Journal of the Spanish Institute for Strategic Studies
ISSN-e: 2255-3479

Miguel Yagües Palazón
Ph.D. in International Security. Instituto General Gutiérrez Mellado (UNED).
E-mail: myaguespalazon@gmail.es

ENVIRONMENTAL CHALLENGES IN OUTER SPACE IN THE FRAMEWORK OF THE SECOND SPACE AGE

Abstract

The second space age (1991-present) is distinguished by two characteristics: the difficulty in reaching space governance agreements with emerging geopolitical actors, unlike the first space age (1957-1990) during which the entire space regulatory framework was structured; and the advent of numerous new public and private space actors –especially from 2010 onwards– triggering a corresponding increase in space activities in order to benefit from space applications such as reconnaissance activities, communications, space positioning systems and meteorology. These two factors are directly affecting the fragile space environment, and placing its sustainability at risk. In the absence of an international regulatory framework, the adoption of national laws is presented here as an alternative means of ensuring the responsible management of the space environment.

Keywords

Space environment; space sustainability; second space age; space governance; new space actors; space debris.

To quote this article:

YAGÜES, M. "Environmental Challenges in Outer Space in the Framework of the Second Space Age". Journal of the Spanish Institute for Strategic Studies. 2018, n.º 12, pp.

THE TRANSITION FROM THE FIRST TO THE SECOND SPACE AGE

The 1960s and 1970s laid the foundations for current space governance, fostered by the commitment of the United States and the former Soviet Union to maintaining strategic stability.

In fact, despite the hostilities associated with the first space age in the framework of the Cold War (1957-1990), the United States and the former Soviet Union managed to maintain a series of negotiations that prevented the military expansion of space, culminating, above all, in the creation of a legal body that established the bases for the moderate use of orbital resources. This legal process began shortly after the beginning of the space age with the inclusion of the atmosphere and outer space under the terms of the Partial Nuclear Test Ban Treaty in 1963 and the subsequent ratification of the Outer Space Treaty (OST) in 1967 that prohibits the deployment of weapons of mass destruction, the national appropriation of celestial bodies by claim of sovereignty and the demilitarisation of the Moon. In addition to the prohibitions embodied in the OST, which has also been described as the *Space Constitution*,[1] a series of rounds of arms control talks followed in 1969 leading to the signing of the Anti-Ballistic Missile Treaty (ABMT) and the SALT Agreements of 1972. Article V of the ABM Treaty, also explicitly prohibits the development, testing or deployment of ABM systems or components which are sea-based, air-based, space-based, or mobile land-based and SALT I prohibited the disturbance of the function of satellites used to verify compliance with the treaties.[2] In addition to military restrictions, the two superpowers designed a set of rules applicable to the civil sphere: in 1968, the Rescue Agreement came into force followed by the Liability Convention in 1972 and the Registration Convention in 1975. These treaties together with the 1979 Moon Treaty –without any concrete legal force because of the small number of states that have ratified it– have become part of the so-called *corpus iuris spatialis*. On the other hand, while negotiations were taking place on the maintenance of space security, the two superpowers were making significant progress in the field of space cooperation. This cooperation process culminated in the détente reached following the signing in the summer of 1972 of the Summit Agreement Concerning Cooperation in Outer Space for Peaceful Purposes between President Nixon and Prime Minister Kosygin that enabled the coupling of the Soyuz-19 and Apollo-18 capsules three years later, in July 1975.[3] Moreover, even in the wake of the Nixon-Brezhnev period, when bilateral relations were muddied following the invasion of Afghanistan and President Reagan's attempts to implement the

1 Wolter, D., *Common Security in Outer Space and International Law*, Geneva: United Nations Institute for Disarmament Research, 2006, p. 19.

2 Office of Technology Assessment, *U.S.-Soviet Cooperation in Space*, Washington, D. C.: U.S. Government Printing Office, 1985, p. 91.

3 Long Callahan, A., "Sustaining Soviet-American Collaboration, 1957–1989", in Krige, J.; Long Callahan, A. & Maharaj, A. (eds.), *NASA in the World: Fifty Years of International Collaboration in Space*, New York: Palgrave Macmillan, 2013, p. 138.

Strategic Defense Initiative (SDI), the two superpowers continued to maintain regular talks and dialogue on space security. An example of this was the announcement by the Soviet Union of a unilateral moratorium on its ASAT weapons tests in the mid-1980s.[4] A few years later, the end of the Cold War offered the United States the opportunity to set itself up as a sole space power, but instead of opting for a unilateral stance, it made overtures of cooperation to Russia that resulted in their joint membership of the International Space Station, ISS.

In the wake of the Cold War, the second space age, (1991-present-day) has shown that the long-standing Russian-American interdependence has remained intact and that in fact, it is so deep-rooted that even in February 2015, at the moment of greatest tension between Russia and the West since the Cold War as a result of the Ukrainian crisis, and with the Obama Administration debating whether to send arms to the Kiev government[5], the TASS news agency reported that the Russian space agency, Roscosmos, had decided to increase Russian participation in ISS from 2020 until 2024.[6] In addition, it is worth mentioning that since the withdrawal of the Space Shuttle programme in 2011, Russia is in charge of transporting American astronauts to the ISS in its Soyuz capsules.

Although the two superpowers quasi-monopolised space activities during the first three decades of the space age, the post-cold war era and especially the beginning of the twenty-first century have witnessed a radical turnaround in space dynamics. These changes include: 1) the new geopolitical landscape in which new emerging powers are modernising their space programmes, including military and dual-use technologies; 2) the increasing number of countries with space agencies and capabilities; 3) the arrival of new private agents, willing to participate in the development of space missions and applications; and as a result of all this: 4) the increased number of objects launched into space, the correlative increase of space debris and its consequent impact on space sustainability.

The concerns being expressed in relation to space sustainability are by no means new; on the contrary, this has been an issue of considerable significance throughout space history. This is borne out by James Moltz, who argues that the main reason for space stability during the Cold War was the superpowers' mutual awareness of the

4 Grego, L., *A History of Anti-Satellite Programs*, Cambridge, Massachusetts: Union of Concerned Scientists, 2012, p. 5.

5 Ryan, M., "Top U.S. general says it is time to consider arming Ukrainian forces". *The Washington Post*, 3 March 2015 <http://www.washingtonpost.com/world/national-security/top-us-general-says-it-is-time-to-consider-arming-ukrainian-forces/2015/03/03/aa68dade-c1d6-11e4-ad5c-3b8ce89f1b89_story.html> [consulted: 15-9-2018].

6 TASS, "Научно-технический совет Роскосмоса одобрил использование МКС до 2024 года" (Nauchno-tekhnicheskij sovet Rorkosmosa odobril ispolzovanie MKS do 2024 goda). *TASS*, Moscú, 24 February 2015 <http://tass.ru/kosmos/1789050> [consulted: 15-9-2018].

serious risks that the deterioration of the space environment posed to the installation of passive military satellites and space exploration in general.[7]

After all, the great dilemma or the crucial aspect of space governance is that it continues to be regulated under agreements based on strategic stability dating from the Cold War era. The fact that these have not been updated means that new developments since the turn of the century could have negative repercussions both on space stability and security and on the space environment, since these were not addressed at the time. Ultimately, this is the issue that the present article aims at turning the spotlight on: discovering the impact of these new dynamics on the space environment and the various ways in which this can be addressed.

THE NEW GEOPOLITICAL SPACE MAP

The end of American and Russian hegemony with the influx of new actors in space has led to the consolidation of the so-called "democratisation of space" insofar as it has made it possible to balance the distribution of power in the international arena. Most of these new actors are located on the continent of Asia.[8]

Specialised literature tends to coincide on the reasons why states want to have their own space capabilities. These are usually: international prestige and status, direct and indirect economic benefits and military capabilities.[9] Enumerating the factors that have favoured the influx of Asian countries, Ajey Lele includes the robust economic growth experienced by these states in recent decades and the strategic power of a large group of these countries. Economic prosperity has been translated by governments into investment in space programmes in order to address solutions in relation to civil administration, human and national security, food security, weather forecasting, the management and monitoring of the environment and natural resources, as well as urban management arising from population growth or border control.[10] Another major factor has been the "search for legitimacy" on the part of non-democratic regimes.[11]

7 Moltz, J. C., *The Politics of Space Security. Strategic Restraint and the Pursuit of National Interests*, California: Stanford University Press, Second edition, 2011, pp. 83-84.

8 Harding, R. C., *Space Policy in Developing Countries: The Search for Security and Development on the Final Frontier*, New York: Routledge, 2013, pp. 2-3.

9 Cheng, D., "Setting Future Directions in Space", in William B. Ruger Chair of National Security Economics Papers, *Defense Strategy and Forces: Setting Future Directions*, vol. 3, Naval War College: Newport, 2007, pp. 224-226; Harding, R. C., *op. cit.*, note 8, p. 4; Moltz, J. C., *Asia's Space Race: National Motivations, Regional Rivalries, and International Risks*, New York: Columbia University Press, 2012, p. 50.

10 Lele, A., *Asian Space Race: Rhetoric Or Reality?* New Delhi: Springer, 2013, pp. 3; 19.

11 Harding, R. C., *op. cit.*, note 8, p. 100.

The link between international prestige and the recognition of power through the development of national space programmes has been called "techno-nationalism" by Joan Johnson-Freese and Andrew Erickson. Techno-nationalism is not a new element that has arisen with the emerging states; it hails from the first space age, when the two superpowers competed with one another in attracting as many states to their spheres of power by showing off their technological prowess. The most reliable prototype at that time was the *Apollo* programme. The concept is associated with the political and economic powers of states, which focus on searching for resources that deliver access to the most advanced technologies, and provide them with international status. Therefore, aspiring powers consequently require advanced space programmes. Moreover, space programmes can have a positive impact on the image of the powers, mitigating their perception as reactionary and aggressive and thus facilitating cooperation.[12]

However, it seems that techno-nationalism is leading emerging nations to rekindle a space race along the lines of that waged between Washington and Moscow during the Cold War. In this new context, although major milestones in near space have already been achieved by the two superpowers, such as the launch of the first astronaut into space, landing on the Moon and the dispatch of probes to all the planets of the solar system, newcomers aspire to be the first among the list of emerging states. James Moltz points out that with such strategies in mind, the objective of emerging countries, and Asian nations in particular, is to pursue the search for continental leadership in economic, political and also in military terms.[13]

Therefore, in spite of the great benefits available to new actors participating in space resources and the democratisation process that it represents for space management, the truth is that space security can be seriously affected by the space race itself and if not properly managed, as in the first space age, it can have destabilising effects. In addition to the space race, space security can be further aggravated by a series of circumstances inherent in Asian countries that to date have hindered cooperation and fuelled rivalry. These circumstances can be summarised as follows:[14]

In the first place, the entry of new actors has meant bipolarity being replaced by multipolarity. As a result, the changeover from a framework characterised by the relative ease with which Moscow and Washington have managed to reach agreements due to a long-standing consensus on security issues, to the coexistence of numerous actors with widely differing security perspectives, renders negotiations and concessions more difficult and arduous. Unlike space legislation and arms control treaties signed between the Soviet Union and the United States, negotiations with emerging states become more complex. An example of this has been the stagnation of the Conference on Disarmament (CD) between 1998 and 2008 because of differences in space doctri-

12 Johnson-Freese, J. & Erickson, A.S., "The Emerging China-EU Space Partnership: A Geotechnological Balancer", *Space Policy*, vol. 22 (1), 2006, pp. 12-13.

13 Moltz, J. C., *op. cit.,* note 9, p. 59.

14 Moltz, J. C., *op. cit.,* note 9, pp. 32-33.

ne between the United States and China, or the rejection by the United States of the PPWT Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects proposed by China and Russia in 2008 and in 2014 within the CD.

