion over space weaponisation in which SSA initiatives play a key role. Indeed, some argue that these latter are the first step towards the acquisition of space-based weaponry. Laurence Nardon, for instance, claims that while the Eisenhower Administration formally excluded the weaponisation of space in 1958, deeming it to be too destabilising, the 2001 Rumsfeld report and the three-phase-USAF plan represent a change in attitude. The 2006 National Space Policy seems to go in the same direction. Despite the denials of the Bush Administration, the principle 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"[72] has been interpreted by many experts as a thinly veiled authorisation of space weaponisation. For instance, Michael Krepon, co-founder of the Henry L. Stimson Center, said this new policy would reinforce international suspicions that the United States may seek to develop, test and deploy space weapons.[73]

However, it seems that this might change under the new U.S. President, Barack Obama. In fact, after Obama's inauguration, the official White House web site was updated with new policy guidelines including one on restoring U.S. leadership in space which confirmed the goals already outlined in Obama's 2008 campaign.[74] Under the heading "Ensure Freedom of Space", US official policy is to "seek a worldwide ban on weapons that interfere with military and commercial satellites; assess possible threats to U.S. space assets and the best military and diplomatic means for countering them; seek to assure U.S. access to space-based capabilities, in part by accelerating programmes to harden U.S. satellites against attack".[75] While experts generally agree that Obama's intentions could lead to a new direction in space diplomacy, most of them are waiting for further specific details such as the definition of the controversial term "space weapon".[76]

Even if tough SSA military implications are prevalent, supporters of the non-weaponisation of space look at the other side of the coin. Indeed, agreeing on the need for better awareness of what happens in space, they adopt a different perspective and consider SSA "as a major tool to enable a continuing peaceful use of space".[77] To this end, a specific proposal is that of Brian Weeden, Secure World Foundation, who recommends the creation of an international civil Space Situational Awareness system whose goal would be to "provide all space actors access to the tools needed for safe and sustainable activity in Earth orbit".[78] The fundamental difference between this kind of system and military SSA is "in the information it provides, focusing only on the locating of an object in Earth orbit and a point of contact for that object, along with information about space weather".[79] Moreover, such a civil system could provide several benefits to the international community. In addition to the traditional information generally provided by SSA systems, Weeden says it could increase international cooperation and transparency (and therefore mutual trust) in space activities and also be a potential verification mechanism for a code of conduct or a space traffic management system that might be created in the future.

4.4.2.2. SSA in Europe

As mentioned above, the European definition of Space Situational Awareness is wider than that used in the U.S. According to the "User Expert Group of ESA SSA Requirement Study", Space Situational Awareness can be defined as "the comprehensive knowledge of the population of space objects, of existing threats and risks, and of the space environment".[80] The term "Space Surveillance" refers, "instead, to the routine operational service of detection, correlation, characterisation and orbit determination of space objects".[81] A certain overlap between the two concepts therefore exists, but "SSA implies more in terms of data processing and use".[82]

The importance that space assets have for U.S. policy is also confirmed in the European context. Indeed, according to the 2007 European Space Policy, space is a strategic tool for independence, prosperity, development and progress from an economic, technological, scientific and societal point of view. Moreover, the use of space assets has become essential, especially for security and defence purposes.[83] To this end, European countries and the EU have developed important space infrastructure (for communications, positioning, monitoring and intelligence applications) that needs to be operated safely to prevent possible collision, disruption or malfunction.[84] SSA activities are crucial in this regard. However, as pointed out in the "Conclusions of the Workshop on Space Security and the

Fig. 12. *GRAVES Space Surveillance System: receiving antennas (source: ONERA).*

Role of the EU" held in Berlin in June 2007[85], Europe does not have an autonomous capability for SSA: some sensors exist at the national level (Figure 12) but they can provide only part of the necessary information. Thus, Europe depends heavily on data provided abroad, namely by the U.S. SSN.