Secondly, there is the related issue of emerging nations with military capabilities but with a lack of tradition in participating in arms control agreements or in negotiations aimed at the promotion of military restrictions. Indeed, Asian member countries have not participated in the approval of arms reduction, cooperation or security treaties, unlike the European states, among others, which participated in the signing of the Treaty on conventional armed forces in Europe, the Mutual and Balanced Force Reductions, and the Helsinki Agreements. The underlying causes hindering the achievement by emerging nations of arms control agreements in space are similar to those described by Paul Bracken in relation to nuclear weapons: the existence of a new "decentralised" international system, characterised by individual decision-makers and disconnected actors where transboundary, regional and global tensions play a key role in terms of cooperation.[15]

Indeed, unlike the cooperation that exists in Europe in relation to the European Space Agency (ESA), whose achievements include, among others, the first landing on a comet of the Philae lander module coupled to the Rosetta space probe, Asia has been characterised by technological independence with a view to achieving self-sufficiency. Ajey Lele has even dubbed it "technological apartheid", with India as its maximum exponent.[16] The result is that the Asian space nations do not cooperate with each other, but their commitments are connected with the United States, Russia and the European Union in terms of importing high-level technology and training. The best illustration of this is Japan's membership of the ISS. This is why, to date, the leading Asian powers have preferred to work with less developed countries to promote their own leadership and their economic and security interests. Since 2008 China has been organising the Asia-Pacific Space Cooperation Organisation (APSCO) which it hopes to develop into a body similar to ESA, but so far it has only managed to bring together underdeveloped countries such as Bangladesh, Iran, Mongolia, Pakistan, Peru and Thailand. Japan has promoted a less formal organisation, the Asia-Pacific Regional Space Agency Forum (APRSAF), whose objective is to promote Japanese national interests.[17] India, for its part, intends to foment greater regional cooperation with Australia, South Korea and Japan in order to compete with China.[18]

15 Bracken, P., *The Second Nuclear Age: Strategy, Danger, and the New Power Politics*, New York: Times Books, 2010, p. 2.

16 Lele, A., *op cit.*, Note 10, p. 14.

17 Moltz, J. C., "Asia's space race", *Nature*, No. 480, 8 December 2011, pp. 171-173, <https://www.nature.com/articles/480171a> [consulted: 15-9-2018].

18 Paracha, S., "Military Dimensions of the Indian Space Program", *Astropolitics: The International Journal of Space Politics & Policy*, vol. 11(3), 2013, p. 163.

Lack of cooperation has meant that military alliances in space are to date non-existent. Unlike the NATO members who have committed to sharing the same missile defence system under the joint coordination of their military space assets, in Asia the picture is diametrically opposed. South Korea has continually refused to share its missile defence system even with another democratic country such as Japan under the aegis of the United States, which is designed to deal with North Korean short, medium and intermediate range missiles. The causes of South Korea's rejection are rooted in the historical tensions between the two countries and in Japan's growing military role in the Far East.[19]

North Korea constitutes an extreme case of lack of cooperation in space. A paradigm of this void was the announcement by the government of Kim Jong-il of the launch of a telecommunications satellite on April 5, 2009. The launch took place, but as occurred with the two previous attempts, it fell into the Pacific Ocean due to the rudimentary technology employed that caused the third and final stage of the rocket to fail.[20] However, in the days leading up to the test, the U.S. and South Korean governments suspected that it was actually a camouflage operation to carry out an ICBM test in contravention of United Nations resolution 1718 (2006).[21] Consequently both South Korea and Japan decided to deploy their anti-missile defence systems.[22]Following the launch and after viewing the satellite imagery, some analysts determined that it was a long-range missile test. The images showed that the launch had adopted a trajectory with a critically horizontal angle, whereas space launches are almost vertical in order to gain height as soon as possible. It was concluded that the launch had "sacrificed altitude for distance", thus resembling an ICBM test to check how far the nuclear warheads would go.[23] The test was widely criticised and this in turn caused North Korea to announce that it would abandon the Six-Party Talks. In any case, it should be noted that North Korea's neighbours do not oppose Pyongyang's development of its space programme as long as it is for peaceful purposes.[24]

19 Sang-Hun, C., "South Korea and China End Dispute over Missile Defense System", *The New York Times*, 30 October 2017, <https://www.nytimes.com/2017/10/30/world/asia/north-korea-nuclear-test-radiation.html> [consulted: 15-9-2018].

20 Brumfiel, G., "Korean satellite misses orbit", *Nature*, 6 April 2009, <http://www.nature.com/news/2009/090406/full/458685a.htm> [consulted: 15-9-2018].

21 Reuters, "North Korea's Taepodong-2 long-range missile", *Reuters*, 25 March 2009, <http://www.reuters.com/article/2009/03/26/us-korea-north-missile-factbox-idUSTRE52P03Q20090326> [consulted: 15-9-2018].

22 Shanker, T. & Sang-Hun, C., "No U.S. Plans to Stop Korea on Missile Test", *The New York Times,* Washington, 30 March 2009, <http://www.nytimes.com/2009/03/31/world/asia/31korea.html?_r=0> [consulted: 15-9-2018].

23 Brumfiel, G., "Analysts spar over launch image", *Nature*, 8 April 2009, <http://www.nature.com/news/2009/090408/full/news.2009.355.html?s=news_rss> [consulted: 15-9-2018].

24 Rendleman, J. D., "Lawful Response to Attacks on Space Systems", in Sadeh E. (ed.), *Space and Defense*, Eisenhower Center for Space and Defense Studies, vol. 4 (1), 2010, Winter, pp. 14-15.

The contextual framework of the emerging space powers is further aggravated when lack of cooperation transforms into direct competition and rivalry. In this context, the Chinese ASAT test of January 2007, which destroyed the inoperative Chinese weather satellite FY-1C at an altitude of 865 kilometres, generated more than 3,400 pieces of waste, of which it is estimated that half will remain in the space until the year 2027.[25] The ASAT test was so significant for space history that some writers have described it as a milestone establishing a dividing line between "space ages". According to some writers, the ASAT test "marked the end of an era characterised by a lack of friction between space-faring nations and a general acceptance of norms governing the common use of space".[26] Thus, the success of the Chinese test not only served to demonstrate to the United States and Russia its technological capabilities, but it also profoundly impacted on the strategies of its neighbouring countries, especially India; a country that ever since has undertaken a review of both its space programmes and the concept of space security.[27] This is what Harsh Pant and Ajey Lele say when they declare that the ASAT test "led the Indian establishment to take the military uses of space more seriously". Among others, the former Chief of the Indian Air Force, PV Naik, declared in January 2010 that "our satellites are vulnerable to ASAT weapon systems because our neighbourhood possesses one", while at the same time urging the development of their own ASAT systems in order to improve their deterrence strategies and reduce the threat on their civil and military satellites. [28] From then on, although India had been developing a space programme for decades largely for civilian purposes, following the Chinese ASAT weapons test a marked military element was introduced and the development of an indigenous anti-ballistic missile programme with ASAT capabilities. In April 2012, it was learned that India had developed a *kill vehicle* that could be incorporated into an Agni-V ballistic missile with sufficient capacity to attack a satellite. The Indian strategy aims at developing ground-based ASAT weapons as providing a means to respond to potential attacks on its satellites without "weaponising" outer space.[29] On the other hand, although the Indian Defense Research Development Organisation (DRDO) declared that it did not intend to carry out real ASAT tests, just simulated tests, certain circles of Indian strate-

25 Gruss, M., "U.S. Official: China turned to Debris-free ASAT Tests following 2007 Outcry", *SpaceNews*, 11 January 2016, <http://spacenews.com/u-s-official-china-turned-to-debris-free-asat-tests-following-2007-outcry> [consulted: 15-9-2018].

26 Conrad, W., Anderson, J. & Jacobs, S., "Arms Control in the Third Space Age: Assessing International Efforts to Regulate Military Operations In Outer Space in the "3 C's" Era", in Coletta, D. (eds.), *Space and Defense*, Eisenhower Center for Space and Defense Studies, vol. 6 (1), Fall, p. 6.

27 Sachdeva, G. S., "Space Policy and Strategy of India", in Sadeh, E. (ed.), *Space Strategy in the 21st Century: Theory and Policy*, Oxon, Oxfordshire, Routledge, 2013, p. 315.

28 Pant, H. V. & Lele, A., "India in Space: Factors Shaping the Indian Trajectory", in Sadeh E. (ed.), *Space and Defense*, Eisenhower Center for Space and Defense Studies, vol. 4 (1), 2010, summer, pp. 52-53.

29 Conrad, W., Anderson, J. & Jacobs, S., "International Negotiations, Emerging Space Powers, and U. S. Efforts to Protect the Military Use of Space", in Coletta, D. (ed.), *Space and Defense*, Eisenhower Center for Space and Defense Studies, vol. 7 (1), 2014, winter, pp. 9-10.

gists have defended real tests in order to prevent India being left out of an international regime like India was with the Nuclear Non-Proliferation Treaty (NPT): they believe that if India had tested a nuclear weapon prior to the NPT, the country would have been grandfathered in as an official nuclear weapon state. By developing an ASAT test, India would obtain the status of an "official ASAT state" and along those same lines the Indian strategists seemed interested in developing an ASAT before the international community decided (whether formally or informally) to ban them.[30] In turn, changes in Indian space policy have been viewed with considerable misgivings in China due to its acquisition of advanced technological capabilities and New Delhi's deterrence strategy.[31]

For its part, Japan has also modified its outlook on space in recent years. Like India, Japan has been developing an entirely civilian space programme for decades. Both article 9 of the Japanese pacifist Constitution and its alliance with the United States curbed Tokyo's interests in acquiring military space capabilities. Consequently, since 1969, Japan has exclusively developed "peaceful and non-military" activities, constituting a restrictive interpretation of OST commitments. However, in 2008, Japan passed the Basic Space Law, whose provisions allow it to make use of "non-aggressive" measures, similar to those adopted by the United States, the former Soviet Union and other space powers. The underlying reasons that have brought about this change are North Korea's nuclear programme with its ballistic missiles and China's growing space capabilities.[32]

In these circumstances the security dilemma paradox has reared its head once again in a broad range of scenarios: South Asia, the Korean peninsula, the "Taiwanese triangle", Indo-China, Japan-China and Iran-Israel, triggering the comment from Ajey Lele that the "Asian region could be viewed as the place which presents the most widespread and exceptional security dilemma in the world».[33]

A GROWING NUMBER OF COUNTRIES WITH SPACE CAPABILITIES

New space races at regional level in the framework of the second space age are currently acknowledged as an undeniable fact. Even in Africa, similar trends are beginning to appear, although on a smaller scale.[34]

30 Samson, V., "India and space security", *The Space Review*, 9 May 2011, <http://www.thespacereview.com/article/1838/1> [consulted: 15-9-2018].

31 Sachdeva, G. S., *op. cit.,* note 27, p. 315.

32 Pace, S., "U.S.-Japan Space Security Cooperation", in Schrogl, K-U., Hays, P. L., Robinson, J., and Giannopapa, D. M. Ch. (eds.), *Handbook of Space Security. Policies, Applications and Programs*, New York: Springer, 2015, pp. 338; 341; 350.

33 Lele, A., *op. cit.,* note 10, p. 23.

34 Adamowski, J., "Angola eyes new satellite as African space race accelerates", *SpaceNews*, 12 June 2018, <https://spacenews.com/angola-eyes-new-satellite-as-african-space-race-accelerates/> [consulted: 15-9-2018].

While the main emerging geopolitical powers are increasing their military capabilities, other states are investing in space technology, although in most cases they are civil rather than military. Due to size constraints, this article will focus on the study and analysis of the Asian continent as outlined in the previous section.