In order to fill this gap and in accordance with the aforementioned Conclusions, Europe has been pursuing plans to create its own SSA assets focusing in particular on the monitoring of space and on the identification of potential natural and man-made threats to its security. In 2006, ESA created a task force on space surveillance and began a series of parallel studies aimed at identifying SSA end-users needs to translate them into technical requirements. Furthermore, in the framework of preparatory action, ESA commissioned a number of studies on possible SSA architecture, hardware, governance and data policy.[86] These initiatives led to a recent decision of the ESA Council at Ministerial level that in November 2008 finally endorsed the SSA preparatory programme.[87] The original idea was to launch a 5-year full programme with a budget of 100 million euros. However, due to the political concerns of Member States, together with changing perspectives related to space weather or near-Earth objects and the general financial and economic crisis, the proposal was then changed to a preparatory and optional programme with a budget of 50 million euros[88] and a time frame of 3 years (2009–2011).[89] As reported by Wolfgang Rathgeber, according to the proposal the programme is composed of a core element and three additional optional elements. The first includes issues that are of concern to most ESA Member States such as governance, data policy and data security as well as architecture and space surveillance. The three optional elements concern space weather and near-Earth objects, breadboarding of radar components and pilot data centres. Practically, the programme largely consists of studies and workshops related particularly to governance and data policy issues, whereas questions referring to space surveillance, space weather and near-Earth objects will be addressed separately. Furthermore, as soon as the data policy section is completed, some pre-cursor SSA services will be established relying on pre-existing national facilities. Hardware activities, such as the above-mentioned breadboarding of radar components together with an initial procurement of assets and components, have been planned.[90]

The ESA preparatory programme is certainly an important step towards the creation of future European autonomous SSA capabilities. Nevertheless, other concrete improvements are needed. In view of its preparatory nature, the ESA programme does not contain suggestions how to concretely realise the future European SSA system. In this respect, some experts suggest that a European SSA system would initially collect data from existing national level assets, mostly ground-based national sensors.[91] But it is likely that this system would gradually change over time, relying more and more on European rather than national assets.

For this reason, its architecture should be flexible enough to adapt to progressive integration at the European level.[92]

A good starting point for a future SSA system could be along the lines of GRAVES, the French national radar system owned and operated by the French Air Force to keep under surveillance and track space objects in LEO. However, considering its predominantly military use together with its national and geographic limits, its possible influence on a European SSA system should be carefully assessed.[93]

The European SSA system's possible future architecture is not the only aspect to be dealt with in future discussions. These should focus on (and find convincing solutions for) two main critical issues: the need to reconcile different end-users' needs and the need to elaborate a mechanism to manage the amount of data coming from national assets in an effective and coordinated way. As regards the first aspect, the European SSA system is generally conceived to be a dual-use system and to provide services for four categories of end-users (institutional, military, commercial and scientific ones) with different needs in terms of security requirements, governance and data policy. The most demanding end-users are military users who require relevant, reactive and precise information together with protection of the confidentiality of security and defence-related data. In this regard, some wonder whether ESA is the appropriate body to handle this kind of data. In fact it seems that military entities are not inclined to deal with security issues in a transparent body such as ESA, deciding instead to mandate the European Defence Agency (EDA) to consolidate the military requirements for an SSA system. Thus the question is how to coordinate civilian and military aspects of security as well as the relationship between ESA and EDA. Recommendations in this regard will be presented at the next ESA Ministerial Council in 2011.[94]

With reference to the second aspect, governance and management of data, a generally acknowledged need is to reconcile the possible coexistence of different data policies in a coordinated and flexible way. Concrete proposals in this regard concern the creation of operational schemes and data exchange formats able to: ensure the optimum availability of information (including necessary redundancy and the avoidance of unnecessary duplication), provide adequate incentives for all potential contributors and, last but not least, take account of military bodies' security concerns and the economic interests of commercial participants.[95]

Europe is an important space actor but, as Nicolas Bobrinsky (ESA) has insightfully said, Europe "has, right now, little to offer".[96] It is generally acknowledged that the development of autonomous SSA capabilities will have important positive effects. SSA would increase European knowledge and understanding of the global situation in space and better prepare Europe to react to any risk posed by

Fig. 13. *Tira System (source: FGAN).*

the loss of satellite or related services or by a collision with an asteroid or a comet.[97] This would also lead to benefits from the strategic point of view since it is likely that the European position towards major space partners, such as the U.S., would be strengthened thus most likely filling in some of the current deep gaps between the two.[98]

4.4.3. Defence, deterrence and SSA

As the above discussion of the complex debate surrounding SSA shows, the U.S. model, based on the primacy of the defence dimension, is predominant. In view of the heavy dependence of the U.S. military on space force multipliers for both conventional military operations and strategic nuclear policy, concerns in this area are well-grounded.