Navigation and space positioning systems represent one of the most illustrative cases of the new multi-polar space age. In addition to the two systems in operation to date, the North American GPS and the Russian GLONASS, two other independent systems can be added: the European navigation systems Galileo and the Chinese BeiDou. It is expected that the 35 BeiDou satellites will provide global services upon completion in 2020. However, multipolarity means that advances are being made elsewhere outside of China. India and Japan also have also aspirations to acquire indigenous and independent navigation systems: the former, through the IRNSS (Indian Regional Navigation Satellite System), a system composed of seven satellites of regional scope covering the subcontinent; and the latter, with the development of the QZSS (Quazi-Zenith Satellite System), a four-satellite navigator in highly elliptical orbit (HEO) designed to provide regional coverage over Japan, the Korean Peninsula and the Yellow Sea. The reasons driving states to achieve independent navigation systems are clear: on the one hand, to distance themselves from GPS-dependence and on the other, to ensure against a lack of access to their services in a crisis context.[35]

Given that studies in space policy tend to focus primarily on the capabilities of the two main Asian powers, China and India, this article will undertake a review of the space capabilities of other actors on the Asian continent.

In the Middle East, Iran became the first Islamic nation and the ninth worldwide to reach the status of space power after the launch of its domestically-made Omid satellite using the Safir-2 launch system, of the Shabab missile class, in February 2009. Although Iran has argued that its space programme is exclusively for civil and peaceful purposes, the West harbours suspicions that it is a dual and clandestine programme whose ultimate objective is the development of long-range missiles. However, irrespective of Iranian military intentions, its space programme is viewed to be both an attempt to gain international prestige and a technological demonstration of potential

ballistic missile capabilities: since then, Iran has offered to provide assistance to other Muslim countries who want to establish a space programme;[36] its national pride and the Islamic regime have been strengthened as a consequence and with its technological development it aspires to achieving greater political presence in the region.[37]

35 Jaramillo, C., *Space Security Index 2013*, Tenth edition, Ontario: Space Security.org, 2013, pp. 41-42.

36 Chow, T., "Iranian Space Launch Capabilities. Fact Sheet", *Secure World Foundation*, 2 September 2010, <http://swfound.org/media/1690/swf_iran_slv_fact_sheet.pdf> [consulted: 15-9-2018].

37 Hsu, J., "Iran's Space Program: Lots of Talk, but a Chance to Shine", *Space.com*, 9 November 2010, <http://www.space.com/9499-iran-space-program-lots-talk-chance-shine.html]> [consulted: 15-9-2018].

With the launch of Rasad-1 in June 2011, Iran has its own spy satellites.[38] The United Arab Emirates (UAE), as part of its international projection strategy, aims to be a leading player in space tourism by becoming a partner and sponsor of Virgin Galactic. However, the project based in Abu Dhabi has encountered continuous delays. One of the UAE's many plans is to send a mission to Mars in 2021.[39] Turkey has to date focused its space strategy on obtaining the capabilities that will allow it to monitor its south-eastern border, the Black Sea and the Mediterranean Sea. With due consideration for its role as a regional power, its investment in the creation of a nascent space industry has defined three main objectives: an increasingly reduced dependence on foreign technology by achieving a 16-satellite network providing communication, reconnaissance and an early warning system against missiles from its neighbours, as well as competing with Russia in the export of satellites to the countries of Central Asia. However, Turkey witnessed how Israel obstructed the purchase of high resolution satellites suspecting that Ankara intended to spy on Israeli territory.[40]

In South Asia, Pakistan has not differentiated between a civil and a military space programme. Due to heavy budgetary restrictions, Islamabad has prioritised its nuclear programme, its arsenal of ballistic missiles and counter-terrorist operations to the detriment of its space programme, with the result that in an Asian context Pakistan lags far behind. The weakened Pakistani space programme contrasts sharply with the strong development of neighbouring India. Moreover, there is a marked reluctance on the part of the other space powers –with the exception of China with whom Islamabad continues to maintain solid cooperation– to share technology with Pakistan, in view of its nuclear capabilities. Chinese support has, however, accentuated Islamabad's military dependence on Beijing.[41]

In North-East Asia, like Pakistan, North Korea has limited space capabilities on account of its ongoing financial problems and huge military expenditure. The North Korean space programme has always been subordinate to its medium and long-range missile programme. Although Pyongyang carried out launches in 1998, 2009 and in the spring of 2012, its rudimentary technology has triggered numerous setbacks. The United States, Japan and South Korea have always harboured suspicions that the launches were really missile tests.[42] However, in December 2012, the Earth observation satellite Kwang-

38 Wright, D., "Rasad-1: Iran Launches Its Second Satellite", *Union of Concerned Scientist*, 16 June 2011, <http://allthingsnuclear.org/rasad-1-iran-launches-its-second-satellite/> [consulted: 15-9-2018].

39 Waters, R. & Kerr, S., "Virgin Group funds tapped for delayed space venture", *Financial Times*, 2 November 2014, <http://www.ft.com/cms/s/0/9d51be70-62b7-11e4-9838-00144feabdc0.html#axzz3aFIjtTZ6> [consulted: 15-9-2018].

40 Stein, A., "Turkey's Space Policy", *Centre for Economics and Foreign Policy Studies*, EDAM Discussion Paper Series 2014/3, May 2014, pp. 4; 10; 13.

41 Lele, A., *op. cit.*, note 10, p. 54-56.

42 Space.com Staff, "North Korea Successfully Launches Satellite: Reports", *Space.com*, 12 December 2012, <http://www.space.com/18867-north-korea-rocket-launch-satellite.html> [consulted: 15-9-2018].

myongsong-3 entered orbit having been launched aboard the long-range missile Unha-3. The success of the launch raised concerns that North Korean missile technology could be exported to countries such as Iran or Pakistan.[43] In 2014, it was revealed that North Korea might have a more powerful rocket than the Unha-3; the KN-08, a transportable ICBM.[44] The success of the satellite has served Pyongyang to project itself domestically and internationally as an emerging power. For its part, ever since the end of the Cold War South Korea has made considerable advances especially in the manufacture of satellites and in the provision of space services. In addition, it has woven a solid network of cooperation with other space actors, especially with the United States, which resulted in sending an astronaut to the ISS in April 2008. It has also maintained links with the EU through its cooperation in Europe's global navigation satellite system Galileo, and with Russia, which has assisted in the manufacture of a launch pad. This cooperation has been favoured by the fact that South Korea is not a military power of the first order. Finally, Japan has been the primary Asian space power for decades. It is the only Asian member of the ISS, with a seasoned satellite industry, a very relevant role in scientific space missions and a long history of space cooperation that has allowed it to lead the APRSAF. However, in 2013 China's expenditure exceeded that of Japan.[45] This *sorpasso* was due not to Japan's lack of interest in space, but to budget constraints. Besides, Japan lags far behind in terms of military applications, which it did not begin to use until 2008 due to restrictions arising from its pacifist Constitution and its privileged access to U.S. technology and space services.[46] This situation has led to considerable foreign dependence exemplified by the installation of its defence system, for which the United States provided not only the interceptor technology, but also early warning radars and infrared spy satellites.[47]

The Southeast Asia region is composed of a group of emerging nations whose technological capabilities are far removed from the main space powers, but which have nevertheless begun to acquire a growing role in space activities. Cambodia is one of them, signing an agreement with China in early 2018 to launch a telecommunications satellite within the framework of the Silk Road, China's Belt and Road

43 Sang-Hun, C. & Sanger, D. E., "North Koreans Launch Rocket in Defiant Act", *The New York Times*, Seoul, 11 December 2011, <http://www.nytimes.com/2012/12/12/world/asia/north-korea-launches-rocket-defying-likely-sanctions.html> [consulted: 15-9-2018].

44 Hansen, N., "North Korea's Sohae Satellite Launching Station: Upgrades Near Completion; Ready for More Launches?" *38 North*, 21 August 2014, <http://38north.org/2014/08/sohae082114/> [consulted: 15-9-2018].

45 Al-Ekabi, C., "Space Policies, Issues and Trends in 2012–2014", *European Space Policy Institute*, ESPI Report 49, 2014, November, pp. 17-18.

46 Moltz, J. C., *op. cit.,* note 9, pp. 75-76.

47 Dawson, C., "Japan Shows Off Its Missile-Defense System", *The Wall Street Journal*, Tokyo, 9 December 2012, <http://www.wsj.com/articles/SB10001424127887323316804578165023312727616> [consulted: 15-9-2018].

Initiative.[48] For its part, Indonesia has focused the priorities of its space programme on the acquisition of three types of applications: terrestrial observation satellites to monitor its maritime space; weather forecasting satellites to deal with natural disasters such as tsunamis; and communication satellites to form a network on all the islands of the archipelago.[49] Taiwan, on the other hand, while benefitting from intense international cooperation with the United States, the EU, Israel and Russia, which has enabled the development of a civilian satellite system, it has been prevented from developing military applications or any form of rocket launch programme on account of its relations with China. Other states that have been promoting their own space programmes are Malaysia, which in October 2007 sent its first astronaut into space. Thailand enjoys a high degree of cooperation with the United States, dating back to the Vietnam War, as well as with China and Japan; its main objective is to develop reconnaissance applications to deal with the risks it faces from cross-border threats, insurgency in the south of the country and contraband. Vietnam, which for years enjoyed close cooperation with the Soviet Union –the first Asian astronaut was Vietnamese– is currently prioritising space technology that will enable it to respond to natural disasters and climate change, with Japan as its main partner.[50]

THE GROWING PARTICIPATION OF PRIVATE ACTORS

The so-called "democratisation of space" is not a question restricted to public programmes. Evidence of a growing number of private actors has put an end to the regime that was born during the Cold War and that for decades was characterised by the use of space by exclusively governmental programmes. This new context, in addition, has highlighted the sustained interest of the private sector in space applications and services. However, it should be noted that there is a marked difference between the two sectors: while states have invested large sums of capital to carry out space missions –the Apollo programme required 400,000 people at a cost of 110 billion of dollars at present-day value– the private sector, on the other hand, has benefited from the advantages of the lowering costs of space technology, and specifically the technology associated with computing, manufacturing and the rocket launch industry.[51]

48 Henry, C., "Cambodia to buy Chinese satellite as relations tighten on Belt and Road Initiative", *SpaceNew*, Washington, 12 January 2018, <https://spacenews.com/cambodia-to-buy-chinese-satellite-as-relations-tighten-on-belt-and-road-initiative/> [consulted: 15-9-2018].

49 Lele, A., *op. cit.,* note 10, p. 114.

50 Moltz, J. C., *op. cit.,* note 9, pp. 251-254; 268-279.

51 Baiocchi, D. & Welser IV, W., "The Democratization of Space", *Foreign Affairs*, May/June 2015, <https://www.foreignaffairs.com/articles/space/2015-04-20/democratization-space?cid=nlc-foreign_affairs_today-050315> [consulted: 15-9-2018].

The push that catapulted the business sector and privatisation did not occur until the 1980s, in the context of the first stage of globalisation, at which time there was an increasing demand for satellite communications, especially television broadcasting and the creation of new companies providing satellite services. Two factors added to this: the changes in US space policy as a result of the Challenger space accident in 1986; and the rivalry triggered by the European space launcher Ariane that spurred on the United States in its bid to develop a domestic commercial space launch industry.[52] The expansion of international networks has been such that during the Iraq War, eighty percent of communications were carried via commercial communications satellites.[53] In fact at the beginning of the previous decade, the GAO (Government Accountability Office) urged that commercial satellites be identified as "critical structures" and included in the National Strategy for Critical Infrastructure Protection to ensure their protection against damaging or destructive actions.[54]

Authors such as Ram Jakhu and Joseph Pelton point out that global economic recession served as a definitive stimulus for the development of the private space industry, as states and government agencies were forced to seek cheaper access to space solutions, understanding that only private enterprises could "implement radical industrial optimisation".[55] Space trade has been increasing over the years with significant growth in manufacturing volume, launches and capital. At the beginning of the decade of 2010, and in the context of a general economic slowdown worldwide, space activity was not showing signs that it had been affected by the financial crisis. None of the 38 private space operators worldwide that existed in 2011 recorded negative growth.[56] Of the $314.17 billion in commercial revenue invested in the sector globally in 2013,[57] three quarters corresponded to commercial activity, with just a quarter of the total from government

52 Fuller, J; Foust, J.; Frappier, C.; Kaiser, D. & Vaccaro, D., "The Commercial Space Industry: A Critical Spacepower Consideration", in Lutes, C. D. & Hays, P. L. (eds.), *Toward a Theory of Space Superpower. Selected Essays*, Washington, D. C.: Institute for National Strategic Studies. National Defense University, 2011, p. 104.