The relative weakness of space assets (as was further demonstrated by the American use of a modified Missile Defence interceptor and related assets in order to destroy a rogue U.S. intelligence satellite in 2008), makes the U.S. an attractive target for an asymmetrical attack (weak to strong). This is particularly true if we bear in mind that in the future an increasing number of countries will have access to space (while at the same time being less reliant on space than the U.S. military) and, due to the absence of a clear identification system, could launch an attack without being identified or held accountable for it.

In this respect, the space environment could look similar to the cybersphere where the current difficulty of tracking the origin of an attack nullifies potential law enforcement or dissuasion responses. In order to re-establish deterrence, it is necessary to field a reliable system that determines the origin of a potential attack against a satellite and makes it possible to manoeuvre to counter the attack and retaliate against it. The system should also be able to avoid false alarms and to distinguish between deliberate attacks and accidental interference.

Attacking a military asset in space is an act of war that carries all the political, legal and operational consequences that apply to ground attacks. Adopting a deterrence policy that clearly states the will and intent to react in a tit-for-tat fashion, not only against another space asset but for example against land-based space facilities that give access to space, would be proportional and stabilising. The availability of a reliable SSA system is essential to establish the credibility of such a deterrent.

A second element of the defence-based model concerns secrecy of information. In the defence realm, where a zero-sum game often prevails, asymmetry is a positive result; therefore, situational knowledge of space gives additional power to the owner of the information. Moreover, in order to be effective, data-collectors, classified intelligence and observation satellites need the highest possible level of secrecy concerning their orbits, characteristics and capabilities.

The situation described above would naturally lead towards the fielding of a number of separate independent national space situational awareness systems. However, such a solution has important shortfalls. The development of a reliable and accurate system is feasible for possibly only one player – the U.S. If they managed to combine their efforts, European countries would also have this potential but to a lower extent. This, however, would have the effect of reducing the confidence of other space powers in national systems (Europeans already do not consider the present U.S. system reliable for both technical and political/access reasons), thus reducing to zero the confidence-building effect of fielding an SSA.

This over-militarised vision of an SSA is not having a positive impact on commercial operators and other users, thus potentially leaving out of the equation a number of stakeholders whose cooperation would be very important for the actual success of a system that aims at avoiding collisions.

4.4.4. SSA as a dual strategic asset

The European approach seems to be taking a different direction. Commercial and institutional non-military assets outnumber dedicated military satellites. Compared to the U.S., European military forces rely less on space assets, with some exceptions regarding France where some space assets are performing conventional military, intelligence and nuclear-related missions. The United Kingdom is noticeably silent in this discussion as its intelligence and command structure relies heavily on the tacit availability of U.S. assets.

The SSA mandate given to ESA by member countries is consistent with the "peaceful purposes" of the organisation. A superficial analysis would suggest that ESA is not sufficiently taking into account the requirements of military operators. However, particularly at the beginning, the European SSA will be the result of the merging of national assets and data in which national governments will exercise strong indirect control, making sure that "sensitive" information will not be shared widely.

Transparency is a paramount principle guiding European efforts, as well as openness to commercial and scientific operators. While recognising the intrinsic dual (civil/military) role of any SSA system, the ESA is reluctantly discussing the security implications of wider availability of data that potentially also applies to classified military observation satellites.

However, national authorities operating in space and security, particularly France, are well aware of the strategic value of controlling space assets. It is no secret that the national French GRAVES system aims to control which foreign (in particular American) intelligence-gathering satellites are actually over-flying France, thus obtaining a bargaining chip in order to convince U.S. authorities to stop publishing sensitive data concerning similar French satellites.[99]

The European Space Agency is rightly seeking to convince its Member States that the few national efforts in this field are providing limited results and offering to move a step forward towards a federated system. Such a system would then constitute the European contribution to a global structure involving information from all willing space nations and commercial operators.

This approach is less concerned with voluntary actions that purposefully interfere with satellites. Instead, it encompasses a series of potential applications regarding the space environment and space traffic where the characterisation of the space object is less important than in the case of military applications while remaining still relevant for determining legal liabilities.