53 DalBello, R., "Commercial Communication Satellites: Assessing Vulnerability in a Changing World", in Logsdon, J. & Adams, G. (eds.), *Space Weapons. Are they needed?* Washington, D. C.: Space Policy Institute. The George Washington University, 2003, p. 271.

54 GAO, *Critical Infrastructure Protection. Commercial Satellite Security Should Be More Fully Addressed*, August 2002, <http://www.gao.gov/assets/240/235485.pdf> [consulted: 15-9-2018].

55 Jakhu, R. S. & Pelton, J. N., "Private Commercial Space Enterprises and Global Governance System", in Jakhu, R. S. & Pelton, J. N. (eds.), *Global Space Governance: An International Study*, Cham, Switzerland: Springer, p. 115.

56 Tortora, J.-J., (2014) "Space Industry and the Financial Crisis", in Al-Ekabi, C.; Baranes, B.; Hulsroj, P. & Lahcen, A. (eds.), *Yearbook on Space Policy 2011/2012. Space in Times of Financial Crisis,* Vienna: Spring, 2014, pp. 177-178.

57 De Selding, P. B., "SES Positioned to Overtake Intelsat in Revenue", *SpaceNews*, Paris, 21 February 2014, <https://spacenews.com/39577ses-positioned-to-overtake-intelsat-in-revenue/> [consulted: 15-9-2018].

spending.[58] Out of a total of 528 US satellites in existence in January 2015, 229 were commercial, 18 civilian, 121 governmental and 160 military.[59]

Since the beginning of the twenty-first century, private initiatives have diversified into four classes:

In first place, the traditional marketing and sale of satellite applications. For example, in February 2017 India set a record with the launch of 104 satellites into space from a single rocket, 88 of which were *Doves*, small satellites weighing just 4.5 kilograms. The satellites are manufactured by the North American company Planet Lab that sells data to governments and commercial entities.[60]

In 2009 three of the leading global satellite communications companies, Intelsat, SES and Inmarsat, with more than 100 satellites between them in geostationary orbit (GEO), proposed the creation of the SDA (Space Data Association), a database designed to record the positions of satellites or planned manoeuvres to reduce the possibility of orbital collisions and frequency interference while aiming to provide situational spatial awareness (SSA). This database represented the first global effort of the satellite industry to address issues common to private satellite operators. The proposal had a double objective: on the one hand, to provide information on the location of commercial satellites, because although this is already available through intergovernmental space surveillance, it is not always accurate and up-to-date, especially in the geostationary arc. Therefore, the aim was to obtain a database that would be independent of government control. The other objective was that it would also function as an information exchange centre.[61]

The second group relates to the provision of space launch services. During the early years of the twenty-first century, private companies and investors reached different milestones. The first of these occurred in 2004 when the SpaceShipOne became the first manned aircraft to perform a suborbital flight, analogous with the early days of commercial aviation in the 1920s and 1930s, when several private airlines were offering commercial transatlantic flights.[62] Other significant examples of

58 Space Foundation, *The Space Report 2014*, Colorado Spring, Colorado: Space Foundation, 2014.

59 Union of Concerned Scientist, *UCS Satellite Database*, Satellite Quick Facts (includes launches through 1/31/15), <https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.W54k_1JoTBJ> [consulted: 1-6-2015].

60 Barry, E., "India Launches 104 Satellites from a Single Rocket, Ramping up a Space Race", *The New York Times*, New Delhi, 15 February 2017, <https://www.nytimes.com/2017/02/15/world/asia/india-satellites-rocket.html> [consulted: 15-9-2018].

61 De Selding, P. B., "Satellite Operators Solicit Bids to Create Orbital Database", *SpaceNews*, Paris, 18 November 2009, <http://www.spacenews.com/article/satellite-operators-solicit-bids-create-orbital-database> [consulted: 15-9-2018].

62 Boot, M., "Space, the Final Free Market", *Council on Foreign Relations*, 7 October 2004, < http://www.cfr.org/space/space-final-free-market/p7433> [consulted: 1-6-2015].

developments in the private enterprise sector have been achieved by the company SpaceX, which sent its first spacecraft, the Dragon, to the ISS, achieving its coupling in May 2012.[63] In December 2013, another milestone in space history was reached: SpaceX launched the Falcon 9 transporting rocket from California to GEO carrying the private communication satellite SES-8 manufactured by the company of the same name[64] and in December 2015 it landed a rocket vertically for the first time in history.[65] These technological advances have led to a race between the main private companies, SpaceX, Blue Origin and Orbital ATK, which are all competing to take over government space launch contracts, previously monopolised by the United Launch Alliance.[66] The development of private space launchers has spread to other regions of the world. In Europe, the European Commission launched the Low-Cost Space Launch as part of the Horizon 2020 programme designed to develop light-load launchers that transport payloads to Low Earth Orbit (LEO) at low cost. One of the competitors is the Spanish company PLD Space. Even China is developing an emerging industry of private launchers with different companies such as LandSpace, after the Chinese government decided in 2014 to open up the space sector to private investment.[67]

The third class is space tourism, with an increasing number of operators, although others have disappeared, as did XCOR Aerospace with its suborbital ship *Lynx*. Although the marketing of space tourism goes back to the first decade of this century, its implementation has been deferred by a series of delays. This is the case of Virgin Galactic, a company that in 2008 set out to operate in 18 months,[68] but a series of setbacks –the most important of which occurred in October 2014 after the accident of the VSS Enterprise– have prevented the first suborbital flights from

63 Chang, K., "First Private Craft Docks with Space Station", *The New York Times*, 25 May 2012, <http://www.nytimes.com/2012/05/26/science/space/space-x-capsule-docks-at-space-station.html> [consulted: 15-9-2018].

64 Klotz, I., "(Another) Giant Leap for SpaceX: Geostationary Orbit", *Discovery News*, 3 December 2013, <http://news.discovery.com/space/private-spaceflight/another-giant-leap-for-spacex-geostationary-orbit-131213.htm> [consulted: 1-6-2015].

65 BBC, "SpaceX rocket in historic upright landing", *BBC News*, 22 December 2015, <http://www.bbc.com/news/science-environment-35157782> [consulted: 15-9-2018].

66 Davenport, C., "As human space flights get closer, the competition for launch contracts heats up", *The Washington Post*, 25 April 2018, <https://www.washingtonpost.com/news/the-switch/wp/2018/04/25/jeffrey-p-bezos-blue-origin-getting-closer-to-flying-tourists-to-space-as-it-begins-to-compete-on-several-fronts/?utm_term=.97a346b79847> [consulted: 15-9-2018].

67 Jones, A., "Chinese startups OneSpace, iSpace succeed with suborbital launches", *SpaceNews*, Helsinki, 7 September 2018, <https://spacenews.com/chinese-startups-onespace-ispace-succeed-with-suborbital-launches/> [consulted: 15-9-2018].

68 BBC, "Branson unveils space tourism jet", *BBC*, 28 July 2008, <http://news.bbc.co.uk/2/hi/science/nature/7529978.stm> [consulted: 15-9-2018].

operating. For its part, the company Blue Origin plans to start selling the first suborbital flight tickets for its New Shepard spaceship in 2019.[69]

And in fourth place is the exploration and exploitation of other celestial bodies, including mining. Its major challenges include SpaceX's "aspirational" timeline to land cargo missions on Mars starting in 2022 and two years later, to send a manned mission with the purpose of forming a colony on the planet.[70] Also in the fray is Bigelow, an American company commissioned to build some of the ISS modules on behalf of NASA, which is simultaneously researching and developing prototypes to send the first private space station into space[71] as well as a lunar space station.[72] Bigelow has in fact initiated a series of procedures aimed at claiming property and mining rights on the lunar surface.[73] Staking claim to property is a very debatable question as space law treaties prohibit such claims, as referred to in OST Article 2, which states that "outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, use or occupation, or by any other means".[74] The 1979 Moon Treaty is even more restrictive on this issue, while Article 11.3 states that "neither the surface nor the subsurface of the moon, nor any part thereof or natural resources in place, shall become property of any State, international intergovernmental or non-governmental organization, national organization or non-governmental entity or of any natural person"[75] However, this Treaty has no binding force due to the small number of states that have ratified it. That is why in order to permit outer space exploitation activities, some states have already begun to enact national legislation regulating private space exploration missions. Luxembourg is a case in point with its *Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressour-*

69 Foust, J., "Blue Origin plans to start selling suborbital spaceflight tickets next year", Washington, 21 June 2018, <https://spacenews.com/blue-origin-plans-to-start-selling-suborbital-spaceflight-tickets-next-year/> [consulted: 15-9-2018].

70 Wall, M., "Elon Musk Wants Giant SpaceX Spaceship to Fly People to Mars by 2024", *Space.com*, 29 September 2017, <https://www.space.com/38313-elon-musk-spacex-fly-people-to-mars-2024.html> [consulted: 15-9-2018].

71 Howell, E., "Bigelow Aerospace: Inflatable Modules for ISS", *Space.com*, 17 January 2013, <http://www.space.com/19311-bigelow-aerospace.html> [consulted: 15-9-2018].

72 David, L., "Private Moon Bases a Hot Idea for Space Pioneer", *Space.com*, 14 April 2010, <http://www.space.com/8217-private-moon-bases-hot-idea-space-pioneer.html> [consulted: 15-9-2018].

73 Klotz, I., "Exclusive - The FAA: regulating business on the moon", *Reuters*, Florida, 3 February 2015, <https://www.reuters.com/article/us-usa-moon-business/exclusive-the-faa-regulating-business-on-the-moon-idUSKBN0L715F20150203> [consulted: 15-9-2018].

74 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.* (Resolution 2222 (XXI) of the General assembly, annex), approved on 19 December 1966, open for signing on 27 January 1967, and in force on 10 October 1967, <http://www.unoosa.org/pdf/publications/STSPACE11S.pdf> [consulted: 15-9-2018].

75 *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies* (resolution 34/68 of the General assembly, annex), approved on 5 December 1979, open for signing on 18 December 1979, and in force on 11 July 1984, <http://www.unoosa.org/pdf/publications/STSPACE11S.pdf> [consulted: 15-9-2018].

ces de l'espace whose first article stipulates that « *[l]es ressources de l'espace sont susceptibles d'appropriation* ».[76] Finally, in relation to activities on the Moon, in September 2007, the Google Lunar X Prize was announced, a competition with a prize of 20 million US dollars for the first privately funded project (although up to 10 percent public financing is permitted) whose mission would complete three requirements: the safe landing of a robot on the moon, a journey of up to 500 meters with the robot-rover on the lunar surface, and the transmission to the Earth of high definition images and videos. The deadline for submission of applications was extended several times until January 2018 when the sponsoring foundation cancelled the contest by confirming that none of the participants could reach the Moon before the deadline of March 31.[77] The prize was characterised by two important phenomena: firstly, that the lunar competition was not limited to projects from within the United States, but extended to South America, Asia and Europe, including Spain;[78] and secondly, that in 2010 NASA announced its intention to contract some of the teams in order to improve technology associated with low-cost lunar missions.[79]

The space environment and space debris

The range of outer space activities carried out by both public and private actors have logically had a significant impact on the space environment. The problem of space sustainability and space debris is exacerbated by the intrinsic environmental characteristics of space. As Joel Primack points out, "space is the most fragile environment that exists because it has the least ability to repair itself".[80] Due to its factorial peculiarities, space is very different to the terrestrial environment.

Thus, since the first critical fragmentation of a satellite in June 1961,[81] and a prolific series of fragmentations during the 1970s and 1980s, the issue of space debris has

76 *Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace*, Journal officiel du Grand-Duché de Luxembourg, Signed: 20/07/2017; Published: 28/07/2017, <http://legilux.public.lu/eli/etat/leg/loi/2017/07/20/a674/jo> [consulted: 15-9-2018].

77 Foust, J., «https://spacenews.com/google-lunar-x-prize-to-end-without-winner/», *SpaceNews*, 23 January 2018, <https://spacenews.com/google-lunar-x-prize-to-end-without-winner/> [consulted: 15-9-2018].

78 Basulto, D., "One small step for man, one giant step for the commercialization of the moon", *The Washington Post*, 12 February 2015, <http://www.washingtonpost.com/blogs/innovations/wp/2015/02/12/one-small-step-for-man-one-giant-step-for-the-commercialization-of-the-moon//> [consulted: 15-9-2018].

79 Al-Ekabi, C., "Developments in Space Policies, Programmes and Technologies Throughout the World and in Europe", in Al-Ekabi, C.; Baranes, B.; Hulsroj, P. & Lahcen, A. (eds.), *Yearbook on Space Policy 2011/2012. Space in Times of Financial Crisis*, Vienna: Spring, 2014, p. 117.

80 Primack, J., "Debris and Future Space Activities", in Motlz, J. C. (ed.), *Future Security in Space: Commercial, Military, and Arms Control Trade-Offs*, Center for Non-proliferation Studies, Occasional Paper, 2002, p. 1.

81 Portree, D. S. F. & Loftus, Jr. J. P., *Orbital Debris: A Chronology*, NASA, 1999, January, p. 4.

captured the attention of governments and the scientific community.[82] Recognition of the need to address the problem arose not only in the wake of the co-orbital ASAT tests carried out by the Soviet Union but also with the explosions during the second phase of the Delta rockets, whose first brak-ups occurred in 1973.[83] Currently, forecasts suggest that space pollution will increase in coming years due to increased space activity, explosions in orbit and accidental collisions between space objects. In fact, some simulations on waste evolution suggest that even if space launches were stopped, the current amount of LEO waste would generate such a chain of collisions that after 50 years, it would be impracticable to operate in the region.[84] Given that the debris annual growth rate is around five percent,[85] there are major concerns that the LEO will suffer from the so-called "Kessler Syndrome", a scenario presented in 1978 by Donald Kessler, who predicted that at a critical point the rate of accumulation of waste would grow faster than its rate of decomposition, reaching a scenario in which the density of objects in Low Earth Orbit (LEO) would be high enough for collisions between objects to set off a "cascade of collisions", thus rendering space activities and the use of satellites unfeasible.[86]

Space debris is defined by the Inter-Agency Space Debris Coordination Committee, IADC, as "all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional".[87] Looking at the issue in greater detail, we can say that space debris includes: satellites whose functional life has ended but which remain floating in space; the upper stage launchers of rockets in transfer orbits; "operational waste" or fastening and protection elements for a satellite during its launch phase; fragmentation waste due to collisions; accidental or intentional explosions; the waste of propellers used to move satellites to GEO through a transfer orbit; or the deterioration of materials due to the extreme conditions of space weather.[88] Of all the orbital objects catalogued, 94 percent are classified as debris.[89] However, in addition to the threats posed by abandoned satellites or other operational

82 NASA, *History of On-Orbit Satellite Fragmentations*, Orbital Debris Program Office, 2008, p. 1.

83 IAA, International Academy of Astronautics, *Position Paper on Space Debris Mitigation. Implementing Zero Debris Creation Zones*, 2005, p. 8.

84 Liou, J-C. & Johnson, N. L., "A Sensitivity Study of the Effectiveness of Active Debris Removal in LEO", *Acta Astronautica*, 2009, vol. 64:2-3, p 236.

85 Pelton, J. N., *Space Debris and Other Threats from Outer Space*, New York: Springer, 2013, p. 5.

86 Stenger, R., "Scientist: Space weapons pose debris threat", *CNN*, 3 May 2002, <http://edition.cnn.com/2002/TECH/space/05/03/orbit.debris/index.html?_s=PM:TECH> [consulted: 15-9-2018].

87 IADC, Inter-Agency Space Debris Coordination Committee, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*, 2010, p. 1.

88 Alby, F., "The Space Debris Environment and its Impacts", in Rathgeber, W.; Schrogl, K. & Williamson, R. A. (eds.), *The Fair and Responsible Use of Space: An International Perspective*, Vienna: Springer, 2010, pp. 60-61.

89 IAA, International Academy of Astronautics, *op. cit.*, note 83, p. 4.

waste, much has been written about the so-called "second generation waste", that is, the small particles generated as a result of impact between space objects.[90] While 5,400 pieces of space junk of over 10 centimetres were tracked in 1980, their number has now increased to more than 21,000.[91] In addition, there are around 500,000 pieces between 1 and 10 centimetres in diameter and more than 100 million particles of less than one centimetre estimated to be in orbit. Current technology permits the recording of particles of up to 3 millimetres in LEO.[92] The principal monitor for tracking, cataloguing and identifying space debris is the US *Space Surveillance Network* (SSN).

According to David Wright,[93] there are two main sources of space debris. The first is "routine space activity". This includes debris released in the process of launching satellites and debris created by the break-up of defunct satellites or booster stages in orbit, either due to explosions from leftover fuel or collisions with a second object. The second source of debris is the intentional destruction of satellites in orbit by the testing or use of kinetic-energy ASAT weapons, which are intended to destroy satellites by physically colliding with them at high speed.[94] Wright argues that a satellite of up to 8 tons such as the Envisat European satellite[95] would be completely destroyed if hit by a 20-kilogram kinetic weapon which can travel at 7.5 km per second. The danger posed by debris arising from routine activities or intentional collisions is the potential destruction of other satellites and manned missions as they are pieces that at the moment of impact reach 10 km per second in LEO. Depending on size, the damage caused by waste can range from faults in satellite sensors and panels to the complete destruction of the satellite thus unleashing a "cloud of debris".

Currently, there is a widely-shared recognition among the major space powers of the fragility of the space environment. The reason for this is that the aforementioned IADC has designated both the LEO and GEO in their guidelines under the umbrella term of "protected regions".[96] LEO, which extends up to 2,000 kilometres, is the most congested region with the highest concentration of space objects, and is the area in which manned missions are developed. GEO protection is not reduced to its circular

90 Williams, M., "Safeguarding Outer Space: on the road to debris mitigation", in United Nations Institute for Disarmament Research (ed.), Security in Space: the Next Generation, Geneva: United Nations, 2008, pp. 84.

91 Pelton, J. N., *op. cit.*, note 85, p. 5.

92 NASA Orbital Debris Program Office. Orbital Debris Frequently Asked Questions. <https://www.nasa.gov/news/debris_faq.html> [consulted: 15-9-2018].

93 Wright, D., "Orbital Debris Produced by Kinetic-Energy Anti-Satellite Weapons", in United Nations Institute for Disarmament Research (ed.), *Celebrating the Space Age. 50 Years of Space Technology, 40 Years of the Outer Space Treaty*, Geneva: United Nations, 2007, pp. 155-156.

94 NASA, *op. cit.*, note 82, p. 2.

95 Wright, D., *op. cit.*, note 93, p. 159.

96 IADC, Inter-Agency Space Debris Coordination Committee, *IADC Space Debris Mitigation Guidelines*, 2007, p. 6.

and equatorial orbit at 35,786 kilometres, but extends to ± 200 kilometres and to ± 15 degrees.

One factor that plays an essential role in mitigating LEO waste is the effect of atmospheric drag. This element is "the resistive force of the molecules of the atmosphere".[97] Given this resistive force, the atmospheric drag exerts a negative and a positive influence on satellites. The negative effect implies that the atmospheric resistance generates a disturbance in the trajectory of the satellites, slowing them down and forcing them to use fuel to maintain stable orbits. The atmospheric pressure becomes even denser if the pressures from solar radiation are added to the atmospheric drag.[98] The positive effect, on the contrary, means that once the fuel is exhausted and therefore the speed that keeps it in orbit, the satellite progressively loses altitude and ends up re-entering the atmosphere and once inside it, disintegrates and vaporises after being exposed to high heat flows between 90 and 75 kilometres. The disintegration is not complete because it is estimated that between 20 and 40 percent of the waste ends up reaching the surface of the Earth.[99] Atmospheric density decreases as altitude increases and the effects of the drag finish gradually fade to reach 965 kilometres.[100] Thus, an object at an altitude between 350 and 400 kilometres would take a year and a half before it re-enters the atmosphere; several decades if it is located at 700 kilometres, and more than two centuries if it is above 800 kilometres.[101] Unfortunately, satellites are neither distributed equidistantly nor remain close to the densest areas of atmospheric drag; the highest concentration is between 650 and 900 kilometres and between 1,400 and 1,500,[102] regions where the North American constellations are located: Iridium (790 kilometres), Globalstar (1,410 kilometres) or the Russian Rodnik (1480 kilometres), that is, in areas where the drag is either very weak or simply non-existent. In fact, the number of satellites that orbit at altitudes below 500 kilometres is very small.

In relation to LEO, there are two events that have significantly increased the amount of waste. The first was the aforementioned ASAT test conducted by China in January 2007 that collided with the obsolete Chinese satellite Fengyun-1C at 865 kilometres and at a speed of 32,400 km per hour. The impact caused a twenty percent increase in the

97 U.S. Army Training and Doctrine Command, Army Space Reference Text, chapter 5, *Space Division*, 2000, <http://fas.org/spp/military/docops/army/ref_text/> [consulted: 24-1-2017].

98 Priester, W., Roemer, M., & Volland, H., "The Physical Behavior of the Upper Atmosphere deduced from Satellite Drag Data", *Space Science Reviews*, 1967, vol. 6:6, pp. 708-710.

99 Роскосмос: Тгк "Прогресс М-27м" прекратил существование (Roskosmos: Tgk "Progress M-27m" prekratil sushhestvovanie), 8 May 2015, <https://www.roscosmos.ru/21474/> [consulted: 15-9-2018].

100 U.S. Army Training and Doctrine Command. *óp. cit.*, note 97, chapter 5.

101 National Research Council, *Orbital Debris. A Technical Assessment*, Washington, D. C.: The National Academies Press, 1995, p. 29.

102 Yanofsky, D. & Fernholz, T. *Quartz*. This is every active satellite orbiting Earth. <http://qz.com/296941/interactive-graphic-every-active-satellite-orbiting-Earth/> [consulted: 15-9-2018].

number of registered particles and unleashed a cloud of debris that extended from 200 to 3,850 kilometres, encompassing the entire Low Earth Orbit.[103] At the beginning of 2014, 90 percent of these pieces of space junk were still in orbit.[104] The second was the accidental collision between the Russian satellite Cosmos-2251 and the American satellite Iridum-33 in February 2009 at 790 kilometres. The collision occurred above the Taimyr Peninsula, in the northernmost area of Siberia. This fact is significant given that the greatest risks and collision probabilities are concentrated at the poles.[105] These two events alone resulted in 5,500 tracked pieces of space junk and 36 percent of the debris in LEO.[106]

Of special interest has been the 2007 ASAT trial on account of its implications on space security and international stability. The test caused a huge imbalance in LEO waste records peaking above 890 kilometres.[107] The collision caused an amount of debris similar to that accumulated over 50 years. Most of the fragments were concentrated at the altitude where the collision occurred, representing a serious threat to satellites that share a similar orbital altitude to those belonging to the US National Oceanic and Atmospheric Administration (NOAA) or the Defense Meteorological Satellite Programme (DMSP). However, over time, the debris cloud has expanded beyond the original orbital plane, forcing operational satellites to perform manoeuvres should they be exposed to a collision. Thus, during the first six months after the ASAT test, the NASA Terra satellite, which orbits at 705 kilometres, had to manoeuvre to avoid fragments of up to 35 centimetres. Initially, the ISS also received orders to manoeuvre[108] but these were cancelled once it was established that the distance was acceptable.[109] Even so, it seems that the collision that damaged the Russian micro-satellite Blits in January 2013 was the result of waste scattered after the ASAT test.[110] On the

103 David, L., "China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth", *Space.com*, 2 February 2007, <http://www.space.com/3415-china-anti-satellite-test-worrisome-debris-cloud-circles-Earth.html> [consulted: 15-9-2018].