However, as the number of nationally owned and common European space assets is bound to increase in the next few years pursuant to programmes having strong security implications such as Galileo, GMES and Musis, the Europeans will increasingly be forced to think strategically and the dual character of the SSA system will emerge strongly.

4.4.5. Reconciling different approaches in the international arena

A Space Awareness system that does not work as a confidence-building measure between potentially competing space actors will inevitably increase the likelihood of a conflictual posture in space that exploits the asymmetrical vulnerability of U.S. military space assets. This could also create an environment in which non-military security and commercial satellites would not be adequately protected.

A commonly agreed governance and data policy system that resolves the trade-off between the effectiveness of the transparency approach and the secrecy requirements of the military and intelligence community could bridge the current gap between the European and U.S. positions. The key to this approach is to allow differentiated access to data according to the real “need to know” of the potential users. In the case of commercial operators and the wider public, this would exclude knowledge of the characterisation of satellites unless specifically requested when an event requiring the assessment of legal liability occurs. U.S. authorities need to take more account of the dual character of space. At the same time, European institutions need to think more strategically. This discussion should take place between all U.S. Space Agencies on the one side and the European Council, the European Commission and ESA on the other.

The problem with other space nations that are not bound by the Transatlantic Alliance is however much more complicated. China and to a lesser extent Russia, as well as other minor space-capable countries such as Iran, would feel potentially threatened by a non-inclusive American or even transatlantic approach to space awareness. As it is unlikely that they will field a national SSA system, the incentive for them to develop ASAT capabilities would be high. This is particularly true due to the complexity and high cost of defending a space asset compared to the relative small cost of attacking it.

However, it has to be made clear that access to global SSA information will imply the acceptance of rules concerning contributions to a common database, the use of data and general behaviour in space. Cooperation cannot be seen as a way of free-riding or, worse, exploiting common knowledge for illicit purposes such as targeting of space assets. Ideally, the effort would include a common set of rules and possibly a treaty re-establishing an ASAT ban. Unfortunately that would be difficult due to the potential use of missile defence systems for that purpose. It will not be easy to strike the right balance between the different needs of nations and users, but it is necessary to reach it soon as the space community cannot afford that further casual or deliberate clashes occur.

[46] For further reference, see Secure World Foundation. "Chinese Anti-Satellite (ASAT) Test." 6 June 2008. SWF Factsheet. 9 Mar. 2009. http://www.secureworldfoundation.com.
[47] Nardon, Laurence. "Space Situational Awareness and International Policy." Oct. 2007. Document de travail 14. Institut Français des Relations Internationales. 15 June 2009. http://www.ifri.org/files/Espace/Docu_14_SSA_Nardon.pdf.
[48] "Report of the Commission to Assess U.S. National Security Space Management and Organization." 11 Jan. 2001. Executive Summary. Pursuant to public Law 106–65. 15 June 2009. http://www.fas.org/spp/military/commission/executive_summary.pdf.
[49] Nardon, Laurence. "Space Situational Awareness and International Policy." Oct. 2007. Document de travail 14. Institut Français des Relations Internationales. 15 June 2009. http://www.ifri.org/files/Espace/Docu_14_SSA_Nardon.pdf: 2.
[50] For a more specific list of space surveillance purposes, see Air University Website. http://www.au.af.mil/au/awc/awcgate/usspc-fs/space.htm.Last accessed 9 Mar. 2009.
[51] Hitchens, Theresa. "Ante up on Space Situational Awareness." Space News 12 Mar. 2007: 19.
[52] Nardon, Laurence. "Space Situational Awareness and International Policy." Oct. 2007. Document de travail 14. Institut Français des Relations Internationales. 15 June 2009. http://www.ifri.org/files/Espace/Docu_14_SSA_Nardon.pdf: 2.
[53] Marta, Lucia and Giovanni Gasparini. "Europe's Approach to Space Situational Awareness: a Proposal." Yearbook on Space Policy 2007/2008: From Policies to Programmes. Eds. Kai-Uwe Schrogl, Charlotte Mathieu and Nicolas Peter. Vienna: SpringerWienNewYork, 2009: 1.
[54] Such as Maui, Hawaii and Eglin, Florida; Thule, Greenland and Diego Garcia, Indian Ocean.
[55] Of the space objects tracked, 7% are operational satellites (in which the US is most interested), 15% are rocket bodies and 78% are fragmentation and inactive satellites. http://www.au.af.mil/au/awc/awcgate/usspc-fs/space.htm. Last accessed 9 Mar. 2009.
[56] The SSN has been tracking space objects since 1957 when the Soviets opened the space age with the launch of Sputnik I. Since then, 24,500 space objects orbiting Earth have been tracked. http://www.au.af.mil/au/awc/awcgate/usspc-fs/space.htm. Last accessed 15 June 2009.
[57] For more details, see Secure World Foundation. "Space Situational Awareness." 10 June 2008. SWF Factsheet. 9 Mar. 2009. http://www.secureworldfoundation.com.
[58] The catalogue is available publicly at http://space-track.org. Last accessed 16 June 2009.
[59] de Selding, Peter B. "French say "Non" to US Disclosure of Secret Satellites." 8 June 2007. Space.com. 9 Mar. 2009. http://www.space.com.
[60] Marta, Lucia and Giovanni Gasparini. "Europe's Approach to Space Situational Awareness: a Proposal." Yearbook on Space Policy 2007/2008: From Policies to Programmes. Eds. Kai-Uwe Schrogl, Charlotte Mathieu and Nicolas Peter. Vienna: SpringerWienNewYork, 2009: 11.
[61] U.S. Air Force Space Command. Strategic Master Plan FY06 and Beyond. 1 Oct. 2003. 15 June 2009. http://www.wslfweb.org/docs/Final%2006%20SMP–Signed!v1.pdf: 22.
[62] Ibid.: 4.
[63] SFA is defined as the "capabilities to execute missions with weapons systems operating from or through space which hold terrestrial target at risk", U.S. Air Force Space Command. Strategic Master Plan FY06 and Beyond. 1 Oct. 2003. 15 June 2009. http://www.wslfweb.org/docs/Final%2006%20SMP–Signed!v1.pdf: 2.
[64] U.S. Air Force Space Command. Strategic Master Plan FY06 and Beyond. 1 Oct. 2003. 15 June 2009. http://www.wslfweb.org/docs/Final%2006%20SMP–Signed!v1.pdf: 2.
[65] Ibid.: 22.
[66] Nardon, Laurence. "Space Situational Awareness and International Policy. " Oct. 2007. Document de travail 14. Institut Français des Relations Internationales. 15 June 2009. http://www.ifri.org/files/Espace/Docu_14_SSA_Nardon.pdf: 2.
[67] Ibid.: 2.
[68] Ibid.: 3.