104 NASA, "Fengyun-1C Debris Cloud Remains Hazardous", *Orbital Debris*, Quarterly News, 2014, vol. 18:1, January, pp. 2-3.

105 European Space Agency, The Space Debris Story 2013, <http://www.esa.int/esatv/Videos/2013/04/The_Space_Debris_Story_2013/The_Space_Debris_Story_2013_-_English> [consulted: 15-9-2018].

106 Bowen, B. E. (2014) "Cascading Crises: Orbital Debris and the Widening of Space Security", *Astropolitics: The International Journal of Space Politics & Policy*, 2014, vol. 12:1, p. 49.

107 NASA, ó*p. cit.*, note 82, p. 4.

108 Zenko, M., "The danger of space debris", *CNN World*, 24 September 2011, <http://globalpublicsquare.blogs.cnn.com/2011/09/24/the-danger-of-space-debris/> [consulted: 15-9-2018].

109 Johnson, N. L.; Stansbery, E.; Liou, J-C.; Horstman, M.; Stokely, C. & Whitlock, D., "The Characteristics and Consequences of the Break-up of the Fengyun- 1C spacecraft", *Acta Astronautica*, 2008, vol. 63:1-4, pp. 128; 134.

110 David, L., "Russian Satellite Hit by Debris from Chinese Anti-Satellite Test", *Space.com*, 8 March 2013, <https://www.space.com/20138-russian-satellite-chinese-space-junk.html> [consulted: 15-9-2018].

other hand, there is not always scope for manoeuvre because most of the objects in space are not controlled, thus rendering a large number of potential collisions unavoidable.[111] Although the option of reinforcing satellite materials has been considered, this has finally been discarded since it would add considerable weight, thereby increasing launch costs and the waste cloud in the case of fragmentation. Therefore, the strengthening of materials only applies to manned missions such as the ISS.[112]

As for GEO, until recently it was presumed that geostationary satellites were safe from kinetic collisions. However, the Chinese test of May 13, 2013 has triggered much debate. Although China asserts that it was a high-altitude research rocket, the United States considers that it was actually a concealed ASAT trial at an altitude of more than 10,000 kilometres.[113] David Wright calculated that based on the limited public data available, the peak of the flight exceeded 10,000 kilometres, and that if it had not manoeuvred horizontally, the altitude reached would have hovered between 23,000 and 36,000 kilometres. If these calculations are correct, this would imply that China would have sufficient ASAT capacity to reach not only the global positioning satellites located in the Medium Earth Orbit (MEO) but also the communication and early warning satellites in GEO.[114]

An ASAT with such a far-reaching scope has important geostrategic connotations, including the issue of space debris. From a comparative point of view, GEO has a series of advantages and disadvantages over LEO. One of the advantages relates to orbital speed: space objects in GEO travel less than half the speed of those in LEO, at 3 km per second compared to 7.8 km per second, respectively. In addition, GEO has a single equatorial orbit that rotates to the east, unlike LEO that has a greater number of orbital planes. Among the disadvantages is the huge distance that prevents the detailed recording of objects smaller than one meter. As a result, it is not possible to precisely locate or gauge the resulting distribution of satellite explosions and the upper stages of rockets. In addition and most importantly, GEO does not have any natural mechanism for the elimination of waste.[115]

111 European Space Agency, ó*p. cit.*, note 105.

112 POST (Parliamentary Office of Science and Technology), "Space Debris", *UK Parliament*, 2010, No. 355, March, p. 3.

113 Shalal-Esa, A., "U.S. sees China launch as test of anti-satellite muscle: source", *Reuters*, 15 May 2013, <http://www.reuters.com/article/us-china-launch-idUSBRE94E07D20130515> [consulted: 15-9-2018].

114 Wright, D., "How High Did China's May 2013 Launch Go?" *Union of Concerned Scientists*, 13 March 2014, <http://allthingsnuclear.org/dwright/how-high-did-chinas-may-2013-launch-go?> [consulted: 15-9-2018].

115 Flury, W.; Massart, A.; Schildknecht, T.; Hugentobler, U.; Kuusela, J. & Sudnik, Z., "Searching for Small Debris in the Geostationary Ring – Discoveries with the Zeiss 1-metre Telescope", ESA, Bulletin 104, 2000, November, p. 92.

The issue of space debris is aggravated as atmospheric drag has been shown to be the only viable method to reduce waste. This means that mitigation strategies have focused mainly on performing manoeuvres during the last stage of a satellite's useful lifetime in order to descend to the bands where the drag exerts its influence so that in a period of 25 years they can re-enter the atmosphere. The disadvantage of this measure is that long-distance orbital manoeuvres require large amounts of fuel, so the orbital descent is restricted to satellites that are in the intermediate layers of LEO. For satellites in the upper layers of LEO, a widespread solution has been to move them in their final stage to MEO, a much less congested region, upwards of 2,000 kilometres, and create an area that has come to be known as the *graveyard orbit*. A similar solution has been adopted for GEO satellites: transferring them beyond the "protected region", that is, to ± 200 kilometres.[116]

Meanwhile, various studies and research projects have sought to find ways to get rid of waste that remains outside the atmospheric drag. These measures are known as Active Debris Removal (ADR). To date, the common denominator shared by these proposals is their exoticism given the current technological limitations. Among the different series of techniques, Brian Weeden distinguishes three.[117] A first ADR technique that has gained certain popularity is the use of ground- and space-based lasers fired at space debris in order to bring them down from their orbital altitude and enter the bands of atmospheric drag. It has been reported that the ISS could host lasers by the end of the current decade. However, studies to date note that the maximum distance that the laser could reach is 100 kilometres.[118] Given that the ISS orbits at 420 kilometres, it would not reach the most critical bands with the highest concentration of waste: between 800 and 900 kilometres. The risks involved in this technique are obvious, not least of which would be an accidental attack on one of the operational satellites. The accident could disable satellites by "blinding" their optical panels, or destroying them if the intensity of the energy propelled is extremely powerful. Moreover, space is a highly hostile environment. This hostility accelerates the degradation of the space component materials and accelerates their instability. Thus, an old rocket, for example, could be subjected to a sudden charge of directed energy and explode because of the residual fuel stored in its tanks. In addition, laser will always arouse suspicions of dual-use technology, which is why many states could consider it to be an ASAT weapon and would therefore be quite reluctant to opt for its development and use.

116 Alby, F. (2015) "The Issue of Space Debris", in Schrogl, K-U.; Hays, P. L.; Robinson, J.; & Giannopapa, D. M. Ch. (eds.), *Handbook of Space Security. Policies, Applications and Programs*, New York: Springer, 2015, pp. 691-692.

117 Weeden, B. "Overview of the legal and policy challenges of orbital debris removal", *Space Policy*, 2011, vol. 27:1, p. 39.

118 Choi, C. Q. "Space Station Could Get Laser Cannon to Destroy Orbital Debris", *Space.com*, 30 April 2015, <http://www.space.com/29271-space-station-laser-cannon-orbital-debris.html> [consulted: 15-9-2018].

A second technique is rendezvous operations, that is, space vehicles that employ nets, harpoons or other dragging techniques to collect space debris and return it to Earth. NASA has begun testing with TechEdSat-4, a satellite equipped with a kind of parachute that drags space debris into the atmosphere.[119] However, rendezvous operations have raised enormous doubts aside from the problem of dual-use technology. The main question is related to the absence of a formal international definition of functional and non-functional objects insofar as both fall into the same category: space objects. Consequently, in the absence of any distinction, all objects, regardless of their nature, are susceptible to elimination. This question is highly significant in the context of space security, given the existence of "objects in a state of hibernation". In other words, the "capacity to hibernate", obviously not disclosed by the country to which the object belongs, generates considerable uncertainty about their useful life. Accordingly, distrust in relation to rendezvous operations are compounded by the fact that not all states have SSA technology, that is, the ability to "monitor and understand the changes that occur in the space environment", specifically the material capabilities to identify and visually control cleaning tasks.[120] Last, but not least, there is the issue of possible technological patents or military or commercial secrets held aboard some satellites, that will surely lead many states to prevent others from collecting their obsolete objects for fear that they might be examined.

A third technique advocates carrying out "collector" tasks, that is, spacecraft with large surface areas coated in or made of substances that can absorb the momentum of debris impacts, such as foam or rotating panels.

However, despite the major challenges posed by space debris, the response from international law and the UNGA have to date been unambitious. As Jinyuan Su argues,[121] environmental issues were not a priority during the preparation of the OST, as evidenced by Article IX, while its wording was not aimed at "protecting the orbital environment but at preserving scientific space experimentation". Article IX, which stresses the need to govern space activities through the principles of cooperation and mutual assistance, and that the States Parties to the Treaty "shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth", does not have direct enforcement mechanisms but is designed to urge States Parties to refrain from creating space debris while imposing enormous obstacles to one State Party holding another responsible for creating new orbital debris. Indeed, the article pleads not for judicial procedures but for the holding of "international consultations". After the 2007 ASAT test, Japan was the only coun-

119 Alberty, M. "NASA Deploys Satellite Designed to Re-enter Atmosphere Using Revamped Drag Device", *NASA*, 4 March 2015, <http://www.nasa.gov/ames/nasa-deploys-satellite-designed-to-re-enter-atmosphere-using-revamped-drag-device> [consulted: 15-9-2018].

120 Jaramillo, C., *óp. cit.*, note 35, p. 37.

121 Su, J., «The environmental dimension of space arms control», *Space Policy*, 2013, vol. 29:1, p. 62.

try that openly denounced China for undertaking a dangerous act that in its view was a "violation" of OST Article IX.[122]

CONCLUSIONS

The current panorama resulting from an increasing number of new space actors with widely varying security policies has had several consequences; on the one hand, a tilt towards an arms race that could jeopardise space assets; on the other hand, the super powers' refusal to weaken their space strategies has resulted in a significant accumulation of obstacles in the way of new agreements aimed at the correct management of orbital resources and arms control. In short, a greater number of space activities coupled with the absence of regulatory and sanction mechanisms is leading to the greater vulnerability of the space environment. The truth is therefore that a multilateral approach to dealing with the issue of space debris seems very complicated and arduous.

On the other hand, the second space age, especially since 2010, has witnessed a veritable explosion in the field of space activities with the entry of new public actors from all continents as well as an openness to the commercialisation of space by private agents. The following is a typical example: the first two flights of the Block 5 Falcon 9 rocket manufactured by SpaceX transported a satellite from Bangladesh[123] and another from Indonesia[124] in May and August 2018 respectively.

This democratisation has multiple inherent advantages. Many states are in a position to modernise their security systems to better manage threats affecting their national and human security, such as those that range from monitoring rebel troops or drug gangs to preventing of natural disasters or deforestation. Likewise, the possession of satellites has strongly boosted the socio-economic development of many countries, creating solid infrastructures, of radio broadcasting and mobile telephone communications, ocean management and mining exploitation, among others. In addition to these significant advantages, an important effect of the democratisation process is that the new emerging players, aware of the advantages that space benefits bring, and with their increased global influence in line with the new shift in international relations and centres of power in the twenty-first century, may exercise a role in deterring the militarisation of space and the superpowers' ASAT testing by advocating in favour of

122 Moltz, J. C., *óp. cit.*, note 9, p. 104.

123 Henry, C., "How Bangladesh became SpaceX's first Block 5 Falcon 9 customer", *SpaceNews*, Washington, 9 May 2018, <https://spacenews.com/how-bangladesh-became-spacexs-first-block-5-falcon-9-customer/> [consulted: 15-9-2018].

124 Henry, C., "SpaceX launches Telkom Indonesia satellite on first reflight of Block 5 Falcon 9 booster", *SpaceNews*, Washington, 7 August 2018, <https://spacenews.com/spacex-launches-telkom-indonesia-satellite-on-first-reflight-of-block-5-falcon-9-booster/> [consulted: 15-9-2018].

moderation or their elimination, given the indiscriminate risks that these weapons pose to the assets of other space actors. However, while democratisation is beneficial, it can also have negative effects, with space assets being employed by non-democratic states to strengthen their regimes, such as the use of observation satellites for the purpose of monitoring enemy forces.

This combination of benign and negative scenarios also exists in relation to the entrance of private actors. One of the positive consequences is the possibility of private agents such as companies or universities purchasing and acquiring "direct ownership" of satellites. This process has accelerated in recent years with the proliferation of nanosats –satellites of between one and ten kilograms– and the standard CubeSat, measuring ten square centimetres, weighing 1.3 kilograms, with a price tag of $100,000. This proliferation means that over the second half of the present decade, more than 1,000 nanosats are expected to be launched into space.[125] The distribution of nanosats represents a great scientific advance on account of their capacity to carry out countless number of experiments and studies on solar and cosmic radiation or research on space meteorology. However, the reverse effect is also possible if this technology falls into the hands of criminals or terrorists who could avail of reconnaissance nanosats with an image resolution of up to 50 centimetres (50 cm x 50 cm per pixel is the limit that the United States has imposed on commercial satellites). On the other hand, having seen the concerns already raised by private actors in relation to space security and their decisions to adopt security measures, it seems likely that sooner or later they will exercise pressure on their governments urging them to limit their ASAT programmes. Likewise, private agents can galvanise policymakers into reviewing space law and initiating a "liberal" legislative process that addresses such sensitive issues as property rights on the Moon or on Mars. However, it may also be that the new privatisation trends could stimulate a kind of process of "*flags of convenience*" whereby in a bid to reduce costs, operators dissociate themselves from the obligations that determine the "responsible states" in their national legislations and go to other states that impose fewer restrictions when carrying out space operations. Moving facilities from one state to another would not be a very complex process following the model of the now defunct XCOR Aerospace that offered suborbital flights, whose spaceplane *Lynx* was not launched vertically from a launch pad but was a rocket-powered plane designed like any commercial aircraft to be launched from a runway.

The result of all this is that the issue of space debris, along with space weapons, is today one of the main problems facing space security. Moreover, space debris is "considered by many observers to be the most pressing issue of space security."[126] The progressive deterioration of orbital resources is clearly a matter of maximum concern for public and private actors who have invested enormous efforts in achieving SSA capabilities to prevent and avoid collisions generating clouds of space debris. Although NASA has

125 The Economist, "Nanosats are go!" *The Economist*, 7 June 2014, <https://www.economist.com/technology-quarterly/2014/06/07/nanosats-are-go> [consulted: 15-9-2018].

126 Listner, M., "Legal issues surrounding space debris remediation", *The Space Review*, 6 August 2012, <http://www.thespacereview.com/article/2130/1> [consulted: 15-9-2018].

stated that "the probability that two large objects (> 10 cm in diameter) will accidentally collide is very low»,[127] the growing volume of space traffic due to the increasing number of space actors makes the need to adopt measures aimed at mitigating space debris imperative. However, there are numerous and wide-ranging difficulties to be overcome: for example, obstacles of a technical nature, which to date can only be dealt with by atmospheric drag. Active Debris Removal techniques aimed at removing waste from orbit are currently only in the very early stages of development and far from becoming a practical reality for a considerable time. There are also political impediments, as we have seen, because of the tendency for players to prioritise national security above all other considerations. In addition, mitigation measures face major budgetary and legal obstacles.[128] Regarding the legal obstacles, it will be difficult to make any worthwhile progress in waste mitigation without a whole rethinking of the international definition of space waste that would remove the exclusive ownership of states.

Given that the resulting scenario is too complex because of the existing difficulties within the framework of an international strategy to reach multilateral agreements on space debris, an alternative means of strengthening space governance could be through the enactment and adoption of national legislation to authorise and supervise space debris mitigation that could gather momentum and in time lead to an international customary ruling. This is a route that has already been proposed for other insufficiently regulated space activities, such as suborbital flights.[129] An insightful case has been proposed by France: in line with Norm ISO 24113,[130] Article 5 of its 2008 Space Law prescribes the obligation to limit risks associated with space debris,[131] and the Ministerial Order of March 31, 2011 stipulates the obligation to prevent the intentional release of space debris in orbit during nominal operations; the avoidance of ruptures or disintegration in orbit; and the removal of space objects away from protected orbits after the mission (article 21).[132]

127 NASA Orbital Debris Program Office, *óp. cit.*, note 92.

128 Hildreth, S. A. & Arnold, A., "Threats to U.S. National Security Interests in Space: Orbital Debris Mitigation and Removal", *Congressional Research Service*, 8 January 2014, <https://www.fas.org/sgp/crs/natsec/R43353.pdf> [consulted: 15-9-2018].

129 Masson-Zwaan, T., "Liability and Insurance for Suborbital Flights", *Proc. 5th IAASS Conference 'A Safer Space for a Safer World'*, Versailles, France17–19 October 2011 (ESA SP-699, January 2012), and <https://core.ac.uk/download/pdf/15606188.pdf> [consulted: 15-9-2018].

130 Lazare, B., "The French Space Operations Act: Technical Regulations", *Acta Astronautica*, vol: 92 (2), December 2013, p. 211.

131 *LOI n° 2008-518 du 3 juin 2008 relative aux opérations spatiales*, Le Journal officiel de la République française, <https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=LEGITEXT000018939303> [consulted: 15-9-2018].

132 *Arrêté du 31 mars 2011 relatif à la réglementation technique en application du décret n° 2009-643 du 9 juin 2009 relatif aux autorisations délivrées en application de la loi n° 2008-518 du 3 juin 2008 relative aux opérations spatiales*, Le Journal officiel de la République française, <https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000024095828&categorieLien=id> [consulted: 15-9-2018].

BIBLIOGRAPHY

Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (resolution 34/68 of the General Assembly, annex), approved on 5 December 1979, open for signature 18 December 1979, and in force since 11 July 1984.

Adamowski, J., "Angola eyes new satellite as African space race accelerates", *SpaceNews*, 12 June 2018.

Al-Ekabi, C., "Developments in Space Policies, Programmes and Technologies throughout the World and in Europe", In Al-Ekabi, C.; Baranes, B.; Hulsroj, P. & Lahcen, A. (eds.), *Yearbook on Space Policy 2011/2012. Space in Times of Financial Crisis*, Vienna: Spring, 2014, pp. 103-146.

Al-Ekabi, C., "Space Policies, Issues and Trends in 2012–2014", *European Space Policy Institute*, ESPI Report 49, 2014, November.

Alberty, M. "NASA Deploys Satellite Designed to Re-enter Atmosphere Using Revamped Drag Device", *NASA*, 4 March 2015.

Alby, F. (2015) "The Issue of Space Debris", in Schrogl, K-U., Hays, P.L.; Robinson, J.; Moura, D. & Giannopapa, C. (eds.), *Handbook of Space Security. Policies, Applications and Programs*, New York: Springer, 2015, pp. 679-698.

Alby, F., "The Space Debris Environment and its Impacts", in Rathgeber, W., Schrogl, K. & Williamson, R. A. (eds.), *The Fair and Responsible Use of Space: An International Perspective*, Vienna: Springer, 2010, pp. 60-72.

Arrêté du 31 mars 2011 relatif à la réglementation technique en application du décret n° 2009-643 du 9 juin 2009 relatif aux autorisations délivrées en application de la loi n° 2008-518 du 3 juin 2008 relative aux opérations spatiales, Le Journal officiel de la République française.

Baiocchi, D. & Welser IV, W., "The Democratization of Space", *Foreign Affairs*, May/June 2015.

Barry, E., "India Launches 104 Satellites From a Single Rocket, Ramping Up a Space Race", *The New York Times*, New Delhi, 15 February 2017.

Basulto D., "One small step for man, one giant step for the commercialization of the moon", *The Washington Post*, 12 February 2015.

BBC, "Branson unveils space tourism jet" *BBC*, 28 July 2008.

BBC, "SpaceX rocket in historic upright landing", *BBC News*, 22 December 2015.

Boot, M., "Space, the Final Free Market", *Council on Foreign Relations*, 7 October 2004.

Bowen, B. E. (2014) "Cascading Crises: Orbital Debris and the Widening of Space Security", *Astropolitics: The International Journal of Space Politics & Policy*, 2014, vol. 12:1, p. 46-68.

Bracken, P., *The Second Nuclear Age: Strategy, Danger, and the New Power Politics*, New York: Times Books, 2010.

Brumfiel, G., "Analysts spar over launch image", *Nature*, 8 April 2009.

Brumfiel, G., "Korean satellite misses orbit", *Nature*, 6 April 2009.

Chang, K., "First Private Craft Docks with Space Station", *The New York Times*, 25 May 2012.

Cheng, D., "Setting Future Directions in Space", in William B. Ruger Chair of National Security Economics Papers, *Defense Strategy and Forces: Setting Future Directions*, vol. 3, Naval War College: Newport, 2007, pp. 223-234.

Choi, C. Q. "Space Station Could Get Laser Cannon to Destroy Orbital Debris", *Space.com*, 30 April 2015.

Chow, T., "Iranian Space Launch Capabilities. Fact Sheet", *Secure World Foundation*, 2 September 2010.

Conrad, W., Anderson, J. & Jacobs, S., "Arms Control in the Third Space Age: Assessing International Efforts to Regulate Military Operations In Outer Space in the "3 C's" Era", in Coletta, D. (eds.), *Space and Defense*, Eisenhower Center for Space and Defense Studies, vol. 6 (1), Fall, pp. 4-21.

Conrad, W.; Anderson, J. & Jacobs, S., "International Negotiations, Emerging Space Powers, and U. S. Efforts to Protect the Military Use of Space", in Coletta, D. (ed.), *Space and Defense*, Eisenhower Center for Space and Defense Studies, vol. 7 (1), 2014, Winter, pp. 6-25.

DalBello, R., "Commercial Communication Satellites: Assessing Vulnerability in a Changing World", in Logsdon, J. & Adams, G. (eds.), *Space Weapons. Are they needed?* Washington, D. C.: Space Policy Institute. The George Washington University, 2003, pp. 271-296.

Davenport, C., "As human space flights get closer, the competition for launch contracts heats up", *The Washington Post*, 25 April 2018.

David, L., "China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth", *Space.com*, 2 February 2007.

David, L., "Private Moon Bases a Hot Idea for Space Pioneer", *Space.com*, 14 April 2010.

David, L., "Russian Satellite Hit by Debris from Chinese Anti-Satellite Test", *Space.com*, 8 March 2013.

Dawson, C., "Japan Shows Off Its Missile-Defense System", *The Wall Street Journal*, Tokyo, 9 December 2012.

De Selding, P. B., "Satellite Operators Solicit Bids To Create Orbital Database", *SpaceNews*, Paris, 18 November 2009.

De Selding, P. B., "SES Positioned To Overtake Intelsat in Revenue", *SpaceNews*, Paris, 21 February 2014.

European Space Agency, The Space Debris Story 2013.

Flury, W.; Massart, A.; Schildknecht, T.; Hugentobler, U.; Kuusela, J. & Sudnik, Z., "Searching for Small Debris in the Geostationary Ring – Discoveries with the Zeiss 1-metre Telescope", ESA, Bulletin 104, November 2000.

Foust, J., "Blue Origin plans to start selling suborbital spaceflight tickets next year", Washington, 21 June 2018.

Foust, J., "https://spacenews.com/google-lunar-x-prize-to-end-without-winner/", *SpaceNews*, 23 January 2018.