[69] Sheldon, John B. "Space Power and Deterrence: Are We Serious?" Nov. 2008. Policy Outlook. George Marshall Institute, Washington. 15 June 2009. http://www.marshall.org/pdf/materials/616.pdf.
[70] Butterworth, Robert. "Fight for Space Assets, Don't Just Deter." Nov. 2008. Policy Outlook. George Marshall Institute, Washington. 15 June 2008. http://www.marshall.org/pdf/materials/614.pdf.
[71] Ibid.
[72] U.S. National Space Policy. 31. Aug. 2006.
[73] Kaufman, Marc. "Bush Sets Defense as Space Priority." 18 Oct. 2006. The Washington Post 15 June 2009. http://www.washingtonpost.com/wp-dyn/content/article/2006/10/17/AR2006101701484.html.
[74] See http://www.whitehouse.gov/agenda/defense Last accessed 10 Mar. 2009; "Advancing the Frontiers of Space Exploration" http://www.barackobama.com/pdf/policy/Space_Fact_Sheet_FINAL.pdf. Last accessed 16 June 2009.
[75] Brinton, Turner. "Obama Space-Weapon Ban Draws Mixed Response." FoxNews.com. 16 June 2009. http://www.foxnews.com/story.
[76] Ibid.
[77] Nardon, Laurence. "Space Situational Awareness and International Policy." Oct. 2007. Document de travail 14. Institut Français des Relations Internationales. 15 June 2009. http://www.ifri.org/files/Espace/Docu_14_SSA_Nardon.pdf: 3.
[78] Weeden, Brian. "Notes on Civil SSA." Presentation. 46th Session of Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). Vienna, Austria. 17 Feb. 2009. 16 June 2009. http://www.secureworldfoundation.org/siteadmin/images/files/file_277.pdf.
[79] Ibid.
[80] User Expert Group of ESA SSA requirement study, available at:www.sidc.be/esww4/presentations/SWWT/SSA%20-%20Space%20Weather%20Week.ppt. Last accessed 16 June 2009.
[81] Task force on Space Surveillance BNSC, CNES, DLR, ESA, available at: www.sidc.be/esww4/presentations/SWWT/SSA%20-%20Space%20Weather%20Week.ppt. Last accessed 16 June 2009.
[82] User Expert Group of ESA SSA requirement study, available at: www.sidc.be/esww4/presentations/SWWT/SSA%20-%20Space%20Weather%20Week.ppt. Last accessed 16 June 2009.
[83] Marta, Lucia and Giovanni Gasparini. "Europe's Approach to Space Situational Awareness: a Proposal." Yearbook on Space Policy 2007/2008: From Policies to Programmes. Eds.Kai-Uwe Schrogl, Charlotte Mathieu and Nicolas Peter. Vienna: SpringerWienNewYork, 2009: 14; Council of the European Union. Resolution on the European Space Policy. Doc. 10037/07 of 22 May 2007. Brussels: European Union.
[84] Marta, Lucia and Giovanni Gasparini. "Europe's Approach to Space Situational Awareness: a Proposal." Yearbook on Space Policy 2007/2008: From Policies to Programmes. Eds.Kai-Uwe Schrogl, Charlotte Mathieu and Nicolas Peter. Vienna: SpringerWienNewYork, 2009: 1.
[85] EU-Conference on "Security in Space, the Contribution of Arms Control and the Role of the EU", Berlin, 21st–22nd June 2007; Conclusions of the Workshop on space security and the role of the EU, available at: www.sidc.be/esww4/presentations/SWWT/SSA%20-%20Space%20Weather%20Week.ppt. Last accessed 16 June 2009.
[86] Rathgeber, Wolfgang. "Space Situational Awareness (SSA) for Europe, a First Important Step." ESPI Perspective 16, December 2008. 16 June 2009. http://www.espi.or.at/images/stories/dokumente/Perspectives/espi%20perspective%2016.pdf: 1.
[87] ESA. European Space Agency Ministerial Council. The Hague, 25–26 Nov. 2008. Final Conclusions. Doc. ESA PR 44-2008. Paris: ESA.
[88] Eleven Member States subscribed the programme and Spain is going to be the main contributor.
[89] ESA. European Space Agency Ministerial Council. The Hague, 25–26 Nov. 2008. Final Conclusions. Doc. ESA PR 44-2008. Paris: ESA.

[90] Rathgeber, Wolfgang. "Space Situational Awareness (SSA) for Europe, a First Important Step." ESPI Perspective 16, December 2008. 16 June 2009. http://www.espi.or.at/images/stories/dokumente/Perspectives/espi%20perspective%2016.pdf: 2.
[91] Marta, Lucia and Giovanni Gasparini. "Europe's Approach to Space Situational Awareness: a Proposal." Yearbook on Space Policy 2007/2008: From Policies to Programmes. Kai-Uwe Schrogl, Charlotte Mathieu and Nicolas Peter (Eds). Vienna: SpringerWienNewYork, 2009: 7–8.
[92] Ibid.:7–8.
[93] Ibid.: 5.
[94] Rathgeber, Wolfgang. "Space Situational Awareness (SSA) for Europe, a first important step." ESPI Perspective 16, December 2008. 16 June 2009. http://www.espi.or.at/images/stories/dokumente/Perspectives/espi%20perspective%2016.pdf: 2–3.
[95] Ibid.: 2–3.
[96] Interview with Nicolas Bobrinski, Head of ESA Ground Station System Division. 13 Nov. 2008. available at: http://www.esa.int/SPECIALS/Space_Debris/SEMFSG6EJLF_0_iv.html, last accessed 9 Mar. 2009.
[97] Ibid.
[98] Nardon, Laurence. "Space Situational Awareness and International Policy." Oct. 2007. Document de travail 14. Institut Français des Relations Internationales. 15 June 2009. http://www.ifri.org/files/Espace/Docu_14_SSA_Nardon.pdf: 5.
[99] de Selding, Peter. "France Pressures U.S. to Stop Publishing Orbits of French Milsats." 13 June 2007. Space.com. 9 Mar. 2009. http://www.space.com.