Fuller, J; Foust, J.; Frappier, C.; Kaiser, D. & Vaccaro, D., "The Commercial Space Industry: A Critical Spacepower Consideration", in Lutes, C. D. & Hays, P. L. (eds.), *Toward a Theory of Space Superpower. Selected Essays*, Washington, D. C.: Institute for National Strategic Studies. National Defense University, 2011, p. 104-126.

GAO, *Critical Infraestructure Protection. Commercial Satellite Security Should Be More Fully Addressed*, August 2002.

Grego, L., *A History of Anti-Satellite Programs*, Cambridge, Massachusetts: Union of Concerned Scientists, 2012.

Gruss, M., "U.S. Official: China Turned to Debris-free ASAT Tests Following 2007 Outcry", *SpaceNews*, 11 January 2016.

Hansen, N., "North Korea's Sohae Satellite Launching Station: Upgrades Near Completion; Ready for More Launches?" *38 North*, 21 August 2014.

Harding, R. C., *Space Policy in Developing Countries: The Search for Security and Development on the Final Frontier*, New York: Routledge, 2013.

Henry, C., "Cambodia to buy Chinese satellite as relations tighten on Belt and Road Initiative", *SpaceNews*, Washington, 12 January 2018.

Henry, C., "How Bangladesh became SpaceX's first Block 5 Falcon 9 customer", *SpaceNews*, Washington, 9 May 2018.

Henry, C., "SpaceX launches Telkom Indonesia satellite on first reflight of Block 5 Falcon 9 booster", *SpaceNews*, Washington, 7 August 2018.

Hildreth, S. A. & Arnold, A., "Threats to U.S. National Security Interests in Space: Orbital Debris Mitigation and Removal", *Congressional Research Service*, 8 January 2014.

Howell, E., "Bigelow Aerospace: Inflatable Modules for ISS", *Space.com*, 17 January 2013.

Hsu, J., "Iran's Space Program: Lots of Talk, but a Chance to Shine", *Space.com*, 9 November 2010.

IAA, International Academy of Astronautics, *Position Paper on Space Debris Mitigation. Implementing Zero Debris Creation Zones*, 2005.

IADC, Inter-Agency Space Debris Coordination Committee, *IADC Space Debris Mitigation Guidelines*, 2007.

IADC, Inter-Agency Space Debris Coordination Committee, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*, 2010.

Jakhu, R. S. & Pelton, J. N., "Private Commercial Space Enterprises and Global Governance System", in Jakhu, R. S. & Pelton, J. N. (eds.), *Global Space Governance: An International Study*, Cham, Switzerland: Springer, pp. 113-142.

Jaramillo, C., *Space Security Index 2013*, Tenth edition, Ontario: Space Security.org, 2013.

Johnson-Freese, J. & Erickson, A.S., "The Emerging China-EU Space Partnership: A Geotechnological Balancer", Space *Policy*, vol. 22 (1), 2006, pp. 12-22.

Johnson, N. L.; Stansbery, E.; Liou, J-C.; Horstman, M.; Stokely, C. & Whitlock, D., "The Characteristics and Consequences of the Break-up of the Fengyun- 1C spacecraft", *Acta Astronautica*, 2008, vol. 63:1-4, pp.128-135.

Jones, A., "Chinese startups OneSpace, iSpace succeed with suborbital launches", *SpaceNews*, Helsinki, 7 September 2018.

Klotz, I., "(Another) Giant Leap For SpaceX: Geostationary Orbit", *Discovery News*, 3 December 2013.

Klotz, I., "Exclusive - The FAA: regulating business on the moon", *Reuters*, Florida, 3 February 2015.

Lazare, B., "The French Space Operations Act: Technical Regulations", *Acta Astronautica*, vol. 92 (2), December 2013, pp. 209-212.

Lele, A., *Asian Space Race: Rhetoric Or Reality?*, New Dehli: Springer, 2013.

Liou, J-C. & Johnson, N. L., "A Sensitivity Study of the Effectiveness of Active Debris Removal in LEO", *Acta Astronautica*, 2009, vol. 64:2-3, pp. 236–243.

Listner, M., "Legal issues surrounding space debris remediation", *The Space Review*, 6 August 2012.

Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace, Journal officiel du Grand-Duché de Luxembourg, Signed: 20/07/2017; Published: 28/07/2017.

LOI n° 2008-518 du 3 juin 2008 relative aux opérations spatiales, Le Journal officiel de la République Française.

Long Callahan, A., "Sustaining Soviet-American Collaboration, 1957–1989", in Krige, J.; Long Callahan, A. & Maharaj, A. (eds.), *NASA in the World: Fifty Years of International Collaboration in Space*, New York: Palgrave Macmillan, 2013, pp. 127-151.

Masson-Zwaan, T., "Liability and Insurance for Suborbital Flights", *Proc. 5th IAASS Conference 'A Safer Space for a Safer World'*, Versailles, France17–19 October 2011 (ESA SP-699, January 2012.

Moltz, J. C., "Asia's space race", *Nature*, No. 480, 8 December 2011, pp. 171-173.

Moltz, J. C., *Asia's Space Race: National Motivations, Regional Rivalries, and International Risks*, New York: Columbia University Press, 2012.

Moltz, J. C., *The Politics of Space Security. Strategic Restraint and the Pursuit of National Interests*, California: Stanford University Press, Second edition, 2011.

NASA Orbital Debris Program Office. Orbital Debris Frequently Asked Questions.

NASA, "Fengyun-1C Debris Cloud Remains Hazardous", *Orbital Debris*, Quarterly News, 2014, vol. 18:1, January.

NASA, *History of On-Orbit Satellite Fragmentations*, Orbital Debris Program Office, 2008.

National Research Council, *Orbital Debris. A Technical Assessment*, Washington, D. C.: The National Academies Press, 1995.

Office of Technology Assessment, *U.S.-Soviet Cooperation in Space*, Washington, D. C.: U.S. Government Printing Office, 1985.

Pace, S., "U.S.-Japan Space Security Cooperation" in Schrogl, K-U., Hays, P. L., Robinson, J., Giannopapa, C. & Moura, D. (eds.), *Handbook of Space Security. Policies, Applications and Programs*, New York: Springer, 2015, pp. 338-355.

Pant, H. V. & Lele, A., "India in Space: Factors Shaping the Indian Trajectory", in Sadeh E. (ed.), *Space and Defense*, Eisenhower Center for Space and Defense Studies, vol. 4 (1), 2010, Summer, pp. 47-60

Paracha, S., "Military Dimensions of the Indian Space Program", *Astropolitics: The International Journal of Space Politics & Policy*, vol. 11(3), 2013, pp. 156-186.

Pelton, J. N., *Space Debris and Other Threats from Outer Space*, New York: Springer, 2013.

Portree, D. S. F. & Loftus, Jr. J. P., *Orbital Debris: A Chronology*, NASA, January 1999.

POST (Parliamentary Office of Science and Technology), "Space Debris", *UK Parliament*, No. 355, March 2010.

Priester, W., Roemer, M., & Volland, H., "The Physical Behavior of the Upper Atmosphere deduced from Satellite Drag Data", *Space Science Reviews*, 1967, vol. 6:6, pp. 707-780.

PRIMACK, J., "Debris and Future Space Activities", in Motlz, J. C. (ed.), *Future Security in Space: Commercial, Military, and Arms Control Trade-Offs*, Center for Nonproliferation Studies, Occasional Paper, 2002, pp. 1-7.

RENDLEMAN, J. D., "Lawful Response to Attacks on Space Systems", in Sadeh E. (ed.), *Space and Defense*, Eisenhower Center for Space and Defense Studies, vol. 4 (1), 2010, Winter, pp. 3-52.

REUTERS, "North Korea's Taepodong-2 long-range missile", *Reuters*, 25 March 2009.

RYAN, M., "Top U.S. general says it is time to consider arming Ukrainian forces". *The Washington Post*, 3 March 2015.

SACHDEVA, G. S., "Space Policy and Strategy of India", in Sadeh, E.(ed.), *Space Strategy in the 21st Century: Theory and Policy*, Oxon, Oxfordshire: Routledge, 2013, pp. 303-321.

SAMSON, V., "India and space security", *The Space Review*, 9 May 2011.

SANG-HUN, C. & SANGER, D. E., "North Koreans Launch Rocket in Defiant Act", *The New York Times*, Seoul, 11 December 2011.

SANG-HUN, C., "South Korea and China End Dispute Over Missile Defense System", *The New York Times*, 30 October 2017.

SHALAL-ESA, A., "U.S. sees China launch as test of anti-satellite muscle: source", *Reuters*, 15 May 2013.

SHANKER, T. & SANG-HUN, C., "No U.S. Plans to Stop Korea on Missile Test", *The New York Times,* Washington, 30 March 2009.

SPACE FOUNDATION, *The Space Report 2014*, Colorado Spring, Colorado: Space Foundation, 2014.

SPACE.COM STAFF, "North Korea Successfully Launches Satellite: Reports", *Space.com*, 12 December 2012.

STEIN, A., "Turkey's Space Policy", *Centre for Economics and Foreign Policy Studies*, EDAM Discussion Paper Series 2014/3, May 2014.

STENGER, R., "Scientist: Space weapons pose debris threat", *CNN*, 3 May 2002.

SU, J., "The environmental dimension of space arms control", *Space Policy*, 2013, vol. 29:1, pp. 58-66.

TASS, "Научно-технический совет Роскосмоса одобрил использование МКС до 2024 года" (Nauchno-tekhnicheskij sovet Rorkosmosa odobril ispolzovanie MKS do 2024 goda). *TASS*, Moscow, 24 February 2015.

The Economist, "Nanosats are go!" *The Economist*, 7 June 2014.

TORTORA, J.-J., (2014) "Space Industry and the Financial Crisis", in Al-Ekabi, C.; Baranes, B.; Hulsroj, P. & Lahcen, A. (eds.), *Yearbook on Space Policy 2011/2012. Space in Times of Financial Crisis,* Vienna: Spring, 2014, pp. 169-181.

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (resolution 2222 (XXI) General Assembly, annex), approved 19 December 1966, open for signature 27 January 1967 and in force 10 October 1967.

U.S. Army Training and Doctrine Command, Army Space Reference Text, chapter 5, *Space Division*, 2000.

Union of Concerned Scientist, *UCS Satellite Database*, Satellite Quick Facts (includes launches through 1/31/15).

Wall, M., "Elon Musk Wants Giant SpaceX Spaceship to Fly People to Mars by 2024", *Space.com*, 29 September 2017.

Waters, R. & Kerr, S., "Virgin Group funds tapped for delayed space venture", *Financial Times*, 2 November 2014.

Weeden, B. "Overview of the legal and policy challenges of orbital debris removal", *Space Policy*, 2011, vol. 27:1, pp. 38-43.

Williams, M., "Safeguarding Outer Space: on the road to debris mitigation", in United Nations Institute for Disarmament Research (ed.), Security in Space: the Next Generation, Geneva: United Nations, 2008, pp. 81-103.

Wolter, D., *Common Security in Outer Space and International Law*, Geneva: United Nations Institute for Disarmament Research, 2006.

Wright, D., "How High Did China's May 2013 Launch Go?" *Union of Concerned Scientists*, 13 March 2014.

Wright, D., "Orbital Debris Produced by Kinetic-Energy Anti-Satellite Weapons", in United Nations Institute for Disarmament Research (ed.), *Celebrating the Space Age. 50 Years of Space Technology, 40 Years of the Outer Space Treaty*, Geneva: United Nations, 2007, pp. 155-164.

Wright, D., "Rasad-1: Iran Launches Its Second Satellite", *Union of Concerned Scientist*, 16 June 2011.

Yanofsky, D. & Fernholz, T. *Quartz*. This is every active satellite orbiting earth.

Zenko, M., "The danger of space debris", *CNN World*, 24 September 2011.

Роскосмос: Тгк "Прогресс М-27м" прекратил существование (Roskosmos: Tgk "Progress M-27m" prekratil sushhestvovanie), 8 May 2015.

Submited: January 31, 2017.
Accepted: March 1, 2018.